University of Sheffield
Department of Animal and Plant Sciences

Palynological analysis of the Ordovician to Lower Silurian sediments from the Murzuq Basin, southwest Libya

By

Faisal Abuhmida

Thesis submitted in partial fulfilment of the requirements for the degree of Doctor Philosophy

Supervisor Prof. Charles Wellman

September 2013

Centre for Palynology
Department of Animal and Plant Sciences
University of Sheffield

VOLUME 1

ACKNOWLEDGEMENTS

Praise to ALLAH (God), the lord and creator of the universe, who has blessed me with countless blessings: The security of life and source of energy, and my peace and blessings be up on his messenger Mohamed. My family’s support and pleasant work atmosphere have all contributed to achievements of this work.

Many thanks and appreciation to Prof. Charles Wellman for his excellent supervision, valuable advice, encouragement and full assistance throughout the course of study.

I am greatly indebted to the Libyan Petroleum Institute, especially Dr. Abourima Belgassem for this opportunity to carry out such study. Thanks are also extended to the General People‘s Committee for Education, Libya, together with Libya Culture Affairs and Libyan Embassy in London for their support and cooperation.

I would especially like to thank Prof. Bernard Owens (University of Sheffield, UK) for valuable taxonomic corrections, advice and help. Thanks are also extended to technical staff, especially Mr. Steve Ellin, for his help and advice in the Lab work. Special thanks also to the administration office staff in the Department of Animal and Plant Sciences, University of Sheffield, especially Mrs Sue Carter and Mrs Angela Doncaster, for their co-operation

My sincerest thanks to the National Oil Corporation, Libya and the exploration managers of Agip Oil, Repsol operation and Remsa Oil companies for their support and providing the study material.

I am grateful to my brothers Mouhamed, Essam, Abdel Mounam and my father-in-law Ahmed Zoura for their help and support. Special thanks go to my

wife Assya and my children (Sofyan, Roa, Roiya and Rhaf) for their commitment and special patience.

At the end I would like to thanks all the staff and friends in the Libyan Petroleum Institute who's direct or indirect advice helped me to carry out this study.

PALYNOLOGICAL ANALYSIS OF ORDOVICIAN-LOWER SILURIAN SEDIMENTS FROM THE MURZUQ BASIN, SOUTHWEST LIBYA

ABSTRACT

A detailed palynological analysis has been undertaken on 164 core and cutting samples selected from six wells recently drilled in the Murzuq Basin of southwest Libya. The boreholes penetrated Ordovician-Lower Silurian strata belonging to the As Shabiyat, Hawaz, Melez Shugran, Memouniat, Bir Tlacsin and Tanezzuft formations. The majority of the samples proved palyniferous, yielding abundant moderately to well preserved marine palynomorphs (acritarch, chitinozoan, scolecodont and graptolite) and non-marine palynomorphs (spore/cryptospore). The chitinozoans and acritachs enable biostratigraphical age dating and correlation of these strata. Particularly rich assemblages were recovered from the Melez Shugra, shale intercalations in the Memouniat, Bir Tlacsin and Tanezzuft formations. However, the As Shabiyat Formation and the upper part of the Memouniat Formation were barren of palynomorphs and the Hawaz Formation yields only rare, poorly preserved, low diversity assemblage characterized by the abundance of sphaeromorph acritarchs (*Leiosphaerida* spp.). A total of 147 species belong to 57 genera of acritarch, 93 species belong to 23 genera of chitinozoan and 21 species belong to 16 genera of cryptospore/spore have been identified and taxonomically described. Scolecodonts as well as graptolite remains were also recorded (counted but not taxonomically identified).

One Mid Ordovician chitinozoan assemblage zone, four Late Ordovician and six Early Silurian chitinozoan biozones belonging to the North Gondwana zonation are identified. The Late Ordovician chitinozoan biozones indicate that the Melez Shugran Formation ranges from early late Katian-early Hirnantian in age and it is considered to correspond to the *A. nigerica*, *A. merga* and lower *T. elongata* Biozones, the Memouniat Formation is early Hirnantian and is considered to be within the *T. elongata* Biozone, and the Bir Tlacsin Formation

is late Hirnantian in age and is assigned to the *S. oulebsiri* Biozone. The lower Silurian chitinozoan biozones indicate that the lower part of the Tanezzuft Formation is early-mid Rhuddanian and is considered to correspond to the *S. fragilis* and *B. postrobusta* Biozones. The hot shale is constrained to the upper part of the range of *Belonechitina postrobusta.* The middle upper part ranges from late Rhuddanian-Telychian in age and is considered to correspond to the A. *qusaibaensis, C.* cf. *alargada – P. paraguayensis, A. hemeri* and *A. macclurei* Biozones.

Eight acritarch assemblage zones, corresponding stratigraphically to the above chitinozoan biozones, are recognisable and informally designated as follows: Ac-1 Assemblage Zone (mid-late Darriwilian), Ac-2 Assemblage Zone (early late Katian), Ac-3 Assemblage Zone (late Katian), Ac-4 Assemblage Zone (Hirnantian), Ac-5 Assemblage Zone (early Rhuddanian) and Ac-6 Assemblage Zone (mid Rhuddanian), Ac-7 Assemblage Zone (late Rhuddanian-early Aeronian) Ac-8 Assemblage Zone (mid-late Aeronian - Telychian). Four cryptospore/spore assemblage zones, corresponding stratigraphically to the above chitinozoan biozones and acritarch assemblage zones are recognisable and informally designated as follows: Cr-1 Assemblage Zone (mid-late Darriwilian), Cr-2 Assemblage Zone (early late Katian-Hirnantian), Cr-3 Assemblage Zone (early-mid Rhuddanian) and Cr-4 Assemblage Zone (late Rhuddanian-Telychian).

Palynological and palynofacies analysis, used to interpret the depositional environment and locate the initial effects of the Late Ordovician glaciation on the palynomorph assemblages, indicates that the depositional environment is inner shelf marine to marginal marine in the Hawaz Formation (mid-late Darriwilian). It is interpreted as inner shelf marine in the Melez Shugran Formation and the shale intercalations in the lower part of the Memouniat Formation (pre-glacial sediments) (early late Katian-early Hirnantian), and considered that these were generally deposited during a period of overall transgression related to relative sea level rise during glacial advance and loading of the continental shelf and subsequent glacial retreat. The upper part of the Memouniat Formation (early Hirnantian) was barren of palynomorphs

and this can be regarded as evidence of major glacio-eustatic sea level fall (maximum glacial advance), with fresh water influences in Hirnantian. An inner shelf marine environment is also interpreted for the Bir Tlacsin Formation (late Hirnantian) and suggested that it is deposited after the glacial maximum and during a period of overall transgression that result of the melting of the northern Gondwana ice cap. An open marine environment is also indicated for the lower part of the Tanezzuft Formation (early-mid Rhuddanian), before passing up into inner shelf marine (shallow marine) in the middle and upper part (late Rhuddanian-Telychian).

CONTENTS

VOLUME 1

LIST OF ILLUSTRATIONS

VOLUME 2

APPENDIXS

Well A28i-NC186

Enclosure 1: Palynomorph stratigraphic ranges
Enclosure 2: Palynomorph presence/absence ranges
Enclosure 3: Palynomorph abundance
Enclosure 4: Palynofacies

Well B2-NC186

Enclosure 1: Palynomorph stratigraphic ranges
Enclosure 2: Palynomorph presence/absence ranges
Enclosure 3: Palynomorph abundance
Enclosure 4: Palynofacies

Well D1-200

Enclosure 1: Palynomorph stratigraphic ranges
Enclosure 2: Palynomorph presence/absence ranges
Enclosure 3: Palynomorph abundance
Enclosure 4: Palynofacies

Well E1-NC174

Enclosure 1: Palynomorph stratigraphic ranges
Enclosure 2: Palynomorph presence/absence ranges
Enclosure 3: Palynomorph abundance
Enclosure 4: Palynofacies

Well H2-NC186

Enclosure 1: Palynomorph stratigraphic ranges
Enclosure 2: Palynomorph presence/absence ranges
Enclosure 3: Palynomorph abundance
Enclosure 4: Palynofacies

Well I3-NC186

Enclosure 1: Palynomorph stratigraphic ranges
Enclosure 2: Palynomorph presence/absence ranges
Enclosure 3: Palynomorph abundance
Enclosure 4: Palynofacies

CHAPTER 1. INTRODUCTION

The Murzuq Basin of southwest Libya is one of the largest Palaeozoic intracratonic sag basins on the North African Sahara Platform. It contains a huge thickness of rocks of Ordovician-Silurian age. These consist mainly of terrigenous sediments included on the Ash Shabiyat, Hawaz, Melez Shugran, Bir Tlacsin, Memouniat and Tanezzuft formations. The Memuniat Formation provides the primary reservoir, and the Hawaz Formation the secondary reservoir. The Early Silurian Tanezzuft Formation (hot shale) is considered to be the main source rock in the basin. Unfortunately the subsurface geology of these sequences is poorly understood, hampering hydrocarbon exploration. Palynology (the study of organic walled microfossils) allows detailed age dating, stratigraphical correlation and palaeoenvironmental analysis of these deposits based on analysis of core and cutting samples selected from six wells drilled recently in the Murzuq Basin that penetrated the Ordovician-Silurian sediments. Those wells were provided by different oil companies including Remsa, Eni-Oil and Akakus Oil Exploration. The main aims of the research can be summarised as follow:

- Identify and systematically describe the different palynomorph groups in the studied sections.
- Use these palynomorphs to shed light on the age and construct a formal palynological zonation scheme. This will be compared with those recorded in other areas in Libya, North Africa and North Gondwana. This may establish a biostratigraphic scheme to be used for correlation within adjacent basins in Libya.
- Investigate the depositional environment on the basis of palynofacies analysis, in order to locate the initial effects of the Late Ordovician glaciation on the palynomorph assemblages across the Ordovician-Silurian boundary.

CHAPTER 2. GEOLOGICAL SETTING

2.1. Introduction to the Ordovician and Silurian period

The Ordovician is a geological period covering about 44 Ma which started at a major extinction event (Cambrian-Ordovician mass extinction event) at 488.3± 1.7 Ma, and ended with another extinction event (Ordovician-Silurian mass extinction event) at 443.7+ 1.5 Ma, it was characterized by the highest biodiversity levels in the Paleozoic Era (Cooper and Sadler, 2004). After the latest Ordovician extinction, rapid recovery in marine biodiversity marked the Silurian period which covers about 28 Ma extending from 439.7± 1.5 Ma to 416.0 ± 2.8 Ma (Melchin *et al.*, 2004). The appearance and evolution of planktonic graptolites during the Ordovician and Silurian Periods are widely developed in sediments around the world and have played a major role in the recognition and correlation of these sediments. Also during both periods, conodonts have proved to be of similar global biostratigraphic value in carbonate facies. Trilobites and brachiopods enable zonation in shelly facies. Coral stromatoporoid communities provide useful biostratigraphic subdivision in the late Ordovician. Other marine fossils such as chitinozoans and acritarchs have also proved to be useful in the correlation for both periods. However the zonation based on these two groups is still being developed and it is expected that long range correlation and precision will improve (Gradstein *et al*., 2004).

2.1.1. The Ordovician period

2.1.1.1. International division

According to the International Commission on Stratigraphy (ICS), the Ordovician period is divided into three global series and seven stages (Fig. 1). The lower systemic Cambrian-Ordovician boundary is defined by the GSSP in the Green Point section of western Newfoundland by Cooper and Nowlan (1999) and Cooper *et al.* (2001). This boundary coincides with the appearance of conodont *Lapetognathus fluctivagus* at the base of the *L. fluctivagus* Zone at

Green Point. The boundary also coincides with the appearance of the trilobites *Jujuyaspis borealis* and *Symphysurina bulbosa* (Cooper and Sadler, 2004), which are useful for correlation in carbonate successions. The upper systemic Ordovician-Silurian boundary is defined by Melchin and Williams (2000) at the base of the graptolite-based *Akidograptus ascensus* Zone at Dob′s Linn in Scotland.

2.1.1.2. Stages of Early Ordovician Series

2.1.1.2.1. Tremadocian Stage

The name of this stage is derived from Tremadog, a town in North Wales; the lower boundary of this stage is the same as the conodont-based Cambrian-Ordovician boundary. In carbonate successions, this boundary coincides with the appearance of the trilobites *Jujuyaspis borealis* and *Symphysurina bulbosa* (Cooper and Sadler, 2004). The upper and lower boundaries of this stage almost exactly coincide with those of the British Tremadocian Series (Rushton, 1982; Cooper and Sadler, 2004; Webby *et al*., 2004).

2.1.1.2.2. Floian Stage

This stage is defined at the first appearance of the graptolite *Tetragraptus approximatus* in a section exposed in the Diasbrottet quarry on the northwestern slope of Mountain Hunneberg, southern Sweden (Bergström, *et al*., 2004). This biostratigraphic datum has proved a distinctive and reliable marker which is also adopted for the base of the revised British Arenigian Series (Fortey *et al.*, 1995).

2.1.1.3. Stages of the Middle Ordovician Series

2.1.1.3.1. Dapingian Stage

A level in the middle Arenigian of the British Series is being considered by the Ordovician Subcommission as the base of the Dapingian Stage and the Middle

Ordovician Series. This level coincides with the first appearance of a conodont, either *Protoprioniodus aranda or Baltoniodus triangulates,* and the first appearance of the graptolite *Isograptus victoriae lunatus* (Cooper and Sadler, 2004).

2.1.3.2. Darriwilian Stage

The base of the Darriwilian Stage has been placed at the first appearance of the graptolite *Undulograptus austrodentatus* in the Huangnitang section, near Changshan, southeast China (Chen and Bergström, 1995; Mitchell *et al.*, 1997; Cooper and Sadler, 2004). This stage corresponds exactly to the Australasian stage after which it is named (VandenBerg and Cooper, 1992).

2.1.1.4. Stages of the Late Ordovician Series

2.1.1.4.1. Sandbian Stage

The base of the Sandbian and of the Late Ordovician Series is defined at the first appearance of the globally distributed zonal graptolite *Nemagraptus gracilis* in Sularp Brook in Fågelsång, Sweden (Bergström *et al.*, 2000; Cooper and Sadler, 2004). *Nemagraptus gracilis* is also used to define the base of the British Caradocian Series (Fortey *et al.,* 1995) and the Australasian Gisbornian Stage (VandenBerg and Cooper, 1992). This stage also lies within the condont zone *Pygodus anserinus,* which has global correlation value (Cooper and Sadler, 2004).

2.1.1.4.2. Katian Stage

The base of the Katian is defined at the first appearance of the graptolite *Diplacanthograptus caudatus* in sections at Black Knob Ridge, Oklahoma, USA, and Hartfell Spa, southern Scotland, UK. The base of this stage is close to the British Ashgillian Series and Australian Bolindian Stage (Cooper and Sadler, 2004).

2.1.1.4.3. Hirnantian Stage

The classical Hirnatian Stage was the uppermost subdivision of the Ashgillian regional stage of Britain, and is named after Cwm Hirnant near Bala, in northern Wales. The base of this stage coincides with the base of the *Normalograptus extraordinarius-N. ojsuensis* graptolite zone in the Wangjiawan section in China (Chen, 2006). The top of the stage is defined by the base of the overlying Silurian System at the base of the *Akidograptus acuminatus* zone, marked by the first appearance of the graptolite *Akidograptus ascensus* in the Dob's Linn section of southern Scotland (Melchin and Williams, 2000).

2.1.1.5. Previous standard divisions

2.1.1.6. British series

The British series of the Ordovician were until recently widely used around the world. They are classified based on graptolites and conodonts (in ascending order: Tremadocian, Arenigian, Llanvirnian, Caradocian and Ashgillian; Fig. 2.1) and established in North Wales and England. Fortey *et al*. (1995) reviewed and redefined this system. Their classification was accepted and adopted by Cooper and Sadler (2004) and Webby *et al*. (2004). More recently, Cocks *et al*. (2009) discussed and correlated the British series with the international series and stages.

2.1.1.6.1. Tremadocian

Fortey *et al*. (1991) proposed the horizon of appearance of the graptolite *Rhabdinopora flabelliforme sensu lato* at Bryn-llyn-fawr in North Wales to be the base of the Tremadocian. This level was accepted and adopted by Fortey *et al.* (1995) and Cocks *et al*. (2009) to mark the base of the Ordovician and the Tremadocian, especially in areas that lack conodont-yielding limestones.

2.1.1.6.2. Arenigian

Fortey *et al.* (1995) proposed that the base of the Arenigian is to be taken at the base of the *Tetragraptus approximatus z*one. The best section to represent this level in Britain is Trusmador in the Lake District, but the zone base cannot yet be located with any precision (Cooper and Sadler, 2004).

2.1.1.6.3. Llanvirnian

The base of the Llanvirnian has generally been taken at the base of the *Didymograptus artus* zone of the British scheme. Elles (1925) and Fortey *et al.* (1995) indicate an appropriate section for the boundary stratotype in the Llanfallteg Formation in South Wales. However, this boundary cannot be precisely located in low palaeolatitudes and therefore was not favored as an international correlation datum. The Llanvirnian now is included within the Darriwilian which also includes the uppermost part of the Arenigian.

2.1.1.6.4 Caradocian

The base of the Caradocian series has been taken at the base of the graptolite zone of *Nemagraptus gracilis* and the bulk of the Llandeilo Series has been removed to the Caradocian (Fortey *et al*., 1995; Cooper and Sadler, 2004).

2.1.1.6.5. Ashgillian

Fortey *et al.* (1995) correlate the base of the Ashgillian Series with a level within the *Pleurograptus linearis* zone of the British scheme and just above the base of the conodont zone of *Amorphognathus ordovicicus*. Cooper and Sadler (2004) followed Webby *et al*. (2004) in aligning the base with the base of the Australasian Bolindian Stage and the *Amorphognathus ordovicicus* zone.

2.1.1.7. Australasian stages

The Australasian stages are nine graptolite-based stages used for the Ordovician of Australia and New Zealand (VandenBerg and Cooper, 1992). In upward sequence they are the Lancefieldian, Bendigonian, Chewtonian, Castlemanian, Yapeenian, Darriwilian, Gisbornian, Eastonian and Bolindian Stages. They have been proved to be widely applicable in graptolite successions around the world, particulary those representing low palaeolatitude regions such as North America, Cordilleran South America, Greenland and Spitsbergen (Cooper and Sadler, 2004).

2.1.2. The Silurian Period

The Silurian is divided into four series, the Llandovery, Wenlock, Ludlow and Pridoli, (Fig. 2). The upper boundary of the Ordovician forms the lower boundary of the Silurian. As mentioned before, this boundary is defined at the base of the graptolite-based *Akidograptus ascensus* zone at Dob's Linn in Scotland (Melchin and Williams, 2000). The Upper Silurian/Devonian boundary is defined by the last occurrence of graptolite species *Monograptus transgrediens* and the first appearance of the graptolite species *Monograptus uniformis* at the Devonian System (Lochkovian Stage).

2.1.2.1. Stages of the Llandovery Series

2.1.2.1.1. Rhuddanian Stage

The systemic Ordovician-Silurian boundary defines the base of this stage. Melchin and Williams (2000) defined the Rhuddanian Stage that spans the *Akidograptus ascensus* to *Coronograptus cyphus* zones.

2.1.2.1.2. Aeronian Stage

The base of this stage is defined at just below the level of occurrence of the graptolite *Monograptus austerus sequens*, which indicates the *Monograptus triangulatus* zone in the stratotype section at the Trefawr Formation, UK (Melchin *et al*., 2004).

2.1.2.1.3. Telychian Stage

The base of this stage is placed at the base of the graptolite-based *Spirograptus guerichi* zone and the stratotype section is located in Cefn-Cerig, UK (Melchin *et al*., 2004).

2.1.2.2. Stages of the Wenlock Series

2.1.2.2.1. Sheinwoodian Stage

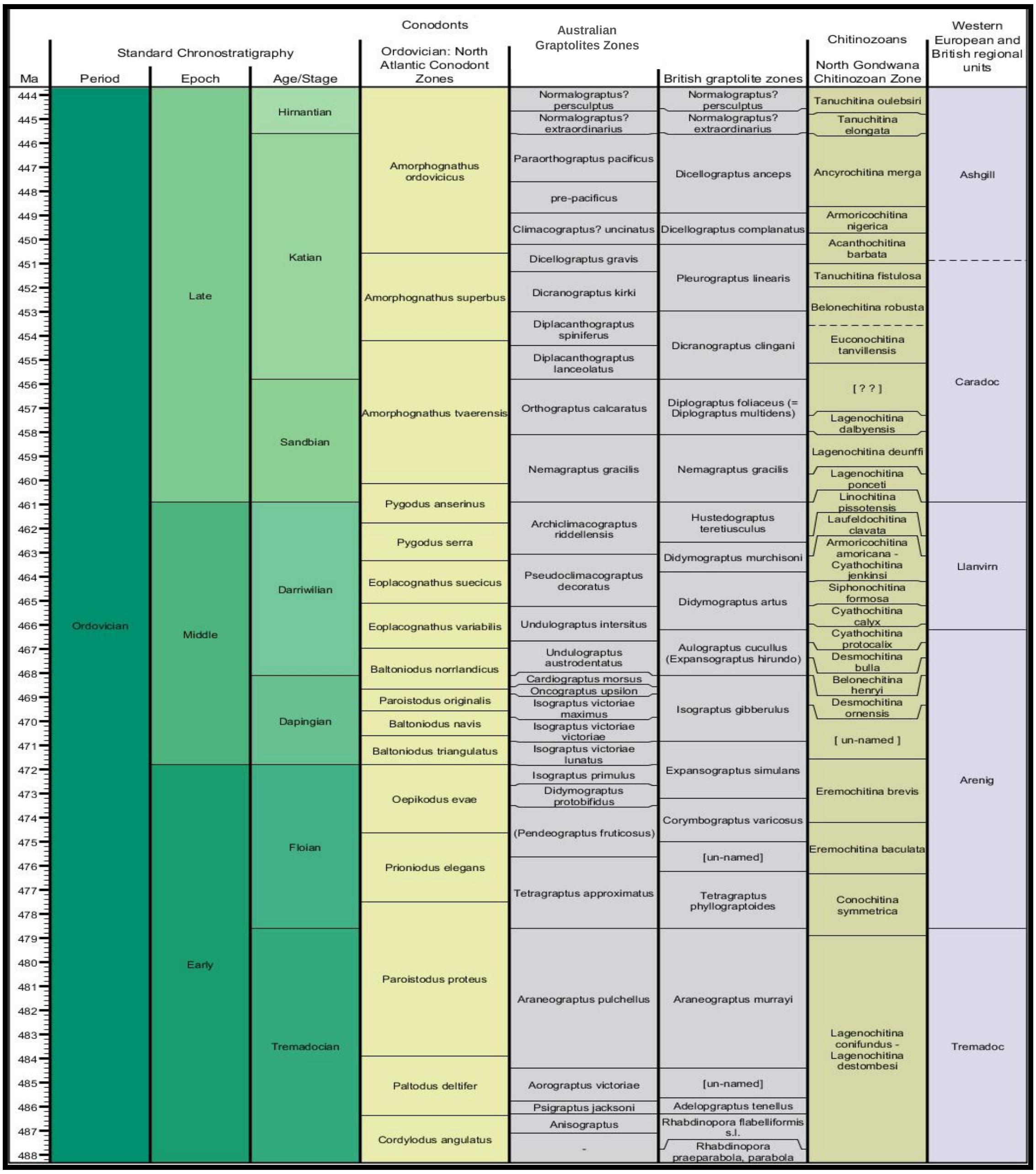


Fig. 1. The Ordovician chronostratigraphy with graptolite, conodont andchitinozoan zonal schemes of Webby *et al*. (2004). Chart is constructed using TimeScale Creator, version 5.3 (Lugowski *et al*. 2012).

The stratotype point of this stage occurs within the *Pterospathodus amorphognathoides* conodont zone at the base of the Buildwas Formation in Hughley Brook, Apedale, UK (Mabillard and Aldridge, 1985). This level is considered to be approximately correlative with the base of the *Cyrtograptus centrifugus* graptolite zone (Melchin *et al*., 2004).

.

2.1.2.2.2. Homerian Stage

The base of this stage is at the point of first appearance of a graptolite fauna containing *Cyrtograptus lundgreni* in the stratotype section in Whitwell Coppice, Homer, UK (Melchin *et al*., 2004).

2.1.2.3. Stages of the Ludlow Series

2.1.2.3.1. Gorstian Stage

The base of the Gorstian is assigned to a level within the graptolite based *Neodiversograptus nilssoni* zone with the stratotype point occuring in Pitch Coppice, Ludlow, UK (Melchin *et al*., 2004).

2.1.2.3.2. Ludfordian Stage

The stratotype point is at Sunnyhill, Ludlow, UK and is considered to approximate the base of the graptolite-based *Saetograptus leintwardinensis* zone (Melchin *et al*., 2004).

2.1.2.4. The Pridoli Series

This series has not been subdivided into stages. It is marked by the first appearance of the graptolite *Monograptus parultimus* in the stratotype section in Pozary, Prague, Czech Republic (Melchin *et al*., 2004).

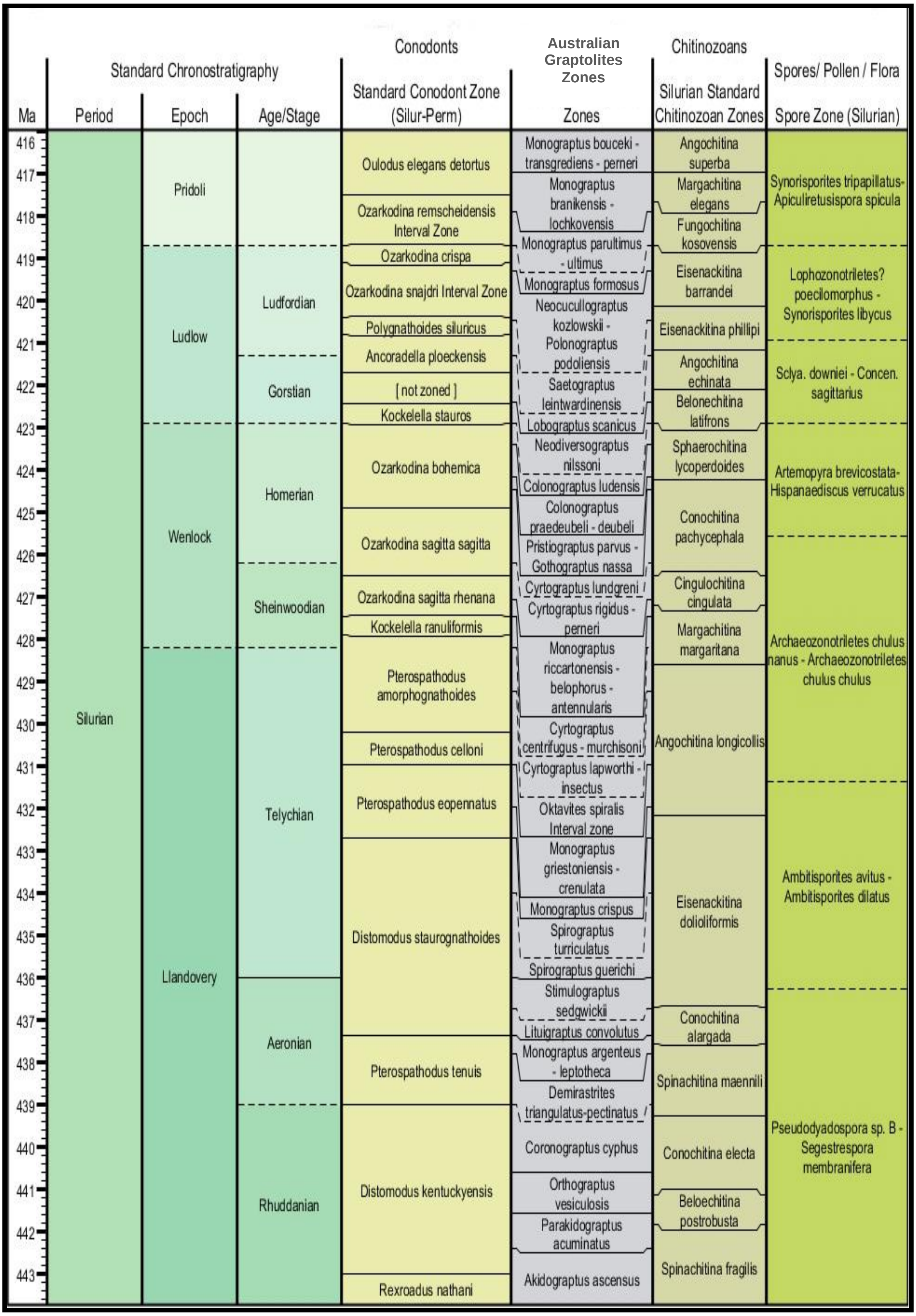


Fig. 2. The Silurian chronostratigraphy with graptolite, conodont and chitinozoan zonal schemes. Graptolite and conodont zonal schemes are generalised schemes from Melchin *et al*. (2004). Chitinozoan zonal scheme is from Verniers *et al*. (1995). Chart is constructed using TimeScale Creator, version 5.3 (Lugowski *et al*., 2012).

2.1.3. Ordovician Silurian Palaeocontinental reconstructions

2.1.3.1. Palaeogeography

During the Ordovician and Silurian periods four major palaeocontinents, Laurentia, Siberia, Baltica and Gondwana, were present, and separated by three major Oceans, the Panthalassic Ocean (Figs.3, 4), Paleotethys Ocean and Iapetus Ocean (Cocks, 2001; Scotese, 2003). The positions of these continents are suggested to be relatively stable and in an equatorial position during the Ordovician and Silurian periods based on palaeomagnetic evidence and the widespread occurrence of tropical carbonate (Cocks, 2001; Fortey and Cocks, 2003). As the Ordovician progressed several terranes including Avalonia, Armorica, Perunica, Iberia and Alpine fragmented from Gondwana and drifted further away from the supercontinent. They developed variable and progressively distinctive faunas of their own until the latest Ordovician.

2.1.3.1.1. Gondwana

Most of the world's land masses were joined to form the supercontinent of Gondwana. Its large stable core comprising Africa, South America, Florida, Arabia, greater India, Antarctica, New Guinea, and most of Australia, (Cocks, 2001; Cooks and Torsvik, 2002; Fortey and Cocks, 2003). During the Ordovician Gondwana started to move southwards and by the mid-Ordovician, it was mostly polar and only its northern margin was equatorial. By the Latest Ordovician Gondwana was located over the South Pole (Fig. 5, 6), that was located within North Africa (Scotese *et al*., 1999; Cocks and Torsvik, 2002; Fortey and Cocks, 2003; Ruban *et al*., 2007). Situated at high latitudes, the super-continent supported a continental-scale glaciation that is recorded throughout western Gondwana (Ghienne *et al*., 2007b). During the Late Ordovician glaciation, ice sheets grew and decayed repeatedly on the West Gondwana platform (Sutcliffe *et al*., 2000; Ghienne *et al*., 2007b; Le Heron and Craig, 2008).

2.1.3.1.2. Laurentia

Laurentia consisted mainly of the North American continent (USA and Canada), Greenland, western Newfoundland, Spitsbergen, the British Isles north of the Iapetus structure and the Chukhot peninsula (today part of Siberia). It is bounded to its south by the Ouachita tectonic belt (Fortey and Cocks, 2003). The Ordovician and Silurian were times of relative tectonic inactivity in Laurentia. Both palaeomagnetic and faunal data suggest that Laurentia was relatively stable in an equatorial position during the entire Ordovician. There is no evidence of any substantial rotation during this period.

2.1.3.1.3. Baltica

Baltica included the great part of Scandinavia, but not the Trondheim area, which has Laurentian affinities, and northern Europe as far south as the Tornquist structure, Russia as far east as Urals, with southern extensions into Kazakhstan and northern extinctions into Pai Khoi and Novaya Zemlya (Cocks and Torsvik, 2002; Fortey and Cocks, 2003). It was situated far south of the equator as late as the Mid Ordovician (Fortey and Cocks, 2003; Scotese, 2003). During the Silurian it had drifted northwards and collided with the eastern margin of Laurentia, closing to the northern branch of the Iapetus Ocean (Scotese, 2003).

2.1.3.1.4. Siberia

The palaeocontinent Siberia consists of a main craton formed by the present day area east of the Urals and north of Asian fold belts (Fortey and Cocks, 2003), but also includes Timyr and Tuva.The continent moved from the south to the north, across the palaeo-equator into northern low temperate latitudes during the Ordovician (Fortey and Cocks, 2002). By the Mid Silurian it had drifted to northerly higher latitudes (Fortey and Cocks, 2003; Scotese, 2003).

2.1.4. Ordovician Silurian palaeoenvironment

2.1.4.1. Palaeoclimate

Regional climate is controlled by global condition, latitude, location and elevation of the area. Most of the Palaeozoic, from the Cambrian to the Early Caboniferous, has been interpreted as a greenhouse period (Berner, 1994; Berner and Kothavala, 2001), interrupted by short-lived ice ages in the Hirnantian (Brenchley, 2004) and the Late Devonian. In the Ordovician palaeogeographic context Laurentia was in a warm equatorial position, whereas Baltica moved from temperate latitude to a warmer subtropical position in the Late Ordovician, as documented by the sediments and fauna (Nestor and Einasto, 1997). The northern Gondwana regions remained at high latitudes and underwent a cold climate during the onset of the Late Ordovician glaciation, especially during the Hirnantian glacial maximum.

The Early and Middle Ordovician climate was suggested to be a ‘greenhouse’ world without polar icecaps, and considered to be a warm climate (Frakes *et al*., 1992), with wide tropical and warm temperate marine belts. Conditions gradually declined into an icehouse with a major glaciation event occurring at the Ordovician-Silurian boundary (Herrmann *et al*., 2004b). The continents were generally covered by shallow seas, creating warm, broad tropical seaways (Scotese, 2003). Using oxygen isotope composition of biogenic phosphate, Basset *et al.* (2007) suggested that the palaeotemperature was about 37°C in the Early Ordovician. Trotter *et al*. (2008) have also suggested modern equatorial temperatures that were sustained throughout the Mid Ordovician. Overall the greenhouse effect dominated most of the Ordovician (Hermann *et al*., 2004).

The Late Ordovician and Early Silurian time is one of the most extensive cool climates in the Phanerozoic (Frakes *et al.* 1992). The Late Ordovician is marked by a massive glaciation event, reported in deposits across Gondwana (Hambrey, 1985), the best documented being those of the central Sahara. Tillites occur over a wide area of Algeria, Libya and Mali (Beuf *et al*., 1971). The resulting glaciation caused the second largest mass extinction in Earths’ history, a eustatic fall of up to 60 m and a significant increase in sediment supply to glaciated continental shelves (Brenchley *et al.*, 1994; 1995; Sutcliffe *et al*., 2000a, b, 2001). The glaciation was possibly of short duration and almost entirely restricted to the *extraordinarius* zone of the Hirnantian stage, which was of <0.5 My duration (Sutcliffe *et al*., 2000b). Palaeoclimates are mainly inferred from geological interpretations of the rock strata by utilizing lithological indicators of climate including coals, evaporites, bauxites and tillites. The Paleomap Project (Scotese, 2003), based on geological interpretations indicate a cold and dry Mid to Late Ordovician environment at high latitudes. By using both global climate models (Herrmann *et al.,* 2004a) and an ocean general circulation model (Herrmann *et al.,* 2004b), for two stages of the Late Ordovician (Caradocian-Ashgilian), models indicate a cold climate (sub 0ºC mean annual temperature) at high latitudes during the Late Ordovician.

Following the Late Ordovician glaciation, the Silurian is generally regarded as a time of gradually warming climate (Frakes *et al.*, 1992). From the Wenlock to the Pridoli the global temperature was warm to hot (Cocks, 2005). Trotter *et al.* (2008) suggested that during the Silurian the temperature returned to its modern equatorial conditions with estimates of 30°C in Wenlock times.

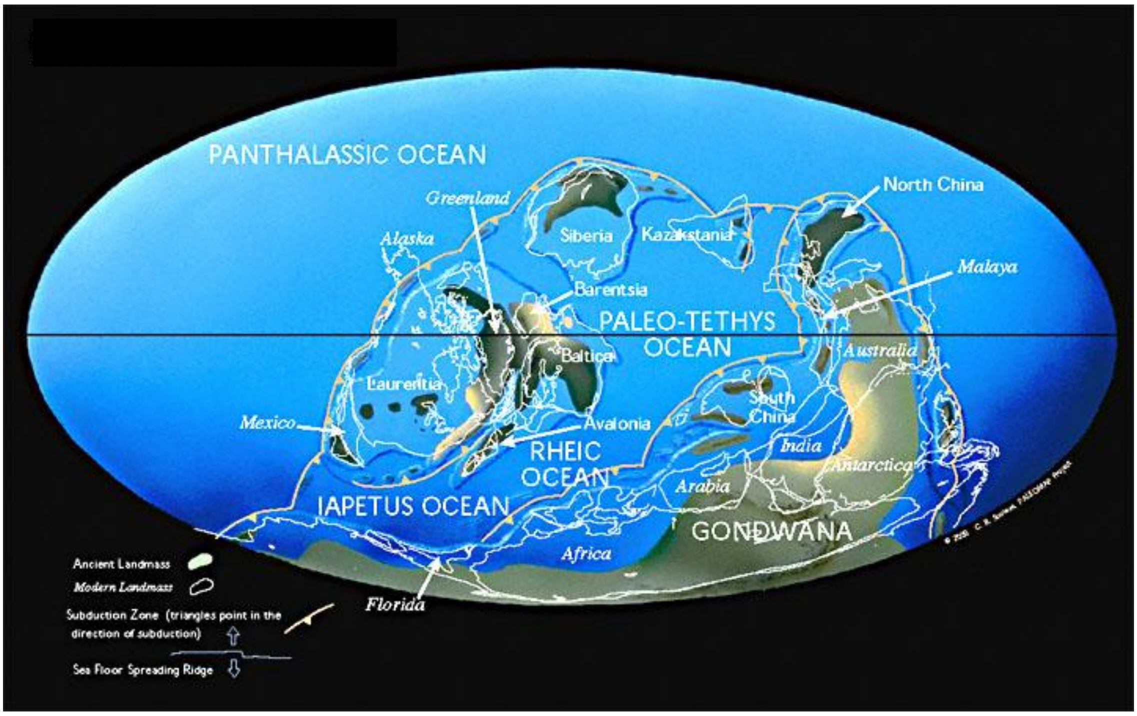

[redacted]

Fig. 3. Main palaeocontinents and their position during the Mid Silurian (from Scotese, 2003).

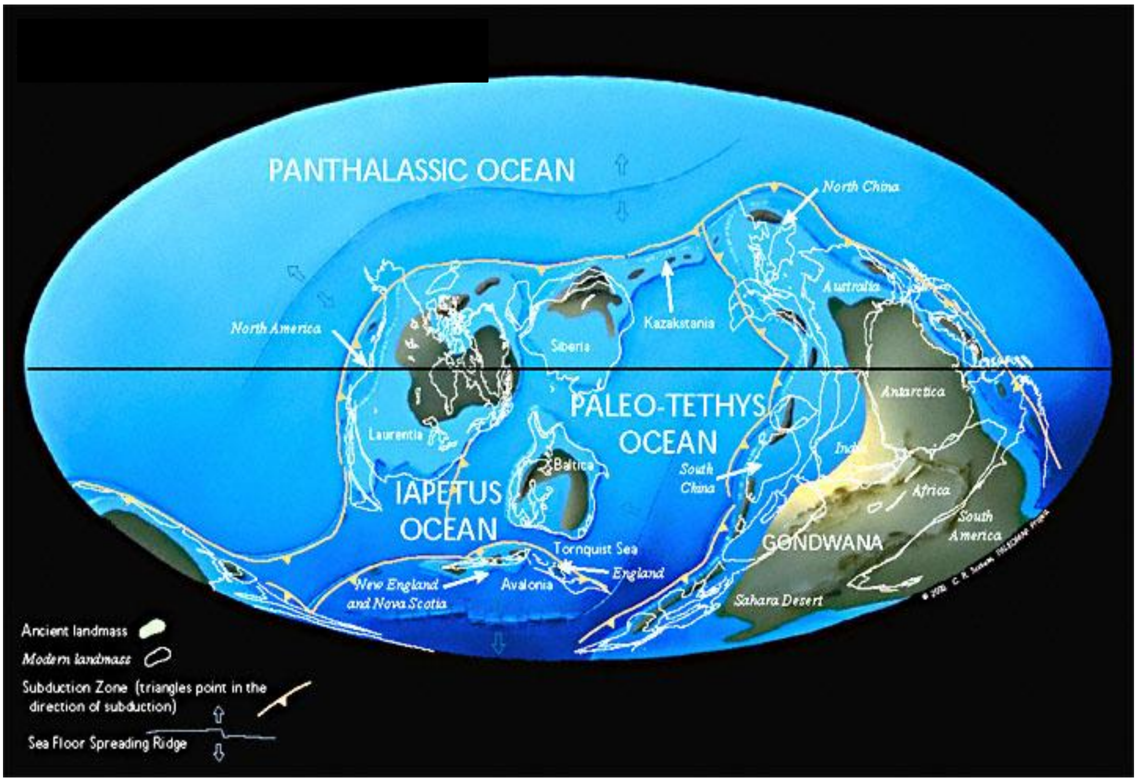


Fig. 4. Main palaeocontinents and their position during the Mid Ordovician (from Scotese, 2003).

LATE ORDOVICIAN –EARLY SILURIAN: 440 Ma

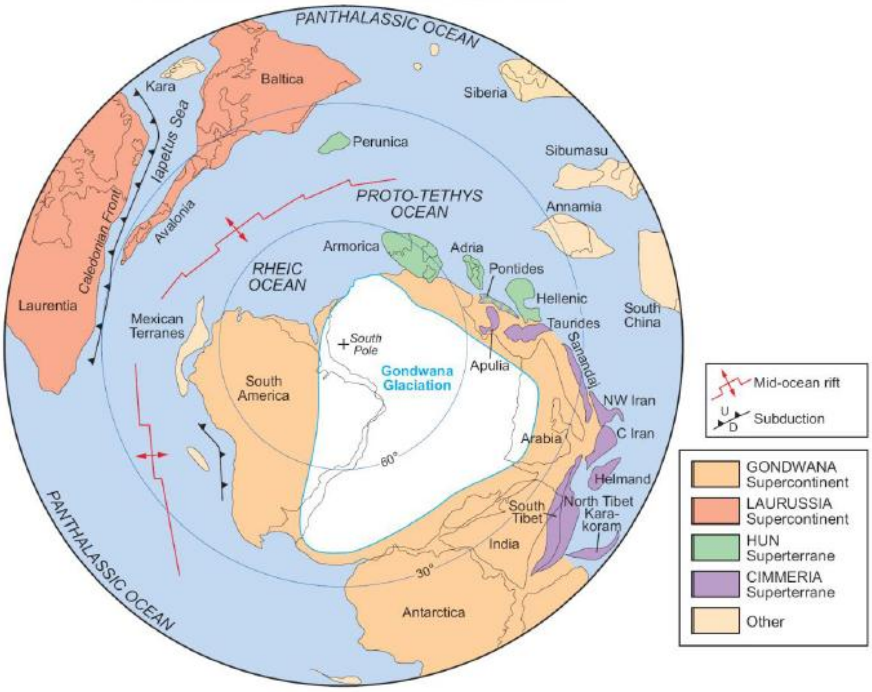


Fig. 5. Plate-tectonic reconstruction of latest Ordovician-earliest Silurian times, showing polar glaciers advanced over regions of Gondwana reaching western Saudi Arabia. From Ruban *et al.* (2007).

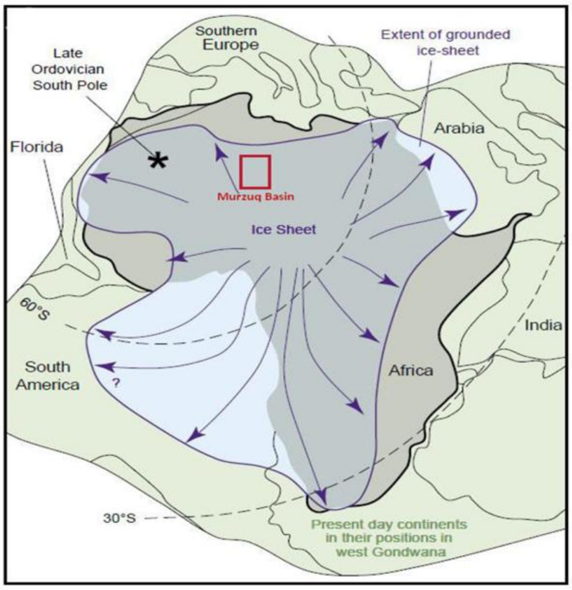


Fig. 6. Palaeogeographic reconstruction of West Gondwana showing the extent of the Late Ordovician ice sheet. (after Beuf *et al*. 1971; Sutcliffe *et al*. 2000a and Le Heron *et al*., 2004).

2.1.4.2. Sea level

Ordovician sea level curves have been proposed by several authors (e.g. Nicoll *et al.*, 1992; Ross and Ross, 1992, 1995; Nielsen, 1992, 2004). Significant, abrupt eustatic changes are recognized in Baltoscandia by Nielsen (2004; Fig. 7). The Nielsen curve indicates that the Ordovician is characterised by average high sea level that may even be the highest in the entire Phanerozoic. Nielsen (2004) recognized three sea level high stand and three lowstand intervals, the early to mid Tremadocian, the mid Arenigian and late Llanvirnian-Caradocian high stand intervals, and the late Tremadocian-early Arenigian, late Arenigian-early Llanvirnian and Ashgillian (Hirnantian) low stand intervals.

Several approaches have also been proposed to estimate eustatic changes for the Silurian (e.g. Johnson *et al.*, 1991; Johnson, 1996; Ross and Ross, 1996; Loydell, 1998). According to Loydell (1998), the highest sea-levels are recorded in the Telychian (Fig. 8). Other highstands occurred in the early Aeronian, early Telychian and early Sheinwoodian. Low sea-levels characterized much of Aeronian and the mid-late Homerian after a period of small amplitude sea-level fluctuations in the late Sheinwoodian-earliest Homerian.

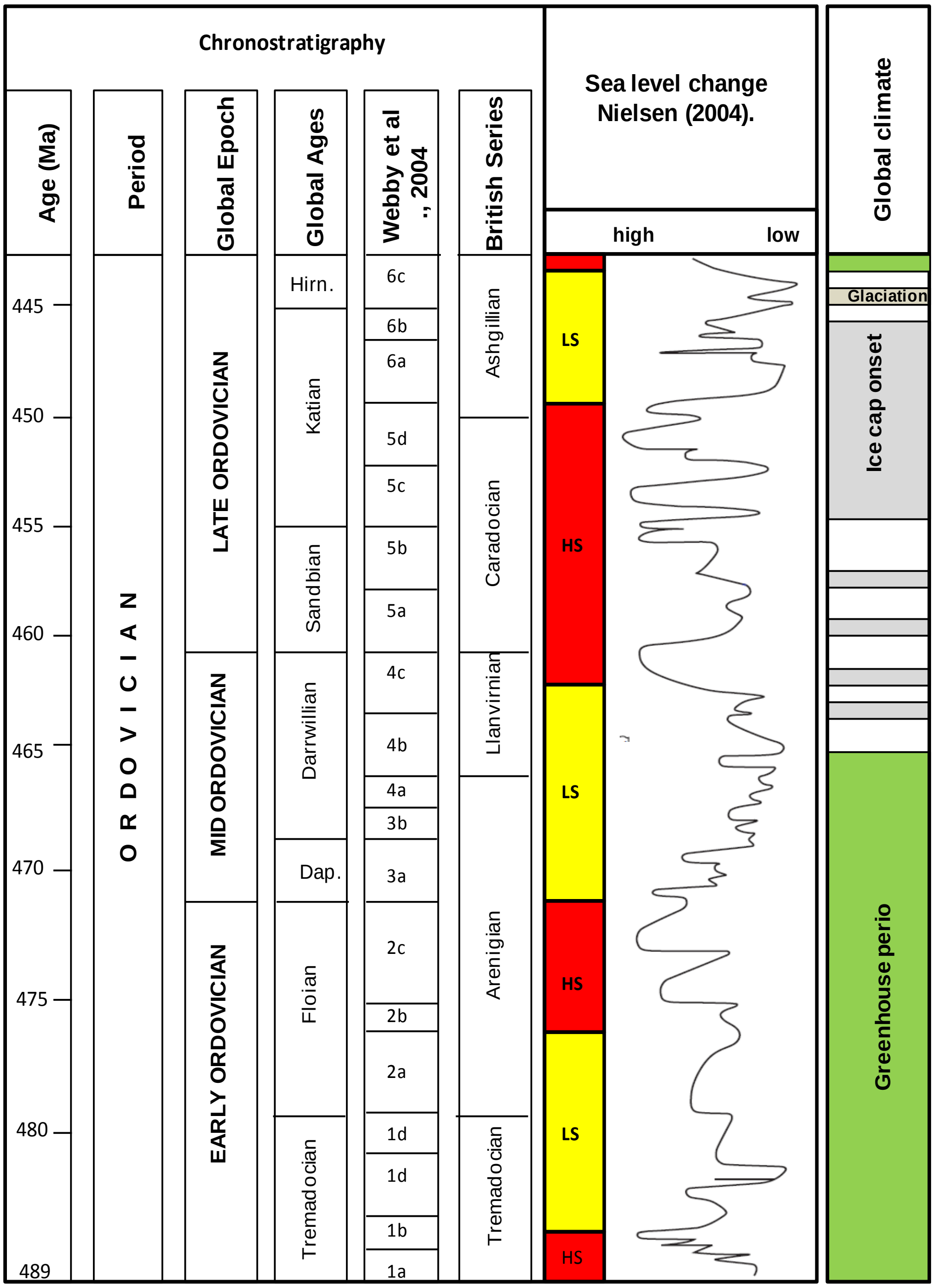


Fig. 7 Sea level curve for the Ordovician of Baltoscandia. Modified from Nielsen (2004) and Achab and Paris (2007).

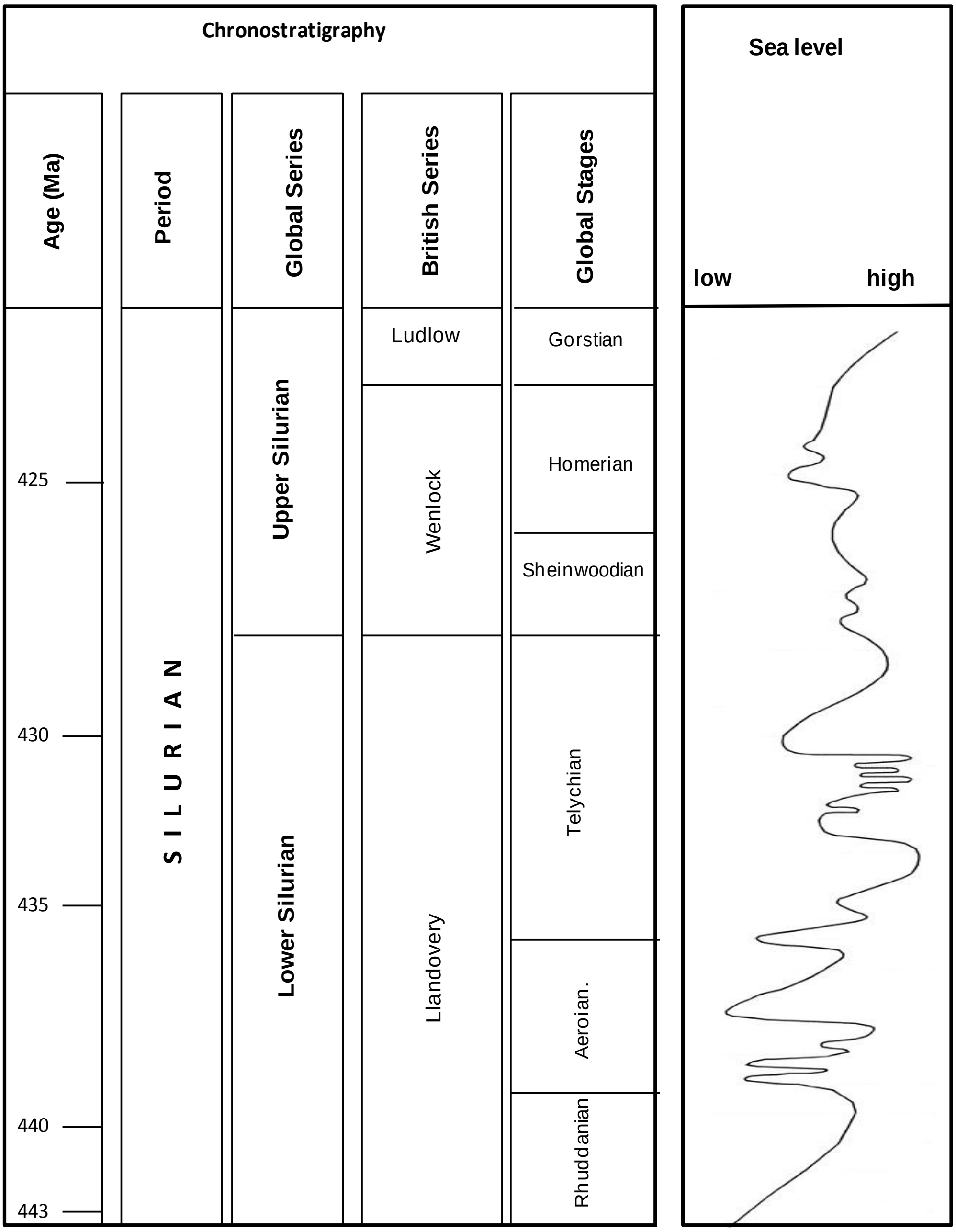


Fig. 8. Global sea level curve for the Silurian. Modified from Loydell (1998).

2.1.5. Ordovician and Silurian life

The Ordovician Period encompasses one of the greatest evolutionary radiations recorded in the Phanerozoic and the resulted biodiversification event is the earliest and most important event in the evolution of the Palaeozoic fauna (Webby 2004). The process of radiation was heterogeneous, in both time and space, and gradual, spanning for more than 40 million years resulting in expansion in what Sepkoski (1995) has termed the Palaeozoic Evolutionary Fauna. This event replaced the Cambrian Evolutionary fauna with considerably more complex Palaeozoic and Modern Evolutionary Faunas (Fig. 9). Genera numbers increased three to fourfold (Trotter *et al.*, 2008) and major generic increases were recorded in brachiopods, trilobites, echinoderms, gastropods, bivalves, ammonoids, graptolites and conodonts (Sepkoski, 1995). According to Zhan *et al.* (2008), brachiopods, trilobites and graptolites were the most diverse and dominant life in all marine environments in the Ordovician times. Also some forms of life appeared in this period like corals and bryozoans (Zhan *et al.*, 2008). It has also been shown that there was an increase in trace fossils complexity and bioturbation (Fortey, 2005).

The Ordovician biodiversification event was terminated by a sudden and catastrophic mass extinction at the end of the Ordovician (Fig. 9) extinguished many marine animal families, making it one of the largest in the Phanerozoic (Sepkoski, 1995; Sheehan, 2001; Brenchley, 2004; Trotter *et al.*, 2008). Trilobites, brachiopods, graptolites, echinoderms, conodonts, corals, and chitinozoans were drastically reduced in generic diversity. The extinction event coincides with the Late Ordovician glaciation and was probably brought about by a combination of cold and fluctuating temperatures, perturbation of the ocean stratification and circulation systems, sea-level fluctuations and reduced shelf and platform-habitable space (Sheehan, 2001; Brenchley, 2004; Trotter *et al.*, 2008).

During the Silurian and after the Late Ordovician mass extinction event, communities were able to re-establish comparable complexity. Invertebrates were abundant and diverse (Cocks, 2005). The benthos was dominated by brachiopods, bivalves, gastropods, corals, stromatoporoids, bryozoans, echinoderms and trilobites. The plankton life remained common and diverse including cephalopods, graptolites, and a variety of microplankton, particularly acritarchs and chitinozoans (Melchin *et al.*, 2004; Cocks, 2005). Fishes became more abundant with jawless fish invading brackish and fresh water. The first true terrestrial ecosystem is represented by convincing fossils of vascular plant These terrestrial ecosystems became more complex, especially during the Late Silurian (Cocks, 2005).

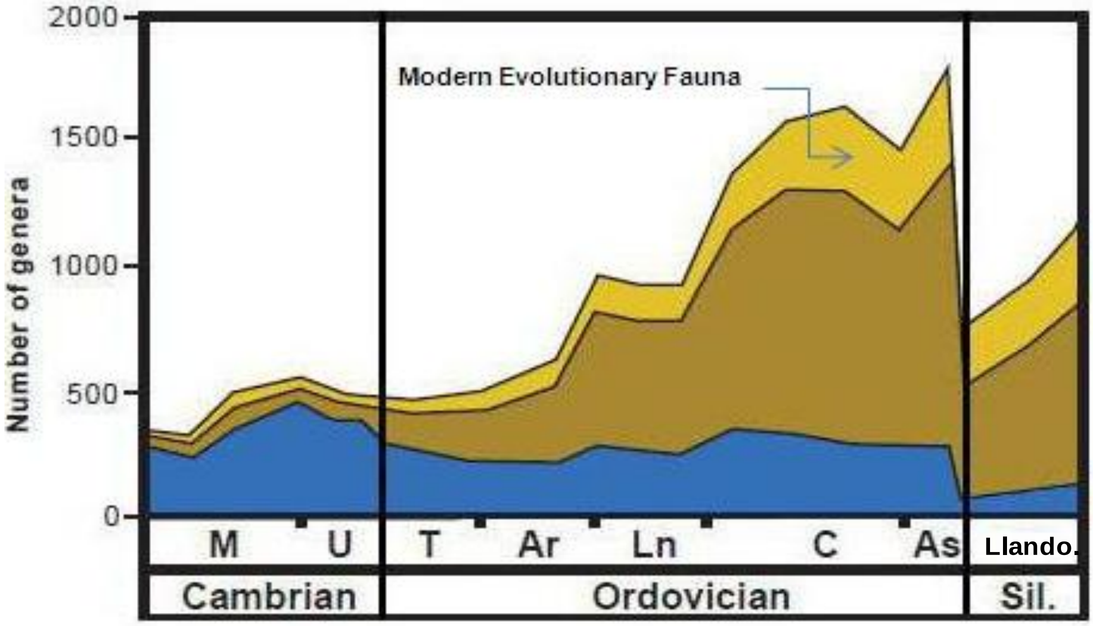


Fig. 9. Biodiversity patterns of marine fauna through geological time. Mid Cambrian to Early Silurian (after Sepkoski, 1995).

2.2 Regional framework

2.2.1 Introduction

Libya occupies an area of some 1.8 million km² with an 1800 km shoreline along the southern margin of the Mediterranean Sea between approximately Lat. 20º-33º N and Long. 10º-25º E. It is bounded on the north by the Mediterranean Sea, on the east by Egypt and the Sudan, on the west by Tunisia and Algeria, on the south by Chad and Niger. It includes a large part of Sahara Desert, which extends across North Africa from the Atlantic Ocean to the Red Sea. Libya contain three climatogeographic zones: the Mediterranean littoral Zone which is most heavily populated and suitable for agriculture; a semi desert zone which is grazing land; a desert zone contain several fertile oases.

2.2.2 Geology of Libya

Libya is a part of Mediterranean foreland formed by the North Africa Shield, and has a sedimentary section that has been subjected to transgressions and regressions since the early Palaeozoic. It is a mix of marine and non marine sediments (shale and sandstone) and other shallow marine carbonates that have been deposited all over the platforms formed in local cratonic basins. The country has proven oil reserves of some 43.7 billion barrels entrapped in Palaeozoic sediments in the Murzuq and Ghadames Basins of northwest and southwest Libya, the Mesozoic and Tertiary sediments in the Sirt Basin of north central Libya (which is responsible for 90 percent of the country’s oil output), the Tripolitania Basin of northwest off shore Libya, and Benghazi and Derna Basins, northeast Libya (Fig. 10).

The main tectonic activity that shaped the structure of Libya (Fig.10) is the compressional early Palaeozoic Pan-African events which created vertical north-south trending basement faults counterbalanced by conjugated northeast-southwest trending faults. The Hercynian correspond to a second major tectonic event. A third extension event (Alpine) is related to the Cretaceous, middle Tertiary and Holocene events. The structure of southern Libya was influenced by the Pan-African event, whereas the central part of Libya was much affected by the Hercynian tectonic events. On the other hand the structures of north Libya are attributed to the Tethyan extension and Alpine tectonic movements (Goudarzi, 1980). The Mediterranean began to develop in the Early Jurassic with a E-W axis direction, but by the Early Cretaceous Mediterranean Sea floor spreading had ceased entirely.

2.2.3. Geology of Murzuq Basin

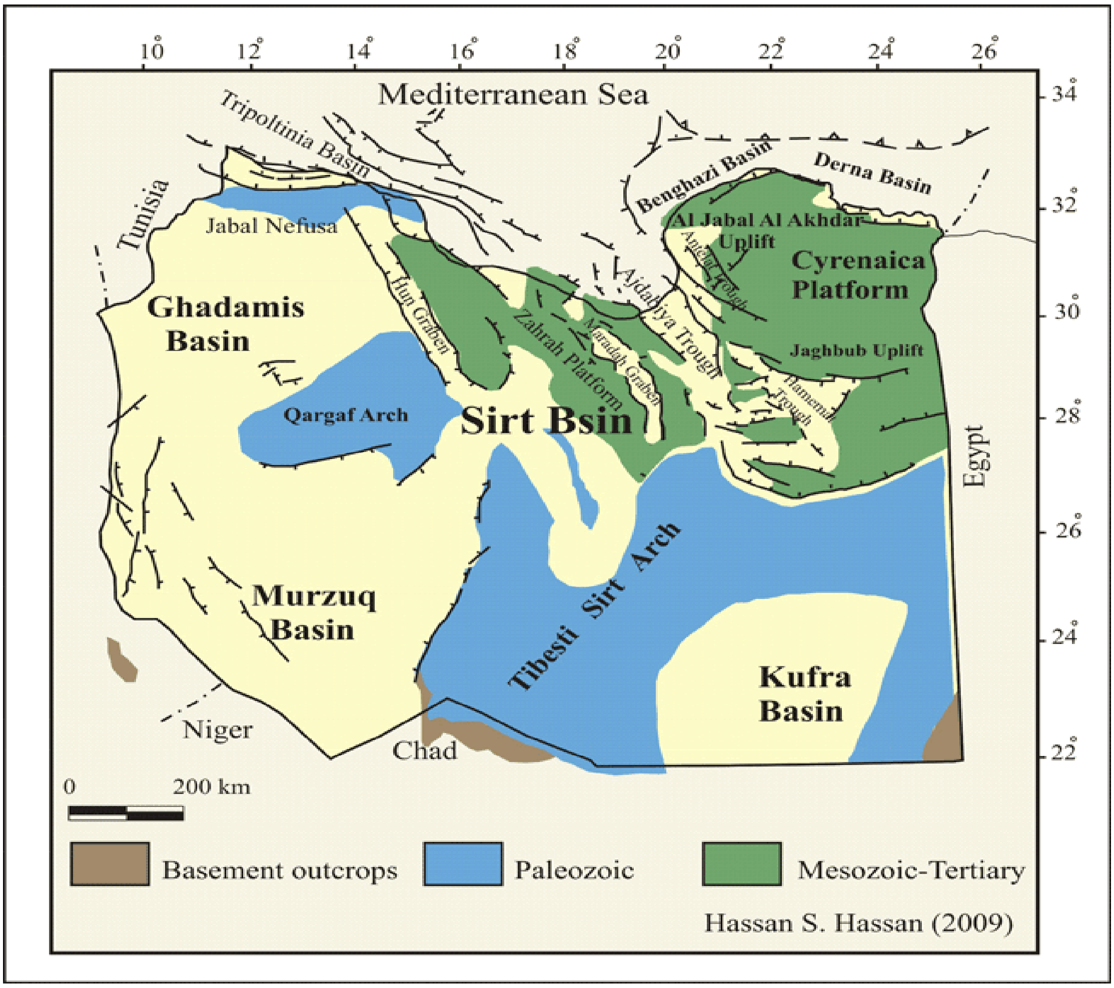
The Murzuq Basin of southwest Libya is one of the largest Palaeozoic intracratonic sag basins on the North African Sahara Platform. The structural fabric of the basin was developed during the late Proterozoic Pan-African orogenic events, which strongly influenced the stratigraphy and depositional patterns within the predominantly Palaeozoic clastic basin fill. However, the basin was filled by Palaeozoic sediments and overlain by Mesozoic and Cenozoic sequences. The total succession has a thickness of up to 3500 m in the central part of the basin. The Palaeozoic sequence comprises Cambrian, Ordovician, Silurian, Devonian and Carboniferous rocks. In spite of recent exploration it is still a poorly explored basin. The Early Silurian Tanezzuft Formation (hot shale) and Middle-Late Devonian Awaynat Wanin Formation (hot shale) are considered to be the main source rocks and the Ordovician Memuniat Formation provides the primary reservoir, the Hawaz Formation is the secondary reservoir (Echikh and Sola 2000). Other local source rocks have been recognized within the Palaeozoic sequences, such as Carboniferous sediments, the Mrar Formation which has contributed to charging of the Palaeozoic and Mesozoic reservoirs in the Murzuq Basin (Sikander *et al*., 2000; Al Festawi *et al*., 2000; Halt, 2002).

2.2.3.1 Geographic Location

The Murzuq Basin is triangular in shape with its point oriented to the south, towards Chad (Bellini and Massa, 1980). The southern half of the basin extends to north Niger and is called the Jadu Basin. It covers an area of over 350,000 km^2. The basin is bounded to the north by the Al Qargaf uplift, to the east by the Tibesti uplift and to the west by the Tihemboka Arch. To the south it extends into Niger and is also known there as the Jadu Basin (Fig.11A).

2.2.3.2 Structural framework

The Murzuq Basin has been affected by several compressional and extensional tectonic events. This tectonic activity commenced during the Precambrian orogenesis which created vertical north-south trending basement faults counterbalanced by conjugated northeast-southwest trending faults (Bellini and Massa 1980; Gouderzi 1980; Echikh and Sola 2000; Al Fasatwi, *et al*., 2000). The Pan-African movements were followed by several other tectonic episodes including the Caledonian orogeny (Wenlockian, early-late Silurian), and Hercynian orogeny (Late Carboniferous) that correspond to the second major tectonic phase which affected the Palaeozoic. This orogeny caused folding, faulting and strong subsidence (Bellini and Massa, 1980). A third was the Alpine orogeny of the Tertiary period. Echikh and Sola (2000) identify seven principal tectonic elements within the Murzuq Basin from west to east. These are the Tihemokah Arch, Alwaynat Trough, Tirinine High, Awbari Trough, Idhain Depression, Brak Bin Ghanimah uplift and Dur Al Qussah Trough (Fig.11B).



Hassan S. Hassan (2009)

Fig. 10. Major tectonic elements and Basins of Libya (after Rusk, 2002).

Al Fasatwi *et al*. (2000) explained that the Murzuq Basin was shaped by two main fault systems. The first system is located in the east of the basin and is the Dor El Qusseh Complex Fault System of northeast-southwest trend. The Dor El Qusseh sub basin is clearly visible, whereas the Brak-Ben Ghenemah Arch, trending northwest-southeast, separates the Dor El Qussah sub basin in the east from the main Murzuq Basin in the west. These fault zones were still tectonically active from Cambro-Ordovican times and continued to be active during Silurian and Early Devonian time. During the Jurassic time the eastern flank of the basin was lifted and since then the Dor El Qusseh has been a mountain chain, whereas several folded units were located along the major north-south Tihembokah Arch in the western part of the basin. This folding separated the Murzuq Basin and Ghadamis Basin in Libya from the Illize Basin in Algeria.

2.2.3.3. Stratigraphic framework

The sedimentary sequences in the Murzuq Basin range from Cambrian to Cretaceous in age. It contains a thick section of Palaeozoic and Mesozoic sediments (Fig.13). These sediments are composed mainly of marine shale, siltstone, sandstone and continental sandstone overlying unconformably the Precambrian rocks. Many researchers have discussed and interpreted the stratigraphic sequences of the Murzuq basin (Mamgain, 1980; Bellini and Massa, 1980; Castro *et al.,* 1985; Pierobon 1991; Echikh and Sola 2000; Davidson *et al*., 2000; Sutcliffe *et al.,* 2000a; Hallet 2002; McDougall and Gruenwald, 2011). They divided the sequences of the Murzuq Basin into several sedimentary units and systems. Here in this work I shall attempt to summarize the Cambro-Ordovician-Silurian stratigraphic sequences of the Murzuq Basin based on that published data.

2.2.3.3.1. Precambrian sequence

The oldest rocks are loosely referred to as the ‘basement complex’ rocks. The Precambrian rocks which form the basement are exposed along the Al Gargaf Arch and are mainly composed of granitic intrusion (Contant and Godarzi, 1976). Ramos *et al.* (2006) reported that the basement is composed of high-grade metamorphic.

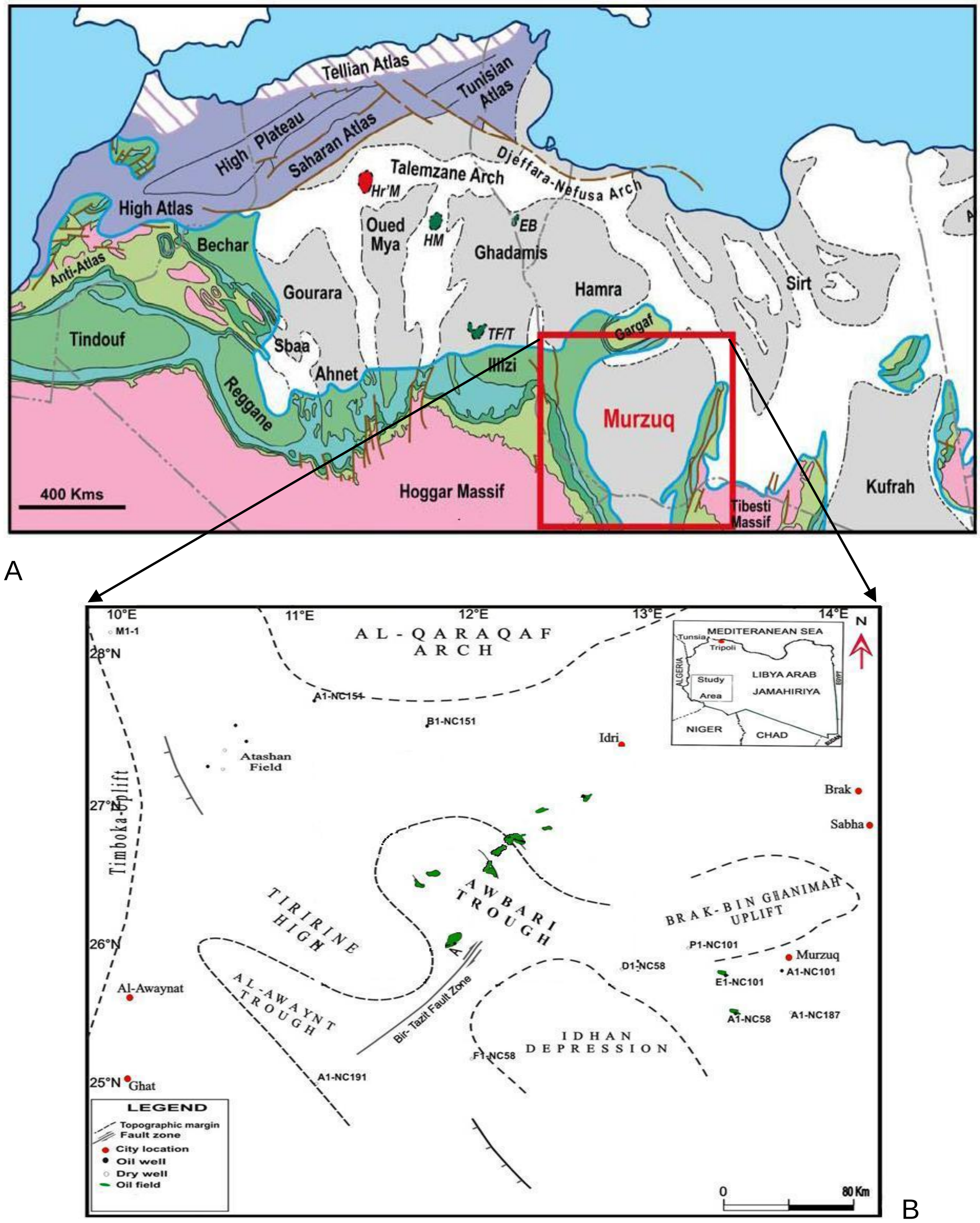


Fig. 11 A, B. Location and tectonic elements maps of the Murzuq Basin southwest Libya. (after Abugares, 2000; Echikh & Sola 2000).)

rocks associated with plutonic rocks as well as low-grade metamorphic to unmetamorphic rocks of Precambrian time (Mourizidie Formation). Both assemblages are cut by a lower Palaeozoic unconformity (Pan-African unconformity) and overlain by Cambrian–Ordovician sequences.

2.2.3.3.2. Cambro-Ordovician sequences

The Cambro-Ordovician system of Libya was first defined in the area of the Al Gargaf Arch. It is widespread over a large portion of the North African craton. Five formations have been recognized within the system, four of them formally introduced by Massa and Collomb (1960). The first sediment to be deposited throughout the basin belongs to the Cambrian Hasawnah Formation and is succeeded by the Ordovician As Shabiyat, Hawaz, Melez Shugran and Memouniat formations as summarized below.

2.2.3.3.2.1. Hasawnah Formation

The Hasawnah Formation begins with a basal conglomerate up to several meters thick that consists mainly of pebbles of quartz. However, most of the Formation comprises of medium to very coarse grained, highly cross-bedded quartzitic sandstone (Aziz, 2000; Davidson *et al.,* 2000; Ramos *et al.,* 2006). The depositional environment of the Hasawnah Formation passes from fluvial at the base of the Formation to shallow marine at the top. Sediment supply was from the south with the sea transgressing from the north (Davidson *et al*., 2000).The Hasawnah Formation is unconformably overlain by the As Shabyiat Formation.

2.2.3.3.2.2. As Shabiyat Formation

The name of the As Shabiyat Formation was introduced by Havlickes and Massa (1973). Most of this formation comprises of medium to coarse grained *Tigillites* (bioturbated sandstone) and has common trace fossils like *Cruziana harlanin*. The greater abundance of siltstones and the diversity of ichnofauna at the base of As Shabiyat Formation, suggested that these rocks were deposited during a transition zone from fluvial to shallow marine environments with a relatively low rate of sedimentation. No fossils are known from this formation. The age is assumed to be Tremadocian in subsurface (Parizek *et al*., 1984).

2.2.3.3.2.3. Hawaz Formation

The Hawaz which forms the secondary hydrocarbon reservoir in the Murzuq Basin was first introduced by Massa and Collomb (1960) and named after Jabal Hawaz on the Al Gargaf Arch. It typically consists of cross-bedded, fine to medium quartizitic sandstone with subordinate siltstone and shale with abundant ichnofossils of the animal burrow *Tigillites*. The basal lithology of this formation is finer than the lowest rock of the As Shabiyat Formation. Vos (1981b) suggested that the formation was deposited in a fan delta complex, which prograded across the Al Gargaf area. Ramos *et al*. (2006) and De Gibert *et al.* (2011) suggested that the whole Hawaz Formation was deposited in a shallow marine environment. Traditionally, this formation was interpreted as Llanvirnian in age (Mamgain, 1980) based on graptolites, brachiopods and trilobites. In the Murzuq Basin, The only available age of the Hawaz Formation is based on acritarch assemblages and as provided by Aziz (2000) from an unpublished report (COREX, 1998). According to this source, the Hawaz Formation is is assigned to the early-mid Ordovician. In the neighboring Al Kufrah Basin Seilacher *et al*. (2002) considered the Hawaz Formation as Arenigian based on the occurrence of certain ichnospecies of the trace fossil *Cruziana.* In the northwestern part of the Murzuq Basin the Hawaz Formation is overlain by shale of the Ordovician Melaz Shuqran Formation

2.2.3.3.2.4. Melaz Shugran Formation

The Melaz Shugran Formation consists of shale, with subordinate siltstone and very fine sandstone beds (Davidson *et al*., 2000; Beswetherick *et al*., 1996). It was probably deposited in a relatively shallow marine environment and the green colour might indicate reducing conditions. Beswetherick *et al.* (1996) also show sediment deformation and suggest that contact with the overlying Memouniat Formation is transitional in nature with no major break in sedimentation. El-Ghali (2005) and McDougall and Gruenwald (2011) suggests that the Melez Shugran was deposited during a period of overall transgression related to relative sea level rise during glacial advance and loading of the continental shelf and subsequent glacial retreat. The Melaz Shugran Formation is dated as Hirnantian (late Ashgill) based on the brachiopod fauna (Gundobin, 1985; Sutcliffe *et al*., 2000a).

2.2.3.3.2.5. Memouniat Formation

The Memouniat Formation forms the main hydrocarbon reservoir in the Murzuq Basin. It consists mainly of sandstone with subordinate siltstone and shale beds (Aziz, 2000; Davidson et *al.,* 2000). The sandstone is typically quartzitic, fine to medium grained, and fairly well sorted. This formation exhibits several facies, although most of the facies are assigned to a high energy, deltaic to marine environment of deposition. Seismic evidence from the subsurface in NC174 indicates that the upper part of the Memouniat Formation may contain a series of deeply incised erosional channels, filled with fluvioglacial sediments (Smart, 2000). Based on a lithology- and sedimentology study, El-Ghali (2005) concluded that the lower and middle Memouniat Formation represents glacial depositional systems and the upper part of the Memouniat Formation was formed as a result of isostatic rebound, associated with relative sea-level fall. A Hirnantian age is assigned to the Memouniat Formation based on the presence on the brachiopod *Plectothyrella crassicosta* in the upper part of the formation (Havlicek and Massa, 1973).

2.2.3.3.2.6. Bir Tlacsin

The Bir Tlacsin Formation is a largely informal name for the black shale and glacial debris flow deposits that are clearly identifiable between the Memouniat Sands and Tanezzuft Shales. The name has never been formally validated, and was not used by the Industrial Research Center. Echikh and Sola (2000) described the Bir Tlacsin Formation as a transitional lithofacies, between the Memouniat Formation Sandstones and the Silurian Tanezzuft Shales. They concluded that the age of the Bir Tlacsin Formation is uncertain and may vary locally; its facies consists of shale with abundant coarse sand grains. Hallet (2002) concluded that the Bir Tlacsin Formation is important from a petroleum systems point of view, because it acts as a barrier between the Memouniat reservoir and the hot Shale source rock. Recently McDougall and Gruenwald (2011) concluded that the Bir Tlacsin represents the final Upper Ordovician package. It is poorly represented in outcrop but present in many wells across the Murzuq Basin with a maximum thickness of 81 m. Sedimentologically it is similar to the Melaz Shugran Formation, composed of interbedded, intensely dewatered silty mudstones or muddy heterolithics and undisturbed laminated mudstones, and the top of the Bir Tlacsin is often marked by a condensed horizon, rich in mudchips and, locally iron-rich sandstones. These are sharply overlain by the graptolitic shales of the Lower Silurian Tanezzuft Formation.

2.2.3.3.3 Silurian Sequences

According to Pierobon (2000), the Silurian sediments are formally grouped into the Tanezzuft and Akakus Formations. The lower contact of the Silurian is generally conformable with the Ordovician Memouniat Formation and the upper contact is disconformable with the continental Lower Devonian rocks. Castro *et al*. (1985) reported the partial or total truncation of the Silurian by an Early to Mid Devonian unconformity in the Dur Al Qussah and west Al Qargaf areas; this very pronounced, basin-wide, unconformity represents a major change in the basin sedimentary and tectonic history. The transgressive Tanezzuft Shale grades upward into the prograding Akakus sandstone and siltstone (Massa Collomb 1960; Burollet *et al.,* 1969; Banerjee, 1980).

.2.3.3.3.1. Tanezzuft Formation

The Tanezzuft Formation (early Llandovery) was first introduced by Desio (1963b) and named after Wadi Tanezzuft located between Ghat and A Awaynat. It is a sequence of dark gray to black, graptolitic shales with intercalations of siltstone and fine grained sandstones often forming rhythmical alternations. It represents the broad marine transgression of the Silurian sea over the North African craton. Klitzsch(1965, 1969) considered the section described by Desio (1936a, b) to be unsuitable as a type section, because the lower contact is not exposed. Therefore, Kiltzsch (1969) proposed and described a type section at Wadi Iyadhar, about 40 km southeast of Ghat city. Lüning *et al*. (1999, 2000,) estimated that the lower-most part of the organic-rich Silurian succession is the source of 80–90% of all Palaeozoic-sourced hydrocarbons in North Africa. Deposition of the Silurian began after the melting of the late Ordovician ice sheets, which led to a major marine transgression that spread from the north, culminating in a highstand with deposition of the Silurian Tanezzuft Formation shales. High contents of organic matter and uranium characterise the lower Silurian ‘‘hot Shale’’, which has a patchy areal distribution. The basal part of the Tanezzuft Formation forms the main hydrocarbon source rock within the basin. In some wells from the Murzuq Basin, the whole thickness of the Tanezzuft Formation may reach more than 700m. The lower part of the Tanezzuft Formation has been dated to the early Llandovery (Davidson *et al*., 2000). Hallet (2002) defined the lower part as Rhuddanian black shale and found that the hot shale is present only in half the wells in the Murzuq Basin. Lüning *et al*. (2000) published an isopach map of the Hot shale in the area of concessions NC115 and NC174, at the northern edge of the basin. Lüning *et al*. (2003) also recorded a *Normalograptus tilokensis* Biozone, of presumably late Hirnantian age, in well E1-NC174 core. Analysis of graptolites from Gargaf and from the Ghat area suggests a Rhuddanian to Aeronian age for the Tanezzuft Formation (Štorch and Massa, 2006). Paris *et al*., (2012) dated the Tanezzuft sequence in well CDEG-2a drilled in Dor el Gussa, eastern Murzuq Basin as Rhuddanian-early Aeronian in age based on the palynological and palynofacies analysis, assigned to *S. fragilis* and *L. nuayyimensis* biozones. They suggest that the whole sequence was deposited in shallow, open marine (but proximal) environment with a minor land shift in the middle of the sequence. Recently, based on chitinozoan biostratigraphical data from E1-NC174 core, Butcher (2013) suggested that the entire core is Rhuddanian age, with the hot shale constrained to the upper part of the range of *Belonechitina postrobusta* and assigned to the mid Rhuddanian. These data are consistent with graptolite data by Loydell (2012) and contradict the suggestion of Lüning *et al.* (2003), in that the base of the core may lay within the uppermost Ordovician.

2.2.3.3.2 Akakus Formation

The Akakus Formation was first introduced by Desio (1936a) after Jabal Akakus in the Ghat area. It consists of fine-medium grained sandstone with abundant trace fossils (*Harlanian, Cruziana, Tijillites*) interbedded with dark gray graptolitic shale in the lower and middle parts. It is a rhythmic fining-upward alternation with overall coarsening upward sucession as described by Desio (1936, 1937). Generally in the Ghadames Basin the Akakus Formation was deposited in a shallow marine environment as suggested by Bracaccia *et al*. (1991). In the eastern Murzuq Basin the upper parts of this formation contains a rich assemblage of primitive vascular plant remains, represented by psilophytes and lycophytes, along with graptolites and acritarchs. Based on acritarch , chitinozoan and miospore assemblages, Tekbali and Wood (1991) suggests an age ranging uppermost Silurian-?Gedinnian. Abuhmida (2000) (unpublished MSc dissertation) showed a similar type of acritarch and miospore assemblages from the Akakus Formation in Well A1-NC40 B, in the Ghadames Basin and assigned to Wenlockian-Ludlovian. The Akakus Formation is apparently absent in wells that are located at the present-day depocenter in Murzuq Basin, which is possibly due to the Caledonian erosion event (Aziz, 1998).

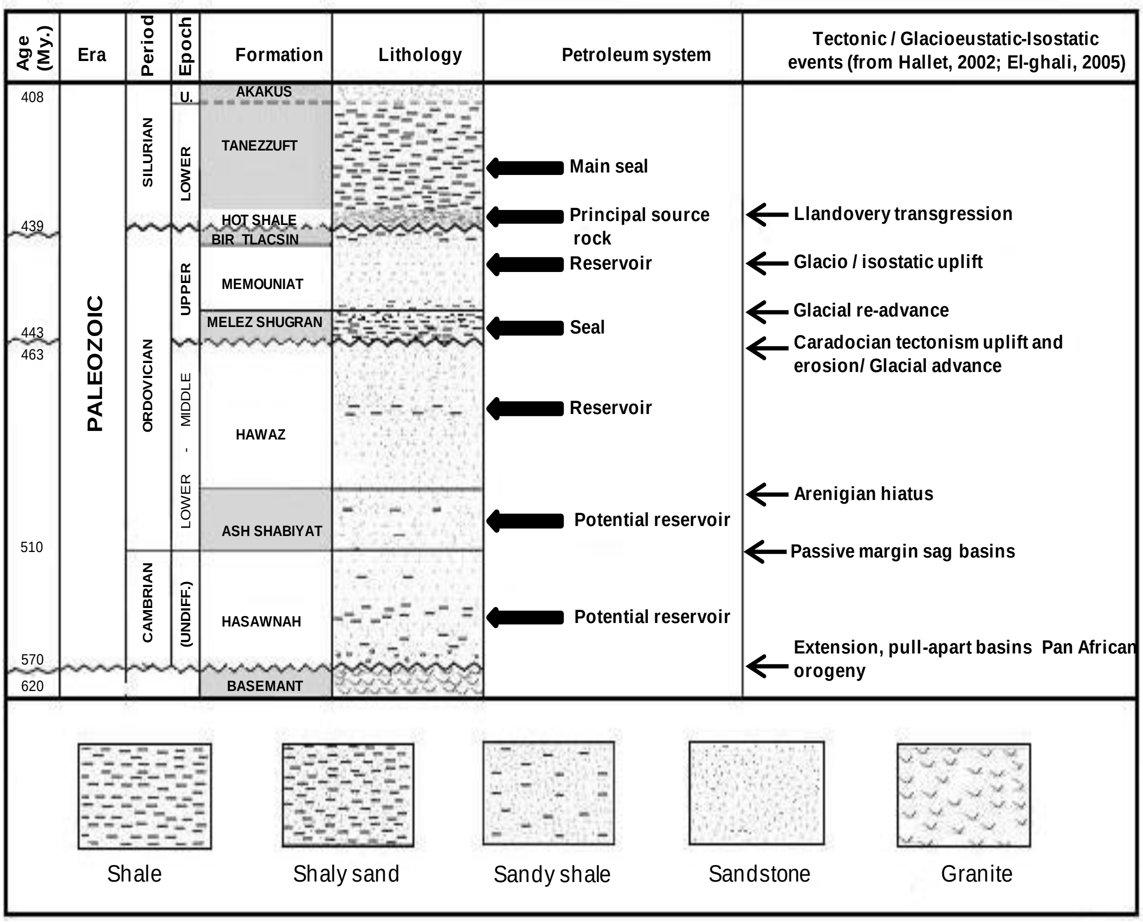


Fig. 12. Simplified lithostratigraphic framework of the Cambro-Ordovician-Silurian sequences in Murzuq Basin (after Hallet, 2002; El-ghali, 2005)

CHAPTER 3. MATERIAL AND METHOD

3.1. Introduction

This part concerns the materials and methodologies which have been used in this study including: sampling and sample preparation techniques involving mechanical (crushing and cleaning) and chemical disaggregation (use of hydrochloric acid, hydrofluoric acid, heavy mineral separation), slide preparation, light microscope analysis and logging techniques (Fig. 13), specimen location and photography and SEM analysis (Fig. 14).

3.2. Material

164 core and cutting samples were selected for palynological analysis from 6 wells drilled in the Murzuq Basin southwest Libya (Fig. 15). The cores and cuttings are stored at the Agip Eni, Remsa and Akakus Oil Companies. The basin contains a large number of wells but the studied wells were selected because they are cored throughout the Ordovician and Silurian sediments.

3.3. Sampling

The core samples were selected from important intervals and lithologies which suitable for palynology analysis (shale and siltstone) together with infill drill cuttings from intervals between the cored sections and non-cored sections such as the Ash Shabiyat and Taneezuft formations. Sample intervals in and between the cored sections vary according to the material available. The samples were collected from the geological core stores of Agip Eni, Remsa and Akakus Oil Company, and processed in the laboratory of the Centre for Palynology, Department of Animal and Plant Sciences, University of Sheffield. Selected core and cutting samples are shown in Appendix 1.

3.4. Sampling preparation techniques

3.4.1. Cleaning (removal of field contamination)

Removal of field contamination was carried out by washing the samples (core or cutting) under running water, to eliminate any possible surface contamination such as drilling mud and soil which may be adhering to or penetrating the samples. In some instances the core samples were split to ensure they were free from any sort of contamination. The cutting samples were subjected to washing by sieving through a combination of 1.7 mm and 0.7 mm clean brass sieves. Then 20 grams from each cutting sample were transferred to a beaker for chemical processing. All beakers were labeled with the number and depth of the samples.

3.4.2. Crushing

The core sample was broken down to pea-size fragment with an average diameter of 1-3 mm using a clean pestle and mortar so as to present a large surface area for acid digestion. Then 20 grams from each core sample were transferred to a beaker for chemical processing. All beakers were labeled with the number and depth of the samples.

3.4.3. Demineralization

3.4.3.1. Removal of carbonate

This was achieved by dissolving the cuttings and crushed core samples in 35% HCl acid which was added gradually with care to control any severe reaction that might happen. The majority of samples didn’t show a strong reaction with HCl. Samples where then left overnight in the fume cupboard. The removal of calcium and magnesium carbonate material is necessary prior to HF treatment to avoid any precipitation of secondary fluoride. At the end of this step, the samples were topped up with warm water and decanted several times (usually from five to six times) until a neutral pH was achieved.

3.4.3.2. Removal of silicate

After the carbonate material has been removed, 40% hydrofluoric acid (HF) was carefully added to digest the silicate. The solution was stirred frequently, left in the fume cupboard for 7-14 days. The supernatant hydrofluoric acid was then decanted off and the sample neutralized by settling and decanting several times (six to seven times).

3.4.3.3. Fine fraction separation

The less than 10 µm fraction was separated from the samples by washing the residue through a 10 µm nylon screen with water. Palynomorphs are held back on the screen and unwanted fine particles passed through. Then the residue was divided into two. One part was used for palynology and the other part for chitinozoan separation, depending on the sample richness.

3.4.3.4. Heavy mineral separation

This technique is used on half of the residue to separate any remaining inorganic minerals from the organic matter. Heavy liquid treatments are used for this purpose, zinc chloride (ZnCl, S.G. 1.95) solution with specific gravity greater than that of organic matter is added together with a few drops of HCl to the residue and centrifuged for 10 minutes. The organic matter in the sample float while the inorganic material sinks. The suspended material is pipetted off and washed through a 10 µm sieve until neutral pH is achieved. The residue then was split into two halves, one for oxidation to prepare palynological slides and the other for kerogen slides.

3.4.3.5. Oxidation

The palynological residue was subjected to oxidation to remove unwanted organic matter and pyrite and in general to clean the sample. This has the effect of making the colour of the remaining organic material (palynomorphs) more visible when viewed under the transmitted light microscope. The oxidation was undertaken by adding a weak solution of nitric acid to the residue. The reaction time is varied from between 5-10 minutes, and in order to avoid over oxidation, the sample is continually assessed by pipetting and viewing the residue under the microscope. Once the desired oxidation level is achieved the residue is washed through a 10 µm sieve until neutral pH is achieved.

3.4.3.6. Mounting and Slide Preparation

A known volume of cleaned and neutralized residue was mixed with a few drops of dispersing solution poly-vinyl acetate (P.V.A) to prevent coagulation of the organic residue on the slide. This mixture then is spread on a 32 by 22 mm cover slip using well labeled pipettes and allowed to dry on a hot plate (25° C) under a dust cover. A clean glass slide (size 26 by 76 mm) is warmed on a hot plate (120°C) and then a few drops of Peropoxy-154 smeared across surface. This is heated to expel air bubbles, after which the cover slip is inverted and dropped on the slide. Care must be taken so as to prevent the formation of small air bubbles. Both the cover slip and glass slide is left on the hot plate (15-20 minutes). The remaining residue is stored with a drop of 10% HCl (to prevent the growth of algae and fungi) in a small labeled tube with a stopper and the same storage method was used for unoxidized residue. Two kerogen slides per sample were prepared for palynofacies and from three to four slides of oxidized residue for biostratigraphic study.

3.5. Light microscope (LM) analysis and counting techniques

The slides were examined using an OLYMPUS BH-2 transmitted light microscope in the University of Sheffield. Identification of specimens was carried out under X40 and X100 objectives and counted under X20 and X40 objectives for each kerogen sample prepared. It was usual to log one slide and scan the other slides for the rare palynomorphs. Account was made by counting 200 particles of organic matter in each sample for palynofacies analysis. For palynomorphs analysis, the abundance and diversity of palynomorphs assemblages including (acritarch, chitinozoan and cryptospore/spore) were determined by counting all the speciemens per first slide and scan the second of each sample.

3.5.1. Specimen location

Specimens were located using an England Universal Finder TM. For example, in the code the H2/1, E22/3 (A) (K/P), H2#1 refers to well sample and core number, E22/3 to the England Finder reference, 1 to the slide code and K/P kerogen / palynology slide.

3.5.2. Photography

Colored photographs were acquired digitally by using OLYMPUS BH-2 transmitted light microscope. The photographs were captured from the micro-imager digital camera that resides on the microscope and connected with the computer. The exposed image was then downloaded to a computer using Automontage software. Finally images were edited using Adobe photoshop software.

3.6. Scaning electron microscope analysis (SEM)

The carbonate and silicate free residues that contains well preserved chitinozoans were chosen for SEM image and sieved at 63µm. A small square of aluminum foil was secured on an SEM stub using glue, and then the round cover slip was placed upon the aluminum foil with the corners of the foil folded to hold the cover slip. The sieved residue were strewn in a small glass dish and then the chitinozoans were picked by very thin brush using a binocular microscope and mounted on the cover slip attached to the SEM stub to be examined using the scanning electron microscope. The remaining residue with the unpicked chitinozoans was used to prepare slides. All stubs were labeled according to their well name and depth. Material on the stubs was then gold coated using an Edwards sputter coater 3150B and analyzed using the Philips XL-20 scanning electron microscope, SEM unit in the Department of Biomedical Sciences, University of Sheffield. After examination with SEM, the cover slip was detached from the stub and mounted on a slide to be examined under light microscope. This method enabled examination of a single specimen under both light microscope and scanning electron microscope. The digital SEM images then downloaded and edited using Adob photoshop software.

3.7. Data compilation and presentation

The computer program (StrataBug software) has been used to generate the illustration of the stratigraphic ranges, presence, absence and the abundance of palynomorphs recorded in each well and the palynofacies charts.

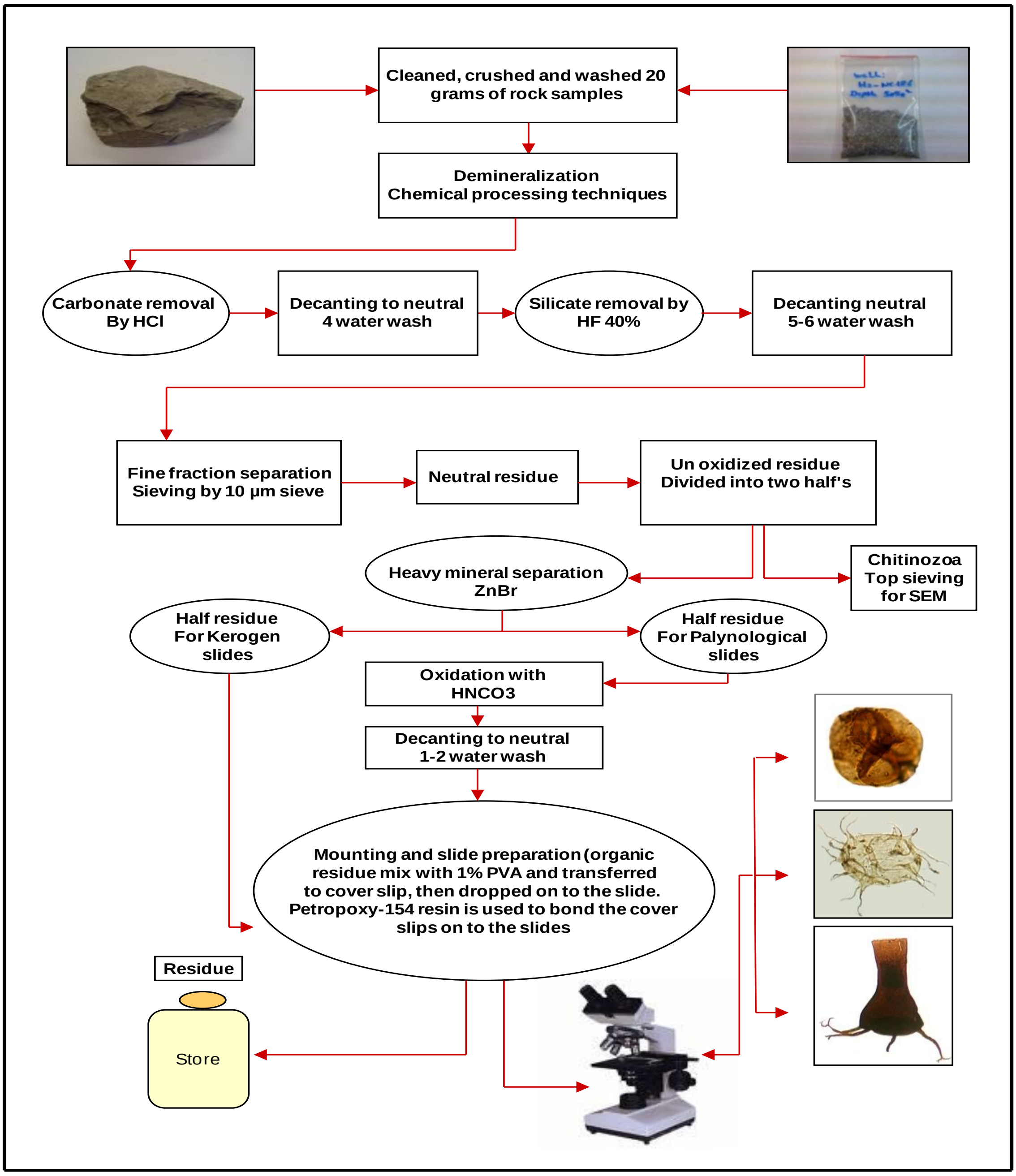


Fig. 13. Abbreviated flow chart for palynological analysis

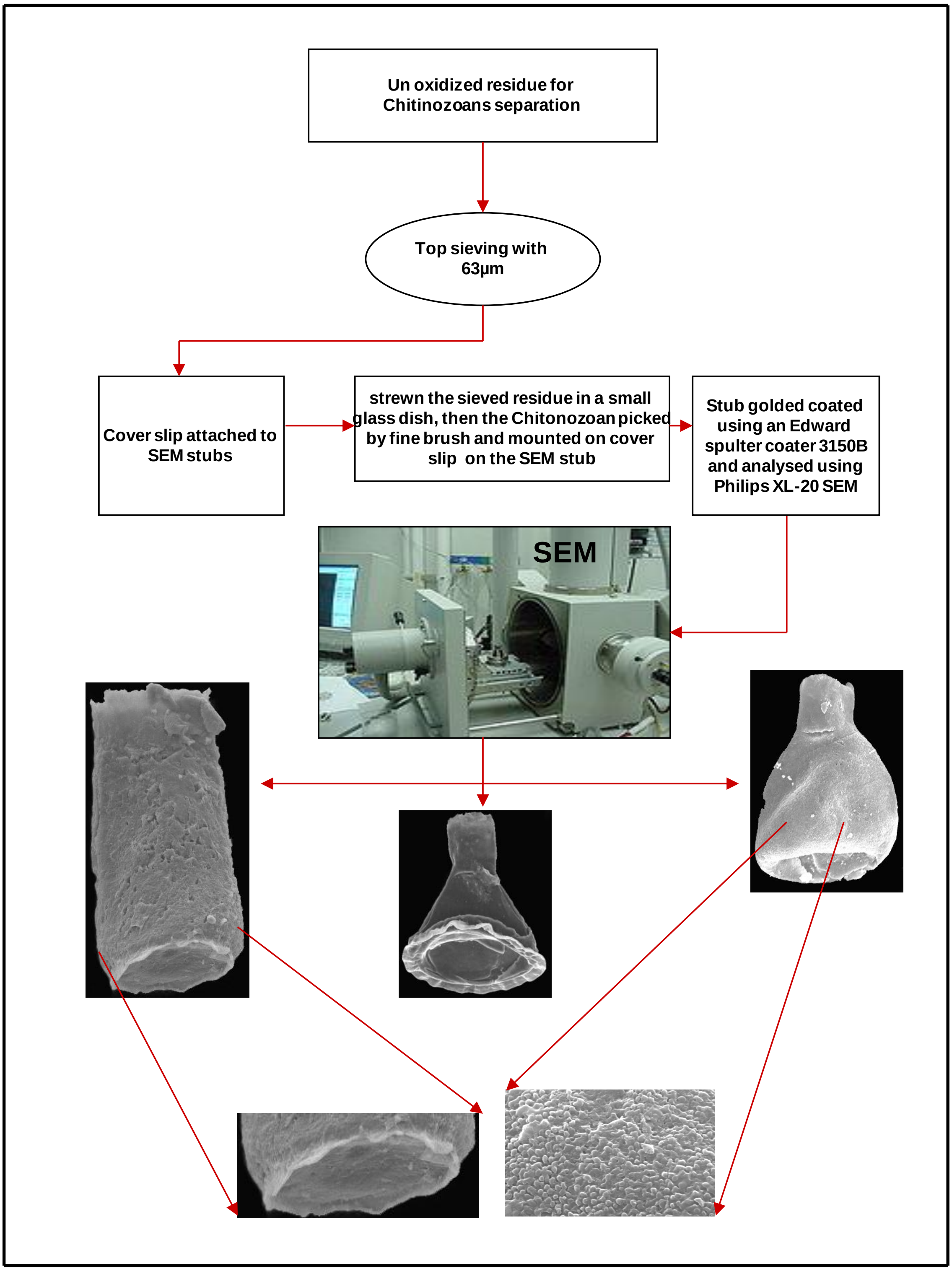


Fig. 14. Scaning electron microscope (SEM) techniques

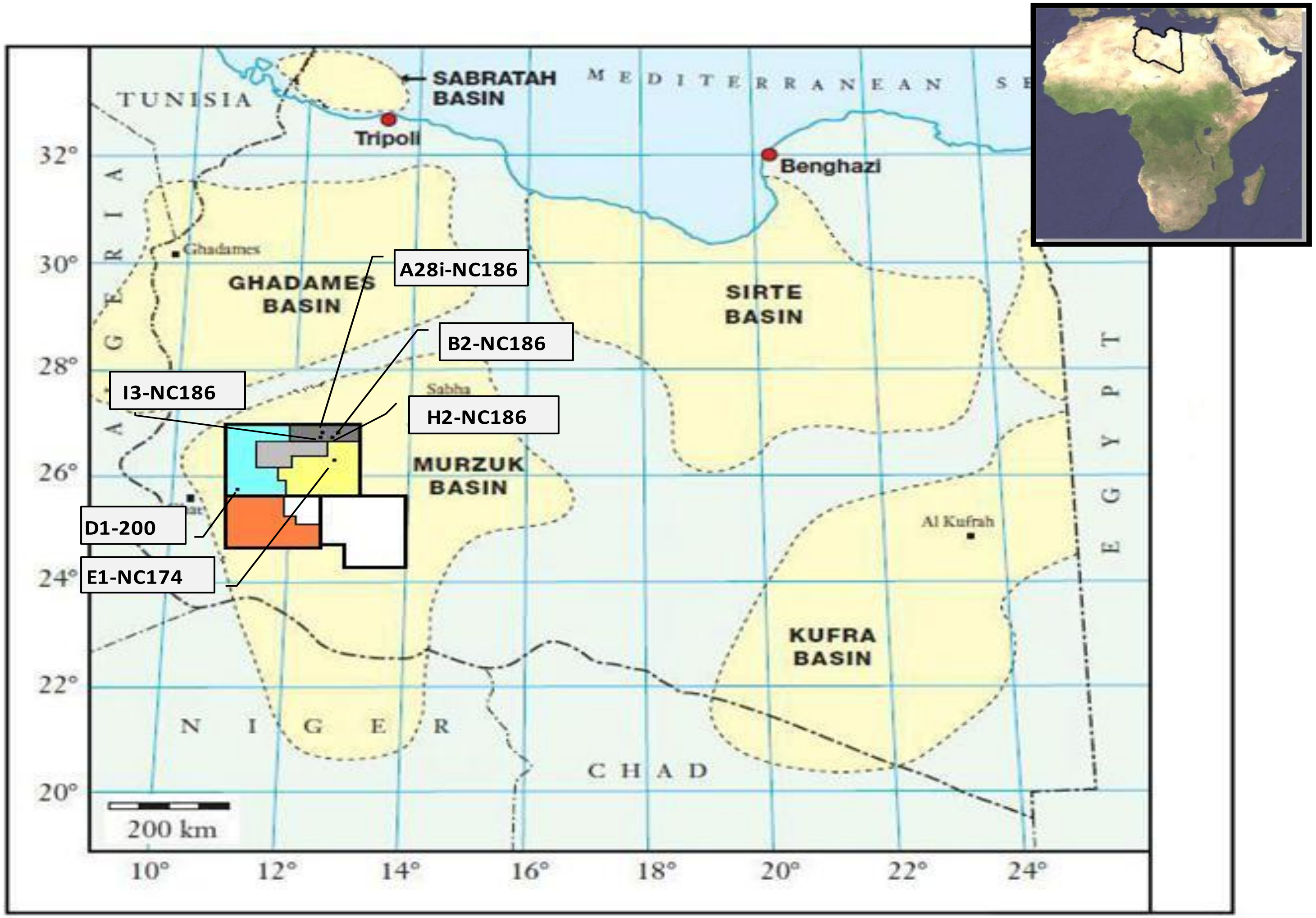


Fig. 15. Location map of studied wells

CHAPTER 4. SYSTEMATIC PALYNOLOGY

4.1 Introduction:

All acritarch, chitinozoan and cryptospore species observed in this study are described and figured. A total of 147 species belong to 57 genera of acritarch, 93 species belong to 23 genera of chitinozoan and 21 species belong to 16 genera of cryptospore/spore have been identified and taxonomically described. Scolecodonts as well as a graptolite remains were also recorded (counted but not taxonomically identified). For formal (published) genera the system used here is as follows; the name of genus, type species and diagnosis, the emendation and other comments are given under remarks. For formal (published) species, the system used here is as follows; the name of species, synonymy listing include basionym, description, dimensions, other comments given under comparision and remarks, it is occurrence and selected previous stratigraphic record.

Attribution to open nomenclature follows recommendations of Bengtson (1988). The abbreviation “cf.” precedes the specific epithet in case of provisional identification. A question mark (?) follows the specific epithet in case of possible but uncertain identification. The abbreviation “sp.” indicates uncertainty in attributing the current species to any of the previously published species, if any, or the present author is not prepared to describe it as a new species. In cases where specific identifications are impossible or has not been attempted, the abbreviation “spp.” is used for acritarchs according to the International Code of Botanical Nomenclature and the abbreviation “ssp.” is used for chitinozoans according to the International Code of Zoological Nomenclature. The dimensions of species are expressed in micrometres (µm) and the following symbols have been used in the acritarchs: L = diameter range or length of the vesicle; Ln = neck length W = vesicle width; P = process length; Wf = flange width. In chitinozoans, L = length of the vesicle including the neck; Dp = Chamber diameter; Dc = for oral tube diameter. In cryptospores and spores, L= diameter range; In all n = number of specimens measured.

4.2 Acritarch systematics

4.2.1 Introduction

The acritarchs described herein are treated as form genera and form species under provisions of the International Code of Botanical Nomenclature (I.C.B.N.; Greuter *et al*., 2000; see also; Fensome *et al*., 1990; Traverse, 1996). Their suprageneric classification has been discussed by several authors (e.g. Wicander, 1974; Servais, 1996; Strother, 1996). Although, the many studies on acritarchs, there is still no stable natural or artificial classification due largely to their unknown biological affinities. A widely accepted approach to arranging acritarch taxa was introduced by Loeblich (1970) who simply listed acritarch taxa alphabetically. This approach was subsequently adopted by Loeblich and Tappan (1976); Wicander and Loeblich (1977); Colbath (1979); Wicander and Wood (1981); Turner (1984); Martin (1993); Vecoli (1999). In this study the acritarchs here are listed alphabetically under “group” name Acritarcha Evitt, 1963 (incertae sedis). However, the genera *Pterospermella* Eisenack 1972, *Tasmanites* Newton, 1785, *Cymatiosphaera* O. Wetzel ex Deflandre, 1954, *Dictyotidium* Eisenack, 1955 and *Leiosphaeridia* are considered assignable to the class Prasinophyceae of the algal division Chlorophyta following Tappan (1980) and Colbath and Grenfell (1995). These genera are considered Palaeozoic counterparts of the extant *Pachysphaera* Ostenfeld, 1893, *Pterosperma* Pouchet, 1893 (including reticulate and flanged forms), and *Halosphaera* Schmitz, 1879. The description of acritarchs provided here is based on examination of taxa under transmitted light microscope; morphological terminology follows that previously outlined by Strother (1996). Accordingly, the description includes vesicle shape, vesicle wall, ornamentation, number of processes, shape, their communication with the vesicle cavity and the excystment structure.

4.2.1.1 Systematic description

PRASINOPHYTE PHYCOMATA

Division **CHLOROPHYTA** Pascher, 1914

Class **PRASINOPHYCEAE** Christensen, 1962

Family **CYMATIOSPHAERACEAE** Mädler, 1963

Genus ***Cymatiosphaera*** O. Wetzel, 1933 emend. Deflandre, 1954 and Deflandre and Cookson 1955

Type species: *Cymatiosphaera radiata* O. Wetzel 1933.

Diagnosis: "shell globular, spherical or ellipsoidal; the external surface divided into polygonal fields by membrane perpendicular to the surface, without any equatorial differentiation of the fields or process of any kind, the outer margin of the membrane straight or slightly concave entire, serrated or somewhat corroded, surface of shell smooth, punctuate or granular." From Deflandre and Cookson (1955, p. 288).

Remarks: The genus *Dictyotidium* Eisenack, 1955 emend. Staplin, 1961 differs from the genus *Cymatiosphaera* in having low solid ridges defining the boundaries between the fields on the vesicle.

Cymatiosphaera* cf. *densisepta Miller and Eames 1982

Plate 5, Fig. 4

Description: Spherical to sub-spherical vesicle, thin, psilate walled. The vesicle divided into more than 20 polygonal fields by membraneous muri varying from 1 to 2µm in height. No excystment structure observed.

Dimensions: L: 40(43)46µm, n = 3.

Remarks and comparision: This species is similar in morphology to *C. densisepta* Miller and Eames, 1982, but it differs in number of polygonal fields and in overall size. It is very similar to the specimens reported by Le Hérissé (2000) from the early Rhuddanian of Saudi Arabia.

Occurence: Tanezzuft Formation, mid Rhuddanian (Llandovery).

***Cymatiosphaera* sp. A**

Plate 5, Figs. 5, 6

Description: Spherical to sub-spherical vesicle, thin, psilate walled. The vesicle divided into approximately 7-9 polygonal fields by membraneous muri varying from 3 to 4µm in height, supported by short processes. No excystment structure observed.

Dimensions: L: 35(40)45µm, n = 4.

Remarks and comparision: This species is similar in morphology to C*ymatiosphaera blaisdonica* Dorning, 1981 but it differs in having a height membraneous muri supported by short processes.

Occurence: Hawaz Formation, mid-late Darriwilian (Llanvirnian).

***Cymatiosphaera* sp. B**

Plate 5, Fig. 7

Description: Spherical to sub-spherical vesicle, thin, psilate walled. The vesicle divided into numerous polygonal fields by membraneous muri varying from 3 to 4µm in height supported by short processes. No excystment structure observed.

Dimensions: L: 30(35)40µm, n = 5.

Remarks and comparision: This species differs from *Cymatiosphaera* sp. A recorded here in having numerous polygonal fields.

Occurence: Hawaz Formation, mid-late Darriwilian (Llanvirnian).

Genus ***Dictyotidium*** Eisenack 1955 emend. Staplin 1961

Type species: *Dictyotidium dictyotidium* (Eisenack) Eisenack 1955.

Diagnosis: “Vesicle spherical; surface reticulate ridges low, distinct, lacunar areas polygonal; some species with two distinctly smaller lacunae, one at each pole; small apiculae or spines may arise from the ridge; papillae may be present in the floor of the lacunae.” From Staplin (1961, p. 417).

Remarks: The genus *Dictyotidium* was diagnosed by (Eisenack) Eisenack 1955 and then emended by Staplin (1961) to include forms with differentiated polar polygons and short ridge spine or other projection.

Dictyotidium dictyotum (Eisenack) Eisenack1955

Plate 7, Fig. 3

For synonymy see Le Hérissé (1989).
Additional synonymy:
1985 *Dictyotidium dictyotum* - Hill *et al.,* pl 9, figs 12.
1989 *Dictyotidium dictyotum* - Le Hérissé, p. 108-109; pl 3, figs 12, 18.
1992 *Dictyotidium dictyotum* - Eley and Legault, p. 77; pl 1, fig. 6.
2003 *Dictyotidium dictyotum* - Ghavidel-syooki, pl 7, fig. 1.
2003 *Dictyotidium dictyotum* - Masiak *et al.*, fig. 10, a.

Description: Spherical to elliptical vesicle, smooth and relatively thick walled. The vesicle surface ornamented with low uniformly 9 -10 polygonal fields. The wall of these polygonal fields is slightly thicker than the vesicle wall. Excystment is straight and will differentiated from the ornamentation.

Dimensions: L: 30(35)40µm, n = 5.

Remarks and comparision: This species is very similar in morphology to *Dictyotidium stenodietyum* Eisenack, 1965, but it differs in having larger polygonal fields.

Occurence: Tanezzuft Formation, mid Rhuddanian (Llandovery).

Selected previous stratigraphic record: Wenlock, Baltic Region (Eisenack 1938, 1955, 1965); late Llandovery, Belgium (Stockmans and Williere 1963; Martin 1965, 1968); late Llandovery, USA (Cramer and Diez, 1972); Mid Silurian, USA (Thusu, 1973a, 1974); Llandovery, England (Hill, 1974); Rhuddanian-Aeronian, England (Hill and Dorning, 1984); Telychian, west Midlands, (Mabillard and Aldridge, 1985); Aeronian, northeast Libya (Hill *et al.,* 1985; Hill and Molyneux 1988); Wenlock, Gotland (Le Hérissé, 1989), Llandovery-early Wenlock, Canada (Eley and Legault, 1992); Llandovery-Wenlock, Iran (Ghavidel-Syooki, 2003); Llandovery, Poland (Masiak *et al*., 2003).

***Dictyotidium* sp. A**

Plate 7, Fig. 4

Description: Spherical to sub-spherical vesicle, smooth, thick walled. The vesicle divided into numerous, fairly uniform polygonal fields. The wall marked by a thickening at the triple junction of the polygonal fields. Excystment structure was not clear.

Dimensions: L: 45(47)50μm, n = 4.

Remarks and comparision: This species differs from *Dictyotidium dictyotum* (Eisenack) Eisenack, 1955 in having a thickening at the triple junction of the polygonal fields.

Occurrence: Hawaz Formation, mid-late Darriwilian (Llanvirnian).

Genus ***Pteroverricatus*** Al-Ameri, 1984

Type species: *Pteroverricatus pequantus* Al-Ameri, 1984

Diagnosis: “Circular or ovoid vesicle enclosed in equatorial membrane. Vesicle wall of central body contain mainly verrucate ornamentations, and the vesicle wall of the membrane is crenulated to develop processes or ornaments of various type.” From Al Ameri (1984, p. 138-139).

Remarks and comparision: The genus *Pteroverricatus* differs from the genus *Pterospermella* Eisenack, 1972, in the type of sculpture of the central body and the membrane.

Pteroverricatus occuliformis Le Hérissé 2000

Plate 20, Fig. 1

2000 *Pteroverricatus occuliformis* - Le Hérissé, p. 79; pl. 6, figs. f, g.

Description: Circular vesicle, surrounded by a thin flange at the equator. The boundary between the vesicle and the flange is commonly dark coloured. The central part shows a large macula or blot, linked to the vesicle border by a thin radial ridge.

Dimensions: L: 22(24)26µm, Wf 5(7)8µm, n = 6.

Remarks and comparision: *Pteroverricatus pequantus* Al-Ameri, 1984 and *Pteroverricatus zonocylindrus,* Al-Ameri, 1984 are differentiated from this species in having verrucae ornamentation.

Occurence: Tanezzuft Formation, Telychian (Llandovery).

Selected previous stratigraphic record: early Telychian, Saudi Arabia (Le Hérissé, 2000).

Pteroverricatus zonocylindrus*,* Al-Ameri, 1984

Plate 20, Fig. 2

1984 *Pteroverricatus zonocylindrus* Al-Ameri, p. 57; pl. 25, figs. 3-5

Description: Circular vesicle, surrounded by a thin flange at the equator. The vesicle ornamented with irregular verrucae. The equatorial zone has a dark area by its contact with the flange. The outer border of flange is crenulated.

Dimensions: L: 32(36)40µm, Wf 8(10)12µm, n = 4.

Remarks and Comparision: This species differs from *Pteroverricatus pequantus* Al- Ameri, 1984 by the type of crenulations and sculpture in the outer border of the flange.

Occurence: Tanezzuft Formation, Telychian (Llandovery).

Selected previous stratigraphic record: Late Llandovery, Libya (Al Ameri, 1984); early Aeronian-Telychian, Saudi Arabia (Le Hérissé *et al.,* 1995).

Family **TASMANITACEAE** Eisenack, 1972

Genus ***Tasmanites*** Newton, 1875

Type species: *Tasmanites punctatus* Newton 1875

Diagnosis: "Hollow spherical, generally comparitively thick-walled and of a very resistant, yellowish to dark red brown hyaline organic substance consisting of organic remains which often are preserved in a disc-shaped compressed state or also irregularly folded. Wall with more or less numerous pores which rarely penetrate the entire wall, but often either end blindly in the thick wall from the outside or from the inside. Pylome present, however usually uncommon. The wall pores are not always visible in each specimen of species; it is essential that they should occur in the majority of the specimens." From Eisenack (1955, p. 341).

Remarks: The genus *Leiosphaeridia* (Eisenack, 1958) Downie and Sarjeant, 1963 emend. Turner, 1984 differs from this genus in having a thin wall without radial pores.

Tasmanites **spp.**

Plate 26, Figs. 5, 6

Description: Spherical, hollow, thick walled vesicle.The vesicle surface ornamented with a numerous radial pores, no excystment structure has been observed

Dimensions: L: 40(55)70μm, n = 8.

Remarks and comparision: In this study all forms with spherical, thick walled and ornamented with numerous radial pores are attributed to this species**.**

Occurrence: Melez Shugran, Memouniat and Bir Tlascin formations, Hirnantian (Ashgillian); Tanezzuft Formation, Rhuddanian-Telychian (Llandovery).

Family **LEIOSPHAERIDIACEAE** Timofeev, 1956 nom. corr. Mädler, 1963

Genus ***Leiosphaeridia*** (Eisenack, 1958) Downie and Sarjeant, 1963 emend. Turner, 1984

Type species: *Leiosphaeridia baltica* Eisenack, 1958.

Diagnosis: “Spherical to ellipsoidal bodies without processes, often collapsed or folded, with or without pylomes. Walls granular, or unornamented, thin or thick, without divisions into fields and transverse or longitudinal furrows or girdles.” From Turner (1984, p. 116).

Remarks and comparision: Sphaeromorph acritarch classification has been reviewed by several authors (e.g. Downie and Sarjeant, 1963; Staplin *et al*., 1965; Turner, 1984; Fensome *et al*., 1990). The latest emended diagnosis of the genus was considered necessary by Turner (1984) to remove reference to an exclusively thin wall.

Leiosphaeridia **spp.**

Plate 13, Figs. 2, 3, 4

Description: Single-layered, hollow, spherical to sub-spherical smooth vesicle. The vesicle surface ranges from transparent and extremely thin to moderately thick walled and usually folded. The vesicle is without processes, envelope or ornamentation and no excystment structure has been observed.

Dimensions: L**:** 10(40)70*µ*m, n = 15.

Remarks and comparison: *Leiosphaerida* species recorded here are of a wide size range with continuous intermediate forms in terms of size and wall thickness. Thus it appears that there is no objective way of splitting these simple forms into several species.

Occurrence: Hawaz Formation, mid-late Darriwilian (Llanvirnian); Melez Shugra, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian); Tanezzuft Formation, Rhuddanian-Telychian (Llandovery).

Family **PTEROSPERMELLACEAE** Timofeev, 1956 nom. corr. Mädler, 1963

Genus ***Pterospermella*** Eisenack, 1972

Type species: *Pterospermella aureolata* Cookson and Eisenack 1958, Eisenack 1972.

Diagnosis: “Organic walled microfossils, consisting when seen from above, of a circular central body which is generally elongatedly oval in axial section or more rarely circular. At the equator there is an annular, concentral flange with a smooth or notched rim. This flange may be smooth or may have radially oriented folds.” Translation from Eisenack (1972, p. 955).

Remarks: The genus *Pterospermella* Eisenack, 1972 is included here as an acritarch with a spherical to sub-spherical vesicle surrounded by an equatorial flange that may display radial folds or ribs. Eisenack (1972) erected this genus to encompass all species, other than the type species previously decribed in

Pterospermopsis Wetzel, 1952. It seems that there is some confusion regarding the taxonomic status of those two genera (see Playford, 1977; Fensome *et al*., 1990) who suggested that in order to resolve the situation, further re-examination of the type material of the genus *Pterospermopsis* compared with the genus *Pterospermella* is needed.

Pterospermella colbathii Vavrdova, 1990

Plate 19, Fig. 3, 4

1990b *Pterospermella colbathii* - Vavrdova, p.240-241; pl. 2, figs. 3, 4, 7, 8.
1999 *Pterospermella colbathii* - Vecoli, p.27; pl. 12, fig. 9.

Description: Spherical vesicle, relatively thick walled with thin, translucent equatorial flange supported by a few radial ribs. The flange surface is finely granulated and the vesicle covered by irregular grana or verrucae. The margin of flange is not smooth, but it is wavy. No excysement structure observed.

Dimensions: L: 17(24)32µm, Wf: 15(17)20µm, n = 4.

Remarks and comparisons: The specimens recorded in the current study conform the original description by Vavrdova (1990)**.**

Occurrences: Hawaz Formation, mid-late Darriwilian (Llanvirnian).

Selected previous stratigraphic record: Arenigian, Bohemia (Prague Basin) (Vavrdova, 1990); Llanvirnian, Tunisia (Vecoli, 1999); Darriwilian, northern Gondwana (Vecoli and Le Hérissé, 2004).

***Pterospermella* sp.A** Al-Ameri, 1986

Plate 19, Fig. 5

1986 *Pterospermella* sp. A - Al-Ameri, pl. 1, fig.1.

Description: Spherical vesicle, thick, not transparent walled with thin and transparent equatorial flange. The contact area between the vesicle and the flange developed in equatorial rim which is parallel to the outer order of the vesicle. The vesicle and flange wall is psilate, and the flange wall is thinner than the vesicle wall. No excystment structure observed.

Dimension: L: 50(60)70 µm, Wf: 10(15)20 µm, n = 10.

Remarks and comparisons: The specimens recorded in the current study conform to the description of Al-Ameri (1986). It is distinguished from *Pterospermella brasiliensis* (Brito) Eisenack *et al*., 1973 by its larger size and in having psilate vesicle and from *Pterospermella hermosita* (Cramer) Eisenack *et al*., 1973 by the absence of verrucate ornamentation.

Occurrence: Tanezzuft Formation, Aeronian-Telychian (Llandoverian).

Selected previous stratigraphic record: late Llandovery, Libya (Al Ameri, 1986).

***Pterospermella*? sp. B**

Plate 19, Fig. 6

Description: Vesicle spherical to sub-spherical, thick, not translucent walled with equatorial irregular flange relatively thick and translucent. The wall of both vesicle and flange is psilate, and the flange wall is thinner than the vesicle wall. No excysement structure observed.

Dimension: L: 45(48)50µm, Wf: 8(10)12µm, n = 8.

Remarks and comparisons: This species is distinguished from other *Pterospermella* species in having a thick, not translucent vesicle wall, and relatively thick and translucent flange.

Occurrences: Hawaz Formation, mid-late Darriwilian (Llanvirnian).

Group **ACRITARCHA** Evitt, 1963 (incertae sedis)

Genus ***Acanthodiacrodium*** Timofeev, 1958 emend.
Deflandre and Deflandre-Rigaud, 1962

Type species: *Acanthodiacrodium dentiferum* Timofeev, 1958.

Diagnosis: “Globular ellipsoidal micro-organisms; smooth or folded equatorial region; poles similar, ornamented with hairs spines and horns; transverse wrinkles present or absent; wall thin or double outline.” From Deflandre and Deflander-Rigaud (1962, p. 194).

Remarks: The genus *Acanthodiacrodium* was diagnosed by Timofeev (1958), and then emended by Deflandre and Deflandre-Rigaud (1962). Loeblich and Tappan (1978) and Martin and Dean (1988) rejected the genus *Priscotheca* Deunff, 1961 and the genus *Actanthodissus* Loeblich and Tappan, 1978 and consider the genus *Acanthodiacrodium* as a senior synonym. This view was accepted by Servais and Molyneux (1997) and Vecoli (1999) and is adopted and followed in this study.

Acanthodiacrodium crassus Loeblich and Tappan, 1978
Plate 1, Fig. 1

1978 *Actinotodissus crassus* - Loeblich and Tappan, p. 1238, 1241;

pl.1, figs. 8, 10.

1988 *Actinotodissus* cf. *crassus* - Hill and Molyneux , p. 45; p. 8, figs. 1, 2.

1995 *Actinotodissus crassus* - Jachowicz, pl. II, fig. 3.

1999 *Acathodicrodium crassus* - Vecoli, p. 28; pl.1, figs. 8, 10.

2000 *Actinotodissus crassus* - Ghavidel-syooki, pl. 3, fig. 9.

2003 *Actinotodissus crassus* - Ghavidel-syooki, pl. 4, fig. 11.

2009 *Acanthodiacrodium crassus* - Vecoli *et al*., pl. 1, fig. 2.

Description: Elliptical to oval vesicle with rounded to polygonal poles, thin, smooth walled. Each pole bears 12-17 hollow, homomorphic, flexible, simple processes that are tapering to acuminate tips and communicating freely with the vesicle cavity. The vesicle is ornamented by variably-spaced longitudinal striations. No excystment structure observed.

Dimensions: L: 30(32)35µm, P: 10(18)26µm, n = 8.

Remarks and comparision: This species differs from *Acathodicrodium costatum* Burmann, 1968 in being smaller in overall size and with longer processes relative to vesicle length and from *Acatinotodissus* cf. *crassus* reported by Molynex (1988) from Ashgillian of northeast Libya in having many processes with hair like termination and the vesicle wall ornamented with longitudinal ridges (striation).

Occurrence: Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian).

Selected previous stratigraphic record: Caradocian, USA (Loeblich and Tappan, 1978); Llanvirinian-Ashgillian, Iran (Ghavidel-syooki, 1996, 2000, 2003); Ashgillian, Canada (Jacobson and Achab, 1985), Jordan (Keegan *et al*., 1990); USA (Miller, 1991), Saudi Arabia (Jachowicz, 1995), Algeria, southern Tunisia, northwest Libya and (Vecoli, 1999; Vecoli *et al.*, 2003, 2009), north Gondwana (Vecoli and Le Hérissé, 2004); Caradocian-Ashgillian, Oman (Molyneux, 2006); Caradocian, Turkey (Paris *et al.*, 2007).

***Acanthodiacrodium* sp. A**

Plate 1, Fig. 2

Description: Tetragonal vesicle with slightly rounded poles. Each pole bears 3-4 hollow, simple, thin, homomorphic processes that are wide at their base, taper to acuminate tips and communicating freely with the vesicle cavity. The vesicle wall is thin and ornamented by variably-spaced longitudinal striations. No excystment structure observed.

Dimensions: L: 22(24)26µm, P: 18(20)22µm, n = 5.

Remarks and comparision: This species differs from *Acathodicrodium crassus* Loeblich and Tappan, 1978, in having a tetragonal vesicle shape and in processes number.

Occurrence: Melez Shugra, Memouniat and Bir Tlacsin formations, late Katian-Hirnantian (Ashgillian).

Genus ***Ammonidium*** (Downie 1963) Lister, 1970

Type species: *Ammonidium microcladum* (Downie 1963) Lister, 1970.

Diagnosis: “Vesicle hollow, spherical to ellipsoidal single walled; vesicle wall smooth or sculptured, processes numerous, evenly spaced, more or less rigid, hollow tapering, communicating freely with vesicle cavity; distally the processes have equifurcate termination; Excystment by cryptosuture, apical or near equatorial.” From Lister (1970, p. 48).

Remarks: The genera *Naevisphaeridium* Wicander, 1974 and *Hapsidopalla* Playford, 1977 are similar in morphology to the genus *Ammonidium* but they differ in the vesicle ornamentation.

Ammonidium microcladum (Downie, 1963) Lister, 1970

Plate 1, Fig. 3

For synonymy see Le Hérissé (1989).
Additional synonymy:
1989 *Ammonidium microcladum* - Le Hérissé, p. 82-83; pl. 5, figs. 7-13.
1992 *Ammonidium microcladum* - Eley and Legault, p. 76; pl. 1, fig. 1.
2000 *Ammonidium microcladum* - Le Hérissé, pl. a, fig. b.

Description: Spherical to slightly ellipsoidal, single, thin-walled vesicle bearing hollow, thin processes about 20-24 in number. The processes are long, narrow, slightly tapering and communicate freely with the vesicle cavity; distally they have equifurcate, bifurcate, trifurcate or quadrifurcate terminations. The vesicle wall surface is smooth. Excystment observed by simple rupture.

Dimensions: L: 25(27)30µm, P: 7(8)10µm, n = 5.

Remarks and comparision: This species differs from *Ammonidium waldronense* (Tappan and Loeblich 1971) Dorning, 1981a, in having fewer processes.

Occurrence: Tanezzuft Formation, Telychian (Llandovery).

Selected previous stratigraphic record: Wenlock, England (Downie, 1963); early Ludlow, Shropshire England (Lister, 1970); late Llandovery, USA (Cramer, 1970 Cramer and Diez, 1972); late Llandovery-Wenlock, Shropshire England (Doming, 1981), Canada (Eley and Legault, 1992); Mid Silurian, USA (Thusu and Zenger, 1974); Aeronian, England (Hill, 1974; Hill and Doming, 1984), northeast Libya (Hill and Molyneux, 1988); Aeronian-Telychian, northwest Libya (Al-Ameri 1983 unpublished thesis); Telychian-lower Ludlow, Gotland (Le Hérissé, 1989); Llandovery-lower Wenlock, Canada (Eley and Legault, 1992), Saudi Arabia (Le Hérissé, 1995), Lithuania (Jankauskas, 2004); late Landovery-Wenlock, Jordan (Keegan *et al*., 1990); Early Silurian, Belgium (Wauthoz, 2005); mid to late Telychian, Saudi Arabia (Le Hérissé 2000); Llandovery, Scotland (Molyneux 2008); Telychian-early Ludlow, Tunisia (Vecoli, 2009); Wenlockian, Iraq (Al Ameri 2010).

Genus ***Ampullula*** Righi, 1991, emend. Brocke, 1997 and Yan Kui, *et al.,* 2010

Type species: *Ampullula suetica* Righi, 1991.

Diagnosis: “Vesicle ellipsoidal to spherical, seemingly one layered. Vesicle surface smooth to scabrate or granulated, bearing one or more homomorphic or heteromorphic processes. One of the processes may be developed as a prominent tubular, neck-like extension. The process is hollow, not communicating with the vesicle, and its distal edge is sometimes ornamented with protruding tubercles, thin spines, and baculae. The other processes are hollow or solid and proximally not communicating with the vesicle. The distal end is open, mostly widened, slightly convave, and sometimes branched or variably dissected as a calyx. Processes are distributed concentrated on one or two poles or irregularly over the central body. A circular structure is usually observed.” From Yan Kui, *et al.,* (2010, p. 14).

Remarks: The genus *Ampullula* was diagnosed by Righi (1991) then emended by Brocke (1997) to include forms with one or more homomorphic or heteromorphic processes. One of the processes may be developed as a prominent tubular, neck like extension and he included the genus *Stelomorpha* Yin, 1994 as a junior synonym of the genus *Ampullula* Righi, 1991.

Subsequently the genus *Ampullula* has been discussed by several authors (Uutela and Sarjeant, 2000; Ribecai *et al*., 2002). Uutela and Sarjeant (2000) retained and emended the genus *Stelomorpha* and considered the genus *Ampullula* Righi, 1991 as a junior synonym of the genus *Tranvikium* Tynni, 1982*.* Ribecai *et al*. (2002) suggested an additional new genus *Sacculidium,* which is similar to the genus *Ampullula.* The two genera are distinguished by the tube extension, neck like and processes. These processes are much longer in the genus *Ampullula*, distally open and mostly widened and branched. In contrast to the genus *Sacculidium* has a shorter processes that are acuminate distally*,* and included in the '*Stelomorpha-Tranvikium-Sacculidium* plexus. Li *et al*. (2002) stated that the genus *Ampullula* is very important taxon for Lower–Middle Ordovician biostratigraphy. However, the taxonomic history of this genus is complex and made confusing by the reviews of several authors with different taxonomical concepts. Later Yan Kui, *et al.,* (2010) accepted the Brocke (1997) revision and included the genus *Stelomorpha* Yin, 1994 as a junior synonym of the genus *Ampullula*. In the current study the system of Kui, *et al.,* (2010) is adopted. The genus *Aremoricanium* Deunff, 1955 differs from the genus *Ampullula* Righi, 1991, emended Brocke, 1997 and Yan Kui, *et al.,* 2010, in having two concentric layers.

Ampullula suetica Righi, 1991

Plate 1, Figs. 4, 5

1991 *Ampullala suetica* - Righi, p. 123-126; pl. 1. figs 1-6.
1999 *Ampullala suetica* - Vecoli, p. 30; pl. 2. figs 1, 2, 10.

Description: Ellipsoidal to sub-spherical, single, thin, psilate walled vesicle, generally folded bearing a cylindrical, hollow neck-shaped. This neck-shaped is thicker than the vesicle wall, proximally closed with no communication with the vesicle cavity but it may show plug like or dark area around their contact with the vesicle cavity. Distally open and widened with short spines or pinnae. Excystment structure was not clearly visible.

Dimensions: L: 70(77)85µm, P: 8(10)12µm, n = 3.

Remarks and comparision: *Ampullula erchunensis* Brocke, 1997 differs from this species in having numerous processes and a prominent tubular neck.

Occurrence: Hawaz Formation, mid-late Darriwilian (Llanvirnian).

Selected previous stratigraphic record: Arenigian, south China (Tongiorgi *et al*., 1995; Brocke, 1998); late Arenigian- Llanvirnian, Sweden (Righi, 1991; Ribecai and Tongiorgi, 1995); Llanvirnian, Tunisia, Libya (Vecoli, 1999, Vecoli *et al.*, 2003); northern Gondwana (Vecoli and Le Hérissé, , 2004).

Genus ***Anomaloplaisum*** Tappan and Loeblich, 1971

Type species: *Anomaloplaisum lumariacuspis* Tappan and Loeblich, 1971

Diagnosis: "A symmetrically fusiform central body. One side inflated in a broad curve, the other straight inflated; ends produced into polar spines, one of which is commonly shorter than the other; wall thin; polar spines with echinate surface, the tiny prominent spinules or bulbous projections communicating internally with the hollow polar spines; spinules becoming smaller and rare at the base of the processes and disappearing, leaving the central body smooth except near the base of the processes where the echinate surface grades into one with rare scattered grana; no excystemnt opening observed." From Tappan and Loeblich (1971, pp. 388-390).

Remarks: This genus differs from *Disparifusa* Loeblich and Tappan, 1970b, in having a smooth vesicle except for scattered grana near the base of processes. In addition, the vesicle is ornamented with finely longitudinal striae and polar processes ornamented with delicate spines. This ornamentation differentiates this genus from the genera *Dactylofusa* Cramer, 1970, *Eupoiklofusa* Cramer, 1970 and *Poikilofusa* Staplin Loeblich and Tappan, 1978.

Anomaloplaisum johnsium Le Hérissé, Al-Tayyar and Van der Eem, 1995

Plate 1, Figs. 6, 7

1995 *Anomaloplaisum johnsium* - Le Hérissé, Al-Tayyar and Van der Eem, p. 63; pl. I, figs, 1, 2.

Description: Fusiform, elongate, single, smooth, thin walled vesicle, with a few scattered grana and its extremities gradually drawn out into two acuminate processes, one at each pole. The processes are ornamented with delicate spines with varied length and communicating freely with the vesicle cavity. The vesicle wall is ornamented with thin finely longitudinal striations. No excystment structure observed.

Dimensions: L: 190(200)210*μ*m, W: 45(48)50*μ*m, n = 5.

Remarks and comparision: This species differs from *Anomaloplaisum lumariacuspis* Loeblich and Tappan, 1971 and *Anomaloplaisum tappaniae* Cramer and Díez, 1977, in having an ornamentation of longitudinal striations on the vesicle wall.

Occurence: Lower part Tanezzuft Formation, mid Rhuddanian (Llandovery)

Selected previous stratigraphic record: Wenlock, Saudi Arabi (Le Hérissé *et al.*, 1995); early Ludlow, Libya (Al-Ameri, 1980 unpublished thesis).

Genus ***Aremoricanium*** Deunff, 1955

Type species: *Aremoricanium rigaudiae* Deunff, 1955.

Diagnosis: "Micro-organic fossil; color generally yellow or brown, rarely black, formed of two concentric shells; 1) internal globular shell with a more or less apparent low extension carrying a circular perforation; 2) an outer shell, ornamented with long, hollow processes which are open at the base. These processes do not communicate with the space between the two shells. The outer shell has a cylindrical or a cylindro-conical expansion corresponding to the orifice of the internal shell." New translation of Deunff (1955a, p. 228).

Remarks: The genus *Aremoricanium* was diagnosed by Deunff (1955) as being bilayered. Loeblich and MacAdam (1971) demonstrated that this genus possesses a unilayered eilyma. The presence of an internal body was noted by Kjellström (1971a) in specimens from the Middle Ordovician, Sweden. Cramer and Díez (1977) commented that their specimens may or may not have an internal body. However the presence of two different eilyma structures in the same genus would seem incongruous from a biological viewpoint (Vecoli, 1999). The present study supports the view of Loeblich and MacAdam (1971) in that *Aremoricanium* has a very thin and unilayered wall. Such walls are easily folded producing structures simulating an inner layer or an internal body.

Aremoricanium squarrosum Loeblich and MacAdam, 1971

Plate 1, Fig. 8

1971 *Aremoricanium squarrosum* - Loeblich and Mac Adam, p. 44; pl. 18, figs. 1–8.
1971 *Aremoricanium syringosagis* n. sp.- Loeblich and Mac Adam, p. 44; pl. 18, fig. 9.
1979 *Aremoricanium squarrosum* - Colbath, p. 9; pl. 1, fig. 13; pl. 2, fig. 3-4.
1980 *Aremoricanium syringosagis* - Martin, p. 110; pl. 3, fig. 10.
1982 *Aremoricanium squarrosum* - Vavrdova, pl. 1, fig. 2.
1985 *Aremoricanium squarrosum* - Jacobson and Achab, p. 171-172; pl. 1, fig. 4.
1988 *Aremoricanium squarrosum* - Elaoud Debbaj, p. 235; pl. 1, figs. 11, 12.
1995 *Aremoricanium syringosagis* - Jachowicz, pl. II, fig. 9.

1996 *Aremoricanium squarrosum* - Molyneux *et al*., pl. 2, fig. 7.
1997 *Aremoricanium syringosagis* - Vavrdová, fig. 5 E.
2007 *Aremoricanium syringosagis* - Paris *et al*., pl. 5, fig. 17.
2008 *Aremoricanium squarrosum* - Wicander and Playford, p. 49; pl. 1, fig. 5.
2011 *Aremoricanium squarrosum* - Delabroye *et al.*, pl. 1, figs. 1, 2.

Description: Sub-circular to pyriform, smooth, thin walled vesicle, with long neck or expansion which terminates with a circular distal opening (pylome). The vesicle bears flexible, long, hollow, stout, cylindrical processes about 11-13 in number; with blunty rounded distal terminations and closed proximally at short distance above the junction with the vesicle. They are not communicating with the vesicle cavity; their wall is thinner than the vesicle. No excystment structure observed.

Dimensions: L: 64(71)78µm, Ln: 48(49)50µm, P: 27(48)70µm, n = 7.

Remarks and comparision: *Aremoricanium syringosagis* is considered here as a junior synonym of this species following the view of Jacobson and Achab (1985); Fensome *et al*., (1990); Playford and Wicander (2006); Wicander and Playford (2008). *Aremoricanium rigaudae* Deunff, 1955 is smaller than this species and has tapering processes with acuminate tips.

Occurrence: Mlez Shugran, early late Katian-early Hirnantian (Ashgillian); reworked in Bir Tlacsin Formation, late Hirnantian (Ashgillian).

Selected previous stratigraphic record: late Caradocian-Ashgillian, USA (Loeblich and MacAdam, 1971); Caradocian-Ashgillian, Canada (Martin, 1980); Ashgillian, Canada (Jacobson and Achab, 1985), Morocco (Elaoud Debbaj, 1988), Jordan (Keegan *et al*., 1990); late Caradocian, Saudi Arabia (Jachowicz, 1995); late Caradocian-Ashgillian, Laurentia and Gondwana (Molyneux *et al*., 1996); Llanvirnian-Ashgillian, northern Gondwana (Vecoli and Le Hérissé, 2004); Ashgillian, USA (Playford and Wicander, 2006); Late Ordovician, Oman (Molyneux *et al*., 2006); Late Ordovician, southeastern Turkey (Paris *et al*., 2007); Caradocian-Ashgillian, USA (Wicander and Playford, 2008), Katian, Estonia (Delabroye *et al.*, 2011).

Genus ***Baiomeniscus*** Loeblich, 1970

Type species: *Baiomeniscus granulatus* Loeblich, 1970.

Diagnosis: “Small cyst, crescent-shaped to nearly semicircular in outline with extremities rounded to blunty pointed; wall thin, surface ornamented by striae and commonly with grana, either scattered or aligned in rows; no pylome observed.” From Loeblich (1970, p. 711).

Remarks: The genus *Baiomeniscus* Loeblich, 1970 differs from the genus *Lunulidia* Eisenack, 1958, in being smaller in size and having granulated striations rather than being smooth. It differs from the genus *Eupoikilofusa* Cramer 1970, in having a very thin vesicle wall and in lacking processes at the poles.

Baiomeniscus camurus Loeblich, 1970

Plate 2, Figs.1

1970 *Baiomeniscus camurus* - Loeblich, p. 712; pl. 4, A-F.
2001 *Baiomeniscus camurus* - Le Hérissé *et al,* pl. 1, fig.1.
2005 *Baiomeniscus camurus* - Rubinstein, pl. 1, fig. 22.

Description: Vesicle crescent, arcuate to U-shaped, thin, single, transparent walled, wrinkled and striate, its extremities drawn out into two broadly rounded or bluntly pointed ends. The vesicle wall ornamented with grana that are aligned in rows parallel to the longitudinal axis of the vesicle. No excystment structure observed.

Dimensions: L: 80(110)140µm, W: 12(18)24µm, n = 10.

Remarks and comparision: The specimens recorded in the current study shows a variation of vesicle wall ornamentation. It differs from *Baiomeniscus granulates* Loeblich, 1970 in being less broad but strongly curved**.**

Occurrence: Tanezzuft Formation, late Rhuddanian-Telychian (Llandovery).

Selected previous stratigraphic record: Mid Silurian, USA (Loeblich, 1970); Llandovery, Algeria (Jardiné *et al*., 1974); late Aeronian-mid Telychian, Brazil (Le Hérissé *et al,* 2001); Aeronian-Telychian, Argentina (Rubinstein, 2005, 2006).

Genus ***Baltisphaeridium*** Eisenack, 1958b ex Eisenack, 1959
emend. Eiserhardt, 1989

Type species: *Baltisphaeridium longispinosum* (Eisenack) Eisenack, 1959.

Diagnosis: "spherical with some tendency to polyhedral vesicle from which arise homomorphic, typically long and slender, spine-like, hollow processes having simple termination and lacking communication with the vesicle cavity characteristically due to basal plugging of the processes. Eilyma is uni or possibly, multilayered and all types of excystement mode are present as partial, median splitting, and (very rarely) pylomes." Emended diagnosis of Eiserhardt (1989, p. 89-90).

Remarks: Eisenack (1931) described the type species *Baltisphaeridium longispinosum* but he did not discuss the diagnostic morphological features such as excystment structure, processes morphology, their relation with vesicle. Eisenack (1959) and Eisenack (1969) in his emendation did not clarify those features. Turner (1984) created genus *Baltisphaerosum,* and he assigned the forms with a pylome or without excystment structure to *Baltisphaeridum*, and the other forms with a median split to *Baltisphaerosum*. Eiserhardt (1989) emended *Baltisphaeridium* and considered in the genus *Baltisphaerosium* as a junior synonym. Vecoli (1996) accepted Eiserhardt's emendation, and he commented "without a revision of Eisenack's original type specimens, Eiserhardt's (1989) interpretation appears as the most formally correct, even if the presence of different excystment structures within the same genus may be considered unacceptable, indeed incongruous, from a biological viewpoint". Accordingly Vecoli (1996) considered the genus *Actiplion* Loeblich, 1970 and *Baltispherosium* Turner, 1984 as junior synonyms of *Baltisphaeridium* Eisenack, 1958 emended Eiserhardt's, 1989. Wicander *et al.* (1999) noted that the type species *Baltisphaerosum christoferii* Kjellström, 1976, Turner, 1984, does not show an excystment structure nor did Kjellström (1976) specify one in the specific diagnosis. Under this uncertainty of the taxonomic status of *Baltisphaerosum*, the present author provisionally assigns baltisphaerid species to *Baltisphaeridium*, the view which was previously adopted by Wicander *et al*. (1999) and Li *et al*. (2006). *Baltisphaeridium* is generally larger than *Micrhystridium* Deflandre, 1937 emend. Downie and Sarjeant, 1963, and the processes in the former genus do not communicate with the vesicle cavity.

Baltisphaeridium adiastalatum Wicander *et al.,* 1999

Plate 2, Fig 2

1999 *Baltisphaeridium adiastalatum* - Wicander *et al.,* p. 5, figs. 4.6-4.9
2011 *Baltisphaeridium adiastalatum* - Delabroye *et al.,* pl. 2, figs. 5, 6.

Description: Spherical to sub-spherical, single, psilate, smooth, hollow vesicle bearing single-walled, homomorphic, hollow, slender, simple processes about 16-20 in number which gently taper to acuminate distal tips. The base of each process has angular contacts with no communication with the vesicle cavity. Excystment formed by simple splitting structure.

Dimensions: L: 55(58)60µm, P: 22(31)40µm, n = 5.

Remarks and comparision: This species differs from *Baltisphaeridium oligopsakium* Loeblich and Tappan, 1978, in having a psilate vesicle, process wall and the processes has angular contact with the vesicle rather than a basal constriction.

Occurrence: Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-earlyHirnantian (Ashgillian).

Selected previous stratigraphic record: Late Ordovician (Ashgillian), USA (Wicander *et al.,* 1999), Katian-Hirnantian, Estonia (Delabroye *et al.,* 2011).

Baltisphaeridium aliquigranulum Loeblich and Tappan 1978

Plate2, Fig. 3

1978 *Baltisphaeridium aliquigranulum* - Loeblich and Tappan, p. 1247; pl. 3, figs. 4-8

2006 *Baltisphaeridium aliquigranulum* - Playford and Wicander, p. 15, 16; pl. 6, figs. 1,2.

2011 *Baltisphaeridium aliquigranulum* - Delabroye *et al*., pl. 2, figs. 7-8.

Description: Spherical to sub-spherical, single, psilate, smooth, hollow, moderately thick walled vesicle bearing single-walled, homomorphic, hollow, slender, simple processes about 5-7 in number which gently taper to acuminate distal tips. The base of processes have a solid plug with no communication with the vesicle cavity. The process wall is thinner than the vesicle and ornamented with scattered grana; their length is almost twice of the vesicle diameter. No excystment structure observed.

Dimensions: L: 55(58)60µm, P: 62(76)90µm, n = 6.

Remarks and comparision: This species is very similar in morphology to *Baltisphaeridium longispinosum* Eisenack, 1958, but it differs in having processes that are ornamented with scattered grana. The processes in *B. longispinosum* are psilate.

Occurrence: Memouniat and Bir Tlacsin formations, early-late Hirnantian (Ashgillian).

Selected previous stratigraphic record: Late Ordovician (Ashgillian), USA (Loeblich and Tappan, 1978; Playford and Wicander, 2006); Hirnantian, northern Gondwana, (Vecoli and Le Hérissé, 2004), Estonia (Delabroye *et al.,* 2011).

Baltisphaeridium christoferi Kjellström, 1976

Plate 2, Fig. 4

1976 *Baltispherosum christoferi* - Kjellström, p. 16, fig.9
1984 *Baltispherosum christoferi* - Turner, p. 103; pl. 4, figs. 1, 2
1988 *Baltispherosum christoferi* - Molyneux, p. 48; pl. 8, figs. 9, 10

Description: Spherical to sub-spherical, single, psilate, smooth, hollow, thin vesicle bearing single-walled, homomorphic, hollow, slender, simple processes about 15-18 in number which taper gently to acuminate distal tips. The base of processes have solid plug with no communication with the vesicle cavity. The process wall surface is psilate to scabrate, excystment structure formed by medial split.

Dimensions: L**:** 50(56)62µm, P: 35(40)47µm, n = 5.

Remarks and comparision: Turner (1984) transferred this species to his new genus *Baltisphaerosum*. Since the genus *Baltisphaerosum* is rejected, the species is attributed herein to *Baltisphaeridium*. This species is of variable process number but within the same size range of *Baltisphaeridium christoferii* recorded by Kjellström (1976) and Turner (1984). It is very similar in morphology size to *Baltisphaeridium trabeculaespinae* Górka, 1969 and *Baltisphaeridium adiastaltum* Wicander *et al.,* 1999*.* In the current study those species are attributed to *Baltisphaeridium christoferi*.

Occurrence: Melez Shugran and Memouniat formations, early late- late Katian-early Hirnantian (Ashgillian).

Selected previous stratigraphic record: Mid Ordovician, Sweden (Kjellström, 1976); Caradocian, England (Turner, 1984); Ashgillian, northeast Libya (Hill and Molyneux, 1988; Molyneux, 1988); Caradocian-Ashgillian, northern Gondwana (Vecoli and Le Hérissé, 2004); Llanvirnian, Oman (Molyneux *et al*., 2006); Lower Caradocian, Turkey (Paris *et al*., 2007); Llandelio to Caradocian. Iraq (Al-Ameri, 2010).

Baltisphaeridium bramkaense Górka 1979

Plate 2, Fig. 5

1976 *Baltispherosum bramkaense* - Górka, p. 358, pl. 14, fig.1, 2a-c.

Description: Spherical to sub-spherical, single, thick walled vesicle bearing single-walled, homomorphic, hollow, slender, simple processes about eight in number. The processes are fairly wide tapering towards the distal ends which are pointed and provided with small thickenings, narrowing at their base with no communication with the vesicle cavity; their length is equal or greater than vesicle diameter. Two of these processes are bifurcate distally. The vesicle and process wall surface is ornamented with grana. Excystment structure was formed by a medial split.

Dimensions: L: 60(62)65µm, P: 65(70)75µm, n = 7.

Remarks and comparison: This species is very similar to *Baltisphaeridium constrictum* Kjellström, 1971 in the shape of the processes, but it differs in process termination and the granular surface of the vesicle and processes. In addition the size is different. It differs from *Baltisphaeridium perclarum* Loeblich and Tappan, 1978, in the general form of the processes and the presence of bifurcation and in having a granulated vesicle rather than being laevigate. In addition the processes are wider and fitted to the distal ends of a small thickening. This species has two processes distally bifurcated but in the original diagnosis by Górka (1979) show only one bifurcate process.

Occurrence: Bir Tlachine and Memouniat formations, Hirnantian (Ashgillian).

Selected previous stratigraphic record: Llanvirnian-Caradocian, Poland (Górka 1979); Caradocian-Ashgillian, Turkey (Paris *et al*., 2007).

***Baltisphaeridium* cf. *druggi* Loeblich 1970**

Plate 2, Fig. 6

Description: Spherical vesicle with a thick walled, apparently double layered, smooth or finely granulate wall bearing single-walled, homomorphic, hollow, slender, simple processes about eight in number rising from the outer vesicle layer. The processes are transparent, pitted and finely wrinkled and bluntly pointed distally; proximally do not communicate with the vesicle cavity. No excystment structure observed.

Dimensions: L: 15(17)20µm, P: 10(12)15µm, n = 3.

Remarks and comparision: The specimens recorded in the current study are similar in morphology to *Actiplion druggi* Loeblich, 1970 and *Actiplion* cf. *druggi* recorded by Molyneux (1988) from the Ashgillian of northeast Libya but it differs in having smaller vesicle and processes length.

Occurrence: Bir Tlacsin Formation, late Hirnantian (Ashgillian).

Baltisphaeridium klabavense (Vavardová) Kjellström 1971

Plate 3, Figs. 1, 2

1965 *Baltisphaeridium longispinosum* var *klabavense* - Vavardová, p. 353; pl. 2, fig. 1; text-fig. 1

1971 *Baltisphaeridium klabavense* - (Vavardová) Kjellström, p. 14; 1; text-fig. 6.

1984 *Baltisphaeridium klabavense* - Elaoud-Debbaj, pl. III, figs. 8, 9.

1999 *Baltisphaeridium klabavense* - Vecoli, p. 34; pl. 3, figs. 6, 7.

2007 *Baltisphaeridium klabavense* - Le Hérissé et *al*., pl. 1, fig. 11.

Description: Spherical to sub-spherical, single, thin walled vesicle bearing single-walled, homomorphic, hollow processes about twelve in number. The processes are constricted proximally and plugged at their base with no communication with the vesicle cavity. Weakly-developed, small grana or verrucate element ornamented the vesicle surface and process wall. No excystment structure observed

Dimensions: L: 39(47)55µm, P: 18 (24)30µm, n = 4.

Remarks and comparision: The a few broken specimens recorded here have a spherical, thin vesicle with weakly-developed small grana or verrucate element ornamented the vesicle surface and process wall. The processes are constricted proximally and plugged at their base. Based on these characteristics these specimens are attributed to *Baltisphaeridium klabavense.*

Occurrence: Hawaz Formation, mid-late Darriwilian (Llanvirnian),

Selected previous stratigraphic record: Arenigian, France (Rauscher, 1974b); Arenigian-lower Llanvirinian, South China (Brocke et al., 2000); Arenigian-Llanvirnian, Morocco (Fournier-Vians, 1985); Czech Republic (Vavrdová, 1965, 1972, 1977); late Arenigian-Lower Llanvirnian Morocco (Elaoud-Debbaj, 1984), Sweden (Righi, 1991; Ribecai and Tongiorgi, 1995); Llanvirnian, Jordan (Keegan *et al.,* 1990); Libya (Deunff and Massa, 1975); late Llanvirnian, Poland (Górka, 1980); Mid Ordovician, Sweden (Kjelstörm, 1971b), Estonia (Uutela and Tyuni, 1991); Llanvirnian, north Africa (Vecoli, 1999, 2000) mid-late Darriwilian, Saudi Arabia (Le Hérissé et *al*., 2007); Arenigian-earliest Caradocian, northern Gondwana (Vecoli and Le Hérissé, 2004); early Darriwilian, southeastern Turkey (Paris *et al*., 2007).

Baltisphaeridium* cf. *lancettispinae Górka, 1969

Plate 3, Fig. 3

Desription: Globular, relatively thick walled vesicle bearing single, homomorphic, hollow processes about 9-12 in number. The processes are constricted proximally and plugged at their base with no communication with the vesicle cavity and gradually taper to evexate distal tips. The vesicle wall surface may be ornamented with grana and the processes ornamented with spines.

Dimension: L: 50(52)55µm, P: 50(56)62µm, n = 3.

Remarks and comparision: The specimens recorded in the current study are similar in morphology to *B. lancettispinae* Górka, 1969, but the process has evexate distal termination rather than acuminate. *Baltisphaeridium calicispinae* Górka, 1969 differs in having both the vesicle and process wall covered with small spines.

Occurrence: Bir Tlacsin Formation, late Hirnantian (Ashgillian).

Baltisphaeridium latiradiatum (Eisenack, 1931) Eisenack, 1959

Plate 3, Fig. 4

For synonymy see Kjelstörm (1971).

Additional synonymy:

1971a*. Baltisphaeridium latiradiatum* - Kjellstrom, p 28; pl. 2: 1.

1975 *Baltisphaeridium latiradiatum* - Tynni, p. 12; pl. 1: 9.
1979 *Baltisphaeridium latiradiatum* - Górka, p. 361; pl. 16, fig. 1.
2003*. Baltisphaeridium latiradiatum* - Ghavidel-syooki, pl. 4, fig. 2.

Description: Ellipsoidal, single, hollow, thin walled vesicle bearing single-walled, homomorphic, hollow, slender, simple processes about six in number. The processes are constricted proximally and plugged at their base, may be solid plug with no communication with the vesicle cavity and gently taper to acuminate distal tips; their length is equal or longer than the vesicle diameter. The wall surface of the vesicle the process is psilate. No excystment structure observed.

Dimensions: L: 50(52)55µm, P: 62(64)67µm, n = 3.

Remarks and comparision: This species is similar in morphology to *Baltisphaeridium constrictum* Kjellström, 1971b in that their processes have a constricted base, but it differs in having a psilate vesicle wall rather than granulate.

Occurrence: Melez Shugran, Memouniat and Bir Tlacsin formations, ealy late Katian-Hirnantian (Ashgillian).

Selected previous stratigraphic record: Mid Ordovician, Gotland (Kjelstörm 1971); Ordovician, Finland (Tynni, 1975); Llandeilo, Poland (Górka, 1979); Caradocian, Turkey (Paris *et al*., 2007); Llanvirinian-Ashgillian, Iran (Ghavidel-syooki, 2003).

Baltisphaeridium longispinosum delcatum Turner, 1984

Plate 3, Fig. 5

1984 *Baltisphaeridium longispinosum delcatum* -Turner, p. 99-100; pl. 6, figs. 1, 7.

1985 *Baltispherosum longispinosum delcatum* - Molyneux and Paris, pl. 2, fig. 2, 3.
1988 *Baltispherosum longispinosum delcatum* **-** Molyneux, p. 47; pl. 8, fig. 4, 5.
1991 *Baltispherosum longispinosum delcatum* **-** Grignani *et al*., pl. 1, figs. 1,2.

Description: Spherical to sub-spherical single, hollow, psilate, relatively thick vesicle bearing single-walled, homomorphic, hollow, slender, flexible, simple processes about 10-14 in number. The processes are constricted proximally and plugged at their base with no communication with the vesicle cavity and gently taper to acuminate distal tips; their length is approximately equal the vesicle diameter. The process wall is thinner than the vesicle. No excystment structure observed.

Dimensions: L: 47(49)51µm, P: 35(37)40µm, n = 4.

Remarks and comparision: The specimens recorded in the current study are slightly greater in size than the original description by Turner (1984). It is very similar in morphology and size to the specimens recorded by Molyneux (1988) from the Ashgillian of northeast Libya.

Occurrence: Melez Shugran Formation, early late Katian-late Katian (Ashgillian).

Selected previous stratigraphic record: Caradocian, UK (Turner, 1984); Ashgillian, northeast Libya (Molyneux and Paris, 1985; Hill and Molyneux, 1988; Molyneux, 1988); Late Ordovician, southeast Libya (Grignani *et al*., 1991).

Baltisphaeridium longispinosum Eisenack, 1931

Plate 3, Fig. 6, Plate 4, Fig. 1

For synonymy see (Kjellstrom, 1971a, 1976).

Additional synonymy:
1979 *Baltisphaeridium latiradiatum* - Górka, p. 362; pl. 15, fig. 4.
1993 *Baltisphaeridium longispinosum* - Jachowicz , pl. II, figs. 6.
2003 *Baltisphaeridium longispinosum* - Ghavidel-syooki, p. 4, fig. 7.

Description: Spherical to sub-spherical single, hollow, psilate, thin walled vesicle bearing single-walled, homomorphic, long, hollow, slender, flexible, simple processes about 8-16 in number. The processes are faintly curved proximally with no communication with the vesicle cavity and gently taper to acuminate distal tips; their length is greater than the vesicle diameter. The vesicle wall is thicker than the process. No excystment structure observed.

Dimension: L: 56(63)70µm, P: 70(81)92µm, n = 8.

Remarks and comparision: The specimens recorded in the current study conform to the original description by Eisenack (1931).

Occurrence: Melez Shugran Formation, early late Katian-late Katian (Ashgillian).

Selected previous stratigraphic record: Mid Ordovician-late Llandovery, Baltic (Eisenack 1951, 1959, 1962) Ordovician, Sweden (Eisenack 1959; Staplin *et al*., 1965); late Arenigian-Caradocian, Poland (Górka, 1969, 1979); late Caradocian, northwestern Saudi Arabia (Jachowicz, 1995); Llanvirnian-Ashgillian, Iran (Ghavidel-Syooki, 2003); mid Katian-early Hirnantian, northern Gondwana (Vecoli and Le Hérissé, 2004).

Baltisphaeridium perclarum Loeblich and Tappan, 1978

Plate 4, Fig. 2

1978 *Baltisphaeridium perclarum* - Loeblich and Tappan, p. 1235; pl. 6, figs. 5-7

1988 *Baltisphaeridium* cf. *perclarum* - Molyneux, p. 47; pl. 6, figs. 5-7.
1991 *Baltisphaeridium perclarum* - Grignani *et al*., pl. 1, figs. 3, 5.
1999 *Baltisphaeridium perclarum* - Wicander *et al*., p. 9, figs. 4.1-4.
2011 *Baltisphaeridium perclarum* - Delabroye *et al.,* pl. 2, figs. 9-11

Description: Spherical to sub-spherical, hollow, psilate, relatively thick walled vesicle bearing single, homomorphic, hollow, conical, flexible, simple processes about 7-8 in number. The processes are constricted proximally and plugged at their base with no communication with the vesicle cavity and gently taper to acuminate distal tips; their length is variable ranging up to two times of the vesicle diameter, commonly with one or two smaller subsidiary branches, irregularly bifurcated, these branches may be smaller than the others. The vesicle wall surface is psilate while the process is ornamented with fine grana. Excystment structure formed as a simple rupture.

Dimensions: L: 55(60)65µm, P: 85(92)100µm, n = 5.

Remarks and comparision: This species differs from *Baltisphaeridium constrictum* Kjellström, 1971, in having longer processes, laevigate vesicle wall and granulate process wall. *Baltisphaeridium* cf. *perlocum* described by Molyneux (1988) from Ashgillian of northeast Libya have a smaller vesicle, evexate rather than acuminate process termination and psilate wall process.

Occurrence: Bir Tlacsin Formation, late Hirnantian (Ashgillian).

Selected previous stratigraphic record: Ashgillian, USA (Loeblich and Tappan, 1978); Ashgillian, northeast Libya (Hill and Molyneux, 1988; Molyneux, 1988); Caradocian-Ashgillian, southeast Libya (Grignani *et al*., 1991); Caradocian-Ashgillian, USA (Wicander, 1999); Katian, Estonia (Delabroye *et al.,* 2011).

***Baltisphaeridium* sp. A**

Plate 4, Fig. 3

Description: Spherical single, hollow, psilate, relatively thick walled vesicle bearing single-walled, homomorphic, hollow, slender, flexible, simple processes about 8-10 in number. The processes are constricted proximally and plugged at their base with no communication with the vesicle cavity and gently taper to acuminate distal tips; their length is smaller than the vesicle diameter. The process has a thinner wall than the vesicle. No excystment structure observed.

Dimensions: L: 50(52)55µm, P: 37(38)40µm, n = 4.

Remarks and comparision: This species differs from *Baltisphaerdium ingerae* Kjellstörm, 1971, in having fewer processes and a psilate vesicle wall and processes rather than a granulate vesicle and echinate process wall. It is very similar in morphology to *Baltisphaeridium semibulbosum* Górka 1979 and *Baltispliaeridium bulbosum* Kjellström, 1971b but it differs in having fewer processes.

Occurrence: Melez Shugran Formation, early late Katian-late Katian (Ashgillian).

Genus ***Buedingiisphaeridium*** Schaarschmidt, 1963,
emend. Lister, 1970

Type species: *Buedingiisphaeridium permicum* Schaarschmidt, 1963.

Diagnosis: "Vesicle spherical, of moderate size, wall firm, ornamented with low verrucae or conical hollow tubercles, closed at the tip, sometimes thickened at the tip, but always partially hollow, communicating with the vesicle interior." From Lister (1970, p. 60-61).

Remarks: The genus *Buedingiisphaeridium* was diagnosed by Schaarschmidt (1963) then revised by Staplin *et al*., (1965) without referring to the presence of a circular opening as indicated by Schaarschmidt (1963). The proposed emended diagnosis used by Lister (1970) is followed and accepted here.

Buedingiisphaeridium* cf. *pyramidale Lister, 1970

Plate 4, Fig. 4

Description: Subspherical to ellipsoidal, psilate, single, thin walled vesicle bearing numerous smooth, conical, hollow tubercles, which have solid tips and communicate freely with the vesicle cavity. Excystment formed by cryptosuture.

Dimensions: L: 27(28)30μm, P: 0.5(0.7)1.0μm, n = 3.

Remarks and comparision: This species is attributed to the genus *Buedingiisphaeridium* Schaarschmidt, 1963 based on the vesicle wall and process shape. It is simillar in morphology to *B. pyramidale* Lister, 1970 but it differs in lacking striation on the processes which makes it difficult to separate by light microscope.

Occurrence: Tanezzuft Formation, late Rhuddanian-Telychian (Llandovery).

Genus ***Carminella*** Cramer, 1968

Type species: *Carminella maplewoodensis* Cramer, 1968

Dignosis: “Cyst consist of circular inner body covered with closely set, short. solid processes (slightly less the 2µm in length) and the outer tubular vellum extending beyond the central body and truncated at each end, the short processes expand at their distal end and attach to the outer vellum, at polar ends of inner central body the processes are with low spine or bumps, they are various lengths extending far beyond the central body to attach to the inner side of tubular vellum, commonly they extend beyond the well preserved vellum and retain fragments of the thin vellum attached at their distal ends; a few processes seem never to attach to the vellum but project beyond it; outer vellum thin, transparent, about o.4 µm in thickness, finely wrinkled; excystment probably by simple rupture of inner central body." From Cramer (1968, p. 67).

Remarks: The genus *Geron* (Cramer) Cramer, 1969c differs from this genus in having only one cylindrical skirt that terminates in one or numerous processes. Cramer and Diez (1972) considered the genus *Riculasphaera* Loeblich and Drugg, 1968 as a synonym of *Carminella.* Loeblich and Wicander (1976) differentiated the genus *Carminella* from the genus *Riculasphaera* by it's vesicle and the excystment structure. In *Carminella* the excystment was not observed but *Riculasphaera* has a media split.

Carminella maplewoodensis Cramer, 1968

Plate 4, Figs. 5, 6

For synonymy see Le Hérissé (1989).

Additional synonymy:

1989 *Carminella maplewoodensis* - Le Hérissé, p. 88; pl. 5. fig. 16.
2000 *Carminella maplewoodensis* - Le Hérissé, pl. 5, fig. F.
2001 *Carminella maplewoodensis* - Le Hérissé *et al,* pl. 1, fig.4.

Description: Spherical to ellipsoidal, single, thin walled vesicle bearing very fine numerous processes. These processes support the two fine, wrinkled membranes which encircle each poles of the vesicle. The vesicle surface between the poles is unornamented. No excystment structure observed.

Dimensions: L: 45(46)48*µ*m, P: 112(113)115*µ*m, n = 5.

Remarks and comparision: This species is attributed to *Carminella* based on the shape and presence of small solid processes which support the two wrinkled membranes. It is very similar in morphology and size to the specimens reported by Le Hérissé (2000) from the early Telychian of Saudi Arabia.

Occurrence: Tanezzuft Formation, late Rhuddanian-Aeronian (Llandovery).

Selected previous stratigraphic record: late Llandovery, USA (Cramer 1968, 1970, 1971; Cramer and Díez, 1972; Loeblich 1970); Silurian, northwest Spain (Cramer 1969), Wenlock, Argentina (Pöthé de Baldis, 1971, 1975; Rubinstein, 1993); Llandovery – Wenlock, Libya (Richardson and Ioannides 1973); Llandovery-late Ludlow, England (Dorning, 1981; Hill and Dorning, 1984; Hill, 1974; Mabillard and Aldridge 1985; Turner *et al*., 1995); late Llandovery, Canada (Achab, 1976); Devonian, Paraguay (Pöthé de Baldis, 1971); Llandovery- Wenlock, Gotland (Le Hérissé, 1989); early Telychian, Saudi Arabia (Le Hérissé, 2000); late Aeronian-early mid Telychian, Brazil (Le Hérissé *et al,* 2001).

Genus ***Cheleutochroa*** Loeblich and Tappan, 1978
emend. Turner, 1984

Type species: *Cheleutochroa gymnobrachiata* Loeblich and Tappan, 1978.

Diagnosis: “Vesicle spherical with simple conical, hollow, laevigate processes that are solid distally, processes communicate freely with vesicle interior, vesicle wall relatively thick , ornamented with muri forming a reticulate pattern which breaks up into elongate parallel or converging ridges near the processes, directed toward but not extending on the processes, processes laevigate, Excystment by rupture of vesicle wall.” From Turner (1984, p. 105).

Remarks: The genus *Cheleutochroa* was diagnosed by Loeblich and Tappan (1978) and then emended by Turner (1984) to including branching processes. It differs from the genus *Micrhystridium* Deflandre, 1937, in having reticulate ornamentation of the vesicle wall rather than being smooth or with only minor features such as grana.

Cheleutochroa* cf. *diaphorosa Turner, 1984

Plate 5 , Fig. 1

Description: Spherical to sub-spherical, relatively thick walled vesicle bearing single-layered, hollow, thin, smooth processes about 7 in number. They have gently tapering to acuminate distal tips or bifurcate, their length usually slightly greater than the vesicle diameter. The vesicle surface is ornamented with weakly - developed fine grana, these grana do not extend to the processes wall which entirely smooth and may be changes near the processes base into ridges that converge towards the processes base, but not extending on the processes. Excystment structure formed by rupture.

Dimensions: L: 20(22)24µm, P: 20(23)26µm n = 4.

Remarks and comparision: The specimens recorded in the current study are slightly greater in vesicle diameter and has fewer processes than those described by Turner (1984) and others recorded from the Upper Ordovician of northeast Libya by Molyneux (1988), althought the processes have almost the same length. Turner (1984) indicated that the vesicle wall is reticulate under the Scanning Electron Microscope, which revealed the real nature of vesicle wall but he noted that it appears as granulate in transmitted light microscope which not clearly visible in our specimens.

Occurence: Bir Tlacsin Formation, late Hirnantian (Ashgillian).

Cheleutochroa* cf. *gymnobrachiata Loeblich and Tappan, 1978

Plate 5, Fig. 2

Description: Spherical to sub-spherical, relatively thick vesicle bearing single-layered, hollow, thin, smooth processes about eleven in number. They have gently tapering to acuminate distal tips or sometimes bifurcate, their length usually slightly greater than the vesicle diameter. The vesicle have a reticulate surface formed by low muri forming a reticulate pattern occasionally presence of ridges near the base of processes but not extending on the processes. Excystment structure formed by rupture.

Dimensions: L: 15(17)20µm, P: 18(19)20µm, n = 3.

Remarks and comparision: This species is similar in morphology to *C. gymnobrachiata* Loeblich and Tappan, 1978, but it is greater in overall size. *Cheleutochroa bomia* Turner, 1984 has processes length equal to the vesicle diameter, with each process dividing distally either as a single bifurcation or up to third order.

Occurence: Bir Tlacsin Formation, late Hirnantian (Ashgillian).

Genus ***Circinatisphaera*** Miller, 1987

Type Species: *Circinatisphaera enigma* Miller 1987.

Description: "Central body hollow, apparently unilayered, spherical to sub-spherical; outline circular to sub-circular, sharply differentiated from processes. Vesicle surface smooth to granulate, with or without ridges radiating from process bases. Three to numerous, hollow to nearly closed, smooth to granulate, essentially homomorphic processes arise from the vesicle wall and branch distally. Processes closed distally and open proximally to the vesicle cavity. Excystment by circinate suture, with or without thickened rim and a granule or baculum at the excystment suture overlap. Opercula with one or multiple processes." From Miller (1987, p. 102-103).

Remarks: The genus *Circinatisphaera* differs from the genera *Cymbosphaeridium* Lister 1970, *Multiplicisphaeridium* Staplin, 1961 and *Oppilatala* Loeblich and Wicander, 1976, in having a single wall and a circinate suture.

Circinatisphaera enigma Miller. 1987

Plate 5, Fig. 3

1987 *Circinatisphaera enigma* - Miller, p. 104-105; pl. 1, figs. 3-6; Pl. 2, figs. 1-9, 11.

2000 *Circinatisphaera enigma* - (Miller) Le Hérissé, pl. 7, fig. i.

Description: Spherical to sub-spherical vesicle, single walled. Processes are about 4-5 in number slightly tapering to parallel-sided, approximately equidistant, essentially homomorphic, hollow. Proximally they are open, may be constricted near mid-length and distally closed by repeated branching. The vesicle and process wall surface is psilate. Excystment formed by circinate suture,

Dimensions: L: 25(27)30μm, P: 25(27)30μm, n = 5.

Remarks and comparision: This species can be recognized by its thin, single wall, the position of processes, their complex branching at the distal extremities and circinate suture.

Occurence: Tanezzuft Formation, late Rhuddanian-Telychian (Llandovery).

Selected previous stratigraphic record: Early Silurian, Belgium (Martin 1974, 1988); early-mid Telychian, Saudi Arabia (Le Hérissé, 2000).

Genus ***Cymbosphaeridium*** Lister, 1970

Type species: *Cymbosphaeridium bikidium* Lister, 1970.

Diagnosis: "Vesicle hollow, subspherical, double-walled, the inner wall is closely appressed to the outer wall and continuous across the proximal part of the processes. The processes are few and variable in number, hollow, tubiform closed distally and formed from the outer wall. Only the reflected plate formula follows the pattern apical, pre-equatorial, post equatorial, antipical. Excystment is by obvious suture, resulting in the release of an apical operculum consisting of single walled plate". From Lister (1970, p. 63).

Remarks: The genus *Cymbosphaeridium* differs from the genus *Multiplicisphaeridium* Staplin *et al.,* 1965, in having a double walled vesicle and the processes proximally pluged but not communicating with the vesicle cavity, ramifications and a structure of excystment type. The genus *Oppilatala* Loeblich and Wicander, 1976 is similar in morphology to the genus *Cymbosphaeridium* in having a double layered wall and processes not communicating with the vesicle cavity but lacking an operculum bearing one process. The genus *Opillatala* has a simple excystment rupture.

Cymbosphaeridium pilaris typicum Le Hérissé, 1989

Plate 6, Fig. 1

For synonymy see Le Hérissé (1989).

Additional synonymy:

1989 *Cymbosphaeridium pilaris typicum* - Le Hérissé, p. 90-91; pl. 7, figs. 7-8, 17-18.

2002 *Cymbosphaeridium pilaris typicum* - Le Hérissé, pl. 1, figs. 1,2.

Description: Spherical, hollow, double-walled vesicle. The inner wall is thicker than the outer wall. The vesicle bears single-walled, homomorphic, hollow, tubular processes about 9-10 in number which terminate distally to short branches up to second order. The processes are constricted proximally and plugged at their base with no communication with the vesicle cavity; their length is smaller than the vesicle diameter. The vesicle surface is covered with microverrucae while the process surface is psilate and its wall is thinner than the vesicle. Excystment formed by an obvious suture.

Dimensions: L: 28(26)38μm, P: 10(12)15μm, n = 5.

Remarks and comparision: This species differs from *Cymbosphaeridium bikidium* Lister, 1970, in having a micro-verrucate vesicle wall rather than smooth. *Cymboshaeridium pilar* var *pilar* Cramer, 1970 has a coarsely granular vesicle with the grana adjacent to each other. *Cymboshaeridium pilar* var *scarbatum* Cramer, 1970 has a granular vesicle wall but the grana are more widely spaced.

Occurence: Tanezzuft Formation, Telychian (Llandovery).

Selected previous stratigraphic record: Wenlock-early Gedinnian, Spain (Cramer, 1966, 1967, 1970), Ludlow-early Gedinnian, Algeria (Jardiné and Yapaudjan, 1968, Jardine *et al,.* 1972); Wenlock, USA (Thusu, 1973b); late Llandovery-Ludlow, south-eastern Turkey (Erkmen and Bozdogan, 1979); Wenlock, Gotland (Le Hérissé, 1989).

***Cymbosphaeridium* sp. 1** Le Hérissé, 2000

Plate 6, Fig. 2, 3, 4

Description: Spherical, hollow, double-walled vesicle. The inner wall is thicker than the outer wall. The vesicle bears single-walled, homomorphic, hollow, tubular processes about 3-6 in number which terminate distally to short branches up to second order. The processes are constricted proximally and plugged at their base with no communication with the vesicle cavity; their length is bigger than the vesicle diameter. The vesicle and process wall surface is psilate and the vesicle have thicker wall than the process. Excystment formed by an obvious suture.

Dimensions: Dimensions: L: 26(28)30μm, P: 30(34)38μm, n = 7.

Remarks and comparision: The specimens recorded in the current study are similar in morphology to the same specimens described by Le Hérissé (2000) from the mid-late Telychian of Saudi Arabia, but it has a slightly larger vesicle diameter and process length.

Occurence: Tanezzuft Formation, Aeronian-Telychian (Llandovery).

***Cymbosphaeridium* sp. A**

Plate 6, Fig. 5

Description: Spherical, hollow, double-walled vesicle bearing single-walled, homomorphic, hollow, tubular processes about 17-19 in number which taper to acuminate distal tips or bifurcate. The processes are constricted proximally and plugged at their base with no communication with the vesicle cavity; their length is equal half or less half of vesicle diameter. The vesicle and process surface is psilate and the vesicle has thicker wall than the process. Excystment formed by an obvious suture.

Dimension: L: 25(27)30μm, P: 3(4)8μm, n = 7.

Remarks and comparision: This species differs from *Cymbosphaeridium bikidium* Lister, 1970 in the size and -number of processes. *Cymbosphaeridium* sp. 1 Le Hérissé, 2000 has fewer and longer processes.

Occurence: Tanezzuft Formation, Aeronian-Telychian (Llandovery).

Genus ***Dactylofusa*** Brito and Santos, 1965 emend. Cramer, 1970

Type species: *Dactylofusa maranhensis* Brito and Santos, 1965.

Diagnosis: "Vesicle fusiform, elongated with pointed poles. At each pole there may be a simple, equivalent process. Within the same species, the length of the polar processes may vary greatly. The vesicle wall is unilayered and the sculpture distribution symmetry is holomorphic with elements arranged in a pattern which is essentially parallel to the longitudinal axis and with decreasing complexity, size and number of elements towards the poles. The ectoderm surface is ornamented with elements of the echinate kind, over one micron high: echinate, cones short secondarily branched clavate spines, etc. all arranged in longitudinal rows. The vesicle may open by splitting along a straight scar parallel to the axis, at an approximately equatorial position in the vesicle. The vesicle axis may be straight or curved, even within the same species." From Cramer (1970, pp. 79-82).

Remarks: The genus is used here in agreement with Dorning (1994) who considered the four fusiform acritarch genera to be validly published and of practical value. Generic distinction is based on the nature and disposition of sculpture: in *Dactylofusa* (complex short processes, often arranged in rows).

Dactylofusa cucurbita Jardiné *et al.,* 1974

Plate 6, Fig. 6

1974 *Dactylofusa cucurbita* - Jardiné *et al*., p. 128; pl. 3, figs. 5, 6.
1991 *Dactylofusa cucurbita* - Grignani *et al*., pl. 4, figs. 5.
1999 *Dactylofusa cucurbita* - Vecoli, p. 38, 38; pl. 7, fig. 1.

Description: Elongated fusiform, thin, single walled vesicle, its extremities drawn out into two hollow, acuminate, short processes are variable in length communicate freely with the vesicle cavity. The vesicle surface ornamented with tubercles more or less sharp or blunt which are irregular in size, generally coarse and appear solid under optical microscope. They are arranged continuously in longitudinal rows parallel to the longitudinal axis of the vesicle, decreasing towards the vesicle extremities and become as grana on the processes. No excystment structure observed.

Dimensions: L: 100(110)120μm, W: 35(37)40μm, n = 3.

Remarks and comparision: The specimens recorded in the current study closely conform to the original description by Jardiné *et al.,* (1974) from the Caradocian-Ashgillian of the Algerian Sahara.

Occurnce: Melez Shugran and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian).

Selected previous stratigraphic record: Late Ordovician, Czech Republic (Vavrdova, 1988); southeast Libya (Grignani *et al*., 1991); Caradocian-?Ashgillian, Algerian (Jardiné *et al*., 1974); Ashgillian (Hirnatian); Algeria, southern Tunisia and northwest Libya (Vecoli, 1999; Vecoli *et al.* 2000, 2009), northern Gondwana (Vecoli and Le Hérissé, 2004); Late Ashgillian, Turkey (Paris *et al*., 2007).

Dactylofusa striatogranulata Jardiné *et al.,* 1974

Plate 7, Fig. 5, 6

1974 *Dactylofusa striatogranulata* - Jardiné *et al*., p. 128; pl. 2, figs. 1.

1974 *Dactylofusa striatogranulata* - Jardiné *et al.,* p. 137.

1989 *Eupoikilofusa striatogranulata* - Vavrdová, fig. 14-C.

1984 *Poikilolofusa striatogranulata* - Playford and Martin, p. 208, 209, fig. 8, A-F.

1999 *Dactylofusa striatogranulata* - Vecoli, p. 39; pl. 6, fig. 2.

2013 *Dactylofusa striatogranulata* – Le Hérissé *et al*., fig. 8, O.

Description: Elongated fusiform vesicle, single, thin-walled, its extremities drawn out into two hollow, acuminate, short processes which communicate freely with the vesicle cavity. The vesicle surface is ornamented with bluntly terminated spines, closely arranged in a fine uniserial linear pattern. They are arranged continuously in longitudinal rows parallel to the longitudinal axis of the vesicle and becoming finer and less distinct on the basal part of processes. No excystment structure observed.

Dimensions: L: 140(165)190μm, W: 30(33)43μm, n = 6.

Remarks and comparision: The specimens recorded in the current study closely conform to the original description by Jardiné *et al.,* (1974). *Disparifusa hystricosa* Loeblich, 1970 differs from this species in having vesicle wall ornamented with bluntly terminated spines that are randomly arranged.

Occurnce: Memouniat and Bir Tlacsin formations, Hirnantian (Ashgillian).

Selected previous stratigraphic record: Late Ordovician-Early Silurian, Algerian Sahara (Jardiné *et al*., 1974); Late Ordovician, Czech Republic (Vavrdová, 1988, 1989); Llanvirnian, Australia (Playford and Martin, 1984); Ashgillian Algeria, southern Tunisia and northwest Libya (Vecoli, 1999; Vecoli *et al.* 2000); Hirnantian, northern Gondwana (Vecoli and Le Hérissé. 2004), Latre Ordovician (latest Hirnantian)-Early Silurian (Rhuddanian), northern Chad and southeastern Libya (Le Hérissé *et al*., 2013).

Genus ***Deunffia*** Downie, 1960 emend. Cramer, 1970

Type species: *Deunffia monspinosa* Downie, 1960.

Diagnosis: “Vesicle body subspherical to ellipsoidal; the long axis of the body is parallel with the axis of the vesicle. One pole is ornamented by a spine or process which may simple, distally branched, or bears filose sculpture elements. The other pole smooth. Vesicle wall smooth to micro-sculptured. Vesicle symmetry bipolar, hemimorphic; symmetry axis longitudinal.” From (Cramer 1970, p. 56-57).

Remarks: This genus was diagnosed by Downie (1960) and then emended by Cramer (1970) to exclude the size limit of vesicle length (maximum 100µm).

Deunffia brevispinosa Downie, 1960

Plate 7, Fig. 2

For synonymy see Le Hérissé (1989).
Additional synonymy:
1989 *Deunffia brevispinosa* - Le Hérissé, p. 94-95; pl. 8, fig. 1-2.

Description: Spherical to ellipsoidal, hollow, single vesicle bearing single-layered, hollow process which gradually taper to acuminate or pointed tip. This process communicates freely with the vesicle cavity. The vesicle and process wall surface is psilate to finely granulate. No excystment structure observed.

Dimensions: L: 25(28)32μm, P: 22(23)25μm, n = 4.

Remarks and comparision: This species differs from *Deunffia monospinosa* Downie, 1960 in the vesicle size and process length. *Deunffia calva* Cramer, 1970 differs from this species in having an extremely short process.

Occurence: Tanezzuft Fromation, mid Rhuddanian (Llandovery).

Selected previous stratigraphic record: Wenlock, England (Downie, 1960; Hill, 1974; Dorning, 1981); Telychian-Sheinwoodian, UK (Mabillard and Aldridge, 1985), Russia (Sheshegova, 1984), USA (Cramer, 1970), Gotland (Le Hérissé, 1989), Brazil (Cardoso, 2005).

Genus ***Dilatisphaera*** Lister, 1970

Type pecies: *Dilatisphaera laevigata* Lister, 1970.

Diagnosis: "Vesicle hollow, double walled, spherical to sub-spherical; processes few in number, single-walled, hollow, broad; proximally they are closed to the vesicle cavity, distally they are open. Excystment aperture apical, controlled by obvious suture." From Lister (1970, p. 65).

Remarks: The genus *Dilatisphaera* differs from the genus *Umbellasphaeridium* Jardiné *et al*., 1974, in having hollow processes. The genus *Fulgisphaeridium* Deunff, 1980 could be a synonym of this genus (Le Hérissé, 1989). The genus *Folisphaeridium* Lister, 1970 has rosette like processes

Dilatisphaera* cf. *wimanii (Eisenack 1968) Le Hérissé, 1989.

Plate 7, Fig. 1

Description: Spherical to sub-spherical, hollow, double walled vesicle bearing single-walled, hollow, transparent, broad processes about 15 in number. The processes are closed proximally with no communication with the vesicle cavity and distally they are open. The excystment structure is cryptosuture

Dimension: L: 120(125)130µm, P: 15(20)25µm, n = 3.

Remarks and comparison: The specimens recodeded here are distinguished from specimens identified in the Silurian of Gotland by Le Hérissé (1989), in having larger size. It is similar in morphology and size to *Dilatisphaera wimanii* recorded by Delabroye *et al*., 2011 from the Katian of Estonia, but it differs in having a bigger vesicle and shorter and more processes.

Occurence: Melez Shugran Formation, early late Kataian (Ashgillian).

Genus ***Disparifusa*** Loeblich and Tappan, 1970

Type pecies: *Disparifusa hystricosa* Loeblich, 1970.

Diagnosis: “Asymmetrical fusiform central body, inflated on side in a broad curve, straight or concave on the other side, each end produced into a sharp to bluntly pointed polar spine of variable length, wall thin, 0.5 µm or less in thickness, ornamented by numerous short conical spines having no apparent regular arrangement; excystment probably by a longitudinal splitting of the wall on the straight or concave side.” From Loeblich (1970, p. 716).

Remarks: This genus differs from the genus *Leiofusa* Eisenack, 1938 in that it is symmetrical in outline and has spiny ornamentation, and from the genus *Dactylofusa* Brito and Santos, 1965 in outline and in lacking claviform spines arranged in longitudinal rows. The genus *Poikilofusa* Staplin, Jansonius and Pocock, 1965 differs from this genus in having less abundant spines, which are randomly distributed on the vesicle wall.

Disparifusa hystricosa Loeblich, 1970

Plate 7, Fig. 7

1970 *Disparifusa hystricosa* - Loeblich, p. 716-717; figs. 10 A, B; 11 A-C.

Description: Fusiform, elongate thin-walled vesicle, broadly convex on one side and nearly straight on the other side. Polar ends produced into short taper to blunt or pointed tip varying in length. The vesicle wall ornamented with bluntly terminated spines that are randomly arranged and continue onto the processes nearly to the tip and becoming finer on the processes. No excystment structure observed.

Dimension: L: 125(127)130µm, W: 25(27)30µm, n = 6.

Remarks and comparision: This species differs from *Disparifusa perryi* Loeblich and Tappan, 1976, in having larger size and longer process. It differs from *Poikilofusa spinata* Staplin, Jansonius and Pocock, 1965 in having more spines on the vesicle wall.

Occurence: Melez Shugran and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian).

Selected previous stratigraphic record: Mid Ordovician, USA (Loeblich, 1970).

Genus ***Domasia*** Downie 1960, emend. Hill, 1974

Type species: *Domasia trispinosum* Downie, 1960

Diagnosis: “Vesicle hollow sub-spherical to elongatedly ellipsoidal in outline. The long axis of the body is parallel with the axis of the vesicle. At one pole (the posterior) a single, often reduced process and at the opposite (anterior) pole usually two single, sometimes three or one bifurcation processes are present, vesicle wall smooth to microsculptured, unlayered. Vesicle symmetry axis longitudinal, hemimorphic.” From (Hill 1974, p.17).

Remarks: The genus *Domasia* was diagnosed by Downie (1960) and then emended by Hill (1974) to include forms possessing three processes at the interior end instead of the usual two.

Domasia limaciforme (Stockmans and Willière) Cramer, 1970

Plate 8, Fig. 1

For synonymy see Le Hérissé (1989).

Additional synonymy:

1989 *Domasia limaciforme* - Le Hérissé, p. 101-102; pl. 8, fig. 19.

Description: Elongated triangular, hollow, single, thin walled vesicle. The long sides of the vesicle are slightly convex and grade into the broad based process. The processes are three in number arising from each corner of the vesicle. They are simple, hollow, communicate freely with the vesicle cavity and gradually taper to acuminate tips. The vesicle and process wall surface is psilate. No excystment structure observed

Dimensions: L: 30(34)38µm, W: 25(26)27µm, P: 28(30)32µm, n = 4.

Remarks and comparision: This species originally was placed in the genus *Veryhachium,* Cramer 1970 and then transfered to the genus *Domasia*, as discussed by several authors. The elongated triangular vesicle shape and long processes distinguish this species from other *Domasia* species. *Domasia symmetrica* Cramer, 1970 has a narrow elongated vesicle with a broad-based process.

Occurence: Tanezzuft Formation, mid Rhuddanian (Llandovery).

Selected previous stratigraphic record: Early Silurian, Belgium (Stockmans and Williéré, 1963); Llandovery-Wenlock (Martin, 1965, 1969); Aeronianian-Telychian, England, (Hill, 1974; Hill and Dorning, 1984), northeast Libya (Hill and Molyneux, 1988); late Llandovery (Telychian)-early Wenlock, Gotland (Le Hérissé, 1989), Lithuania (Jakauskas and Gritytë, 2004); Telychian-Sheinwoodian, Brazil (Cardoso, 2005).

Genus ***Electoriskos*** Loeblich, 1970

Type species: *Electorisokos aurora* Loeblich, 1970.

Diagnosis: "Circular to sub-circular central body, wall apparently single layered, psilate, shagrenate to granulate with numerous slender, flexible but solid processes which do not communicate with the interior of the central body." From Loeblich (1970, p. 717).

Remarks: The genus *Electorisokos* differs from the genus *Comasphaeridium* Staplin, Jansonius and Pocock, 1965, in lacking the densely crowded hair like processes and from the genus *Filisphaeridium* Staplin, Jansonius and Pocock, 1965, in lacking distal differentiation of the processes.

***Electoriskos* sp. A**

Plate 8, Fig. 2

Description: Spherical to sub-spherical, thin, single walled vesicle bearing, thin, solid, and homomorphic processes more than 40 in number. The processes communicate freely with the vesicle cavity and taper gently to acuminate tips. The wall surface of the vesicle and process is psilate. No excystment structure observed.

Dimensions: L: 16(19)22µm, P: 6(7)8µm, n = 2.

Remarks and comparision: This species differs from *Electoriskos* sp*.* Loeblich, 1976 from the Mid Silurian in its smaller size and in having long processes.

Occurence: Hawaz Formation, mid-late Darriwilian (Llanvirnian).

Genus ***Eupoikilofusa*** Cramer, 1970

Type species: *Eupoikilofusa* (*Leiofusa*) *striatifera* (Cramer 1964), Cramer 1970.

Diagnosis: “Vesicle fusiform, elongated, with pointed poles. At each pole there may be simple, equivalent processes. Within the same species the length of the polar processes may vary greatly. The vesicle wall is unilayered, and the sculpture distribution symmetry is holomorphic with element, arranged in a pattern parallel to the longitudinal axis, and with decreasing size. The ectoderm surface is ornamented with the element of the striate kind; rugulae, striae, fossulae or microechinate elements in longitudinal oriented rows. The vesicle may open by spliting along the axis at approximately an equatorial position. The vesicle axis may be straight or curved, even in the same species.” From Cramer (1971, p. 80-83).

Remarks: The genus is used here in agreement with Dorning (1994) who considered the four fusiform acritarch genera to be validly published and of practical value. Generic distinction is based on the nature and disposition of sculpture: in *Eupoikilofusa* (striate ornament).

***Eupoikilofusa* cf. *ampulliformis* Martin 1968**

Plate 8, Fig. 3

Description: Fusiform, single, moderately transparent, thin-walled vesicle with its extremities drawn out into two relatively long, conical, psilate, hollow processes which gently taper to acuminate distal tips. Proximally the processes communicate freely with the vesicle cavity. The vesicle surface ornamented with densely minute papillae to crowded hair like. No excystment structure observed.

Dimensions: L: 85(90)95µm, W: 20(22)25µm, n = 8.

Remarks and comparision: The species is very similar in morphology and vesicle ornamentation to *Eupoikilofusa ampulliformis* Martin, 1968, but it differs in size and in having longer processes.

Occurrence: Tanezzuft Formation, Aeronian-Telychian (Llandovery).

Eupoikilofusa cantabrica Cramer 1964

Plate 8, Fig. 4

For synonymy see Le Hérissé (1989).

Additional synonymy:

1989 *Eupoikilofusa cantabrica* - Le Herisse, p. 132, 133, figs. , 1-6.

Description: Fusiform, thin, moderately transparent, single walled vesicle with its extremities drawn out into two long, conical, psilate, hollow processes which gently taper to acuminate distal tips. Proximally the processes communicate freely with the vesicle cavity. The vesicle surface ornamented with numerous fine granular striations, these striations approximately parallel to longitudinal axis of the vesicle. No excystment structure observed.

Dimensions: L: 100 (110)120µm, W: 18(26)34µm n = 10.

Remarks and comparision: This species differs from *Leiofusa tumida* Downie, 1959, in having a vesicle ornamented with numerous fine granular striations.

Occurence: Tanezzuft Formation, Aeronian-Telychian (Llandovery).

Selected previous stratigraphic record: early Gedinnian, Spain (Cramer, 1964a, 1970); late Llandovery-early Wenlock, USA (Cramer, 1968); Llandovery-Ludlow, Libya (Richardson and Ioannides, 1973), Turkey (Erkmen and Bozdogan, 1979); Llandovery-early Gedinnian, Algeria (Jardiné *et al.*, 1974), Ludlow, UK (Doming, 1981); late Ludlow-early Gedinnian, Libya (Al-Ameri, 1983, unpublished thesis); Wenlock, Gotland (Le Hérissé, 1989); Aeronian-Telychian, northeast Libya (Hill and Molyneux 1988); late Ludlow, Saudi Arabia (Le Herisse, 1995).

Eupoikilofusa ctenista Loeblich andTappan, 1978

Plate 8, Fig. 5

1978 *Eupoikilofusa ctenista* - Loeblich and Tappan, p.1263; pl. 8, figs. 8, 9.
1995 *Eupoikilofusa ctenista* - Jachowicz, pl. II, fig. 10
1995 *Eupoikilofusa ctenista* - Molyneux, p. 48; pl. 9, fig. 10, 11.
2000 *Dactyolofusa ctenista* - Ghavidel-syooki, pl. 4, fig. 10.
2004 *Eupoikilofusa ctenista* - Rubinstein *et al.*, , p. 1050; pl. 2, fig. 8.
2008 *Dactylofusa ctenista* - Wicander and Playford, p50; pl. 1, figs. 9, 10.

Description: Elongated fusiform, thin, single walled vesicle with its extremities gradually and without distinction drawn out into two short, conical, hollow processes which taper to acuminate distal tips. The vesicle surface ornamented with striations forming discontinuous ridges that do not extend on to the processes. The wall between ridges is psilate. No excystment structure observed.

Dimensions: L: 150(160)170µm, W: 25(30)35μm, n = 5.

Remarks and comparision: This species is very similar in morphology to *Eupoikilofusa parvuligranosa* Loeblich and Tappan, 1978, but it differs in the wall being laevigate between the ridges and lacking grana.

Occurence: Memouniat and Bir Tlacsin formations, Hirnantian (Ashgillian).

Selected previous stratigraphic record: Ashgillian, USA (Loeblich and Tappan, 1978; Wicander and Playford, 2008); early Ashgillian, Saudi Arabia (Jachowicz, 1995); Ashgillian, northeast Libya (Hill and Molyneux, 1988), Iran (Ghavidel-Syooki, 2000); Late Ordovician (Hirnatian), northwest Argentina (Rubinstein *et al.*, 2004); Ashgillian (Hirnantian) northern Gondwana (Vecoli and Le Hérissé. 2004),

Eupoikilofusa* cf. *ctenista Loeblich and Tappan 1978

Plate 8 , Fig. 6

Description: Elongated fusiform, thin, single walled vesicle with its extremities gradually and without distinction drawn out into two short, conical, hollow processes which gently taper to acuminate distal tips. The vesicle surface ornamented with striations forming discontinuous ridges that extend on to the processes. The wall between ridges is psilate. No excystment structure observed.

Dimensions: L: 190(200)210µm, W: 20(22)25µm, n = 7.

Remarks and comparision: This species is very similar to *E. ctenista* Loeblich and Tappan, 1978, but it differs in the wall striations, which extended onto the processes and along the entire vesicle length.

Occurence: Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian).

Eupoikilofusa platynetrella Loeblich and Tappan, 1978

Plate 9, Fig. 2

1978 *Eupoikilofusa platynetrella* - Loeblich and Tappan, p. 1263-1264; pl. 8, fig. 10.

2008 *Dactylofusa platynetrella* - Wicander and Playford, p.50-51; pl. 1, figs. 11, 12, 16, 17.

2013 *Dactylofusa platynetrella* – Le Hérissé *et al*., fig. 8, N.

Diagnosis: Fusiform, relatively broad, thin-walled vesicle with its extremities gradually and without distinction drawn into two short, conical, hollow processes which taper to acuminate distal tips. One of the processes sharper tipped than the other. The vesicle surface is ornamented with discontinuous striations. Excystment structure formed as longitudinal slit.

Dimensions: L: 100(110)120µm, W: 32(37)42µm, n = 5.

Remarks and comparison: This species is very similar in morphology to *Eupoikilofusa striata* Staplin, Jansonius and Pocock, 1965, but it differs in being broader and more fusiform in vesicle shape, with one process sharper tipped than the other.

Occurence: Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian).

Selected previous stratigraphic record: Ashgillian, USA (Loeblich and Tappan, 1978; Wicander and Playford, 2008), Algerian and southern Tunisia (Vecoli, 1999); Hirnantian northern Gondwana (Vecoli and Le Hérissé, 2004, Late Ordovician (Hirnantian), northern Chad and southeastern Libya (Le Hérissé *et al*., 2013).

Eupoikilofusa rhikne Loeblich, 1970

Plate 8, Fig. 7

1970 *Leiofusa rhikne* - Loeblich, p. 726, fig. 19 E-I.
2005 *Leiofusa rhikne* - Cardoso, p. 737; pl. 3, fig. 40.

Description: Elongated fusiform, single, thin walled vesicle with its extremities drawn out into two short, conical, hollow processes, with no sharp division between the vesicle and process. The vesicle surface is finely wrinkled by longitudinal oriented striations which form discontinuous ridges parallel to the longitudinal axis of the vesicle that do not extend onto the processes. No excystment structure observed.

Dimensions: L: 250(265)280µm, W: 20(26)32µm, n = 8.

Remarks and comparision: This species is similar to *Leiofusa filifera* Downie, 1959 but does not approach the maximum size of the species and it differs in having shorter polar processes. *Eupoikilofusa ctenista* Loeblich and Tappan, 1978 differs from this species in size, process length and the wall striations forming discontinuous ridges.

Occurence: Tanezzuft Formation, late Rhuddanian-Telychian (Llandovery).

Selected previous stratigraphic record: Mid Silurian, USA (Loeblich, 1970); Llandovery (Cramer and Diez, 1977); Aeronian-Gorstian, Brazil (Cardoso, 2005).

Eupoikilofusa saetosa Le Hérissé, 2000

Plate 8, Fig. 8 and Plate 9, Fig. 1

2000 *Euopoikilofusa saetosa* - Le Hérissé, p. 76; pl. 3, fig.i.

Description: Fusiform vesicle with commonly a crescent shape, single, transparent thin-walled with its extremities drawn out into two long, hollow, fine processes which taper distally to sharp point, clearly differentiated from the vesicle. The vesicle is ornamented with fine striations parallel to the longitudinal axis of the vesicle and the crests are ornamented by microspines. No excystment structure observed.

Dimensions: L: 75(88)100µm, W: 17(18)20µm, n = 8.

Remarks and comparision: The specimens recorded in the current study are very similar in morphology and vesicle ornamentation to the specimens described by Le Hérissé (2000) from the mid Rhuddanian of Saudi Arabia but it has relatively long processes.

Occurence: Tanezzuft Formation, late Rhuddanian-early Telychian (Llandovery).

Selected previous stratigraphic record: mid Rhuddanian, Saudi Arabia (Le Hérissé 2000).

Eupoikilofusa striata (Staplin, Jansonius & Pocock1965)

Plate 9, Fig. 3

For synonymy see Elaouad Debbaj (1988).
Additional synonymy:
1988 *Eupoikilofusa striata* - Elaouad Debbaj, p. 236, 237; pl. 2, figs. 1-6.
1999 *Dactylofusa striata* - Vecoli, p. 39; pl. 6, fig. 1
2000 *Dactyolofusa striata* - Ghavidel-syooki, pl. 4, fig 12.
2001 *Dactyolofusa striata* - Ghavidel-syooki, pl. 6, fig 2.
2004 *Eupoikilofusa striata* - Rubinstein *et al*., p. 1050, text figure 5E.
2013 *Eupoikilofusa striata* – Le Hérissé *et al*., fig. 8, R.

Description: Elongate fusiform, single, thin-walled vesicle with its extremities gradually and without distinction drawn out into two blunt tipped to acuminate processes. The vesicle surface ornamented with numerous, longitudinally directed, continuous or discontinuous striations which converge at the poles. No excystment structure observed.

Dimensions: L: 100(115)130µm, W: 22(26)30µm, n = 5.

Remarks and comparision: This species differs from *Poikilofusa spinata* Staplin, Jansonius and Pocock, 1965, in lacking of any type of surface ornamentation of spines, but it is ornamented with longitudinal ridges traversing the vesicle.

Occurence: Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian).

Selected previous stratigraphic record: Ashgillian, Morocco (Elaouad Debbaj, 1988), Canada (Jacobson and Achab, 1985); Late Ordovician (Hirnatian), Argentina (Rubinstein *et al.,* 2004), Iran (Ghavidel-syooki, 2000, 2001); Llanvirnian - Ashgillian, Algeria (Jardiné *et al*., 1974), Late Ordovician (latest Hirnantian)-Early Silurian (Rhuddanian), northern Chad and southeastern Libya (Le Hérissé *et al*., 2013).

Eupoikilofusa striatifera (Cramer 1964) Cramer and Diez, 1970

Plate 9, Fig. 4

1964 *Leiofusa striatifera* - Cramer, p. 35, pl. 2, figs. 9, 13.

1970 *Eupoikilofusa striatifera* - Cramer and Diez, p. 85, 86; pl. III, figs. 51-54; 58, 59; IV, figs. 65, 72, 74; fig. 25 G.

1985 *Eupoikilofusa striatifera* - Jacobson and Achab, p. 182; pl. 3, fig. 3.

1987 *Eupoikilofusa striatifera* - Smelror, pl. 1, fig. 4.

2013 *Eupoikilofusa striatifera* - Le Hérissé *et al*., fig. 8, P.

Derscription: Elongate fusiform, single, thin-walled vesicle with its extremities gradually drawn out into two pointed processes, one at each pole. The processes are conical with acuminate distal tips, and poorly-differentiated from the vesicle. The vesicle surface ornamented with continuous longitudinal fold-like striations which are variable in length, number and spacing between them. The striations tend to fade away towards the poles. No excystment structure observed.

Dimensions: L: 100(150)200µm, W: 18(24)30µm, n = 9.

Remarks and comparision: The specimens recorded in the current study conform to the description of Cramer and Diez (1970).

Selected previous stratigraphic record: Llandovery, England (Hill and Dorning, 1984), Turkey (Erkmen and Bozdogan, 1979), northeast Libya (Hill and Molyneux, 1988), Norway (Smelror, 1987); Ashgillian, Canada (Jacobson and Achab, 1985); Turkey (Paris et al., 2007); Caradocian-Ashgillian, Algeria (Jardiné *et al*., 1974); Llandovery, England (Molyneux, 2008); Sandbian-Silurian, northern Gondwana (Vecoli and Le Hérissé, 2004), LateOrdovician (latest Hirnantian)-Early Silurian (Rhuddanian), northern Chad and southeastern Libya (Le Hérissé *et al*., 2013).

Occurence: Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian); Tanezzuft Formation, early Rhuddanian-Telychian (Llandovery).

***Eupoikilofusa* sp.A**

Plate 9, Fig. 5

Description: Elongate fusiform, single, relatively thick-walled vesicle with its extremities drawn out into short, conical, hollow processes which taper to acuminate tips. The vesicle surface ornamented with continuous finely longitudinal striations which are variable in length that do not extend on to the processes. No excystment structure observed

Dimensions: L: 280(292)310µm, W: 55(57)60µm, n = 5.

Remarks and comparision: This species differs from *Anomaloplaisum lumariacuspis* Loeblich and Tappan, 1971, in lacking spines on the processes wall and from *Anomaloplaisum tappaniae* Cramer and Díez, 1977, in having a vesicle ornamented with fine striations and lacking spines on the processes wall. *Poikilofusa spinata* Staplin *et al.,* 1965 has spines arranged discontinuously in longitudinal rows on the vesicle wall.

Occurence: Tanezzuft Formation, mid Rhuddanian (Llandovery).

Genus ***Evittia*** Brito, 1967 emend. Lister, 1970

Type Species: *Evittia sommeri* Brito, 1967.

Diagnosis: "Vesicle hollow, subspherical to polygonal, single-walled; vesicle wall may be smooth or sculptured; processes are heteromorphic, hollow, invariably granular to echinate, communication freely with the vesicle cavity. Excystment by cryptosuture, apical or near equatorial." From Lister (1970, p. 66).

Remarks: The genus *Evittia* was diagnosed by Brito (1967) who stated that the processes had a micoverrucate wall, then emended by Lister (1970) who showed that the processes wall have granulate to echinate sculpture. However there is no essential difference between the emended diagnosis of *Evittia* provided by Lister (1970), and the diagnosis of *Diexallophasis* by Loeblich (1970). Therefore, the synonymy of *Evittia* Brito, 1967 emend. Lister, 1970 and *Diexallophasis* Loeblich, 1970 as proposed by Le Hérissé (1989), is accepted and followed here. This genus differs from the genus *Multiplicisphaeridium* Staplin, 1961 by the presence of granular to echinate wall processes and from the genus *Baltisphaeridium* Eiserhardt, 1989 in having processes that communicate freely with the vesicle cavity.

Evittia denticulata (Stockmans and Williére) Loeblich 1970

Plate 9, Fig. 6

1985 *Diexallophasis denticulata* - Jacobson and Achab, p. 178; pl. 2, figs. 4, 6.
1995 *Diexallophasis denticulata* - Rubinstein, fig. 2.12.
2004 *Diexallophasis denticulata* - Jankauskas and Grityte, pl. 1, fig. 9.

Description: Spherical or sub-spherical, single, thin walled vesicle ornamented with variable small low grana which become sparse near the base of the processes. Processes, about 6-8 in number, are hollow and communicate freely with the vesicle cavity. The processes are very variable in width and bifurcation at distal end. They taper to distal end where tips are simple, bifurcated, secondarily bifurcated or trifurcated. The surface of the process may be smooth or ornamented with coarse grana to echinate. No excystment structure observed.

Dimension: L: 20(35)50µm, P: 15(30)45µm, n = 10.

Remarks and comparision: The forms attributed to *Evittia denticulata* in this study include forms with variation in ornamentation and process tip morphology. They are very similar to the forms illustrated by Loeblich (1970).

Occurence: Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian); Tanezzuft Formation, early Rhuddanian-Telychian (Llandovery).

Selected previous stratigraphic record: Ashgillian-Llandovery, northeast, Libya (Hill and Molyneux, 1988); Ashgillian, Canada (Jacobson and Achab, 1985); late Llandovery, Lithuania (Jankauskas and Grityte, 2004); Silurian, Iraq (Al-Ameri, 2010).

Evittia sanpetrensis (Cramer 1964b ex Cramer 1970a) Dorning 1981b

Plate 10, Fig. 1, 2

For synonymy see Le Hérissé (1989).
Additional synonymy:
1989 *Diexallophasis sanpetrensis* - Le Hérissé, p. 130; pl. 12, figs. 11-14.
2003 *Diexallophasis sanpetrensis* - Masiak *et al*., fig. 10, f.

Description: Spherical, single, thin walled vesicle. Processes about nine in number, hollow, thin, single-layered which communicate freely with the vesicle cavity; their length is shorter than the vesicle diameter and tapering to simple and short ramifications distal tips. The surface of the vesicle is psilate while the processes ornamented with granulate to echinate elements, which are perpendicular to the long axis of the processes. No excystment structure observed**.**

Dimensions: L: 25(26)28*μ*m, P: 10(11)13*μ*m, n = 10.

Remarks and comparision: This species differs from *Evittia* sp. 1, Le Hérissé, 2000, in having more processes and a psilate vesicle wall. *Evittia remota* (Deunff) Playford, 1977 has processes longer than the vesicle diameter.

Occurence: Tanezzuft Formation, early Rhuddanian-Telychian (Llandovery).

Selected previous stratigraphic record: late Llandovery-early Gedinnian, Spain (Cramer, 1966, 1969); Late Ordovician-Silurian, Belgium (Martin, 1968); Llandovery–Gedinnian, USA (Cramer and Diez, 1970, 1972); late Llandovery, Canada (Achab, 1976); early Devonian, Uruguay (Pothe de Baldis, 1978); Ludlow, UK (Dorning, 1981); Llandovery-Ludlow, Turkey (Erkmen and Bozdogan, 1979); early Llandovery, Canada (Eley and Legault, 1988); Llandovery, Gotland (Le Hérissé, 1989), Poland (Masiak *et al*., 2003).

Evittia remota podolica Kir'yanov, 1978.

Plate 10, Figs. 5, 6

1978 *Diexallophasis denticulata* var. *podolica* - Kir'yanov, p. 42; pl. 12, fig. 4.
1989 *Evittia rmota podolica* - Le Hériseé, p. 128; pl. 12, figs. 16-18.

Description: Spherical, thin walled vesicle ornamented with very dense fine grana. Processes about 4-8 in number, hollow, single-layered which communicate freely with the vesicle cavity; their length is longer than the vesicle diameter and tapering to simple and short ramifications tips with branches usually simple bifurcation. The process surface is ornamented conical spines perpendicular to the long axis of the processes and become more prominent with longitudinal ridges at the base of process. No excystment structure observed.

Dimensions: L: 20(23)25*µ*m, P: length 30(31)32*µ*m, n = 5.

Remarks and comparision: The specimens recorded in the current study are very similar in morphology to the specimes illustrated by Le Hériseé (1989) from Gotland, but in general have bigger vesicle size. *Evittia virgultata* Le Hériseé, 1989 has vesicle wall ornamented with prominent grana.

Occurence: Tanezzuft Formation, Aeronian-Telychian (Llandovery).

Selected previous stratigraphic record: Llandovery, Podolia, (Kir'yanov, 1978); Wenlock (Shenwoodian-base Homerian), Gotland (Le Hérissé, 1989).

Evittia remota (Deunff) Playford, 1977

Plate 11, Fig. 1

For synonymy see Vecoli (1999).
Additional synonymy:
1999 *Evittia remota* - Vecoli, p. 41-42; pl. 7, fig. 3-7
2004 *Evittia remota* - Rubinstein and Vaccari**,** p. 1050, text figure 6A.
2008 *Evittia remota* - Ghavidel Syooki, pl. II, fig. 8.
2009 *Evittia remota* - Vecoli, pl. II, fig. 11.

Description: Tetrahedral to sub-spherical thin, single walled vesicle ornamented with finely grana. Processes are about 6 -8 in number, four processes arising from the corner of the vesicle and the other two arising from the central area of vesicle. The processes are flexible, heteromorphic, and ornamented with grana to echinate elements. Distally they are simple, branched and bifurcate to first, second order or digitate. No excystment structure observed.

Dimensions: L: 25(30)35*µ*m, P: 15(30)45*µ*m, n = 8.

Remarks and comparison: According to Playford (1977) *Diexallophasis denticulatum* Stockmans and Willière, 1963 and *Diexallophasis granulatispinosum* Downie, 1963 are junior synonyms of this species. We prefer to retain these forms in the genus *Evittia* according to Le Hérissé (1989). However, we also agree with Mullins (2001) who used an informal *Diexallophasis remota* (Deunff) emended Playford, 1977 group that could contain our specimens.

Occurence: Tanezzuft Formation, mid Rhuddanian-Telychian (Llandovery).

Selected previous stratigraphic record: Late Ordovician-Ludlow, Tunisia (Vecoli, 2000); Late Ordovician, Iran (Ghavidel-Syooki, 2008); Devonian, Argentina (Ottone, 1996); Llandovery, Poland (Masiak *et al*., 2003); late Katian-Silurian, northern Gondwana (Vecoli and Le Hérissé. 2004).

***Evittia* sp. 1** Le Hérissé, 2000

Plate 10, Figs. 3, 4

2000 *Evittia* sp. - Le Hérissé, p. 78; pl. 9, fig. a

Description: Spherical, thin, finely granulate walled vesicle. Processes about nine in number, single, thin, hollow which communicate freely with the vesicle cavity; their length is shorter than the vesicle diameter and tapering to simple and short ramification tips. The surfaces of the processes ornamented with granulate to echinate elements, which are perpendicular to the long axis of the processes and become more prominent with longitudinal ridges at the base of processes. No excystment structure observed**.**

Dimensions: L: 25(26)28*µ*m, P: 10(11)13*µ*m, n = 8.

Remarks and comparision: This species differs from *Evittia sanpetrensis* (Cramer 1964b ex Cramer 1970a) Dorning 1981b, in having fewer processes and finely granulate vesicle wall. *Evittia remota* (Deunff) Playford 1977 has processes longer than the vesicle diameter.
Occurence: Tanezzuft Formation, early Rhuddanian-Telychian (Llandovery).

Selected previous stratigraphic record: Telychian, Saudi Arabia (Le Hérissé, 2000).

***Evittia?* sp.**

Plate 9, Fig. 7

Description: Sub-spherical, single, moderately thick-walled vesicle. Processes about six in number, hollow, slender which taper to fairly solid but it seems to be bulbous termination and proximally communicate freely with the vesicle cavity. The majority of the processes are simple terminations. The vesicle and process wall surface appears unornamented. No excystment structure observed.

Dimensions: L: 24(30)37μm, P: 24(28)32μm, n = 4.

Remarks and comparision: This species is very similar in morphology to *Evittia remota* (Deunff) Playford 1977, which is distinguished by its generally thinner ornamented vesicle wall and broader more columnar processes, with broader tips and its digitate branching. However, the described species is unusual as it appears to be laevigate. The majority of *Evittia* have distinctly ornamented vesicles and granulate, echinate processes and digitate process branching typical of *Evittia*.

Occurence: Tanezzuft Formation, mid Rhuddanian (Llandovery).

Genus ***Frankea*** Burmann, 1970 emend. Servais, 1993

Type species: *Frankea hamata* Burmann, 1970.

Diagnosis: " Triangular central body, with triradially arranged processes, which are hollow at the base and split distally at one point into unbranched pinnae. The number of the terminal pinnae (two or more) and the ratio of process length to central body diameter are variable but constant for each specimen. The wall texture of the central body is smooth to finely granulate or shows overall the vesicle a strait ornament parallel to the vesicle side." From Servais (1993, p. 80).

Remarks: The genus *Frankea* was diagnosed by Burmann (1970) and then emended by Servais (1993) who described four species conforming to the original diagnosis *Frankea breviuscula* Burman, 1970, *F. hamata*, Burman, 1970, *F. hamulata*, Burman, 1970 and *F. sartbernardensis* (Martin) Colbath, 1986. The two important characters that distinguish *Frankea* from other genera are the triangular shape of the central body and the processes which split at one point into un-branched pinnae. This genus and its species have been reviewed in detail by Servais (1993), Fatka *et al*. (1997) and Vecoli *et al*. (1999). *Frankea* is applied here according to the emendation of Servais (1993) which was necessary to include granulate and striate specimens. In agreement with Fatka *et al*. (1997) and Vecoli *et al*. (1999), *Fatkia* Vavrdová, 1995 is considered as a junior synonym of *Frankea.*

Frankea breviuscula Burmann, 1970

Plate 11, Fig. 2

For synonymy see Vecoli (1999)
1999 *Frankea breviuscula* - Vecoli, p. 42-43; pl. 8. figs. 6, 8.
2011 *Frankea breviuscula* - Vanguestaine and Wauthoz, p. 9; pl. I. figs. J-K.

Description: Equilateral to sub-triangular, smooth, thin walled vesicle with slightly convex sides. Processes are three in number arising from each corner of the vesicle. The processes are hollow, homomorphic and communicate freely with the vesicle cavity; their length is approximately equal half of the vesicle diameter. They are brached distally into three, homomorphic, acuminate pinnae. No excystment structure observed.

Dimensions: L**:** 24(26)28*µ*m, P: 10(11)12*µ*m, n = 2.

Remarks and comparision: Although, only a few broken specimens, with one short process were observed in this study. It is possible that these specimens belong to the genus *Frankea*. However, it is still questionable as firm identification requires a complete specimen. But based on the vesicle shape, process length and the processes branched into three acuminate pinnae, these specimens are attributed to *Frankea breviuscula.*

Occurence: Hawaz Formation, mid-late Darriwilian (Llanvirnian).

Selected previous stratigraphic record: Caradocian (Turner, 1982); late Arenigian, UK (Turner and Wadge, 1979; Rushton and Molyneux, 1989); Llanvirnian, Germany (Burmann, 1970), Czech Republic (Vavrdova, 1979), Portogal (Elaouad-Debbaj, 1981), England (Millward and Molyneux, 1992), southern Tunisia and northwest Libya (Vecoli, 1999; Vecoli *et al*., 2000), Belgium (Vanguestaine and Wauthoz, 2011); Darriwilian-Sandbian, northern Gondwana (Vecoli and Le Hérissé, 2004).

Frankea hamata (Martin) Colbath, 1986

Plate 12, Fig. 1

For synonymy see Servais (1993)

Additinoal synonymy

2004 *Frankea hamata* - Brück and Vanguestaine, fig. 8 (12).

2011 *Frankea hamata* - Vanguestaine and Wauthoz, p. 9; pl I, fig. L.

Description: Equilateral to sub-triangular smooth, thin walled vesicle with slightly convex sides. Processes are three in number arising from each corner of the vesicle. The processes are hollow, homomorphic and communicate freely with the vesicle cavity; their length smaller than the vesicle diameter. They are brached distally into two homomorphic, acuminate pinnae. The pinnae length is approximately equal to length of processes. No excystment structure observed.

Dimensions: L: 22(24)26μm, P: 5(6)7μm, n = 2.

Remarks and comparision: This species differs from *Frankea sartbenardensis* (Martin) Colbath, 1986, in having two pinnae at the distal termination of the processes.

Occurence: Hawaz Formation, mid-late Darriwilian (Llanvirnian).

Selected previous stratigraphic record: Llanvirnian, England (Burman, 1970); Arenigian, England (Turner and Wadge, 1979; Rushton and Molyneux, 1988; Molyneux, 1979; Millward and Molyneux, 1992); Belgium (Vanguestaine and Wauthoz, 2011); Llandelio, north Wales (Molyneux in Thythall *et al*., 1987); Arenigian-Llanvirnian, Irland (Brück and Vanguestaine, 2004); Darriwilian-Sandbian, northern Gondwana (Vecoli and Le Hérissé, 2004).

Frankea longiuscula Burmann, 1970

Plate 11, Fig. 3, 4

For synonymy see Vecoli (1999).
Additional synonymy:
1999 *Frankea longiuscula* - Vecoli *et al*., pl. 2, figs. 1, 2, pl. 3, fig. 2.
2007 *Frankea longiuscula* - Le Hérissé *et al*., pl. 1, fig. 12.

Description: Triangular, smooth, thin walled vesicle with slightly convex sides. Processes are three in number arising from each corner of the vesicle. The processes are hollow, homomorphic and communicate freely with the vesicle cavity; their length greater twice than the vesicle diameter. They are brached distally into four or five homomorphic, acuminate pinnae. The processes may be plugged at their bases. No excystment structure observed.

Dimensions: L: 40(44)48*μ*m, P: 70(73)76*μ*m, n = 2.

Remarks and comparision: Although, only a few broken specimens, with three long processes are observed in this study, it is possible that these specimens belong to the genus *Frankea*. But based on the vesicle shape and process length and the process branched into four homomorphic acuminate pinnae, these specimens are attributed to *Frankea breviuscula.*

Occurence: Hawaz Formation, mid-late Darriwilian (Llanvirnian).

Selected previous stratigraphic record: Llanvirnian, Germany (Burmann, 1970); late Arenigian, Morocco (Cramer and Díez, 1977), Jordan (Keegan *et al.,* 1990), Germany (Servais, 1993), southeast Tunisia and northeast Libya (Vecoli, 1999; Vecoli *et al.,* 2000); Llanvirnian-Caradocian, northern Gondwana (Vecoli and Le Hérissé, 2004); late Arenigian-Llanvirnian, Saudi Arabia (Le Hérissé *et al*., 2007); Hirnantian, Turkey (Paris *et al*., 2007); Mid Ordovician, Belgium (Vanguestaine, 2008).

***Frankea* sp. A**

Plate 12, Fig. 2

Description: Equilateral to sub-triangular, smooth, thin walled vesicle with straight to slightly convex sides. Processes are three in number, arising from each corner of the vesicle. The processes are hollow, homomorphic and communicate freely with the vesicle cavity and may be pluged at their bases; their length is approximately equal to the vesicle diameter. They are brached distally into three homomorphic, acuminate pinnae. No excystment structure observed.

Dimensions: L: 24(26)28*μ*m, P: 24(26)28*μ*m, n = 3.

Remarks and comparision: This species differs from *Frankea sartbenardensis* (Martin) Colbath, 1986 and *Frankea longiuscula* Burmann, 1970 in the ratio of process length to vesicle diameter.

Occurence: Hawaz Formation, mid-late Darriwilian (Llanvirnian).

Genus ***Geron*** Cramer 1966a, emend. Cramer, 1969a

Type species: *Geron guerillerus* Cramer 1967a.

Diagnosis: "Complex acanthomorphic acritarch composed of an ovoid, spherical or ellipsoidal inner body or cyst which is concentrically enveloped by first outer membrane or ectoderm which (a) is drawn out at one pole (the basal pole), into one to numerous hollow to filose spines or (b) forms a cylindrical skirt terminating into one or numerous filose sculpture or processal element . The first outer membrane (or ectoderm), is generally smooth but may be adorned by tiny sculpture elements, such as broad based grana, spines, etc. In well preserved specimens of at least one species (*G. guerillerus*) a third membrane, the periderm, may be present. It was not determined how the periderm is attaced to the ectoderm. The periderm is sack-like in form; the opening permiting the long processes formed by the continuation of the ectodermal membrane to stick. The periderm is adorned by tiny, ideally palmate, sculptural element connected distally to one another by an anastomosing net-like structure such as that found in the genus representatives of *Tunisphaeridium.*" From Cramer (1969a, p. 165).

Remarks: The genus *Geron* Cramer 1969a differs from the genus *Carminella* Cramer, 1968, in having only one cylindrical skirt that terminates in one or numerous processes.

***Geron* sp. 1** Le Hérissé, 2000

Plate 12, Fig. 3

2000 *Geron* sp. 1 - Le Hérissé, p. 78; pl 3, fig. H.

Description: Spherical to sub-spherical vesicle. Characterized by relatively short cylindrical skirt surrounding the central body and closly appressed to it.
Dimensions: L: 25(26)28 *µ*m, cylinder skirt 40(42)45*µ*m, n = 5.

Remarks and comparision: The specimens recorded in the current study are vey simillar in morphology to *Geron* sp. 1 (plate. 3, fig. h) described by Le Hérissé, 2000 from the late Rhuddanian of Saudia Arabia. *Geron gracillis* Cramer, 1969b differs from this species in having two long slender processes at one pole, totally surrounded by membranenous material which also surrounds the vesicle, and the other pole is smooth.

Occurence: Tanezzuft Formation, late Rhuddanian-early Telychian (Llandovery).

Selected previous stratigraphic record: late Rhuddanian, Saudia Arabia (Le Hérissé, 2000).

Genus ***Helosphaeridium*** Lister 1970

Type species: *Helosphaeridium calvispinosum* Lister 1970.

Diagnosis: "Spherical to ellipsoidal vesicle, single walled, ornamented with small, numerous, evenly spaced, solid or hollow processes flaring distally in claviform fashion; excystment by cryptosuture." From Lister (1970, p.76).

Remarks: The genus *Lophosphaeridium* Timofeev 1959 emended by Downie 1963 and Lister 1970, differs from the genus *Hellosphaeridium* in having an ornament of solid tubercles. The genus *Buedingiisphaeridium* Schaarschmidt, 1963 has conical hollow tubercles communicating with the vesicle cavity.

Helosphaeridium* cf. *latispinosum Lister, 1970

Plate 12, Fig, 4

Description: Ellipsoidal to ovoid, moderately thin, single-layered vesicle ornamented with numerous, evenly spaced, small, solid, homomorphic processes which are dilated distally. The processes are frequently making contact with those adjacent. Excystment formed by cryptosuture.

Dimensions: L: 100(107)115µm, P: 3(4)5µm, n = 4.

Remarks and comparision: The specimens recorded in this study are very similar in morphology to *Helosphaeridium latspinosum,* but it differs in having larger vesicle diameter and process lengths. *Helosphaeridium paxillum* Vecoli, 1999 has abundant and uniformly distributed, distinctly clavate processes and the presence of densly arranged bacula on the polar extremities.

Occurence: Melez Shugran, Memouniat and Bir Tlachine formations, early late Katian-Hirnantian (Ashgillian).

***Helosphaeridium* sp. A**

Plate 12, Fig, 5

Description: Vesicle with more or less ovoid in shape, moderately thin, single wall. Processes are numerous, small, homomorphic, close spaced, solid, distal termination seems to be flat or circular expansions. Excystment formed by near equatorial cryptosuture.

Dimensions: L: 30(35)44µm, P: 0.6(1)1.4µm, n = 4.

Remarks and Comparision: Although, only a few specimens were recorded in this study, they are attributed to *Hellosphaeridium* based on the processes shape and excystment structure.

Occurence: Hawaz Formation, mid-late Darriwilian (Llanvirnian).

Genus ***Hoegklintia*** Dorning, 1981

Type species: *Hoegklintia visbyense* (Eisenack 1959a) Dorning, 1981b

Diagnosis: “Vesicle sub-spherical to sub-polygonal in outline, large, ill defined from processes, wall thin, laevigate; three to several processes, thin walled, broad ill defined base, distally branched, bifurcate to multifurcate in one to three order; the distal termination is sharp to somewhat blunt, often with some darkening of the process wall at the tip” From Dorning (1981, p. 192).

Remarks: This genus differs from the genus *Estiastra* Eisenack, 1959, in having bifurcated to multifurcating processes. The genus *Multisphaeridium* is generally small and has a thicker vesicle.

Hoegklintia visbyense (Eisenack 1959a) Dorning 1981b

Plate 13, Fig. 1

For synonymy see Le Hérissé (1989).
Additional synonymy
1988 *Hoegklintia visbyense* – Eley and Legault, p. 58; pl. 2, fig. 1..
1989 *Hoegklintia visbyense* - Le Hérissé, p. 147-148; pl. 15, figs. 8, 11, 12.
1995 *Hoegklintia visbyense* - Le Hérissé, pl. 1, fig. 8.
2011 *Hoegklintia visbyense* – Delabroye *et al.,* pl. 6, figs. 4, 5, 9, 10.

Description: sub-polygonal, thin walled vesicle bearing wall thin walled, broad base processes about 4 in number which communicate freely with the vesicle cavity, distally bifurcated with sharp termination. No excystment structure observed.

Dimension: L: 80(120)160µm, P: 35(44)52µm, n = 4.

Remarks and comparison: Based on the the vesicle shape and the process bifurcation, this species is attributed to *H. visbyense*. It is distinguished from *Hoegklintia coralline* (Eisenack, 1959a) Le Hérissé, 1989 and *Hoegklintia digitata* (Eisenack, 1959a) Le Hérissé, 1989, in having fewer, shorter and less branched processes. It is very similar to the specimens reported by Delabroye *et al*., (2011) from southern Estonia.

Occurence: Tanezzuft Formation, mid Rhuddanian (Llandovery).

Selected previous stratigraphic record: Wenlock, Gotland (Eisenack, 1959, 1965); late Llandovery-Wenlock, USA (Cramer, 1970; Cramer and Diez, 1972); late Llandovery, Anticosti (Duffield and Legault, 1981, 1982) Telychian-Sheinwoodian, Gotland (Le Hérissé, 1989); early Llandovery, southern Ontario (Eley and Legault, 1988); Llandovery, (Vecoli, 2008); late Hirnantian, southern Estonia (Delabroye, *et al*., 2011).

Genus ***Leiofusa*** Eisenack, 1938 emend. Combaz *et al*., 1967

Type species: *Leiofusa fusiformis* (Eisenack), Eisenack 1938.

Diagnosis: "Vesicle hollow, fusiform with simple pointed process at each pole, processes varying in length from less than one tenth to as much as five times the length of the body, Vesicle wall unilayered, psilate to microgranulate. Sculptural element not arranged in longitudinal rows. The long axis of the vesicle coincides with the longitudinal symmetry axis. Vesicle symmetry longitudinal, homomorphic, longitudinal axis straight or essential so pylome circular slit shaped, or formed by equatorial spliting." From Eisenack (1979, p. 333).

Remarks: The genus is used here in agreement with Dorning (1994) who considered the four fusiform acritarch genera to be validly published and of practical value. Generic distinction is based on the nature and disposition of sculpture: in *Leiofusa* (laevigate vesicle).

Leiofusa estrecha Cramer, 1964
Plate 12, Fig. 6

For synonymy see Le Hérissé, (1989).

Additinoal synonymy:
1989 *Leiofusa estrecha* - Le Hérissé, p.149; pl, 13, figs. 11-13, 17.
2003 *Leiofusa estrecha* - Ghavidel Syooki, pl. 6, fig. 3.
2004 *Leiofusa estrecha* - Mullins, pl. 11, fig. 1.

Description: Elongate fusiform, hollow, smooth, single, thin-walled vesicle with its extremities drawn out into two long processes at each pole. The process ends in a blunt point; there is a gradual transition from the vesicle to the processes at each pole. No excystment structure observed.

Dimensions: L: 280(297)315μm, W: 20(22)25μm, n = 5.

Remarks and comparision: This species is distinguished from other *Leiofusa* species in being psilate and length of more than 250µm**.**

Occurence: Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian); Tanezzuft Formation, mid Rhuddanian-Telychian (Llandovery).

Selected previous stratigraphic record: Ludlow-Gedinian, Spain (Cramer, 1964a, b, 1968 and 1969); late Llandovery-Gedinnian, Algeria (Jardine and Yapaudjian, 1968), Silurian, France (Moreau - Beniot, 1969); Silurian–Devonian (Eisenack, 1971) Landovery-early Ludlow, USA (Cramer, 1968; Cramer and Diez, 1971); Silurian, Libya (Richardson and Ioannides, 1973), Wenlock, USA (Thusu, 1973); Late Ordovician-Silurian, France (Moreau- Beniot, 1974); late Llandovery, Canada (Achab, 1976); Late Ordovician-early Silurian, Anticosta Island, Quebec (Duffield and Legault, 1981); Silurian, Libya (Al Ameri, 1984 unpublished theisis); Llandovery (Aeronian), Gotland (Le Hérissé, 1989); Ludlow, England (Mullins, 2001, 2004); Lllandovery–Wenlock, Iran (Ghavidel-syooki, 2003).

Leiofusa fusiforms Eisenack 1934 ex Eisenack 1938a

Plate 12, Fig. 7

For synonymy see Eisenack *et al*. (1976) and Turner (1984).
Additional synonymy:
1984 *Leiofusa fusiformis* - Turner, p. 115-116; pl. 12, fig. 4.
1985 *Leiofusa fusiformis* - Jacobson and Achab, pl. 5, figs. 9, 10.
1999 *Leiofusa fusiformis* - Vecoli, p. 45; pl. 9, fig. 1.
2008 *Leiofusa fusiformis* - Wicander and Playford, p. 53; pl. 4, figs. 1, 2, 10.

Description: The vesicle is elongate fusiform, hollow, smooth, single, thin-walled with its extremities drawn out into two long hollow processes which taper to acuminate distal tips. The processes are well differentiated from the vesicle and communicate freely with the vesicle cavity. No excystment structure recorded.

Dimension: L: 250(262)275*µ*m, W: 20(27)35*µ*m, n = 10.

Remarks and comparision: This species distinguished from *Leiofusa litotes* Loeblich and Tappan, 1976, which lacks distinct processes, and from *Leiofusa tumida* Downie, 1959, which has a more inflated, oval vesicle.

Occurence: Melez Shugran, Memouniat and Tlacsin formations, early late Katian-Hirnantian (Ashgillian).

Selected previous stratigraphic record: Ordovician, Baltic (Eisenack, 1934, 1938a); Caradocian and Ashgillian, Bohemia, (Vavrdová, 1965, 1966); early Llandovery, Brazil (Combaz *et al*., 1967); Silurian, Brazil (Eisenack, 1968); late Llanvirnian, east Germany, Bohemia (Burmann, 1970); Arenigian, Czech Republic, Bohemia, (Vavrdová, 1972); Silurian, Canada (Thusu, 1973a); Llanvirnian, France (Rauscher, 1974); Caradocian, Shropshire, UK (Turner, 1984); Ashgillian, Canada (Jacobson and Achab, 1995), Ludlow, Saudi Arabia (Le Hérissé *et al*., 1995); Late Silurian, Argentina (Rubinstein, 1995); Llanvirnian, Tunisia and Algeria, (Vecoli, 1999); Caradocian to Silurian, northern Gondwana (Vecoli and Le Hérissé, 2004); Late Ordovician to Silurian, USA (Wicander and Playford, 2008).

Leiofusa* cf. *fusiformis Eisenack 1934 ex Eisenack 1938a

Plate 12, Fig. 10

Description: The vesicle is fusiform, hollow, smooth or single, thin-walled, with its extremities drawn out into two solid, long, hollow, flexible processes which taper to acuminate distal tips and proximally communicate freely with the vesicle cavity. The processes are clearly differentiated from the vesicle. No excystment structure observed.

Dimension: L: 85(92)100μm, W: 20(22)25μm, n = 5.

Remarks: This species is very similar in morphology to *Leiofusa fusiformis* Esienack, 1938, but it differs in having slightly long processes and smaller vesicle length. It differs from *Leiofusa litotes* Loeblich and Tappan, 1976, which lacks distinct processes, *Leiofusa tumida* Downie, 1959, has more inflated and oval vesicle.

Occurence: Hawaz Formation, mid-late Darriwilian (Llanvirnian); Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian).

Leiofusa litotes Loeblich and Tappan, 1976

Plate 12, Fig. 8

1976 *Leiofusa litotes* - Loeblich and Tappan, p. 1271; pl. 12, figs. 1,2.

1988 *Leiofusa* aff. *L. litotes* - Hill and Molyneux, p. 49; pl. 9, figs. 8, 9; pl. 10, fig. 1.

2000 *Leiofusa litotes* - Ghavidil syooki, pl.4, fig. 9.

2004 *Leiofusa litotes* - Rubinstein *et al*., p. 1051; pl. 2, fig. 1.

2008 *Leiofusa litotes* - Wicander, p. 53; pl.3, figs. 1, 2.

Description: The vesicle is elongate fusiform, hollow, smooth, single, thin-walled with its extremities drawn out into two hollow processes which taper to acuminate distal tips. These processes are not clearly differentiated from the vesicle. Excystment structure formed via an equatorially situated sub-circular pylome.

Dimensions: L: 245(250)255μm, W: 20(22)25μm, n = 7.

Remarks and comparision: This species is similar in morphology to *Liofusa estrecha* Cramer, 1965, but it differs in that the transition from vesicle to process is very gradual so that their boundary is difficult to determine, whereas the vesicle of *Liofusa estrecha* tapers rapidly to the processes, and the apparently more flexible processes taper little to their distal end. It differs from *Leiofusa fusiformis* Eisenack, 1938, which has distinct processes, differentiated from the vesicle, and it is similar to *Leiofusa filifera* Downie, 1959, but the latter have very flexible processes that taper to acuminate distal tips.

Occurence: Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian).

Selected previous stratigraphic record: Ashgillian, USA (Loeblich and Tappan, 1978), Libya (Hill and Molyneux, 1988), Iran (Ghavidel-Syooki, 2000); Late Ordovician (Hirnatian), northwest Argentina (Rubinstein *et al*., 2004).

Leiofusa* cf. *litotes Loeblich and Tappan, 1976
Plate 12, Fig. 9

Description: The vesicle is elongate fusiform, hollow, smooth, single, thin-walled with its extremities drawn out into two short processes which taper to acuminate distal tips. The processes are not clearly differentiated from the vesicle. No excystment structure observed.

Dimensions: L: 185(192)200μm, W: 15(17)20μm, n = 8.

Remarks and comparision: This species is similar in morphology to *L. litotes* Loeblich and Tappan, 1976, but it differs in having shorter and wider processes. It is very similar to *Leiofusa* aff. *litotes* from the Late Ordovician of northeast Libya illustrated by Molyneux (1988) but it differs in having smaller vesicle width.

Occurence: Melez Shugran, Memouniat and Bir Tlachine Formation, late Katian-Hirnantian (Ashgillian).

***Leiofusa* cf. *tumida* Downie, 1959**

Plate12, Fig. 11

1988 *Leiofusa* aff. *tumida*-Molyneux, p. 49; pl. 9, Fig. 5.

Description: The vesicle is ovate, hollow, smooth, single, and thin-walled with its extremities drawn out into two long, flexible processes which taper to acuminate distal tips .The processes are clearly differentiated from the vesicle. No excystment structure recorded.

,

Dimensions: L: 22(27)32μm, W: 18(20)22μm, n = 8.

Remarks and comparision: The specimens recorded in the current study are very similar in morphology and size to the *Leiofusa* aff. *tumida* Downie, 1959 recorded by Molyneux, (1988) from Ashgillian of northeast Libya.

Occurence: Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian)

Selected previous stratigraphic record: Ashgillian, northeast Libya (Hill and Molyneux; Molyneux 1988); Ashgillian (Hirnantian)-Silurian, north Gondwana (Vecoli and Le Hérisse, 2004), late Llandovery, Scotland (Molyneux *et al.,* 2008).

Genus ***Leprotolypa*** Colbath, 1979

Type species: *Leprotolypa evexa* Colbath, 1979.

Diagnosis: “Vesicles spherical, giving rise to a small number of hollow, simple processes which communicate freely with vesicle interior. Processes thin walled, simple, conical, sharply differentiated from vesicle, distally bluntly rounded, not tapering to sharp point. Most processes of fairly uniform length. Rare processes may bifurcate distally, producing two short, blunt branches. Vesicle wall has rough texture differing from that of the smooth or finely granulate process wall. Excystment unobserved.” From Colbath (1979, p. 16).

Remarks: The genus *Leprotolypa* Colbath, 1979 is distinguished from the genus *Polygonium* Vavrdová, 1966 emended Sarjeant and Stancliffe, 1994 and the genus *Micrhystridium* Deflandre 1937 emended Downie and Sarjeant 1963, in having processees sharply distinguished from the vesicle, and in the blunt distal process termination. The genus *Evittia* Brito, 1967 emended Lister, 1970 differs in having digitate processes and does not have a sharply defined central vesicle and the process wall is granulate to echinate sculpture, and the genus *Baltisphaeridium* Eisenack, 1958b ex Eisenack, 1959 emend. Eiserhardt, 1989 has pluged processes not communicating with the vesicle cavity.

Leprotolypa evexa Colbath, 1979

Plate 13, Fig. 5

For synonymy see Vecoli (1999).
Additional synonymy:
1999 *Leprotolypa evexa* - Vecoli, p. 45, 46; pl. 9, figs. 7, 9.
2006 *Leprotolypa evexa* - Li *et al*., p. 115; pl V, 8
2009 *Leprotolypa evexa* - Vecoli *et al*., p. 44; pl. I, fig. 6.

Description: Spherical to sub-spherical thin, coarsely walled vesicle. Processes about 4-6 in number, homomorphic, hollow, communicate freely with vesicle cavity. These processes are cylindrical to sub-cylindrical, tapering very slightly to a distally bluntly-rounded distal tip, occasionally on same specimen tapering to acuminate tip or rarely bifurcating to produce blunt branches. The process wall is smooth. No excystment structure observed.

Dimension: L: 20(29)38*µ*m, P: 14(21)28*µ*m, n = 5.

Remarks and comparison: The coarsely sculpture of vesicle with few smooth, blunty pointed processes are the main diagnostic features of the genus *Leprotolypa* Colbath, 1979. The specimens recorded here differ from the type material that their processes exceed half of the vesicle diameter. It is very similar to the specimens recorded from the Ashgillian of Tunisia, Algeria by Vecoli (1999) and Vecoli *et al.,* (2009).

Occurence: Memouniat and Bir Tlacsin formations, Hirnantian (Ashgillian).

Selected previous stratigraphic record: Caradocian, USA (Colbath, 1979), China (Li *et al.,* 2006); Llandovery, USA (Miller and Eames, 1982); Ashgillian, Algeria, Tunisia and northwest Libya (Vecoli 1999; Vecoli., *et al.,* 2000), Hirnantian, Tunisia (Vecoli *et al.,* 2009); Caradocian-Hirnantian, northern Gondwana (Vecoli and Le Hérissé, 2004).

Genus ***Lophosphaeridium*** Timofeev 1959, emend. Downie 1963 and Lister 1970

Type species: *Lophosphaeridium rarum* Timofeev 1959, 1959 ex Downie, 1963.

Diagnosis: “Vesicles hollow, single-walled with ornament of solid tubercules. Excystment by cryptosuture.” From Lister (1970, p, 61).

Remarks: The genus *Lophosphaeridium* was diagnosed by Timofeev 1959, then emended by Downie 1963 and Lister 1970 to include all the forms characterized by a spherical to ellipsoidal vesicle, single layered and bears small solid tubercles of varied form (e.g. grana, bacula or cone like). It is distinguished from the genus *Leiosphaeridia* Eisenack 1958, emended Downie and Sarjeant 1963 by possession of a wall ornament. The genus *Prothosphaeridium* Timofeev, 1959 is considered as a junior synonym of L*ophosphaeridium*.

Lophosphaeridium acinatum Wicander *et al*., 1999

Plate 13, Fig. 6

1999 *Lophosphaeridium acinatum* - Wicander *et al*., p. 15; fig. 8- 6, 8-11.
2008 *Lophosphaeridium acinatum* - Wicander and Playford , p. 53; pl. 4, fig. 3.

Description: Spherical to sub-spherical, commonly with arcuate compression folds, thin-walled vesicle bearing numerous, closely spaced, discrete, solid, psilate, botryoidal processes. The general form of processes is that of verrucae of varying size. No excystment structure observed**.**

Dimensions: L: 45(55)65*µ*m, n = 5.

Remarks and comparison: The specimens recorded here are very similar in morphology to those described by Wicander *et al*. (1999). It differs from *Lophosphaeridium papulatum* Martin, 1983 in the morphology of the processes and their close packing.

Occurence: Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian).

Selected previous stratigraphic record: Ashgillian, USA (Wicander *et al*., 1999; Wicander and Playford, 2008).

Lophosphaeridium fuscipetiolatum (Cramer and Díez 1977a) Vecoli, 1999

Plate 13, Fig. 7

1977 *Prothosphaeridium fuscipetiolatum* - Cramer and Diez, p. 352; pl. 3, figs. 1-5; tex-fig. 3:1.
1999 *Lophosphaeridium fuscipetiolatum* - Vecoli, p. 47; pl10, fig. 7.

Description: Spherical to sub-spherical in outline, thin, folded vesicle bearing low-conate and flat verrucate to nipple-shaped dark elements. Most of these elements are distally solid. They are irregularly distributed over the entire vesicle.

Dimensions: L: 60(65)70μm, n = 3.

Remarks and comparison: Only a few broken specimens were observed in this study. But based on the vesicle shape and the ornamentation, these specimens are attributed to *Lophosphaeridium fuscipetiolatum.* The specimens recorded in the current study are very similar in morphology and size to the specimens illustrated by Cramer and Diez (1977) from the Arenigian of Morocco.

Occurence: Hawaz Formation, mid-late Darriwilian (Llanvirnian).

Selected previous stratigraphic record: late Arenigian, Morroco (Cramer and Diez, 1977); Arenigian-Llanvirnian, Morroco (Elaouad-Debbaj, 1984); Llanvirnian, Tunisia (Vecoli, 1999); Darriwilian (upper Arenigian-Llanvirnian), northern Gondwana (Vecoli and Le Hérissé, 2004).

***Lophosphaeridium* sp. A**

Plate 13, Fig. 8

Description: Spherical to sub-spherical, thin, single, commonly folded vesicle ornamented with closely, evenly distributed fine grana or verrucae like form. No excystment structure observed.

Dimensions: L: 40(43)45*µ*m, n = 4.

Remarks: This species is distinguished from other *Lophosphaeridium* species in having dense, evenly distributed verrucae like form.

Occurence: Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian)

***Lophosphaeridium* sp. B**

Plate 13, Fig. 9

Description: Spherical, thin walled vesicle, bearing numerous, dense closely spaced, discrete, solid, psilate processes of verruca like form, evenly distributed. No excystment structure observed**.**

Dimensions: L: 45(50)55*µ*m, n = 4.

Remarks and comparison: This species distinguished form other *Lophosphaeridium* species in having dense, closely spaced, discrete, solid, psilate processes of verruca like form that are evenly distributed.

Occurence: Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian)

Genus ***Micrhystridium*** Deflandre 1937 emend.
Downie and Sarjeant 1963

Type species: *Micrhystridium inconspicuum* Deflandre, 1935, Deflandre, 1937.

Diagnosis: "Hystrichospheres with spherical or oval shells not divided into field or plates, bearing processes with closed tips, most often simple, rarely branching or ramifying, without distal connections of any kind. The processes are generally of one type only. Mean and modal diameter of shell less than 20 µm." From Downie and Sarjeant (1963).

Remarks: This genus has been emended several times (e.g. Staplin, 1961; Downie and Sarjeant, 1963; Staplin *et al*., 1965; Sarjeant, 1967; Lister, 1970; Sarjeant and Stancliffe, 1994). The complex history of this genus has been reviewed in detail by Sarjeant (1967), Lister (1970), Eisenack *et al*. (1979), Turner (1984), Sarjeant and Stancliffe (1994). The most recent emendation by Sarjeant and Stancliffe (1994) encompasses taxa which may be single- or bilayered, taxa with hollow or solid processes and taxa with simple or furcate processes. In agreement with Wicander *et al*. (1999), the present author considers that the emendation of Sarjeant and Stancliffe (1994) is too broad and encompasses too many dissimilar features. The genus *Micrhystridium* is distinguished from the genus *Veryhachium* Deunff, 1954 *ex* Downie, 1959 emend. Turner, 1984 in having more processes which by their position and number do not affect the shape of the vesicle. *Baltisphaeridium* is larger with processes that have closed bases. *Polygonium* Vavrdová, 1966 emend. Sarjeant and Stancliffe, 1994 differs in having a larger, with broad based processes, merging with the vesicle. *Multiplicisphaeridium* Staplin, 1961 shows distally furcate or ramifying processes.

Micrhystridium stellatum Deflandre 1945

Plate 13, Fig. 10

For synonymy see see Lister, 1970.

Additional synonymy:

1973 *Micrhystridium stellatum* - Richardson and Ioannides, pl. 10, fig. 2.

1982 *Micrhystridium stellatum* - Duffield, p.176; pl. 8, fig. 9.

1987 *Micrhystridium stellatum* - Smelror, p.145; pl. III, fig. 10.

1988 *Micrhystridium stellatum* - Eley and Legault, p. 60; pl. 1, fig. 7.
1992 *Micrhystridium stellatum* - Eley and Legault, p. 85; pl. 2, fig. 11.

Description: Polygonal to sub-polygonal, psilate, single, thin-walled vesicle bearing homomorphic, short, conical processes about 8-16 in number. The processes communicate freely with the vesicle cavity with wide bases and tapering to acuminate distal tips; their length approximately equal to the vesicle diameter. No excystment structure observed.

Dimensions: L: 14(17)20*µ*m, P: 10(11)12µm, n = 7.

Remarks and comparision: *Micrhystridium inflatum* (Downie) Lister, 1970 differs from *M. stellatum* in the vesicle exhibiting a great sphericity with less broad processes base, greater vesicle diameter more than 30 *µ*m and the processes length equal or greater than the vesicle diameter.

Occurrence: Tanezzuft Formation, late Rhuddanian-Telychian (Llandovery).

Selected previous stratigraphic record: Llandovery-Ludlow, Libya (Al- Ameri, 1983 unpublished theisis); Llandovery, England (Hill 1974, 1984), Norway (Smelror, 1987), Canada (Eley and Legault, 1988, 1992); Aeronian-Telychian, northeast Libya (Hill and Molyneux, 1988); early Wenlock, England (Turner *et al*., 1995); Telychian-Sheinwoodian, Brazil (Cardoso, 2002); late Llandovery, Scotland (Molyneux *et al*., 2008).

Micryhistridium* cf. *equispinosum Downie 1982

Plate 13 , Fig. 11

Description: Polygonal, psilate, thin walled vesicle bearing numerous, smooth, simple, homomorphic processes about 24 in number. The processes communicate freely with the vesicle cavity with wide bases and tapering to acuminate distal tips which appear almost solid; their length approximately equal to vesicle diameter. No excystment structure observed.

Dimensions: L: 14(16)18µm, P: 8(9)10µm, n = 3.

Remarks and comparision: This species differs from *Micrhystridium stellatum* Deflandre 1945 in the shape and great number of its process. It is very similar in morphology to *M. equispinosum* Turner, 1984 in the vesicle and processes morphology but it differs in having shorter processes. *Micrhystridium filiferum* Rasul, 1979 has slightly longer processes.

Occurence: Hawaz Formation, mid-late Darriwilian (Llanvirnian).

***Micrhystridium* sp. A**

Plate 14, Fig. 1

Description: Polygonal, probably sub-spherical when inflated, psilate thin walled vesicle bearing smooth, simple, homomorphic numerous processes about forty in number. The processes communicate freely with the vesicle cavity and tapering to acuminate distal tips; their lengths are approximately equal in length and smaller than the vesicle diameter. No excystment structure observed.

Dimensions: L: 18(19)20*µ*m, P: 8(10)12*µ*m, n = 4.

Occurrence: Tanezzuft Formation, late Rhuddanian-Telychian (Llandoverian).

Remarks and comparision: This species differs from *Micrhystridium stellatum* in having more processes and their length is smaller than the vesicle length.

Genus ***Moyeria*** Thusu 1973

Type species: *Eupoikilofusa cabotti* Cramer 1970 emend. Thusu 1973.

Diagnosis: “Vesicle rounded subspherical, moderately thick wall, ornamentation with spiral grooves and forming a reticulation formed by two rows of grooves crossing one another forming a square or diamond-shaped surfaces.” From emended diagnosis of Thusu (1973b).

Remarks: The genus *Moyeria* is described as a freshwater euglenoïd by Gray and Boucot (1989) and as an enigmatic sporomorph which should be considered as an acritarch rather than a cryptospore by Steemans (2000). Dorning and Harding (1998) suggested that it represents a terrestrial to freshwater acritarch.

Moyeria cabotti Thusu 1973

Plate 13, Fig. 12

1971 *Eupoikilofusa cabottii* - Cramer, pl. 4, figs. 66, 67.
1982 *Moyeria cabottii* - Miller and Eames, pl. 3, fig. 3.
2004 *Moyeria cabottii* - Rubinstein *et al*., text fig. 6
2006 *Dactylofusa cabottii* - Li *et la*., pl. II, figs, 3-7.
2007 *Moyeria cabottii* - Paris *et al.* pl. 5, fig. 18.
2013 *Moyeria cabottii* – Le Hérissé *et al*., fig. 9, L.

Diagnosis: Ellipsoidal to ovoidal vesicle, which lacks polar processes. The vesicle is ornamented with helicoid striations of varying highly in width and spacing arranged symmetrically and converging at the poles. No excystment structure observed.

Dimensions: L: 60(62)65*μ*m, W: 8(12)16*μ*m, n = 5.

Remarks and comparision: The various vesicle shapes exhibited in this species are result of compression. It is not fusiform in shape, lacks polar processes, and has helicoidal striations not longitudinal ornamentation. These features distinguish this species from *Dactylofusa* Brito and Santos emend. Cramer, 1970 and *Eupoikilofusa* Cramer, 1971.

Occurrences: Memouniat Formation, early Hirnantian (Ashgillian), .

Selected previous stratigraphic record: Ashgillian., China (He and Yin, 1993); late Caradocian, Saudi Arabia (Jachowicz, 1995); Llandovery, Saudi Arabia (Le Hérissé *et al*., 1995); Caradocian, China (Li, 1995; Li and Wang, 1997); Ordovician-Silurian, Argentina (Rubinstein *et al.,* 2004); Late Ordovician, Oman (Molyneux *et al*., 2006); Late Ordovician, northwestern China (Li *et al*., 2006); Ashgill, Turkey (Paris *et al*., 2007); late Katian-Hirnantian, northern Gondwana (Vecoli and Le Hérissé, 2004), Late Ordovician (Hirnantian)-Early Silurian (Rhuddanian), northern Chad and southeastern Libya (Le Hérissé *et al*., 2013).

Genus ***Multiplicisphaeridium*** Staplin, 1961 emend. Lister, 1970

Type species: *Multiplicisphaeridium ramispinosum* Staplin 1961.

Diagnosis: “Vesicle hollow sphaerical to ellipsoidal, single walled; process with closed tips, heteromorphic simple or compound branching, wall smooth or with minor ornamentation; no differentiation between vesicle wall and process; processes cavity in open connection with vesicle interior; Excystment by cryptosuture, apical or near equatorial.” From Lister (1970, p. 83).

Remarks: The genus *Multiplicisphaeridium* was diagnosed by Staplin (1961) then emended by Staplin *et al*., (1965) and Eisenack (1969) to include the forms with proximally open processes. Lister 1970 discussed this genus in detail and emended it to include only forms excysting via a cryptosuture and having processes that exhibit either simple or compound branching. This emendation was accepted by Turner (1984) and is adopted in the current study.

Multiplicisphaeridium bifurcatum Staplin, Jansonius and Pocock, 1965.

Plate 14, Fig. 2

For synonymy see Vecoli (1999).
Additional synonymy:
1999 *Multiplicisphaeridium bifurcatum* - Vecoli, p. 47; pl. 10, fig. 2.
1999 *Multiplicisphaeridium bifurcatum* - Wicander *et al*., p. 19, fig, 10.4.
2000 *Multiplicisphaeridium bifurcatum* - Ghavidel-syooki, pl. 3, fig. 15.
2004 *Multiplicisphaeridium* cf. *bifurcatum* - Rubinstein *et al.,*p. 1051; text – fig.6c.
2007 *Multiplicisphaeridium bifurcatum* - Ghavidel-syooki, pl. III, fig. 3.

Description: Spherical to sub-spherical, hollow, smooth vesicle with thin, hollow, simple flexible processes about 11-13 in number. The processes communicate freely with the vesicle cavity and distal terminations are combined with bifurcate processes. No excystment structure observed.

Dimensions: L: 23(25)27µm, P: 20(22)25µm, n = 5.

Remarks and comparision: The specimens recorded in the current study conform to the original describtion of Staplin, Jansonius and Pocock (1965).

Occurrence: Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian); Tanezzuft Formation, late Rhuddanian-Telychian (Llandovery).

Selected previous stratigraphic record: Late Ordovician, Czech Republic (Vavrdová, 1988); Ashgillian, Canada (Staplin *et al*., 1965; Jacobson and Achab, 1985), USA (Wright and Meyers, 1981; Miller, 1991; Wicander *et al* 1999); Mid Ordovician, U.S.A (Loeblich and Tappan, 1978); Ashgillian, Algeria (Vecoli, 1999); Ordovician-Silurian, Argentina (Rubinstein *et al.,* 2004); Caradocian-Ashgillian, Iran (Ghavidel-syooki, 2000, 2006); Ashgillian, Turkey (Paris *et al*., 2007); Katian-Silurian, northern Gondwana (Vecoli and Le Hérissé, 2004).

Multiplicisphaeridium irregulare Staplin, Jansonius and Pocock, 1965

Plate 14, Fig. 3

1965 *Multiplicisphaeridium irregulare* n. sp. - Staplin *et al*., p. 183; pl. 18, fig. 18.

1978 *Multiplicisphaeridium irregulare* - Loeblich and Tappan, p.1277; pl. 14, fig. 3.

1985 *Multiplicisphaeridium irregulare* **-** Jacobson and Achab, pl. 6, fig. 2.

1999 *Multiplicisphaeridium irregulare* **-** Wicander *et al*, pp. 19, fig, 9.9-9.12.

2000 *Multiplicisphaeridium irregulare* **-** Ghavidel-syooki, pl. 3, fig. 11.

2006 *Multiplicisphaeridium irregulare* **-** Li *et al*., pl. V, figs. 4-6.

2006 *Multiplicisphaeridium irregulare* **-** Ghavidel-syooki, pl. IV, fig. 6.

2008 *Multiplicisphaeridium irregulare* **-** Wicander and Playford, p.54; pl. 3, fig. 6.

2013 *Multiplicisphaeridium irregulare* – Le Hérissé *et al*., fig. 8, L.

Description: Polygonal vesicle, hollow, smooth, thin walled vesicle with hollow, flexible, simple, smooth processes about 15-20 in number. The processes communicate freely with the vesicle cavity. They are either simple with acuminate tips or irregularly branched. No excystment structure observed.

Dimensions: L: 20(22)25µm, P: 15(17)20µm, n = 6.

Remarks and comparison: This species exhibits a greater degree of process heteromorphy than *Multiplicisphaeridium bifurcatum* Staplin, Jansonius and Pocock, 1965, the processes with regular first order distal bifurcation characterizing *M. bifurcatum.*

Occurrence: Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian); Tanezzuft Formation, late Rhuddanian-Telychian (Llandovery).

Selected previous stratigraphic record: Middle Ordovician, Anticosti Island (Staplin, *et al.,* 1965); late Caradocian, Saudi Arabia (Jachowicz, 1995); Late Ordovician, USA (Wicander *et al.,* 1999); Katian-Silurian, northern Gondwana (Vecoli and Le Hérissé, 2004); Late Ordovician, China (Li *et al*., 2006); Caradocian-Ashgillian, Iran (Ghavidel-syooki, 2000, 2006); Caradocian, Oman (Molyneux *et al*., 2006); Late Ordovician, USA (Wicander and Playford, 2008), Late Ordovician (Hirnantian)-Early Silurian (Rhuddanian), northern Chad and southeastern Libya (Le Hérissé *et al*., 2013).

Multiplicisphaeridium circumscriptum Le Hérissé, 1995

Plate 14, Fig. 4

1995 *Multiplicisphaeridium circumscriptum* - Le Hérissé, p. 67-68; pl. III, fig. 5.
2000 *Multiplicisphaeridium circumscriptum* - Le Hérissé, pl. 4, fig. d.

Diagnosis: Spherical to sub-spherical, relatively thick walled vesicle ornamented with grana. Processes are about 6-8 in number, heteromorphic, hollow and smooth which communicate freely with the vesicle cavity, with prominent circular rim (thickened border), at the junction with the vesicle. They are either simple with acuminate tips or irregularly branched. No excystment structure observed.

Dimensions: L: 24(26)28µm, P: 22(24)26µm, n = 5.

Remarks and comparision: The specimens recorded in the current study conform to the original description by Le Hérissé (1995). It is similar to *Multiplicisphaeridium irregulare* Staplin, Jansonius and Pocock, 1965, in the occurrence of simple processes together with branching ones, but it differs in having granular ornamentation of the vesicle, and also in showing a prominent circular rim (thickened border), at the junction with the vesicle.

Occurrence: Tanezzuft Formation, mid Rhuddanian (Llandovery).

Selected previous stratigraphic record: late Rhuddanian, Saudi Arabia (Le Hérissé, 1995, 2000).

Multiplicisphaeridium fermosum Cramer 1970a ex Eisenack *et al.,* 1973

Plate 14, Fig. 5

1979 *Multiplicisphaeridium fermosum* - Erkmen and Bozdoğan, pl. 1, fig.5.

Description: Spherical to sub-spherical vesicle, relatively thick, psilate, single walled vesicle bearing cylindrical, hollow, smooth processes are 6-10 in numbers branched at their extremity. The processes communicate freely with the vesicle cavity and distally they are columnar, bifurcate then brached to first order. No excystment structure observed.

Dimensions: L: 32(34)38µm, P: 30(33)36µm, n = 7.

Remarks and comparison: The specimens recorded in the current study conform to the original diagnosis of Cramer 1970a ex Eisenack *et al.,* 1973.

Occurrence: Tanezzuft Formation, mid Rhuddanian (Llandovery).

Selected previous stratigraphic record: Late Llandovery, USA (Cramer and Diez, 1972); Llandovery, Turkey (Erkmen and Bozdoğan, 1979).

Multiplicisphaeridium* cf. *brazusdesnodem Cramer, 1964

Plate 15, Fig. 1

Description: Spherical, hollow, single, relatively thick walled vesicle clearly differentiated from short, solid, smooth, hollow processes about sixteen in number. The processes are distributed regularly and communicate freely with the vesicle cavity. Distally they terminate to simple bifurcate and then branched to second bifurcation; their length is smaller than the half of the vesicle diameter. No excystment structure observed.

Dimension: L: 30(33)35µm, P: 15(16)17µm, n = 4.

Remarks and comparision: The specimens recorded in the current study are very similar in morphology to *M. brazusdesnodem* illustrated by Al Ameri (2010) from the Llandovery of Iraq. However, in this study this species is differentiated from *M. brazusdesnodem* Cramer, 1964 in having fewer processes in number that are shorter in length. *Multiplicisphaeridium fisheri* (Cramer 1968a) Lister, 1970 is similar in morphology and construction, but their processes are more clearly branched and they have sharper tips, and the vesicle wall is thinner. *Multiplicisphaeridium rochesterense* (Cramer and Díez 1972) Eisenack *et al*., 1973 differs in having irregularly branched processes to multifurcate and it has a larger number of processes.

Occurence: Tanezzuft Formation, mid Rhuddanian (Llandovery).

Multiplicisphaeridium* cf. *raspa (Cramer 1964) Lister 1970

Plate 14, Fig. 6

Description: Sub-spherical to ellipsoidal, thin, smooth walled vesicle with smooth, hollow, hetromorphic processes about 17-20 in number. The processees are curved in proximal contact and communicate freely with the vesicle cavity. Distally they are simple bifurcate and then branched to a second bifurcation; their length is about the half of the vesicle diameter. Process width is varied, some are very slender whilst others have wide bases. No excystment structure observed.

Dimensions: L: 12(14)16µm, P: 4(6)8µm, n = 4.

Remarks and comparison: *M. raspa* (Cramer 1964) Lister 1970 has processes simple with acuminate tips or they may exhibit up to 3rd order distal branching.

Occurence: Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian); Tanezzuft Formation, late Rhuddanian-Telychian (Llandovery).

***Multiplicisphaeridium* sp. A**

Plate 15, Fig. 2

Description: Spherical to sub-spherical, smooth, thin walled vesicle bearing processes about ten in number with irregular branching. The processes communicate freely with the vesicle cavity; their length is smaller than the vesicle diameter. No excystment structure observed.

Dimensions: L: 20(23)25µm, P: 20(21)22µm, n = 4.

Remarks and comparison: This species is similar in morphology to *Multiplicisphaeridium monki* Le Hérissé, 1989 from the Silurian of Gotland, but it differs in having multifurcate processes.

Occurence: Melez Shugran, Memouniat and Bir Tlachine formations, late Katian-Hirnantian (Ashgillian); Tanezzuft Formation, late Rhuddanian-Telychian (Llandovery).

Genus ***Navifusa*** Combaz, Lange and Pansart 1967 ex Eisenack 1976

Type species: *Navifusa navis*, Eisenack 1976

Diagnosis: “Shell in the form of more or less elongate ellipse, or of rod with rounded extremities; vesicle wall simple, smooth or ornamented.” From Eisenack, (1976, p.53).

Remarks: The genus *Navifusa* included here are fusiform acritarch with rounded poles. The genus *Leiofusa* Eisenack 1938 emend Combaz *et al*. 1967 has an acuminate tip at each pole of the vesicle**.**

***Navifusa* sp. A**

Plate 15, Fig. 3

Description: Elongated naviform vesicle with relatively straight parallel sides and broadly rounded polar ends which lacking processes. The vesicle is very thin and entirely smooth. No excystment structure observed

Dimensions: L: 137(141)145µm, W: 50(52)55µm, n = 5.

Remarks and comparision: This species is similar in morphology to *Navifusa punctata* Loeblich and Tappan, 1978, but it differs in having psilate vesicle wall rather than punctae.

Occurence: Melez Shugran and Memouniat formations, late Katian-Hirnantian (Ashgillian).

Genus ***Neoveryhachium*** Cramer, 1970

Type species: *Neoveryhachium carminae* (Cramer) Cramer 1970.

Diagnosis: “Vesicle symmetry regular, morphology determined by number of processes which are simple and branched of the veryhachid kind, ornamentation by minor sculpture. The vesicle open through pylomes, vesicle wall double; the ectoderm is tightly enveloped by a third wall layer, the periderm.” From Cramer (1970, p. 203).

Remarks and Comparision: The genus *Neoveryhachium* differs from the genus *Veryhachium* Turner, 1984 by the presence of rectangular striations on the vesicle. Species of *Veryhachium* have a smooth vesicle wall.

Neoveryhachium carminae (Cramer 1964) Cramer, 1970

Plate 15, Fig. 4

For synonymy see Le Hérissé (1998).
Additional synonymy:
2004 *Neoveryhachium carminae* - Stricanne *et al*., pl. I, fig. 9.
2009 *Neoveryhachium carminae* - Vecoli *et al*., pl. II, fig. 9.
2013 *Neoveryhachium carminae* – Le Hérissé *et al*., fig. 8, C.

Description: The vesicle is hollow, rectangular with concave sides. Each corner of the vesicle bears a hollow, simple and smooth process which tapers to acuminate distal tip. The processes are co-planar with expanded bases and they communicate freely with the vesicle cavity.The process length is variable and smaller in length than the vesicle diameter. No excystment structure observed.

Dimensions: L: 12(23)34µm, P: 7(11)15µm, n = 10.

Remarks and comparision: *Neoveryhachium* sp. A of Molyneux (1988) differs from this species in having a single bifurcated striation parallel to the long axis, present in each side of flattened vesicle. The striations bifurcate near each end, the branches diverging toward the corner, it has long processees. *Neoveryhachium carminae constricta* Le Hérissé, Al-Tayyar and Van der Eem, 1995 differs from this species in having strongly concave sides and wide-based processes. *Neoveryhachium distinctum* Sinha, Prasad and Srivastava, 1998, has convex sides and shorter processes.

Occurence: Melez Shugran, Memouniat and Bir Tlacsin formations, late Katian-Hirnantian (Ashgillian); Tanezzuft Formation, early Rhuddanian-Telychian (Llandovery).

Selected previous stratigraphic record: Silurian, Belgium (Martin, 1974); Late Ordovician-Silurian, France (Rauscher, 1974; Moreau-Beniot, 1974); Wenlock-Ludlow, Gotland (Le Hérissé, 1898); Llandovery, Saudi Arabia (Le Hérissé *et al*., 1995); Late Ordovician, Bolivia (Gagnier *et al*., 1996); early Ludlow, Sweden (Stricanne *et al*., 2004); late Caradocian-Silurian, northern Gondwana (Vecoli and Le Hérissé, 2004); Hirnantian, southeastern Turkey (Paris *et al*., 2007); Hirnantian, Saudi Arabia (Miller and Al-Ruwaili, 2007); Hirnantian, southern Tunisia (Vecoli *et al*., 2009), Late Ordovician (Hirnantian)-Early Silurian (Rhuddanian), northern Chad and southeastern Libya (Le Hérissé *et al*., 2013).

.

Neoveryhachium* cf. *carminae (Cramer 1964) Cramer, 1970

Plate 15, Fig. 5

Description: Rectangular vesicle, hollow, with concave sides. Each corner of the vesicle bears a long, hollow, simple and smooth process which taper to acuminate distal tip and communicate freely with the vesicle cavity. These processes are equal in length; their length is bigger than the vesicle diameter. No excystment structure observed.

Dimensions: L: 15(17)20, P: 25(27)30µm, n = 5.

Remarks and comparision: This species is very similar in morphology to *Neoveryhachium carminae* (Cramer 1964) Cramer, 1970, but it differs in having longer processes.

Occurence: Memouniat and Bir Tlachine formations, Hirnantian (Ashgillian); Tanezzuft Formation, late Rhuddanian-Telychian (Llandovery).

Neoveryhachium carminae constricta Le Herisse, 1995

Plate 15, Fig. 6

1995 *Neoveryhachium carminae constricta* **-** Le Hérissé, p. 69; pl. 1, fig. 5.

2000 *Neoveryhachium carminae constricta* **-** Le Hérissé, pl. 4, fig. f; pl. 5, fig. e.

Description: The vesicle is hollow, compressed laterally and subquadratic in outline, with a characteristic ornamentation of low oriented folds on the surface. Each angle bears a simple process with an expanded base which taper to acuminate distal tip or rounded apices. The processes are not sharply differentiated from the vesicle, they are smooth and hollow and freely communicating with the vesicle cavity. No excystment structure observed.

Dimensions: L: 15(17)20µm, P: 10(11)13µm, n = 8.

Remarks and comparision: The specimens recorded in the current study conform to the original description of Le Herisse (1995) from the Rhuddinian - early Telychian of Saudi Arabia.

Occurence: Tanezzuft Formation, late Rhuddanian-early Telychian (Llandovery).

Selected previous stratigraphic record: Rhuddanian-early Telychian, Saudi Arabia (Le Hérissé 1995, 2000).

***Neoveryhachium* cf. *carminae constricta* Le Herisse, 1995**

Plate 15, Fig 7

Description: Pentagonal, hollow, thin walled vesicle ornamentated with low oriented folds on the surface. Each corner of the vesicle bears a hollow, simple, smooth process which taper to acuminate distal tip. The processes communicate freely with the vesicle cavity. No excystment structure observed

Dimensions: L: 18(19)20µm, P: 8(9)10µm, n = 4.

Remarks and comparision: This species is similar in morphogy to *Neoveryhachium carminae constricta* Le Herisse, 1995 but it differs in having a pentagonal vesicle shape, bearing five processes rather than subquadrate.

Occurence: Tanezzuft Formation, late Rhuddanian-early Telychian (Llandovery).

Genus ***Ordovicidium*** Tappan and Loeblich, 1971

Type species: *Ordovicidium elegantulum* Tappan and Loeblich, 1971.

Diagnosis: “ Vesicle spherical, having numerous hollow rigid processes that do not communicate with the vesicle, taper very little distally, and are multifurcate; rarely, simple processes occurring with multifurcate ones; wall double-layered, the processes arising from the outer layer and being easily detached to leave a rimmed scar or hole exposing the inner layer; vesicle wall rather thick, laevigate to microgranulate; inner wall layers in some species also micro-granulate; processes wall thin, hyaline, smooth or micro-granulate; excystment by rupture or splitting of the vesicle wall.” From Loeblich and Tappan (1971, p. 398-400).

Remarks: The genus *Orodovicidium* is considered to be a junior synonm of the genus *Peteinosphaeridium* Staplin, Jansonius and Pocock, 1965 or the genus *Baltisphaeridium*. However, this genus differs from the genus *Peteinosphaeridium* in lacking the prominent, commonly elevated cyclopyle (pylome) and having excystment by a simple rupture, and in lacking the winged or strutted processes. It differs from the genus *Baltisphaeridium* Eisenack, 1958b ex Eisenack, 1959 emended Eiserhardt, 1989, in having multifurcate processes. Furthermore, the processes of *Baltisphaeridium* are plugged and do not communicate with the vesicle cavity. The genus *Multiplicisphaeridium* has branched processes, but, unlike the present genus, their cavities communicate freely with that of the vesicle.

Ordovicidium elegantulum Tappan and Loeblich, 1971

Plate 16, Fig. 1

For synonymy see Elaoud-Debbaj (1988).
Additional synonymy:
1988 *Ordovicidium elegantulum* - Elaoud-Debbaj, p. 239; pl. 2, fig. 10.
1995 *Ordovicidium elegantulum* - Jachowicz, pl. II, fig. 2.
1999 *Ordovicidium elegantulum* - Vecoli, p. 50; pl. 11, fig. 10.
2006 *Ordovicidium elegantulum* - Ghavidel-syooki, pl. IV, fig. 7.
2006 *Ordovicidium elegantulum* - Li *et al*., pl. VII, figs. 1-3.

Description: Vesicle is spherical, thick walled. Processes are 9-10 in number, cylindrical, heteromorphic, hollow, thin wall. The vesicle and process surface is smooth. The processes do not communicate with vesicle cavity, but sealed at their base by vesicle wall, taper very gently to bifurcate distal ends and bifurcate or trifurcate again, producing pinnae that are nearly perpendicular to process length. No excystment structure observed.

Dimensions: L: 40(45)50μm, P: 20(23)25μm, n = 5.

Remarks and comparision: The specimens recorded here have fewer processes than the type material. However, the number of processes was not considered as a diagnostic feature by Tappan and Loeblich (1971). It is very similar to the specimens described and illustrated by Vecoli (1999) from Ashgillian of Algeria. *Ordovicidium gracile* Colbath, 1979 differs in having longer, narrower processes.

Occurence: Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian).

Selected previous stratigraphic record: Mid Ordovician, USA (Tappan and Loeblich, 1971); Caradocian, USA (Colbath, 1979); Late Ordovician, Canada (Martin, 1980, 1983); Caradocian, UK (Turner, 1984); Ashgillian, Czech Republic (Vavrdová, 1988, 1989), Morocco (Elaoud-Debbaj1988); Llandeilo-Ashgillian, Estonia (Uutela and Tynni, 1991); Caradocian-Ashgillian, Sweden (Eiserhardt, 1992); late Caradocian-early Ashgillian, Saudi Arabia (Jachowicz, 1995); Caradocian, China (Li and Wang, 1997); Ashgillian, Algeria, Tunisia and northwest Libya (Vecoli, 1999, 2000); Caradocian-Ashgillian, Iran (Ghavidel-Syooki, 2006); Caradocian, China (Li *et al*., 2006); Caradocian, Iraq (Al-Ameri, 2010), Late Ordovician (Hirnantian), northern Chad and southeastern Libya (Le Hérissé *et al*., 2013).

Ordovicidium **sp. A**

Plate 16, Fig. 2

Description: Spherical to sub-spherical, single, relatively thick walled vesicle bearing thin-walled hollow, processes about 6-8 in number. The processes have angular contacts but do not communicate with the vesicle cavity, taper into bifurcate distal ends which bifurcate to second order. The vesicle surface is smooth while the process is ornamented with fine grana. No excystment structure observed.

Dimensions: L: 40(47)55µm, P: 12(18)25µm, n = 3.

Remarks and Comparision: The specimens recorded here are attributed to *Ordovicidium* on the basis of the furcate processes that do not communicate with the vesicle and lack a basal plug. It is similar to *Ordovicidium heteromorphicum* (Kjellstorm) Turner, 1984 and specimens from the Upper Ordovician of northeast Libya illustrated by Molyneux (1988) in having heteromorphic, simple and bifurcate processes, but it differs in vesicle size and in having fewer, longer processes. It is very similar to *Ordovicidium* sp. cf. O. *heteromorphicum* recorded by Vecoli (1999) from Tunisia. *Ordovicidium gracile* Colbath, 1979 differs in having more, longer and narrower processes.

Occurence: Memouniat and Bir Tlacsin formations, Hirnantian (Ashgillian).

Genus ***Orthosphaeridium*** Eisenack, 1968 emend. Turner, 1984

Type species: *Orthosphaeridium rectangulare* (Eisenack, 1963) Eisenack, 1968.

Diagnosis: “Vesicle hollow, rectangular to circular in outline, bearing few (2-8) long, hollow, simple processes that taper to a sharp point; rarely a process may divide. Process interior is always separated from the vesicle cavity by a solid proximal plug. Excystment structure is an apparently straight split in a median or equatorial position.” From Turner (1984, p. 125).

Remarks and Comparision: Turner (1984) emended this genus to include forms with spherical vesicles. Eisenack *et al*. (1976) and Rauscher (1974) considered *Baltisphaera* Burmann, 1970 as a junior synonym of *Orthosphaeridium*. This argument was accepted by Turner (1984) and adopted here.

Orthosphaeridium bispinosum Turner, 1984

Plate 16, Fig. 3

1984 *Orthosphaeridium bispinosum* - Turner, p. 125; pl. 2, figs. 1-3; pl. 4, figs. 3, 5.

1999 *Orthosphaeridium bispinosum* - Keegan *et al*., pl. III, fig.3.

Description: Elongated, sub-spherical, hollow vesicle ornamented with dense short spines. The vesicle bears two polar long, simple, slender, hollow, processes. These processes have acuminate tips, plugged at their bases, constricted proximally and do not communicate with the vesicle cavity. The spiny ornamentation may extend to the processes. Excystment structure is a median split

Dimensions: L: 60(72)84μm, P: 92(121)150μm, n = 6.

Remarks and comparision: *Orthosphaeridium quadrinatum* (Burmann, 1970) Eisenack *et al*., 1976 differs from this species in having four processes and of *Orthosphaeridium ternatum* (Burmann, 1970) Eisenack *et al*., 1976, differs in having three processes.

Occurence: Melez Shugran, early late Katian (Ashgillian).

Selected previous stratigraphic record: Caradocian, Shropshire (Turner, 1984); Caradocian-early Ashgillian, Jordan (Keegan *et al*., 1990); late Caradocian, northwestern Saudi Arabia (Jachowicz, 1995); Sandbian-Katian, northern Gondwana (Vecoli and Le Hérissé, 2004); Early Ordovician, northern England (Molyneux, 2009); Caradocian-Ashgillian, Iraq (Al-Ameri, 2010).

Orthosphaeridium insculptum Loeblich and Tappan 1971

Plate 17, Fig. 1, 2

1970 *Orthosphaeridium inflatum* - Loeblich and Tappan, fig. 1.

1978 *Orthosphaeridium insculptum* - Elaouad Debbaj, p. 47-48, pl. 13, fig. 2-3

1980 *Orthosphaeridium insculptum* - Martin, pp. 112, pl. 3, fig. 1-4

1985 *Orthosphaeridium insculptum* - Jacobson and Achab, p. 188, pl. 7, fig. 6.

1988 *Orthosphaeridium insculptum* - Elaouad Debbaj, p. 238-239, pl. 1, fig. 5; pl. 2, fig. 17.

1999 *Orthosphaeridium insculptum* - Wicander *et al*., p. 19, figs. 10.2, 10.5, 10.6.

2001 *Orthosphaeridium insculptum* - Ghavidel-syooki, pl 7, figs. 1,4

2003 *Orthosphaeridium insculptum* - Ghavidel-syooki ,pl. 4, fig. 10

2006 *Orthosphaeridium insculptum* - Ghavidel-syooki, pl. IV, fig. 5.

Description: Subquadrate vesicle, thick, single wall, and ornamented with grana. Processes are eight in number variable in length, four of them lie at the corner of the vesicle and the others are arising from the faces of the vesicle, flexible, thin whip like at their distal extremity, proximally communicate freely with the vesicle cavity and may be semi-constricted at base, tapering to acuminate tips. Processes wall is covered with grana extending along the process and becoming progressively smaller and finally disappearing. Excystment structure is recognized by rupture and splitting of central body into two halves.

Dimension: L: 65(76)87μm, P: 50(55)60μm, n = 5.

Remarks and Comparision: *Orthosphaeridium densiverrucosum* Kjellstrom, 1971 differs from this species in having verrucate ornamentation on both the vesicle and process wall. *Orthosphaeridium vibrissiferum* Loeblich and Tappan 1971 has granulose spines on the vesicle wall and fewer processes. *Orthosphaeridium octospinosum* has psilate wall.

Occurence: Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian).

Selected previous stratigraphic record: Late Ordovician (Ashgillian), USA (Loeblich, 1970), Portugal (Elaouad Debbaj,1978), Canada (Jacobson and

Achab, 1985), Canada (Martin, 1980), Morocco (Elaouad Debbaj), USA. (Wicander *et al*., 1999), Saudi Arabia (Jachowicz, 1995) and Iran (Ghavidel-syooki, 2000); Llanvirnian- Ashgillian, northearn and eastern central Iran (Ghavidel-syooki, 2001, 2003).Caradoian-Ashgillian, northern Iran (Ghavidel-syooki, 2006).

Orthosphaeridium rectangulare (Eisenack 1963b) Eisenack 1968bPlate 16, Fig. 4, 5

For synonymy see Wicander *et al*. (1999).

Additional synonymy:

1999 Orthosphaeridium rectangulare - Wicander *et al*., p. 19, 21; figs.10.1, 10.3.

2008 *Orthosphaeridium rectangulare* - Wicander and Playford., p. 54; pl. 4, fig. 9.

Description: Sub-quadrate, psilate, thick walled vesicle bearing four long, simple, slender, hollow processes ending with acuminate tips arising from each corner of the vesicle The bases of the processes are slightly constricted where they are plugged and do not communicate with the vesicle cavity. The vesicle wall is thicker than the processes. Excystment recognized by medial split, the halves commonly found separately in the studied specimens

Dimensions: L: 70(74)78µm, P: 100(106)112µm, n = 3.

Remarks and comparision: The specimens recorded here have sub-quadrate vesicle. However, the author herein agrees with the discussions of Wicander *et al*. (1999). *O. rectangulare* is similar in morphology to *Orthosphaeridium quadrinatum* (Burmann, 1970) Eisenack, Cramer, and Diez, 1976, but it differs in having a psilate vesicle and processes.

Occurence: Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian); reworked in Tanezzuft Formation, mid Rhuddanian (Llandovery).

Selected previous stratigraphic record: Ashgillian, USA (Miller, 1991; Wicander et al., 1999; Loeblich, 1970; Playford and Wicander, 2006; Wicander and Playford, 2009), Canada (Jacobson and Achab, 1985; Martin, 1988); Llanvirnian–Caradocian, Gotland, (Kjellström, 1971); ?Llanvirnian–Ashgillian, Iran (Ghavidel-syooki, 2001, 2003); Caradocian-Ashgillian, Gotland, Sweden (Eisenack, 1968; Eiserhardt, 1985); Ashgillian, Estonia (Uutela and Tynni, 1991), Morocco (Elaouad-Debbaj, 1988), Jordan (Keegan et al., 1990); Katian-Hirnantian, Iran (Ghavidel-syooki, 2011), southern Estonia (Delabroye *et al.,* 2011).

Orthosphaeridium octospinosum Eisenack, 1968
Plate 17, Fig. 3, 4.

For synonymy see Elaouad Debbaj (1988).
Additional synonymy:
1988 *Orthosphaeridium octaspinosum* - Elaouad Debbaj, p. 239; pl. 1, fig. 1, 2, 6, 7, 18.
2000 *Orthosphaeridium octaspinosum* - Ghavidel-syooki, pl. 5, fig. 4.
2003 *Orthosphaeridium octaspinosum* - Ghavidel-syooki, pl. 4, fig. 1.

Description: Sub-quadrate vesicle, thick, single, psilate wall. The vesicle bears 7-8, slightly long, hollow, thin, flexible, whip like processes ending with acuminate tips. They are variable in length, four of them lie at the corner of the vesicle and the others are arising from the faces of the vesicle.The processes may be semi-constricted at their bases and do not communicate with the vesicle cavity. Excystment structure is recognized by rupture and splitting of central body into two halves.

Dimension: L: 55(57)60µm, P: 45(50)55µm, n = 6.

Remarks and comparision: *Orthosphaeridium insculptum* Loeblich and Tappan, 1971, has both vesicle and processes wall ornamented with grana.

Occurence: Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian).

Selected previous stratigraphic record: Late Ordovician (Ashgillian.), USA (Loeblich, 1970), Portugal (Elaouad Debbaj, 1978), Morocco (Elaouad Debbaj, 1988); Llanvirian- Ashgillian, northern and eastern central Iran (Ghavidel-syooki, 2000, 2001, 2003).

***Orthosphaeridium* spp.**

Plate 17, Fig. 5, 6.

Description: Quadrangular vesicle in outline, single, thick wall, psilate. The vesicle bears 6-8 hollow, thin walled processes ending with acuminate tips. They are slightly constricted at the junction with the vesicle where it is plugged and do not communicate with the vesicle cavity. The processes are usually smooth or ornamented with weakly-developed verrucae at their distal ends. Excystment structure is recognized by median split dividing the vesicle to two halves.

Dimensions: L: 50(65)80µm, P: 40(43)46µm, n = 5.

Remarks and comparision: This species characterised by a thin, psilate vesicle wall and weakly-developed verrucae on process walls. In the current study all species having the same ornamentation are attributed to this group.

Occurence: Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian).

Genus ***Pirea*** Vavrdová, 1972

Type species: *Pirea dubia* Vavrdová, 1972

Dignosis: “Acritach with pear to bottle-shaped shell, wall single layered, psilate, granulate or with transversal ribs (micro-striate). Apical horn clavate, capitate; antiapical end broadly rounded.” From Vavrdová (1972, p.82).

Remarks: The genus *Pirea* is similar to the genus *Deunffia* Downie, 1960, but differs in the process termination. In *Deunffia* the apical process terminates in a point or branches while in *Pirea* it is clavate or capitate.

Pirea dubia Vavrdová, 1972

Plate 18, Fig. 3

1972 *Pirea dubia* - Vavrdová, p. 83, pl. 1: 4.
1974 *Pirea dubia* - Cramer and Diez, p. 188; pl. 28, figs. 1-7.
1997 *Pirea dubia* - Ghavidel-syooki, pl. 2, fig. 5.

Description: Unilayered, thin, smooth pear- to bottle-shaped vesicle with a short, conical, hollow apical process tapering gradually from the body and closed distally as shown by dark colour at the extreme distal termination of apical pole. The process is closed distally. No excystment structure observed.

Dimensions: L: 40(50)60µm, W: 10(18)26µm, n = 6.

Remarks and comparision: This species differs from *Pirea ornata* Burmann, 1970, Eisenack *et al*., 1976, and *Pirea ornatissima* Cramer and Díez, 1977, in being entirely smooth without any sculptural elements.

Occurence: Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian).

Selected previous stratigraphic record: Arenigian, Bohima (Vavrdová 1972); upper Arenigian-early Llanvirnian, Morocco (Cramer and Diez, 1974); Arenigian-Mid Ordovician, Iran (Ghavidel-syooki 1997).

Pirea* cf. *dubia Vavrdová, 1972

Plate 18, Fig. 4

Description: Unilayered, thin, smooth pear- to bottle-shaped vesicle with a long, conical, hollow apical process tapering gradually from the vesicle and closed distally with presence dark in colour at the extreme distal termination of apical pole. No excystment structure observed.

Dimensions: L: 55(60)65µm, P: 10(18)26µm, n = 4.

Remarks and comparision: This species differs from *Pirea dubia* Vavrdová, 1972, in having long apical hollow process. *Pirea columbifera* Vavrdová, 1990, has a long apical horn and fine granulate sculpture.

Occurence: Hawaz Formation, middle-late Darriwilian (Llanvirnian).

Pirea* cf. *sinensis Li Jun, 1987

Plate 18, Fig. 1, 2

Description: The vesicle is ovate in shape, hollow, single, thin walled, bearing short single process drawn out from the apical side closed distally and slightly rounded tip. It communicates freely with the vesicle cavity. The vesicle wall covered with small, solid often capitate spines distributed randomly. Excystment is by a pylome at the antiapical end.

Dimensions: L: 40(44)48μm, W: 20(24)26μm, n = 5.

Remarks and Comparision: This species is similar in morphology to *Pirea sinensis* Li Jun**,** 1987 from Arenigian of China but it differs in the arrangement of spines along the apical end. It forms longitudinal rows in *Pirea sinensis*, which are difficult to see in the specimens recorded here. In addition to that, the apical end is distally closed and slightly expanded. *Pirea ornatisma* Cramer and Diez, 1977 ornamented with solid sculptural elements on the lower part of the vesicle but apically the wall is smooth. *Pirea ornate* (Burmann) Eisenack, Cramer and Diez, 1976 ornamented with solid sculptural elements on the lower part of the vesicle that become longer and more closely spaced towards the anti-apical portion.

Occurence: Melez Shugran and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian).

Genus ***Poikilofusa*** Staplin, Jansonius and Pocock, 1965
emend. Loeblich and Tappan, 1978

Type species: *Poikilofusa spinata* Staplin, Jansonius and Pocock, 1965.

Diagnosis: A fusiform vesicle whose polar extremities are drawn out into processes; surface sculptured by grana or spinules arranged in discontinuous longitudinal rows.” From Loeblich and Tappan (1978, p. 1281).

Remarks and Comparision: The genus is used here in agreement with Dorning (1994) who considered the four fusiform acritarch genera to be validly published and of practical value. Generic distinction is based on the nature and disposition of sculpture: in *Poikilofusa* there is an ornament of small, simple element or processes randomly distributed.

Poikilofusa ciliaris Vecoli, 1999

Plate 18, Fig. 5

1999 *Poikilofusa cilaris* Vecoli, 1999, pp. 53; pl 13, figs. 1, 9.

Description: Vesicle fusiform, thin-walled, single-layered with the two poles progressively drawn into flexible, hollow acuminate processes. These processes are communicating freely with the vesicle cavity. The vesicle surface ornamented with numerous spines which are ± regularly-spaced and may be arranged in longitudinal rows. No excystment structure observed.

Dimensions: L: 95(100)105µm, W: 15(20)25µm, n = 2.

Remarks and comparision: A few broken specimen are recorded here with one short process and the vesicle ornamented with numerous spines which are ± regularly-spaced and may be arranged in longitudinal raws. Based on that, these specimens are attributed to *P. ciliaris. Poikilofusa spinata* Staplin, Jansonius and Pocock, 1965, has longer apical processes and different sculpturing (i.e. longer, irregularly-spaced, conically-based spines).

Occurence: Hawaz Formation, mid-late Darriwilian (Llanvirnian).

Selected previous stratigraphic record: Llanvirnian, Tunisia, Libya (Vecoli, 1999); Llanvirnian, northern Gondwana (Vecoli and Le Hérissé, 2004).

Poikilofusa spinata Staplin, Jansonius and Pocock, 1965

Plate 18, Fig. 6

1965 *Poikilofusa spinata* - Staplin, Jansonius and Pocock, p. 186; pl. 18, figs. 25, 26.
1985 *Poikilofusa spinata*? - Molyneux, pl. 1, figs. 6, 9, 12.
1999 *Poikilofusa spinata* - Vecoli, p. 53; pl. 13, fig. 8.

Description: Fusiform vesicle, thin walled its extremities drawn out into two short processes which taper to acuminate distal tips. These processes are approximately equal in length. The vesicle is ornamented with spines arranged discontinuously in longitudinal rows which decrease in length and size toward vesicle extremities, and continue onto the processes nearly to the tip where they change to grana. No excystment structure observed.

Dimensions: L: 180(190)200µm, W: 35(40)45µm, n = 8.

Remarks and comparision: The specimens recorded in the current study conform to the original description of Staplin, Jansonius and Pocock 1965. They are very similar in morphology to the specimens recorded by Vecoli (1999) from the Late Ordovician of Algeria and Tunisia.

Occurrences: Melez Shugran and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian).

Selected previous stratigraphic record: Llanvirian, Czech Republic (Vavrdová, 1986); Ashgillian, Canada (Staplin *et al*., 1965; Jacobson and Achab, 1985); Ashgillian, Libya (Hill and Molyneux, 1988; Molyneux, 1988); Ashgillian, Tunisia, Algeria and Libya (Vecoli, 1999, 2000); Late Ordovician, Iran (Ghavidel-syooki, 2006).

Genus ***Polygonium*** Vavrdová, 1966 emend.
Sarjeant and Stancliffe, 1994

Type Species: *Polygonium gracile* Vavrdová, 1966.

Diagnosis: "Vesicle hollow, polygonal to sub-polygonal, generally greater than 20 µm in diameter. Eilyma smooth to granulate, thin (about 0.5-1 µm), bearing 11 or hollow, simple homomorphic spines distributed in more than one plane about the vesicle. Distally the spines are acuminate, closed and sometimes solid; proximally they may be relatively broad-based. When hollow, the spine interiors communicate freely with the vesicle cavity. No differentiation is apparent between the spines and vesicle wall. Opening of vesicle by cryptosuture." From Sarjeant and Stancliffe (1994, p 42, 43).

Discussion: Vavrdová (1966) proposed the genus *Polygonium* and described the processes as having a consistent concentric arrangement which she considered as a diagnostic feature. Eisenack (1969) erected the genus *Goniosphaeridium* which is a very similar to *Polygonium* in gross morphology. Turner (1984) retained both genera but he commented that *Goniosphaeridium* could be a junior synonym of *Polygonium* if the process arrangement is considered as coincidental and not a consistent feature. Sarjeant and Stancliffe (1994) emended the genus *Polygonium* and considered *Goniosphaeridium* as a junior synonym of *Polygonium*. This view is adopted here and is also in agreement with Le Hérissé (1989); Albani (1989); Fensome *et al*., (1990); Moczydłowska and Crimes (1995); Moczydłowska (1998, 2005); Vecoli (1999). The genus *Veryhachium* differs from *Polygonium* in having fewer processes which lie in a single plane, and the genus *Baltisphaeridium* is differentiated by the polygonal outline of the vesicle. The elongation of the vesicle of the genus *Acanthodiacrodium* distinguishes it from *Polygonium*. The genus *Micrhystridium* is smaller and has narrow-based processes.

Polygonium gracile Vavrdová, 1966 emend. Sarjeant and Stancliffe, 1996

Plate 18, Fig. 7

For synonymy see Sarjeant and Stancliffe, 1996.

Additional synonymy:

1985 *Polygonium gracile* - Jacobson and Achab, pl. 7, figs. 8, 9.

1992 *Polygonium gracile* - Ottone *et al*., pl. 3, figs. 3, 10.
1999 *Polygonium gracile* - Wicander *et al*., fig. 12.4-12.7.
2006 *Polygonium gracile* - Li *et al*., pl. IV, figs. 4, 5.
2008 *Polygonium gracile* - Wicander and Playford, pl. 4, figs. 17, 18.

Description: Polygonal to subpolygonal vesicle, hollow, smooth, thin walled. Processes about 15-20 in number, smooth, hollow, homomorphic are drawn out from the vesicle. They are distributed in more than one plane and communicatie freely with the vesicle cavity. The processes are wide-based and taper to acuminate tips. No excystment structure observed.

Dimensions: L: 22(26)32µm, P: 16(22)26µm, n = 5.

Remarks and comparision: *Polygonium connectum* Kjellström, 1971b differs from this species in having evexate to bulbous process tips. *Polygonium conjunctum* Kjellström, 1971b, has processes longer than the vesicle diameter.

Occurrences: Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian).

Selected previous stratigraphic record: Arenigian, central Bohemia (Vavrdová, 1966, 1972); Arenigian, France (Rauscher, 1971, 1974); Tremadocian, Shropshire, England (Rasul and Downie, 1974); Tremadocian, Libya (Deunff and Massa, 1975); late Arenigian-late Llanvirnian, central Bohemia (Vavrdová, 1977); Late Ordovician, Bulgaria (Kalvacheva, 1978), Early Devonian, southern England (Richardson and Rasul, 1978, reworked specimens); latest Tremadocian-Llanvirnian, Isle of Man, UK (Molyneux, 1979); Late Cambrian-late Llanvirnian, England (Downie, 1984); Arenig, central Sardinia (Tongiorgi *et al.*, 1984; Albani *et al*., 1985a, Albani, 1989); Arenigian, Hungary (Albani *et al*., 1985a); Ashgillian, Canada (Jacobson and Achab, 1985); early Arenigian, South China (Li, 1987; 1990), Tremadocian-Arenigian boundary, Spain (Mette, 1989); Arenigian, South China (Lianda, 1991); Early Ordovician, Argentina (Ottone *et al*., 1992); Late Ordovician, USA (Wicander *et al*., 1999); late Arenigian-early Llanvirnian, southern China (Brocke *et al*., 2000);

Tremadocian- Hirnantian, northern Gondwana (Vecoli and Le Hérissé, 2004); Tremadocian-Arenigian, Iran (Ghavidel-syooki, 2006); Late Ordovician, northwestern China (Li *et al*., 2006), USA (Wicander and Playford. 2008); Early Ordovician, Oman (Molyneux *et al*., 2006).

Polygonium conjunctum (Kjellström 1971a) Sarjeant and Stancliffe 1994

Plate 19, Fig. 1

1971 *Goniosphaeridium conjunctum* - Kjellström 1971, p. 43, 44; pl. 3, fig 5.
1985 *Goniosphaeridium* cf. *conjunctum* - Molyneux, p. 48; pl. 9, figs. 2, 3.

Description: Polygonal to sub-polygonal vesicle, hollow, smooth, single, thin walled. Processes about 12-15 in number, smooth, hollow, homomorphic are drawn out from the vesicle. They are distributed in more than one plane, and communicatie freely with the vesicle cavity. They are broad based and taper to acuminate tips; their length is longer than the vesicle diameter. No excystment structure observed.

Dimensions: L: 22(24)25µm, P: 25(30)35 µm, n = 3.

Remarks and Comparision: *Polygonium gracile* Vavrdová, 1966 emend. Sarjeant and Stancliffe, 1996 has a processes shorter than the vesicle diameter.

Occurrences: Bir Tlacsin Formation, Hirnantian (Ashgillian).

Selected previous stratigraphic record: Mid Ordovician, Sweden (Kjellström, 1971a).

***Polygonium* sp. A**

Plate 19, Fig. 2

Description: Polygonal to sub-polygonal vesicle, hollow, smooth, single, thin walled. Processes about 22-24 in number, smooth, hollow, homomorphic and spine like are drawn out from the vesicle. They are distributed in more than one plane and communicatie freely with the vesicle cavity. They are broad based and taper to acuminate tips; their length is shorter than the vesicle diameter. No excystment structure observed.

Dimensions: L: 25(28)35µm, P: 18(19)20µm, n = 5.

Remarks and comparison: *Polygonium polyacanthum* (Eisenack, 1965) Sarjeant and Stancliffe, 1994, has shagreenate vesicle wall and the process wall is granulate.

Occurence: Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian).

***Polygonium* sp.1** Le Hérissé, 2000

Plate 18, Fig. 8

2000 *Polygonium* sp.1 Le Hérissé, pl. 2, j.

Description: Polygonal to sub-polygonal, hollow, smooth vesicle with single-layered, smooth, hollow, homomorphic processes are drawn out from the vesicle. The proceses have acuminate tips and communicatie freely with the vesicle cavity; their length is shorter than the vesicle diameter. No excystment structure observed.

Dimensions: L: 30(35)40µm, P: 18(19)20µm, n = 4.

Remarks and comparison: The specimens recorded in the current study are similar in morphology to specimens recorded by Le Hérissé (2000) from early Rhuddanian of Saudi Arabia.

Occurence: Tanezzuft Formation, mid Rhuddanian (Llandovery).

Selected previous stratigraphic record: early Rhuddanian, Saudi Arabia (Le Hérissé, 2000).

Genus ***Rhopaliophora*** Tappan and Loeblich, 1971
emended. Playford and Martin, 1984

Type species: *Rhopaliophora foliatilis* Tappan and Loeblich, 1970.

Diagnosis: "Vesicle originally spherical to ovoidal; outline circular to oval. Vesicle wall single-layered; psilate or with minor ornamentation, e.g. microcostate or finely echinate. Processes discrete, variable in number but often abundant; relatively broad compared to their length; cylindrical to prismatic, more or less homomorphic, although precise form may be variable among different specimens of the same species due to preservational effects; composed of thin membranous wall that is psilate or only slightly sculptured. Process interiors hollow but not communicating with the vesicle cavity; distal extremites closed, with or without minor knobby projections. The thin walls of the processes may be laterally contracted, producing outwardly concave sides and a consequent petaloid appearance in surface view; thus, in transverse section the processes may appear X- or Y- shaped the ultimate radial-extremities being simple or divergent. Excystment opening in the form of one or two pylomes with thickened or elevated rims; the vesicle is often ovate where two pylomes are present. In the later case, the pylomes are diametrically opposed to one another on the vesicle's longitudinal axis; or else one pylome may be situated on the axis and the other slightly to one side of it. Operculum psilate." From (Playford and Martin, 1984, p. 209).

Remarks: The genus *Rhopaliophora* diagnosed by Tappan and Loeblich (1971) then emended by Playford and Martin (1984) to include spherical or ovoidal forms with one or two pyloms, that unilayered wall and the processes are more or less homomorphic, prismatic or cylindrical and not communicating with the vesicle cavity and including enveloping membrane. The specimens recorded in the current study, possessing an apparently similar process-connecting membrane, were attributed to *Rhopaliophora* Playford and Wicander (1988).

?*Rhopaliophora* sp. A

Plate 20, Fig. 3

Description: Vesicle originally spherical to sub-spherical, relatively thick, psilate wall with numerous compression folds. Processes are about 6-8 in number, more or less prismatic but prone to folding/distortion due to their very thin walls; regularly distributed, diaphanous, hollow,. They are apparently closed distally, their proximal contact is angular to subangular and not communicating with vesicle cavity. Excystment not clearly observed.
Dimensions: L: 55(58)60μm, P: 13(14)25μm, n = 2.

Remarks and comparision: Only a few specimens, with 6-8 more or less prismatic processes prone to folding/distortion were recorded in this study. It is possible that these specimens belong to the genus *Rhopaliophora*. However, it is still questionable as firm identification requires a complete specimen.

Occurence: Hawaz Formation, mid-late Darriwilian (Llanvirnian).

Genus *Solisphaeridium* Staplin, Jansonius and Pocock 1965

Type species: *Solisphaeridium stimuliferum* Staplin *et al*., 1938

Diagnosis: "Vesicle is spherical, wall relatively firm and rigid; several to numerous firm spines, hollow or solid, relatively long and slender, tapering continuously towards the closed tips. Spines have a tendency to reduce their cavity through secondary deposition of wall material but, if present, the cavity communicates freely with the vesicle. ." From Staplin *et al*. (1965, p. 183-184).

Remarks and Comparision: This genus differs from the genus *Baltisphaeridium* (Eisenack 1958) Eisenack 1969 in lacking hollow processes separated from the vesicle cavity by solid plugs and excystment structure. It can distinguish from the genus *Elektorisoks* Loeblich, 1970 which has abundant cylindrical, solid hair like processes. Following their emendation of the genus *Micrhystridium*, Sarjeant and Stancliffe (1994) considered *Solisphaeridium* as a junior synonym of *Micrhystridium*. This view is not adopted herein and *Solisphaeridium* is retained and differentiated from *Micrhystridium* by being larger than 20µm which is considered as a characteristic feature for *Micrhystridium*.

***Solisphaeridium* cf. *solare* Cramer and Diez*,* 1977**

Plate 20, Fig. 4

Description: Unilayered, smooth, hollow, spherical to sub-spherical vesicle bearing homomorphic, hollow, simple processes about forty in number. The process have slightly wide bases tapering to acuminate tips and communicate freely with the vesicle cavity. No excystment structure observed

Dimensions: L: 15(17)18µm, P: 6(7)8µm, n = 3.

Remarks and comparision: This species is very similar in morphology to *Solisphaeridium solare* Cramer and Diez**,** 1977 from late Arenigian of Morocco but it is smaller in overall size. *Solisphaeridium eriza* Cramer *et al.,* 1976, has processes bases which are relatively wider and rapidly taper to form fine needle tips.

Occurence: Hawaz Formation, middle-late Darriwilian (Llanvirnian).

Genus ***Stellechinatum*** Turner 1984

Type species: *Stellechinatum celestum* Turner 1984

Diagnosis: “Vesicle hollow with polygonal or sub-polygonal outline. Wall thin (<1 μm), single layered. Eight or more simple, hollow, proximally open, tapering processes having wide bases, curving proximal contacts and acuminate distal terminations. Process stems ornamented with small grana or spines that may become hair like distally. This ornament may extend onto the vesicle surface.” From Turner, (1984, p137).

Remarks: This genus was considered by Le Hérissé (1989) to be a junior synonym of *Polygonium,* with only minor consideration given to the surface ornamentation. Later, Vecoli (1996) considered the ornamentation in retaining the two genera separately. In this study, a clear separation between the two forms can be observed, and hence, *Stellechinatum* and *Polygonium* are retained as two separate genera. The genus *Uncinisphaera* Wicander, 1974, is distinguished by its spherical vesicle and slender processes. The greater number of processes distinguishes this genus from the genus *Villosacapsula* Loeblich and Tappan, 1976. The ornamentation on the processes (grana or spines) distinguishes this genus from the genus *Polygonium* Vavrdová, 1966 emend. Sarjeant and Stancliffe, 1994, which has finely granulate or smooth processes.

Stellechinatum celestum (Martin 1969) Turner 1984

Plate 20, Fig. 5

For synonymy see Turner (1984).
Additional synonymy:
1984 *Stellechinatum celestum* - Turner, p. 138; pl. 14, figs. 3, 4.
1985 *Stellechinatum celestum* - Turner, pl. 5, fig. 4.
1999 *Stellechinatum celestum* - Vecoli, p. 55, 56; pl. 13, figs. 3, 7.

Description: Polygonal vesicle, hollow, single-layered formed by gradual merging of wide-based processes, generally 7 - 10 in number. The processes are simple, hollow, homomorphic and cone-shaped, and taper gradually to acuminate tips. They are distributed in more than one plane and communicate freely with the vesicle cavity. The processes are ornamented with slender, short spines. This ornamentation is less obvious on the vesicle surface. No excystment structure observed.

Dimensions: L: 20(26)33µm, P: 18(28)33µm, n = 4.

Remarks and comparision: This species differs from *Stellechinatum brachyscolum* Turner, 1984, which has numerous processes and strongly developed spines. It differs from *Stellechinatum helosum* Turner, 1984 which has numerous and narrow processes and ornamented with grana rather than spinae, and from *Stellichinatum uncinatum* (Downie) Molyneux, 1987, in having a fewer processes with characteristically wide bases.

Occurence: Melez Shugran and Memouniat formations, early late Katian-early Hirnantian (Ashgillian).

Selected previous stratigraphic record: Silurian, Belgium (Martin, 1966, 1969; probably reworked specimens); late Llanvirnian, Bohemia, (Burmann, 1970); Arenigian-Lanvirnian, France (Martin, 1973); Ordovician and Silurian, Algeria (Jardiné *et al*., 1974); Llanvirnian, Czech Republic (Vavrdová, 1977); late Arenigian, Belgium (Martin and Rickards, 1979); Caradocian, Shropshire (Turner, 1984); Llandeilo, UK (Turner, 1985); Llandeilo, UK (Molyneux, 1990; in Molyneux *et al*., 1996); early Llanvirnian, Belgium (Servais and Maletz, 1992); early Caradocian, Saudi Arabia (Jachowiz, 1995); Llanvirnian, northern Trans

European Suture Zone (Vecoli and Samuelsson, 2001); Llanvirnian-Caradocian, northern Gondwana (Vecoli and Le Hérissé, 2004); Mid Ordovician, Saudi Arabia (Le Hérissé *et al*., 2007).

Genus ***Stelliferidium*** Deunff, Górka and Rauscher, 1974

Type Species: *Stelliferidium striatulum* (Vavrdová, 1966) Deunff, Górka and Rauscher, 1974.

Diagnosis: "Vesicle sub-hemispherical, bearing a large circular to polygonal polar opening of which the diameter equal to or larger than the radius of the vesicle. The opening may be shut off by an operculum, which is occasionally serrate, of the same outline, granulate or reticulate. The vesicle wall may be simple or double and is ornamented by processes of varying morphology but from the base of which always originates a divergent system of crests which are arranged in a star-shaped pattern. The outlines of the stars define a net of polygonal meshes on the surface of the vesicle. A veil may be present." Translation of Deunff *et al*. (1974) by Eisenack *et al*. (1979).

Remarks: Servais and Eiserhardt (1995) included *Stelliferidium* within the "Galeate" acritarchs, which are characterized by a "hemispherical vesicle outline with a large polar excystment opening closed by a detachable operculum". Palacios *et al*. (2009) considered the presence of a pylome, radiating striations and cylindrical processes with conical bases to be diagnostic characteristics of *Stelliferidium*. They suggested that *Timofeevia* differs from this genus in having conical or tapering processes, a thin vesicle wall with psilate or weakly granulate ornamentation, absence of excystment opening and absence of breakage into pentagonal plates.

Stelliferidium philippotii (Henry) emend.

Deunff, Gorka and Rauscher, 1974

Plate 20, Fig. 6

For synonymy see Vecoli (1999).
Additional synonymy:
1999 *Stelliferidium philippotii* - Vecoli, p. 56; Pl 14, fig. 9.

Description: Spherical to hemispherical, brown in colour vesicle, thin, single layered modified by a wide circular opening. The vesicle bears numerous 50-70 uniformly-distributed, hollow, cylindrical, short, thick-layered processes, which are plugged at the base and do not communicate with the vesicle cavity. They are thinner-walled than the vesicle and may be bifurcate or trifurcate distally. The processes are smooth and the vesicle is ornamented with weakly-developed fine striations which radiate from the process bases.

Dimensions: L: 38(42)49µm, P: 3(4)5µm, n = 5.

Remarks and comparision: The specimens recorded in the current study are slightly similar to the speciemens recorded by Vecoli (1999) from the Llanvirinian of Tunisia. It differs from *Stelliferidium velatum* Vecoli, 1996, in having more numerous and smaller processes and an appreciably larger vesicle. *Stelliferidium striatulum* (Vavrdová) Deunff, Górka and Rauscher, 1974 has fewer and longer processes.

Occurence: Hawaz Formation, mid-late Darriwilian (Llanvirnian).

Selected previous stratigraphic record: Llanvirinian, France (Henry, 1966; Paris and Deunff, 1970; Rauscher, 1974 a, b), Tunisia (Vecoli, 1999).

Stelliferidium striatulum (Vavrdová) Deunff, Górka and Rauscher, 1974

Plate 21, Fig. 1

1966 *Baltisphaeridium striatulum* s. sp.- Vavrdová, pl. 1, figs. 2a, b; pl. 2, fig. 3.

1969 *Baltisphaeridium striatulum* - Martin, pl. 5, figs. 246, 257, pl. 6, figs. 2, 19, 20.

1974 *Stelliferidium striatulum* - Deunff *et al*., pl. 6, figs. 2, 19, 20.

1999 *Stelliferidium striatulum* - Vecoli, p. 56, 57; pl. 14, figs. 7, 8, 10.

2000 *Stelliferidium striatulum* - Maziane-Serraj *et al*., pl. II, fig. 7.

2006 *Stelliferidium striatulum* -Achab *et al*., pl. I, fig.4.

2006 *Stelliferidium* sp. - Molyneux *et al*., pl. 2, fig.1

2007 *Stelliferidium striatulum* - Le Hérissé *et al*., pl. 1, fig. 17.

2013 *Stelliferidium striatulum* - Yan Kui *et al*., pl. IV, fig. 5

Description: Spherical to hemispherical vesicle, thin, single layered modified by a large excystment opening. The vesicle bears numerous 25-30 uniformly-distributed, hollow, cylindrical processes, which are plugged at the base and do not communicate with the vesicle cavity. They are thinner-walled than the vesicle and may be bifurcate or trifurcate distally. The processes are smooth and the vesicle is ornamented with weakly-developed fine striations which radiate from the process bases.

Dimensions: L: 38(42)42µm, P: 7(9)10µm, n = 3.

Remarks and comparision: It is difficult to distinguish this species from *Stelliferidium stelligerum* Górka, 1967, but as stated by Albani (1989) that *Stelliferidium striatulum* has stronger and fewer processes than *Stelliferidium stelligerum.*

Occurence: Hawaz Formation, mid-late Darriwilian (Llanvirnian).

Selected previous stratigraphic record: Arenigian, Czech Republic (Vavrdová, 1966); Tremadocian, Belgium (Martin, 1969); Arenigian-Llanvirnian, France (Rauscher, 1974); Llanvirnian, Libya (Deunff and Massa, 1975); Llanvirnian, Morocco (Deunff, 1977); Tremadocain, Algeria (Baudelot and Géry, 1979); Arenigian, Belgium (Martin and Rickards, 1979); Arenigian-Llanvirnian, Morocco (Elaouad-Debaj, 1984); Late Cambrian-early Arenigian, British Isles (Downie, 1984); Llandeilo, South Wales (Turner, 1985); Arenigian, Sardinia (Albani, 1989); Llanvirnian, Jordan (Keegan *et al*., 1990); Llanvirnian, Algeria, Tunisia and northwest Libya (Vecoli, 1999, Vecoli *et al*., 2000); early to mid Arenigian, southeast Ireland (Maziane-Serraj *et al*., 2000); Llanvirnian, northern Trans European Suture Zone (Vecoli and Samuelsson, 2001); Arenigian, Argentina (Achab *et al*., 2006); Llanvirnian, Oman (Molyneux *et al*., 2006); Arenigian-early Caradocian, northern Gondwana (Vecoli and Le Hérissé, 2004); late Arenigian-late Llanvirnian with acme in the early Llanvirnian, Saudi Arabia (Le Hérissé *et al.,* 2007). Vecoli (1999) commented that this species attained its acme in the early-mid Llanvirnian and does not occur in either pre-Arenigian or post Llandeilo sediments and all occurrences recorded beyond this range are misidentified or reworked; Lower-Mid Ordovician, China (Yan Kui *et al*., 2013).

Stelliferidium stelligerum (Górka) ememd. Deunff, Górka, and Rauscher, 1974Gorka and Rauscher, 1974

Plate 21, Figs. 2, 3

For synonymy see Vecoli, 1999.
Additional synonymy:
1999 *Stelliferidium stelligerum* – Vecoli, p. 56; pl 14, figs. 4-6.
2001 *Stelliferidium stelligerum* - Hussein Mehrjerdi, pl 3, fig. 1.
2001 *Stelliferidium stelligerum* - Ghavidel-syooki, pl 1, fig. 3.
2006 *Stelliferidium stelligerum* - Ghavidel-syooki, pl II, fig. 8.
2009 *Stelliferidium stelligerum* - Aráoz, fig. 15, H.

Description: Spherical to hemispherical vesicle, thin, single layered modified by a small excystment opening. The vesicle bears numerous 50-60 uniformly-distributed, hollow, cylindrical processes, which are plugged at the base and do not communicate with the vesicle cavity. They are thinner-walled than the vesicle and may be bifurcate or trifurcate distally. The processes are smooth and the vesicle is ornamented with weakly-developed 4-5 striations radiating from the base of each process, generally reaching the adjacent process base.

Dimensions: L: 38(42)42µm, P: 7(9)10µm, n = 3.

Remarks and comparision: As discussed by Albani (1989) that *Stelliferidium stelligerum* Górka, 1967. Albani (1989) distinguished this species from *Stelliferidium striatulum* that in having smaller excystement structure and more processes.

Occurence: Hawaz Formation, mid-late Darriwilian (Llanvirnian).

Selected previous stratigraphic record: lower Tremadocian, central Sardinia (Di Milia and Tongiorgi, 1993); Tremadocian, France (Martin, 1973; Rauscher, 1971, 1974a; Baudelot and Bessiere, 1977; Cocchio, 1982), Spain (Mette, 1989); late Tremadocian, Sweden (Tongiorgi *in* Bagnoli *et al.,* 1988), Poland (Gorka, 1967, 1969); Tremadocian-Arenigian boundary, Spain (Wolf, 1980); Arenigian, France (Rauscher, 1974b), central Sardinia (Albani *et al.,* 1985a), late Arenigian, Morocco (Elaouad-Debbaj, 1984); Caradocian, England (Turner, 1982; reworked specimens); Tremadocian, Iran (Ghavidel-syooki, 2006), (Gorka, 1967); Arenigian, Iran (Ghavidel-syooki, 2001); Floiano-Darriwilian, Argentina (Aráoz, 2009); early Arenigian, Russia (Raevskaya *et al*., 2004); Tremadocian-Darriwilian, northern Gondwana (Vecoli and Le Hérissé, 2004), Algeria, Tunisia and northwest Libya (Vecoli, 1999; Vecoli *et al*., 2003); early-mid Tremadocian, Algeria (Vecoli, 1996)

Occurence: Hawaz Formstion, Llanvirnian (mid-late Darriwilian).

Stelliferidium simplex (Deunff) Deunff, Gorka and Rauscher, 1974

Plate 21, Figs. 4, 5

2000 *Stelliferidium* cf. *simplex* - Maziane-Serraj *et al*., pl.1, fig. 5.

2001 *Stelliferidium simplex* – Ghavidel-syooki, pl.3, fig. 8.

Description: Vesicle spherical to sub-spherical but appear hemispherical due to polar opening with psilate and thick, slightly striate wall. The striae appear to radiate from the bases of processes. The processes are numerous, hollow, smooth, thin, short and distributed regularly. The processes bases appear pluged, acuminate and capitate distal termination.

Dimensions: L: 34(37)40µm, P: 6(8)9µm, n = 2.

Remarks and comparision: The specimens included here have short processes with acuminate and capitate distal termination, it is very similar in morphology to *Stelliferidium* sp. recorded by Ribecai and Tongiorgi (1995) from the Arenigian of Sweden.

Occurence: Hawaz Formation, mid-late Darriwilian (Llanvirnian).

Selected previous stratigraphic record: early to mid Arenigian, southeast Ireland (Maziane-Serraj *et al*., 2000); Tremadocian-Arenigian, Iran (Ghavidel syooki, 2001); Tremadocian, Oman (Molyneux *et al*., 2005), Algeria, Tunisia and Libya (Vecoli, 1999; Vecoli *et al.,* 2000).

Genus ***Striathotheca*** Burmann, 1970

Type species: *Striathotheca principalis* (Downie) Burmann, 1970.

Diagnosis: “Central body tetragonal or polygonal in outline, at the corners without basal constriction passing over into gradually tapering, hollow processes (limited in number). The processes and/or the central body are provided with a striate sculpture which is arranged in a fan-shape. The four-sided basic shape may be altered by concave arching of the outer sides in relation to the basal width of the processes, which generally pass gradually into the central body. Additional deviations from the basic shape result from shortening of the sides, reduction of processes, unequal development of processes and additional processes. The relatively close striation may be limited to the processes alone or may overlap from those on both sides on the central body in a fan-shaped development. The ribs have a subparallel position to the adjacent sides of the central body. The centrally located ribs differ from the peripheral ones by a slightly greater degree of curvature. In the middle part of the body, the ribs of each fan-system are partially interrupted or they become strongly divergent ('Vergenzscheitelpunkte'). Ribs of adjoining fan-systems may merge or enter alternatively into the intervals.” Translation of Burmann (1970, p. 299-300) by Servais (1997).

Remarks: The genus is applied here following the concept of Burmann (1970). The emendation by Sarjeant and Stancliffe (1994) is rejected for reasons stated by Servais (1997, p.57-60).

***Striatotheca* sp. A**

Plate 21, Fig. 6

Description: Rectangular vesicle with slightly curved sides bears four long processes arising from the corners of the vesicle. The processes are variable in length and approximately equal the vesicle diameter, smooth, conical, hollow and communicate freely with the vesicle cavity. The junction between the processes and the vesicle is either gradual, resulting in wide-based processes, or sharply-defined, resulting in narrow-based processes. Sub-parallel striations are strongly developed on the vesicle and converge at the process bases.

Dimensions: L: 18(20)22µm, P: 10(14)18µm, n = 4.

Remarks and comparision: The specimens recorded here are similar to *Striatotheca pricipalis parve* Burmann, 1970, but they are smaller in vesicle diameter and have relatively long process. They differ from *Striatotheca* sp.A recorded by Molyneux (1988) from Ashgillian of northeast Libya in overall size. This species has processes approximately equal to the vesicle diameter.

Occurence: Melez Shugran and Bir Tlacsin formations, early late Katian-late Hirnantian (Ashgillian).

***Striatotheca* sp. B**

Plate 21, Fig. 7

Description: Rectangular vesicle with slightly curved sides bears four short processes arising from the corners of the vesicle. The processes are smaller in length than the vesicle diameter, smooth, conical, hollow and communicate freely with the vesicle cavity. The junction between the processes and the vesicle is either gradual, resulting in wide-based processes, or sharply-defined, resulting in narrow-based processes. Sub-parallel striations are strongly developed on the vesicle and converge at the process bases.

Dimensions: L: 25(28)30µm, P: 5(8)10µm, n = 3.

Remarks and Comparision: The species is simillar in morphology and combination of striation and vesicle size to *Striatotheca* sp.A recorded by Molyneux (1988) from northeast Libya but it differs in having shorter processes.

Occurence: Melez Shugran and Bir Tlacsin formations, early late Katian-late Hirnantian (Ashgillian).

Genus ***Tectitheca*** Burman, 1968

Tye species: *Tectitheca valuta* Burman, 1968

Diagnosis: "Central body five-sided in outline, differentiated into a conical upper and a cylindrical lower portion; along its longitudinal axis it is either compressed or elongated. Slowly tapering, unbranching, generally long processes are regularly arranged at different levels of the central body. The cavities of these processes are freely connected with the body cavity. The compressed or elongated conical upper portion of the central body grades into one single apical process which serves to orientate the specimen as it lies in the longitudinal axis of the central body. In the transitional zone from the conical to the cylindrical position of the central body (median line), there are four processes; at the basal line of the apical pole there are two peripheral processes. The number of the processes is limited by the requirement of their regular arrangement; however, the number may vary, e.g., by the intercalation of additional process levels at the cylindrical portion of the central body whereby the additional processes generally show an alternating attitude with respect to the primary processes." Translation of Burmann (1968) by Eisenack *et al*. (1976, p. 801).

Remarks: The genus *Tectitheca* is characterized by its five-sided vesicle which distinguishes it from the genus *Polygonium* Vavrdová, 1966 emended Sarjeant and Stancliffe, 1996. *Stellichinatum* Turner, 1984 differs from this genus in having grana or spines ornamentation on the processes.

Tectitheca spinifera Burmann, 1968

Plate 22, Fig. 1

1978 *Tectitheca spinifera* - Dean and Martin, p. 9; Tar. 3, fig. 10.
1989 *Tectitheca spinifera* - Hamman *et al.*, p. 87; Taf. 3, fig. 22.

Description: Smooth, hollow, single-layered, five-sided vesicle which bears wide-based processes, about seven processes in number. The processes are hollow and homomorphic and taper gradually to acuminate tips. They are distributed in more than one plane and communicating freely with the vesicle cavity. The processes are smooth except a single process ornamented with well-developed slender, short spines. No excystment structure observed.

Dimensions: L: 22(24)25µm, P: 5(7)9µm, n = 5.

Remarks and Comparision: This species differs from *Tectitheca* sp. A in having only a single ornamented process whereas all processes in *Tectitheca* sp. A are ornamented with short spines.

Occurence: Hawaz Formation, mid-late Darriwilian (Llanvirnian).

Selected previous stratigraphic record: Llanvirnian, Russia (Burmann, 1968); Arenigian, Newfoundland (Dean and Martin, 1978); Arenigian-? Llanvirnian, Germany (Hamman *et al.*, 1989).

***Tectitheca* sp. A**

Plate 22, Fig. 2

Description: Smooth, hollow, single-layered, rectangular or pentagonal vesicle bears wide based processes usually seven in number. The processes are hollow and homomorphic and taper gradually to acuminate tips. They are distributed in more than one plane and communicating freely with the vesicle cavity. The processes are ornamented with well-developed slender, short spines. No excystment structure observed.

Dimensions: L: 40(52)55µm, P: 15(13)20µm, n = 5.

Remarks and Comparision: *Stellichinatum* species are similar to this species in having spiny processes. However, this taxon is assigned to *Tectitheca* on the basis of the vesicle shape and wall (psilate). *Tectitheca spinifera* Burmann, 1968 has only a single ornamented process.

Occurence: Hawaz Formation, mid-late Darriwilian (Llanvirnian).

Genus ***Tunisphaeridium*** Deunff and Evitt, 1968

Type species: *Tunisphaeridium concentricum* Deunff and Evitt, 1968.

Diagnosis: “Acritarchs with an overall spherical to ellipsoidal or pyriform outline composed of a central sphaeroidal [*sic*] vesicle bearing numerous rod like, apparently solid, processes whose extremities are interconnected by a diaphanous membrane alone, by a membrane reinforced with a network of faint to conspicuous filaments that radiate from the process tips, or by such filaments with only traces of a membrane. No pylome observed.” From Deunff and Evitt (1968, p. 2).

Remarks: The genus *Tunisphaeridium* is distinguished by its membrane or filaments which interconnect the extremities of the radial processes.

Tunisphaeridium tentaculiferum (Martin) Deunff and Evitt 1968

Plate 22, Fig. 3

For synonymy see Le Hérissé (1989).
Additional synonymy:
1989 *Tunisphaeridium tentaculiferum* - Le Herisse, p. 139; pl. 26, fig. 13.
1992*Tunisphaeridium tentaculiferum* - Eley and Legault, p. 87; pl. 3, fig. 6.
2000 *Tunisphaeridium tentaculiferum* - Ghavidel-syooki, pl. 6, fig. 4.
2000 *Tunisphaeridium tentaculiferum* - Le Hérissé, pl. 3, fig. A.

Description: Spherical to sub-spherical, psilate, hollow, thin-walled vesicle ornamented with numerous solid processes about 10-40 in number. The processes length sometimes exceeding half of the vesicle diameter and do not communicate with the vesicle cavity. Distally they are multifurcate, their tips interconnected by relatively coarse filaments which form a network which is concentric with the central vesicle.

Dimensions: L: 18(30)41µm, P: 11(17)23µm, n = 6.

Remarks and comparision: This species differs from *Tunisphaeridium parvum* Deunff and Evitt, 1968, in having fewer processes which are about 10-40µm. It differs also from *Tunisphaeridium caudatum* Deunff and Evitt, 1968, in lacking a long single process or a small group of neighbouring processes being clearly longer than most of the rest of the processes.

Occurence: Tanezzuft Formation, late Rhuddian-early (Telychian Llandovery).

Selected previous stratigraphic record: Mid Silurian, USA (Thusu and Zenger, 1974), late Llandovery-Ludlow, Turkey (Erkmen and Bozdoğan, 1979); Aeronian-Telychian, England (Hill, 1974); Ludlow-? Gedinnian, Sahara Algeria (Jardiné *et al.*, 1974); Llandovery-Wenlock, England (Hill and Dorning 1984) Llandovery, Norway (Smelror, 1987); Aeronian, northeast Libya (Hill and Molyneux 1988); Llandovery-early Wenlock, Canada (Eley and Legault 1992); Rhuddinian- Aeronian, Saudi Arabia (Le Herisse, 1995); mid Rhuddanian, Saudi Arabia (Le Hérissé, 2000).

Tunisphaeridium caudatum Deunff and Evitt, 1968
Plate 22, Fig. 4

For synonymy see Eisenack *et al*., (1973).
Additional synonymy
1996 *Tunisphaeridium caudatum* - Ottone, p. 138; pl. 10, fig.1.
1985 *Tunisphaeridium caudatum* - Jacobson and Achab, p. 193;pl. 8, fig. 6.
1988 *Tunisphaeridium caudatum* - Hill and Molyneux, pl. 6, figs. 14,15.
2000 *Tunisphaeridium caudatum* - Ghavidel-syooki, pl. 6, fig7.
2000 *Tunisphaeridium caudatum* - Le Hérissé, pl. 4, fig. A.

Description: Spherical to sub-spherical hollow, psilate, thin-walled vesicle with numerous, rod-like, apparently solid processes. Distal terminations of these processes are connected by a diaphonous membrane and/or filaments. A small group of neighbouring processes are longer than the rest with some processes are transitional in length. The longer process extends beyond the enveloping membrane or filament.

Dimensions: L: 17(24)28µm, P: 9(17)21µm, n = 5.

Remarks and comparision: This species is distinguished from other *Tunisphaeridium* species such as *Tunisphaeeridium parvum* Deunff and Evitt, 1968 in having some longer process than the rest of the processes.

Occurrences: Tanezzuft Formation, Aeronian- Telychian (Llandovery).

Selected previous stratigraphic record: Llandovery-Wenlock, England (Hill, 1974; Dorning, 1981); Ashgillian, Canada (Jacbson and Achab, 1985); Llandovery, northeast Libya (Hill and Molyneux, 1988), Saudi Arabia (Le Hérissé *et al*., 1995); Late Silurian, Argentina (Rubinstein, 1995); Late Rhuddanian, Saudi Arabia (Le Hérissé, 2000); Mid-Late Devonian, Argentina (Ottone, 1996), Brazil (Quadros, 1999); Early Silurian, Iran (Ghavidel-syooki, 2000); Rhuddinian, Oman (Molyneux, 2005); Silurian, Argentina (Pöthe de Baldis, 1974, 1997); Wenlock, Iraq (Al-Ameri, 2010).

Genus ***Tylotopalla*** Loeblich, 1970 emend.
Sarjeant and Vavrdová, 1997

Type Species: *Tylotopalla digitifera* Loeblich, 1970.

Diagnosis: "Vesicle typically of small size, generally less than 30µm in diameter. Processes short, their length less than 25% of the vesicle diameter.

Broad-based and most often tapering, their cavities open to the vesicle interior. Form of processes highly variable, both between species and often on a single individual; they may be acuminate, branched in regular or irregular pattern, or may form a tuft or rosette of small spinelets. Eliyma variously ornamented-coarsely granulate, regulate, scabrate or verrucate-but not divided into fields by lines or crests and not echinate. This ornament may or may not extend onto the processes. Opening of the vesicle by cryptosuture." From emended diagnosis of Sarjeant and Vavrdová (1997, p. 32).

Remarks: The genus *Tylotopalla* was diagnosed by Loeblich (1970) then emended by Sarjeant and Vavrdová (1997) to place limits of process and to emphasize the importance vesicle ornamentation, Later Le Hérissé (1989) adds the presence of longitudinal ribs on the process in the species *Tylotopalla caelamenicutis* and *Tylotopalla digitifera.* Also he reported the forms with long processes such as *Tylotopalla robustispinosa,* are very similar in morphology to species of the genus *Evittia*, but it differs in lacking of ramifications of the processes.

Tylotopalla aniae (Jardiné) Fensome, Williams, Barss, Freeman and Hill, 1990
Plate 22, Fig. 5

1974 *Baltisphaeridium aniae* - Jardiné, p. 120; pl. I, figs. 6, 6a.

Description: Spherical, single, hollow, thin-walled vesicle ornamented with fine grana. The vesicle bears single-walled, homomorphic, hollow, slender, simple processes about 4 in number which gently taper to slightly branched tips and communicate freely with the vesicle cavity. The junction of the processes with the vesicle body is marked by a sharp line which delimits a circular areola generally ornamented with radial grooves extending on the lower part of the processes. No excystment structure observed.

Dimensions: L: 22(25)28µm, P: 13(7)25µm, n = 4.

Remarks and comparision: The specimens recorded here are very similar to the specimen illustrated by Jardiné *et al*. (1974) from Llandovery of Algeria, but it has shorter processes.

Occurrence: Tanezzuft Formation, late Aeronian- early Telychian (Llandovery).

Selected previous stratigraphic record: Llandovery, Algeria (Jardiné *et al*., 1974).

Tylotopalla caelamenicutis Loeblich, 1970

Plate 22, Figs. 6, Plate 23, Fig. 1

For synonymy see Le Hérissé (1989).
Additional synonymy:
1989 *Tylotopalla caelamenicutis* - Le Hérissé, p. 195; pl. 26, figs. 5-10
1992 *Tylotopalla caelamenicutis* - Eley and Legault, p. 88; pl3, fig. 10.
1995 *Tylotopalla caelamenicutis* - Le Hérissé, p II, fig. 2.
2000 *Tylotopalla caelamenicutis* - Le Herisse, pl. 7, figs. g, h.
2003 *Tylotopalla caelamenicutis* - Masiak *et al*., pl. 10, figs. j.

Description: Spherical to sub-spherical, thin-walled vesicle ornamented with fine grana which appear as striations around the process base. The processes are short, numerous and visible from one side which taper gently to slightly branched tips with slight notches also on the sides of some processes.

Dimensions: L: 22(25)28 µm, P: 4(7)10 µm, n = 7.

Remarks and comparision: This species differs from *Tylotopalla digitifera* Loeblich and Tappan, 1970 in having a greater number of processes and in their being low and conical.

Occurence: Tanezzuft Formation, mid Rhuddanian (Llandovery).

Selected previous stratigraphic record: Telychian, USA (Loeblich, 1970), Austria (Martin, 1978); Llandovery-early Wenlock, England (Doming, 1981); Llandoyery (Telychian), Gotland (Le Herisse, 1989); Llandovery-early Wenlock, Canada (Eley and Legault, 1992), Jordan (Keegan *et al*., 1990); Aeronian-early Telychian, Saudi Arabia (Le Herisse, 1995); early-mid Telychian, Saudi Arabia (Le Hérissé, 2000); Llandovery, Poland (Masiak *et al.,* 2003); late Llandovery, Scotland (Molyneux *et al*., 2008).

Tylotopalla* cf. *deerlijkianum Martin, 1974

Plate 23, Fig.2

Description: Spherical to sub-spherical, thin-walled vesicle ornamented with fine grana. The vesicle bearing processes about fifteen in number. The processes are short, conical may be with ribs which may extend to the top of processes but it seems to be an acuminate tip under the light microscope, bifurcating is not clear. Excystment is formed by equatorial split.

Dimensions: L: 30(34)37µm, P: 3(6)8µm, n = 8.

Remarks and comparison: *Tylotopalla deerlijkianum* Martin, 1974 differs from this species in having short and conical processes ornamented with radiating ribs extending to the top of the process and the vesicle wall is ornamented with grana as described by Le Herisse (1989). The specimens recorded in the current study are attributed to *Tylotopalla* based on the vesicle, processes shape and excystment structure.

Occurrence: Tanezzuft Formation, mid Rhuddanian (Llandovery).

Genus ***Uncinisphaera*** Wicander, 1974

Type Species: *Unicinisphaera lappa* Wicander, 1974.

Diagnosis: "Vesicle spherical, wall thin, granulate; numerous processes drawn out from vesicle, opening into and communicating freely with vesicle interior; process surface echinate, processes flexible and taper to a sharp point; excystment by splitting of vesicle wall." From Wicander (1974, p.34).

Remarks: As commented by Wicander (1974) the genus *Uncinisphaera* is distinguished from the genus *Micrhystridium* Deflendre 1937, emended Sarjeant and Stancliffe *et al*., 1994 by its echinate processes. Furthermore, the *Uncinisphaera* specimens recorded herein are generally of larger size than *Micrhystridium.* The genus *Stellechinatum* Turner, 1984 is distinguished by its polyhedral vesicle and conical, broad-based processes.

Uncinisphaera fusticula Vecoli, 1999

Plate 23, Figs. 3, 4

For synonymy see Vecoli (1999).

Additional synonymy:

1999 *Uncinisphaera fusticula* - Vecoli, p. 59; pl. 15, figs. 5, 10; pl. 16, fig. 2.

Description: Spherical to sub-spherical, smooth, thin-walled vesicle bearing 14-25 homomorphic, hollow, possibly solid, cylindrical processes tapering to simple acuminate distal tips. These processes communicate freely with the vesicle cavity and ornamented with well-developed small and short spines. No excystment structure observed.

Dimensions: L: 40(43)45µm, P: 10(13)15µm, n = 3.

Remarks and comparision: The specimens recorded in the current study are morphologically very similar to the specimens described by Vecoli (1999).

Occurence: Hawaz Formation, mid-late Darriwilian (Llanvirnian).

Selected previous stratigraphic record: Llanvirnian, Tunisia (Vecoli, 1999); Early-Mid Ordovician, Saudi Arabia (Le Hérissé *et al*., 2007); middle Arenigian-early Caradocian, northern Gondwana (Vecoli and Le Hérissé, 2004).

Genus ***Veryhachium*** Deunff 1954 ex Downie 1959
emend. Turner 1984

Type species: *Veryhachium trisulcum* (Deunff, 1951) ex Deunff, 1959

Diagnosis: “Vesicle thin-walled, polygonal, with processes from the angles forming an integral part of the vesicle, major processes in a single plane, commonly with accessory processes at various positions on the vesicle, processes distally closed and simple. Surface may be ornamented with grana or may be smooth. Excystment is by the formation of an epytiche.”. From (Turner, p. 139).

Remarks: The genus *Veryhachium* was emended by Turner (1984) who stated that the wall be smooth or ornamented with grana. Forms with short spines or echinae are included in the genus *Villosacapsula* Loeblich and Tappan, 1976.

Veryhachium lairdi (Deflandre, 1946) Deunff, 1959 *ex* Downie, 1959
Plate 23, Fig. 5

For synonymy see Turner (1984).
Additional synonymy:
1984 *Veryhachium lairdii* - Turner, p. 141, 142; pl. 11, figs. 4.
1985 *Veryhachium lairdii* - Turner, pl. 7, figs. 1, 2.
1985 *Veryhachium lairdii* - Wicander and Playford, pl. 7 fig. 3.

1992 *Veryhachium lairdii* - Ottone *et al.*, pl. 3, fig. 8.
1996 *Veryhachium lairdii* - Ottone, pl. 10, fig. 9.
1998 *Veryhachium valiente* - Sinha *et al.*, pl.5, fig.14.
1998 *Veryhachium lairdii* - Sinha *et al*., pl. 5, fig. 17.
1999 *Veryhachium lairdii* - Vecoli, p. 60; pl. 17, fig. 10.
2006 *Veryhachium lairdii* - Achab *et al.*, pl. 1, fig. 27.
2009 *Veryhachium lairdii* - Vecoli *et al.*, pl. I, fig. 3.
2013 *Veryhachium lairdii* - Yan Kui *et al*., pl. IV, fig. 4

Description: The vesicle is square to rectangular, hollow, thin and single-layered with slightly convex to concave sides. Each angle of the vesicle bears conical, hollow, flexible process tapering to acuminate distal tip, and communicate freely with the vesicle cavity. The process length is variable but approximately equal to the vesicle diameter. The vesicle and process wall surface is psilate. Excystment is an epityche.

Dimensions: L: 24(25)26µm, P: 24(25)26µm, n = 9.

Remarks and comparision: The specimens recorded in the current study are accommodated in *Veryhachium lairdii* in which the processes are approximately equal to the vesicle diameter. This distinguishes *Veryhachium lairdii* from *Veryhachium* aff. *lairdii* recorded in the Upper Ordovician of northeast Libya by Molyneux (1988) and *Veryhachium oklahomense* Loeblich, 1970a.

Occurnce: Hawaz Formation, mid-late Darriwilian (Llanvirnian); Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian); Tanezzuft Formation, late Rhuddanian-Telychian (Llandovery).

Selected previous stratigraphic record: Mid-Late Ordovician, Algeria (Jardiné *et al*., 1974); Late Devonian, USA (Wicander and Playford, 1985); Llandeilo, Wales (Turner, 1985); Late Ordovician, Libya (Molyneux, 1988); Early Ordovician, Argentina (Ottone *et al*., 1992); Silurian, Saudi Arabia (Le Hérissé *et al*., 1995); Devonian, Argentina (Ottone, 1996); late Tremadocian–early Arenigian, Spain (Servais and Mette, 2000); latest Tremadocian, Belgium

(Breuer and Vanguestaine, 2004); Ordovician, northwestern Argentina (Achab *et al*., 2006); Late Ordovician, Iran (Ghavidel-Syooki, 2006); Llanvirnian, Oman (Molyneux *et al*., 2006); Ordovician, southeastern Turkey (Paris *et al*., 2007); Early Ordovician, northern England (Molyneux, 2009); Late Ordovician-Silurian, southern Tunisia (Vecoli *et al*., 2009); Tremadocian-Silurian, northern Gondwana (Vecoli and Le Hérissé, 2004), northern Chad and southeastern Libya (Le Hérissé *et al*., 2013); Lower-Middle Ordovician, China (Yan Kui *et al*., 2013).

Veryhachium* cf. *lairdii (Deflandre, 1946) Deunff, 1959 *ex* Downie, 1959

Plate 23, Fig. 6

Description: The vesicle is rectangular, hollow, thin and single-layered with slightly convex to concave sides. Each angle of the vesicle bears short, conical, hollow, flexible process tapering to acuminate distal tip, and communicate freely with the vesicle cavity. The process length is smaller than the vesicle diameter. The vesicle and process wall surface is psilate Excystment is an epityche.

Dimensions: L: 24(25)26µm, P: 5(6)7µm, n = 9.

Remarks and comparision: The specimens recorded in the current study are distinguished from *Veryhachium lairdii* (Deflander, 1946) Deunff, 1954 ex Downie, 1959 and *Veryhachium oklahomense* Loeblich, 1970a by the ratio of process length. In addition the processes are narrow proximally and acuminate distally. They are very similar to *Veryhachium* aff. *lairdii* from the Late Ordovician of northeast Libya by described by Molyneux (1988) but it differs in having shorter processes.

Occurence: Hawaz Formation, Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian).

Veryhachium oklahomense Loeblich, 1970a

Plate 23, Fig. 7

For synonymy see Le Hérissé (1989).
Additional synonymy:
1984 *Veryhachium oklahomense* - Turner, p. 144, 145; pl. 11, fig. 7.
1985 *Veryhachium oklahomense*? - Molyneux and Paris, pl.4, figs. 3-7.
1985 *Veryhachium oklahomense*?- Molyneux and Paris, pl.4, figs.3-7.
1985*Veryhachium lairdii* - Jacobson and Achab, pl. 9, fig. 2.
1988 *Veryhachium oklahomense* - Molyneux, pl. 11, fig. 11.
1995 *Veryhachium oklahomense* - Ribecai and Tongiorgi, pl. 3, fig. 7.
2003 *Veryhachium oklahomense* - Ghavidel-syooki, pl. 5, figs. 1, 4.
2004 *Veryhachium oklahomense* - Rubinstein and Vaccari, fig. 6D.
2006 *Veryhachium oklahomense*, - Raevskaya *et al*., pl. I, fig. 6.

Description: The vesicle is rectangular, hollow, single and thin-walled with slightly curved sides. Each angle of the vesicle bears long, conical, hollow, flexible process tapering to acuminate distal tip, becoming hair-like at their distal end, and communicate freely with the vesicle cavity. The process length is twice the diameter of the vesicle or longer. The vesicle and process wall surface is psilate. Excystment is an epityche

Dimensions: L: 22(26)30µm, P: 25(34)42µm, n = 8.

Remarks and comparision: The specimens attributed to *Veryhachium oklahomense* in the current study have a small vesicle and relatively long processes, and the vesicle diameter is approximately half of the processes length. These specimens have similar process length to *Veryhachium longispinosum* Jardine *et al*., 1974, but it differs in having smaller vesicle diameter. It differs from *Veryhacium lairdii* (Deflandre 1946) Deunff 1954 ex Downie 1959, in having smaller size, quadrate outline with straight sides, and longer processes.

Occurence: Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian)

Selected previous stratigraphic record: Ashgillian, Oklahoma (Loeblich, 1970); Ashgillian, USA (Loeblich and Tappan, 1978); Caradocian, Canada (Martin, 1983); Caradocian, Shropshire, England (Turner, 1984); Ashgillian, northeast Libya (Molyneux and Paris, 1985; Molyneux, 1988; Hill and Molyneux, 1988); Caradocian-Ashgillian, Czech Republic (Vavrdová, 1988); Arenigian-Ashgillian, Estonia (Uutela and Tynni, 1991); early Ashgillian, Saudi Arabia (Jachowicz, 1995); Arenigian, Sweden (Ribecai and Tongiorgi, 1995); Llanvirnian-Ashgillian, Iran (Ghavidel-syooki, 2001; 2003); Ordovician-Silurian boundary, northwest Argentina (Rubinstein and Vaccari, 2004); Late Ordovician, northern Gondwana (Vecoli and Le Hérissé, 2004); Ordovician, Oman (Molyneux *et al*., 2006); Darriwilian, northern Russia (Raevskaya *et al*., 2006); Late Ordovician, USA (Wicander and Playford, 2008). Wicander *et al*. (1999) considered the Arenigian-Llanvirnian occurrences of this species to be questionable.

Veryhachium reductum (Deunff 1959) Jekhowsky 1961

Plate 24, Fig. 1

1997 *Veryhachium reductum* - Ghavidel-syooki, pl. 4, fig. 8.
1988 *Veryhachium reductum* var A - Molyneux, p. 52; pl. 11, figs. 10, 12.
2001 *Veryhachium reductum* - Ghavidel-syooki, pl. 6, fig. 6.

Description: The vesicle is triangular, hollow, single and thin-walled with slightly convex sides. Each angle of the vesicle bears short, conical, hollow, flexible process tapering to acuminate distal tip, and communicate freely with the vesicle cavity. The vesicle and process wall surface ornamented with grana. No excystment structure observed.

Dimensions: L: 28(32)35µm, P: 5(7)8µm, n = 7.

Remarks and comparision: This species differs from *Villosacapsula setosapellicula* Loeblich and Tappan, 1969 in having a vesicle ornamented with grana.

Occurence: Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian)

Selected previous stratigraphic record: Ashgillian, Iran (Ghavidel-syooki, 1997, 2001); Ashgillian, northeast, Libya (Molyneux, 1988).

Veryhachium* cf. *strangulatum Le Herisse, Al-Tayyar and Van der Eem, 1995

Plate 25, Fig. 1

Description: The vesicle is sub-quadratic, single and thin-walled with concave sides. Each angle of the vesicle bears long, conical, hollow, flexible processes tapering to acuminate distal tip, and communicate freely with the vesicle cavity with a broad base; their length is longer than the vesicle diameter. The vesicle and process wall surface is psilate No excystment structure observed.

Dimensions: L: 13(16)18µm, P: 35(39)42µm, n = 4.

Remarks and comparision: This species is similar in morphology to *Veryhachium strangulatum* Le Herisse, Al-Tayyar and Van der Eem, 1995 from the early Silurian of Saudi Arabia, but it differs in having smaller vesicle diameter and longer processes.

Occurence: Memouniat and Bir Tlacsin formations, Hirnantian (Ashgillian).

Veryhachium subglobosum Jardine *et al*., 1974

Plate 24, Fig. 2

1974 *Veryhachium subglobosum* - Jardine *et al*., p. 115-116; pl. 1, fig. 2.
1985 *Veryhachium subglobosum* - Molyneux and Paris, pl. 3, fig 4.
1991 *Veryhachium subglobosum* - Grignani *et al*., pl. 3, figs. 1-3.
1999 *Veryhachium subglobosum* - Vecoli. pp. 60-61; pl. 17, fig. 2.
2000 *Veryhachium subglobosum* - Molyneux and Al Hajri. pl. 2, fig. B.
2013 *Veryhachium subglobosum* – Le Hérissé *et al*., fig. 8, O.

Description: The vesicle is triangular, hollow, single and relatively thick-walled with convex sides. Each angle of the vesicle bears conical, hollow, flexible process tapering to acuminate distal tips, and communicate freely with the vesicle cavity. The processes have thickening at their contact with the vesicle. The vesicle and process wall surface is psilate. Excystment is an epityche.

Dimension: L: 35(45)55µm, P: 30(48)65µm, n = 10.

Remarks and comparision: This species is distinguished from *Veryhachium ellesmerense* Staplin, 1978 by the thickening of the spines at their contact with the vesicle and excystment by epityche.

Occurence: Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian).

Selected previous stratigraphic record: Caradocian-?Ashgillian, Algeria (Jardine *et al*., 1974); Late Ordovician, southeast and northeast Libya (Grignani *et al*. 1991; Molyneux and Paris, 1985; Hill and Molyneux, 1988), southern Iran (Ghavidel-Syooki, 1996), Jordan (Keegan *et al*., 1990), Saudi Arabia (Jachowicz, 1995; Molyneux and Al-Hajri, 2000), Tunisia and Algeria and northwest Libya (Vecoli, 1999; Vecoli *et al.,* 2000); Ashgillian, northern Gondwana (Vecoli and Le Hérissé, 2004), Late Ordovician (Hirnantian), northern Chad and southeastern Libya (Le Hérissé *et al*., 2013).

Veryhachium trispinosum (Eisenack, 1938a) Stockmans and Willière, 1962 "complex"

Plate 24, Fig. 3, 4, 5

For synonymy see Turner (1984)

Additional synonymy:

1984 *Veryhachium trispinosum* - Turner, p. 146, 147; pl. 11, fig. 3.
1985 *Veryhachium trispinosum* - Wicander and Playford, pl. 7, figs. 10, 11.
1999 Ver*yhachium trispinosum* - Wicander *et al*., pl. 4, figs. 19, 23.
2004 Ver*yhachium trispinosum* - Breuer and Vanguestaine, pl. III, fig. 13.
2006 *Veryhachium trispinosum* group - Achab *et al*., pl. 1, fig. 28.
2006 *Veryhachium trispinosum* - Molyneux *et al*., pl. 2, fig. 4.
2008 *Veryhachium trispinosum* - Wicander and Playford, p. 56; pl. 4, figs. 19, 23.
2007 *Veryhachium trispinosum* - Zhu *et al*., pl. IV, fig. 9.

Description: The vesicle is triangular, hollow, thin and single-walled with straight to slightly convex sides. Each angle of the vesicle bears short or long, conical, hollow, flexible process tapering to acuminate distal tips, and communicate freely with the vesicle cavity; their length is variable relative to the vesicle diameter. The vesicle and process wall surface is psilate. Excystment structure is an epityche.

Dimensions: L: 24(36)48µm, P: 13(26)40µm, n = 9.

Remarks and comparision: This species is abundant in the studied samples and it shows a variation in process length relative to the vesicle diameter. This species differs from *Veryhachium downiei* Stockmans and Williere, 1962a, in being larger in size and from *Veryhachium irroratum* Loeblich and Tappan, 1969 and *Villosacapsula setosapellicula* (Loeblich 1970) Loeblich and Tappan, 1976 in having a smooth vesicle wall rather than grana or microspine.

Occurence: Hawaz Formation, mid-late Darriwilian (Llanvirnian);Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian(Ashgillian); Tanezzuft Formation, early Rhuddanian-Telychian (Llandovery).

Selected previous stratigraphic record: Ordovician, Baltic (Eisenack, 1938a); Ordovician, Brittany (Deunff, 1959); Wenlock, Shropshire (Downie, 1959); Wenlock, USA (Thusu, 1973b); Llandovery, northeast Libya (Hill *et al*., 1985; Hill and Molyneux, 1988); Wenlock, Shropshire (Turner *et al*., 1995); Silurian, Poland (Porębska *et al*., 2004); Arenigian-Ashgillian, northern Gondwana (Vecoli and Le Hérissé, 2004); late Tremadocian, Belgium (Breuer and Vanguestaine, 2004); Ordovician, northwestern Argentina (Achab *et al*., 2006); Ordovician, Oman (Molyneux *et al*., 2006); Middle-Late Ordovician, southeastern Turkey (Paris *et al*., 2007); Mid Devonian, China (Zhu *et al*., 2008); Late Ordovician, USA (Wicander and Playford, 2008); Early Ordovician, UK (Molyneux, 2009), Upper Ordovician (Hirnantian)-Early Silurian (Rhuddanian), northern Chad and southeastern Libya (Le Hérissé *et al*., 2013); Lower-Middle Ordovician, China (Yan Kui *et al*., 2013).

Veryhachium* cf. *trapezionarion Loeblich, 1970

Plate 24, Fig. 6

Description: The vesicle is **r**ectangular, single, thin walled with straight to slightly curved sides bears six processes. Four arising from the coner of the vesicle and other two arising from the broad face of the vesicle. The processes are, conical, hollow, flexible tapering acuminate distal tip or to a sharp point, and communicate freely with the vesicle cavity; their length is bigger that the vesicle diameter. The vesicle and process wall surface is psilate No excystment structure observed

Dimensions: L: 13(14)15µm, P: 14(15)16µm, n = 5.

Remarks and comparision: This species is very similar to *V. trapezionarion* Loeblich, 1970 in morphology and in having the same number of processes but it differs in the length of the processes arising from the broad face relative to the vesicle diameter. It differs from *Veryhachium rhomboidium* Downie, 1959 in having thinner wall and longer processes.

Occurence: Tanezzuft Formation, Aeronian-mid Telychian (Llandovery).

Veryhacium valiente Cramer, 1964b

Plate 25, Fig. 2

For synonymy see see Loeblich and Tappan, 1970.
Additional synonymy:
1970 *Veryhacium valiente* - Loeblich; p. 744-745, fig. 36, C-E.
1974 *Veryhacium valiente* - Hill; p. 197-200, pl. 28 figs. 7-10.
1985 *Veryhacium valiente* - Hill , pl. 9, fig. 9.
2000 *Veryhacium valiente* - Le Herisse, pl. 2, fig. I.

Description: The vesicle is rectangular, single and thin-walled with straight or concave or slightly convex sides depending on the nature of preservation and compression, bears four processes arises from the corners of the vesicle. The processes are smooth, conical, hollow, flexible tapering to acuminate distal tips, and communicate freely with the vesicle cavity. These processes are variable in length and width. The vesicle and processes wall surface is psilate. No excystment structure observed.

Dimensions: L: 24(29)34µm, P: 16(20)25µm, n = 8.

Remarks and comparision: The specimens attributed to *Veryhacium valiente* in the current study are differentiated from *Veryhacium lairdi* (Deflandre, 1946) Deunff, 1959 *ex* Downie, 1959 in being less rectangular in shape and from *Veryhacium* cf. *lairdi* in both the shape of the vesicle and process length.

Occurence: Tanezzuft Formation, Rhuddanian (Llandovery).

Selected previous stratigraphic record: Ludlow, Algeria (Jardiné *et al.,* 1974); Rhuddanian, Saudi Arabia (Le Hérissé, 2000; Le Hérissé *et al*., 1995); Rhuddanian-Telychian, northeast Libya (Molyneux, 1985; Hill and Molyneux, 1988).

Veryhachium wenlockianum (Downie, 1959) Downie and Sarjeant, 1965
Plate 25, Figs. 3, 4

For synonymy see Eisenack *et al*., 1979.

Description: The vesicle is smooth, single, and thin-walled, originally tetrahedral, usually compressed into a triangular outline. The sides are usually of the same length. A hollow process arises from each of the three corners of the triangle and a fourth from the middle of the vesicle surface. The processes are smooth, long, thin, hollow and broad-based. They taper to acuminate tips and open to the vesicle cavity. The processes are typically of equal or closely similar lengths. No excystment structure observed.

Dimensions: L: 13(17)20µm, P: 18(23)28µm, n = 10.

Remarks and comparision: This species is abundant in the studied samples from Lower Silurian (Tanezzuft Formation) and it shows a variation of process length relative to the vesicle diameter.

Occurrences: Tanezzuft Formation, early Rhuddanian-Telychian (Llandovery).

Selected previous stratigraphic record: Llandovery, northeast Libya (Hill *et al*., 1985; Hill and Molyneux, 1988); Wenlock, Shropshire (Turner *et al*., 1995); Silurian, Poland (Porębska *et al*. 2004).

Genus ***Villosacapsula*** Loeblich and Tappan, 1976

Type species: *Villosacapsula setosapellicula* (Loeblich, 1970) Loeblich and Tappan, 1976.

Diagnosis: "Vesicle triangular in outline, with hollow process at each angle in the plane of the vesicle, rarely with one or more supplementary processes arising from the face of the vesicle, processes communicate freely with the vesicle interior; wall thin, surface of vesicle and commonly that of processes with short scattered microspines, excystment by an epityche". From Loeblich and Tappan (1976, p. 306)

Remarks: The genus *Villosacasula* differs from the genus V*eryhacium* Deunff ex Downie, 1959, Turner, 1984 in possessing a spinose rather than granulate or laevigate wall structure. The genus *Arkonia* Burmann, 1970 has a striate wall sculpture.

Villosacapsula irroratum (Loeblich and Tappan), Fensome, Williams, Barss, Freeman and Hill, 1990

Plate 25, Fig. 5

For synonymy see Vecoli (1999).
Additional synonymy:
1999 *Villosacapsula irroratum* - Vecoli, p. 61, pl. 17, figs. 4, 6, 8.
2003 *Veryhachium irroratum* - Ghavidel-syooki, pl. 4, fig. 4.

Description: Triangular, hollow, thin-walled vesicle with triradial arrangement of homomorphic processes. The processes communicate freely with the vesicle cavity and taper gradually to acuminate tips. The vesicle wall is ornamented with grana that extend onto the processes. These granular ornaments are developed out to the process tip becoming sharper and more thornlike distally.

The processes length is bigger than the half of the vesicle diameter. No excystment structure observed.

Dimensions: L: 22(28)35µm, P: 20(27)35µm, n = 8.

Remarks and comparision: *Villosacapsula setosapellicula* (Loeblich 1970) Loeblich and Tappan, 1976 has short processes relative to the vesicle and more obvious sculpture. *Veryhacium trispinosum* (Eisenack 1938) Stockmans and Williere, 1962b has a smooth wall.

Occurence: Melez Shugran, Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian).

Selected previous stratigraphic record: Llandeilo, USA (Loeblich and Tappan, 1969); Ashgillian, Jordan (Keegan, *et al.,* 1990); Llanvirian, Tunisia (Vecoli, 1999); Darriwillian-Hirnantian, northern Gondwana (Vecoli and Le Hérissé, 2004); Llanvirnian-Ashgillian, Iran (Ghavidel-syooki, 2003); Caradocian-Ashgillian, Turkey (Paris *et al*., 2007).

Villosacapsula setosapellicula (Loeblich, 1970) Loeblich and Tappan, 1976.
Plate 25, Fig. 6

For synonymy see Elaouad Debbaj (1988).

Additional synonymy:

1988 *Villosacapsula setosapellicula* - Elaouad Debbaj, p. 240-241; figs. 13-15, 18
1999 *Villosacapsula setosapellicula* - Vecoli, p. 61-61; pl. 17, figs. 1, 9.
2000 *Villosacapsula setosapellicula* - Molyneux and Al Hajri. pl. 2, fig. f.
2008 *Villosacapsula setosapellicula* - Wicander and Playford, p. 56; pl. 4, figs. 20, 24.
2008 *Villosacapsula setosapellicula* - Vecoli *et al*., pl. I, fig. 9.
2013 *Villosacapsula setosapellicula* - Le Hérissé *et al*., fig. 8, A.

Description: Triangular, hollow, thin-walled vesicle, slightly convex sides with triradial arrangement of short, thin, homomorphic processes. The processes communicate freely with the vesicle cavity and taper gradually to acuminate tips. The vesicle and processes are ornamented with short, delicate spines. No excystment structure observed

Dimensions: L: 27(25)35µm, P: 10(13)16µm, n = 9.

Remarks and comparision: Most specimens recorded in the current study have processes that are shorter than the vesicle. *Villosacapsula irrorata* (Loeblich and Tappan, 1969) Fensome, Williams, Barss, Freeman and Hill, 1990, has longer processes and is ornamented with grana rather than spines.

Occurence: Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian).

Selected previous stratigraphic record: Ashgillian, USA (Loeblich, 1970; Miller, 1991; Robertson, 1997; Wicander *et al*., 1999; Playford and Wicander, 2006); Caradocian-Ashgillian, Algeria (Jardiné *et al*., 1974); Caradocian, northwest Libya (Deunff and Massa, 1975); late Caradocian, USA (Colbath, 1979); Caradocian-Ashgillian, USA (Wright and Myers, 1981); Caradocian, Canada (Martin, 1983); Caradocian, UK (Turner, 1984); Ashgillian, northeast Libya (Molyneux and Paris, 1985; Hill and Molyneux, 1988), Morocco (Elaouad Debbaj, 1988); Caradocian-Ashgillian, Czech Republic (Vavrdová, 1988), Jordan (Keegan *et al*., 1990); Ashgillian, Turkey (Dean and Martin, 1992); early Ashgillian, Saudi Arabia (Jachowicz, 1995); Ashgillian, Algeria, Tunisia and northwest Libya (Vecoli, 1999; Vecoli *et al*., 2000); Ordovician/Silurian boundary, northwest Argentina (Rubinstein and Vaccari, 2004); Caradocian-Ashgillian, northern Gondwana (Vecoli and Le Hérissé, 2004); Hirnantian, Turkey (Paris *et al*., 2007); Ashgillian, Saudi Arabia (Miller and Al-Ruwaili, 2007); Caradocain-Ashgillian, USA (Wicander and Playford, 2008); Hirnantian, southern Tunisia (Vecoli *et al*., 2009), Upper Ordovician (Hirnantian), northern Chad and southeastern Libya (Le Hérissé *et al*., 2013).

Genus ***Virgatasporites*** Combaz, 1967

Type species: *Virgatasporites rudii* Combaz, 1967

Diagnosis: "Circular miospore. Trilete mark fairly well defined. The proximal surface is characterized by a system of radial striae have protruding and tending anastomose". Translation from Combaz (1967, p. 12).

Remarks: The genus *Virgatasporites* is described as a miospore with doubtful presence of a trilete mark by Combaz (1967) this has never been confirmed by the subsequent studies that this genus is produced by embryophytes (land plants). It is known only from marine sediments. Therefore, this genus of enigmatic origin should be considered as an acritarchs (Richardson, 1996; Steemans, 2000).

Virgatasporites* cf. *rudii Combaz, 1967

Plate 26, Fig.4

Description: Lenticular, originally bowl-shaped, thin vesicle. The vesicle is ornamented with faint striae which tend to be straight, anastomosting towards the vesicle centre.

Dimensions: L: 25(33)40µm, n = 3.

Remarks and Comparison: The specimens recorded in this study are very similar in morphology to *Virgatasporites rudii* Combaz, 1967, the specimens recorded by Vecoli (1999) of Tremadocian from Tunisia, but it differs slightly in the vesicle thickness and lacking of a circular aperture in the central area as seen in the specimens illustrated by Vecoli (1999, pl. 15, fig. 8). *Virgatasporites baccatus* Vavrdova, 1990 differs from this species, in having a thicker, less densely radial muri and has triangular or slit like aperture in central area

Occurence: Hawaz Formation, mid-late Darriwilian (Llanvirnian).

Genus ***Visbysphaera*** Lister, 1970 emend Le Hérssé, 1989

Type species: *Baltisphaeridium dilatispinosum* (Downie) Lister, 1970.

Diagnosis: "Spherical vesicles or sub-spherical a double-layer wall thickness varies smooth or slightly ornamented, adorned with many heteromorphic processes, hollow forms by the thin outer layer, the length of the process is below average to half the diameter the gall: processes, without communication with the interior of the vesicle are usually dilated: the entire length (piriformes ornaments), in the median ornaments (thorny), or the top (ornaments clubs have rounded ends) simple, simply bifurcated, crowns of thorns short or filamentous spines arranged in a same plane, sometimes anastomosing: processes are distributed randomly, without guidance preferentially, or aligned on ridges or folds the wall that delimit areas of smooth polygonal (restricted distribution). Several species show opening endopylome type, with single tear, as the equivalent of pylome, on the outer layer." From Le Hérssé (1989, p. 189-199).

Remarks: The genus *Visbysphaera* was diagnosed by Lister (1970) then emended by Le Hérissé (1989) to include some morphological characterisics to the process termination by his study of fifteen species from Silurian and of Gotland. Also he reported the difference between *Visbysphaera* species with the genus *Baltisphaeridium* Eisenack, 1958b ex Eisenack, 1959 emended Eiserhardt, 1989 in the process type. The genus *Baltisphaeridium* characterized by simple processes, while the genus *Visbysphaera* is simply bifurcated, crowns of thorns short or filamentous spines. However, the lack of communication of the processes with the vesicle cavity is the main characteristic for both genera. The genus *Multiplicisphaeridium* Staplin, 1961 emended Lister, 1970 differs from the genus *Visbysphaera* in having ramification processes and communicating freely with the vesicle cavity.

Visbysphaera gotlandica (Eisenack 1954a) Kiryanov 1978

Plate 26, Fig. 1

For synonymy see Le Hérissé (1989).

Additional synonymy:

1989 *Visbysphaera gotlandica* - Le Hérissé. p. 207-208; pl, figs. 6-8, text fig. 18.6.

Description: Spherical, single, smooth thick-walled vesicle clearly differentiated from short, hollow processes. Proximally the processes are not communicating with the vesicle cavity and distally slightly thickened or funnel shape (but not open). They may be bifurcate which is not clear under light microscope, but there are also some simple and sharp processes.

Dimensions: L: 37(42)48µm, P: 3(4)6µm, n = 10.

Remarks and comparision: The specimens recorded here show a variation in morphology; one presenting a circular vesicle with thick wall with processes has a rather regular arrangement, the other with a vesicle wall with a thinner wall that has processes which are simple and sharp processes. *Visbysphaera pirifera* (Eisenack) Fensome *et al*., 1990 differs from this species in having processes that expand like a “mushroom” or “balloon”. It differs from *Visbysphaera erratic brevis* Le Hérissé, 1989 by the shape of the process, that are funnel and not sub-cylindrical.

Occurence: Tanezzuft Formation, late Aeronian-Telychian (Llandovery).

Selected previous stratigraphic record: Wenlock, Gotland (Eisenack, 1954); Wenlock Russia (Kiryanov, 1978); Wenlock, Gotland (Le Hérissé, 1989); Llandovery-Ludlow, UK (Dorning, 1981); late Aeronian (Hill, 1985; Hill and Molyneux, 1988); late Llandovery-Wenlock, Lithuania (Jankauskas and Gritytë, 2004); late Llandovery, Scotland (Molyneux *et al*., 2008).

Visbysphaera microspinosa Lister 1970

Plate 26, Fig. 2

For synonymy see Le Hérissé (1989).
Additional synonymy:
1989 *Visbysphaera microspinosa* - Le Hérissé, p. 210-211; pl. 29, figs. 9, 14.
2000 *Visbysphaera microspinosa* - Ghavidel-syooki, pl. 6, fig. 12.
2001 *Visbysphaera microspinosa* - Hussein Mehrjerdi, pl. 6, fig. 3.

Description: Spherical to sub-spherical, hollow, smooth, single, and thick-walled vesicle ornamented with short, hollow and solid spines irregularly distributed on the vesicle surface. No excystment was observed.

Dimensions: L: 22(36)50µm, P: 0.5(1)3µm, n = 7.

Remarks and comparision: The specimens recorded in the current study show a variation of the process type from solid spines to very thin spines. *Visbysphaera gotlandica* Lister 1970 differs in having processes distally slightly thickened or funnel-shaped.

Occurrence: Tanezzuft Formation, late Aeronian-Telychian (Llandovery).

Selected previous stratigraphic record: Llandovery, England (Hill, 1974); Aeronian-Telychian, northeast Libya (Hill, 1985; Hill and Molyneux 1988); LLandovery, Iran (Ghavidel-Syooki, 2000; Hussein Mehrjerdi, 2001), Norway (Smelror, 1987); late Llandovery, Scotland (Molyneux *et al*., 2008).

Visbysphaera pirifera (Eisenack) Fensome et al. 1990
Plate 26, Figs. 3

For synonymy see Le Hérissé, 1989
Additional synonymy:
1989 *Visbysphaera pirifera* **-** Le Hérissé, p. 212, 213; pl. 29, figs. 206, text. fig 19.9.
2003 *Visbysphaera pirifera* **-** Ghavidel-syooki, pl. 6, fig. 7.

2003 *Visbysphaera pirifera* **-** Ghavidel-syooki, pl. 6, fig. 12.

Description: Spherical to sub-spherical vesicle, smooth, relatively thick-walled bearing numerous, thin, transparent, hollow processes about 25-27 in number. The processes are arranged quite regularly on the vesicle surface, and do not communicate with the vesicle cavity. The processes appearance expands like a "mushroom" or "balloon". No excystment structure observed.

Dimensions: L: 45(55)65µm, P: 10(16)22µm, n = 3.

Remarks and comparision: This species is similar to *Visbysphaera dilatispinosa* (Downie) Lister, 1970, in having thin balloon-shaped processes protruding from the thick walled spherical vesicle. However the processes in *V. dilatispinosa* are ornamented with echinae in contrast with small processes in *Visbysphaera pirifera.*

Occurence: Memouniat Formation, early Hirnantian (Ashgillian).

Selected previous stratigraphic record: Silurian, Gotland (Le Hérissé, 1989); Ashgillian- Llandovery, eastern Iran (Mehrjedri Hussein, 2001; Ghavidel-syooki, 2003); Early Silurian, Sweden (Gelsthorpe, 2004); Ludlow, UK (Mullins *et al*., 2004); Wenlock, Scotland (Molyneux *et al*., 2008).

Gen. et sp. Indent. A Vecoli, 1999

Plate 26, Figs. 7

1999 Gen. et sp. Indent, p. 63; pl. 16, fig. 5

Description: The vesicle is spherical, hollow, thin-walled bears single-walled, nearly-homomorphic, hollow processes about 13-16 in number tapering distally to form 2-3 long, first order pinaae in turn branching in to short pinulae up to second order. The processes are constricted proximally through interposition of relatively thick plugs with no communication with the vesicle cavity. The process wall is thinner than the vesicle. In some specimens the vesicle and process wall surface is ornamented with grana or short spines. Excystment structure is formed by equatorial rupture of vesicle.

Dimensions: L: 55(56)62µm, P: 45(50)55µm, n = 5.

Remarks and comparison: As discussed by Vecoli (1999) due to the scarcity of these specimens and their mediocre preservation a confident generic and specific attribution appears impractical. The specimens recorded here are similar in morphology to the specimens described by Vecoli (1999) from the Late Ordovician of Tunisia and Algeria but are bigger in overall size and their processes are some times ornamented with grana or spines. They differ from the genera *Oppilatala* Loeblich and Wicander, 1976, *Excultibrachium* Loeblich and Tappan, 1978 in lacking double wall, and from the genera *Micrhystridium, Evittia* in having a thick basal plug at the base of the processes.

Occurence: Bir Tlacsin Formation, late Hirnantian (Ashgillian); Tanezzuft Formation, mid Rhuddanian (Llandovery).

Selected previous stratigraphic record: Ashgillian, Algeria (Vecoli, 1999)

4.3 Chitinozoan systematics

4.3.1 Introduction

Chitinozoans are treated under provision of the International Code of Zoological Nomenclature (Traverse, 1996; Paris *et al*., 1999). Due to their unknown biological affinity, the classification of chitinozoans is still an artificial sorting more than a true biological classification. Two main trends have been followed in previous publications. Alphabetic sorting of genera and species was adopted by some authors (e.g. Jenkins, 1970; Rauscher, 1974; Laufeld, 1974). Other authors were in favor of a suprageneric classification in which the chitinozoan group was subdivided into Orders, Families and Subfamilies (e.g. Paris, 1981; Achab *et al.*, 1993; Miller, 1996; Paris *et al*., 1999). The classification adopted here is based on Paris *et al*. (1999). The suprageneric and generic classification of the genera identified in this study is shown in Fig. 16. However, for easy reference, the genera are arranged alphabetically rather than supragenerically in the systematics. The description of chitinozoans provided herein is based on examination under both scanning electron and transmitted light microscopes. The terminology and symbols follow those previously discussed by Paris *et al*. (1999). Fig. 17, shows the main morphological features of chitinozoans.

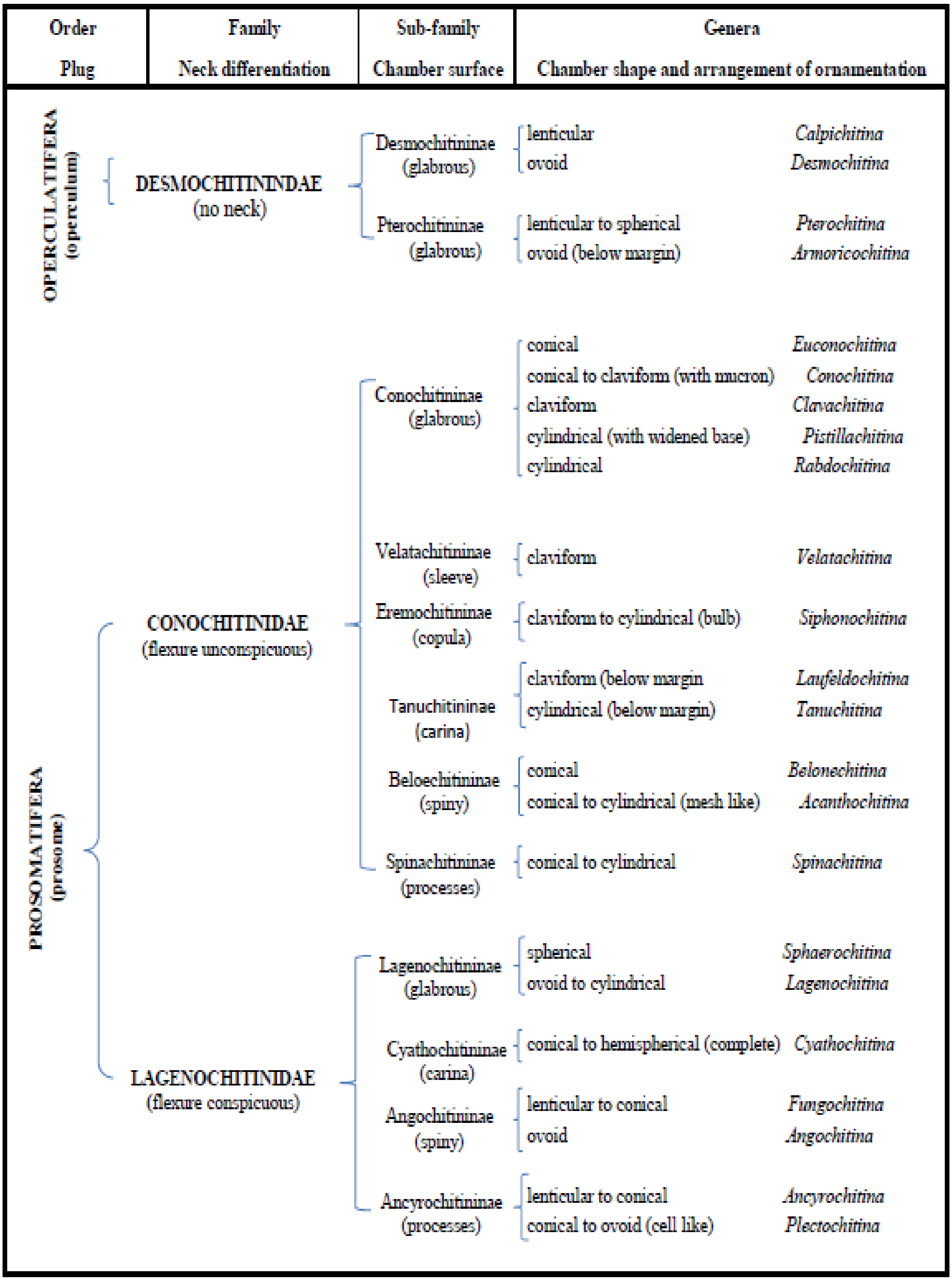
4.3.1.1 Systematic description

Group **Chitinozoa** Eisenack, 1931

Genus ***Acanthochitina*** Eisenack, 1931

Type species: *Acanthochitina barbata* Eisenack, 1931.

Diagnosis: "Conochitinidae with conical to cylindrical chamber and raised meshlike ornamentation; may be surrounded with a membranous sleeve." From Paris *et al*., (1999, p. 562).



Order Plug	Family Neck differentiation	Sub-family Chamber surface	Genera Chamber shape and arrangement of ornamentation	
OPERCULATIFERA (operculum)	**DESMOCHITINIDAE** (no neck)	Desmochitininae (glabrous)	lenticular	*Calpichitina*
			ovoid	*Desmochitina*
		Pterochitininae (glabrous)	lenticular to spherical	*Pterochitina*
			ovoid (below margin)	*Armoricochitina*
PROSOMATIFERA (prosome)	**CONOCHITINIDAE** (flexure unconspicuous)	Conochitininae (glabrous)	conical	*Euconochitina*
			conical to claviform (with mucron)	*Conochitina*
			claviform	*Clavachitina*
			cylindrical (with widened base)	*Pistillachitina*
			cylindrical	*Rabdochitina*
		Velatachitininae (sleeve)	claviform	*Velatachitina*
		Eremochitininae (copula)	claviform to cylindrical (bulb)	*Siphonochitina*
		Tanuchitininae (carina)	claviform (below margin	*Laufeldochitina*
			cylindrical (below margin)	*Tanuchitina*
		Beloechitininae (spiny)	conical	*Belonechitina*
			conical to cylindrical (mesh like)	*Acanthochitina*
		Spinachitininae (processes)	conical to cylindrical	*Spinachitina*
	LAGENOCHITINIDAE (flexure conspicuous)	Lagenochitininae (glabrous)	spherical	*Sphaerochitina*
			ovoid to cylindrical	*Lagenochitina*
		Cyathochitininae (carina)	conical to hemispherical (complete)	*Cyathochitina*
		Angochitininae (spiny)	lenticular to conical	*Fungochitina*
			ovoid	*Angochitina*
		Ancyrochitininae (processes)	lenticular to conical	*Ancyrochitina*
			conical to ovoid (cell like)	*Plectochitina*

Fig. 16. Suprageneric and generic classification of the chitinozoans described in this study. Modified from Paris et al. (1999).

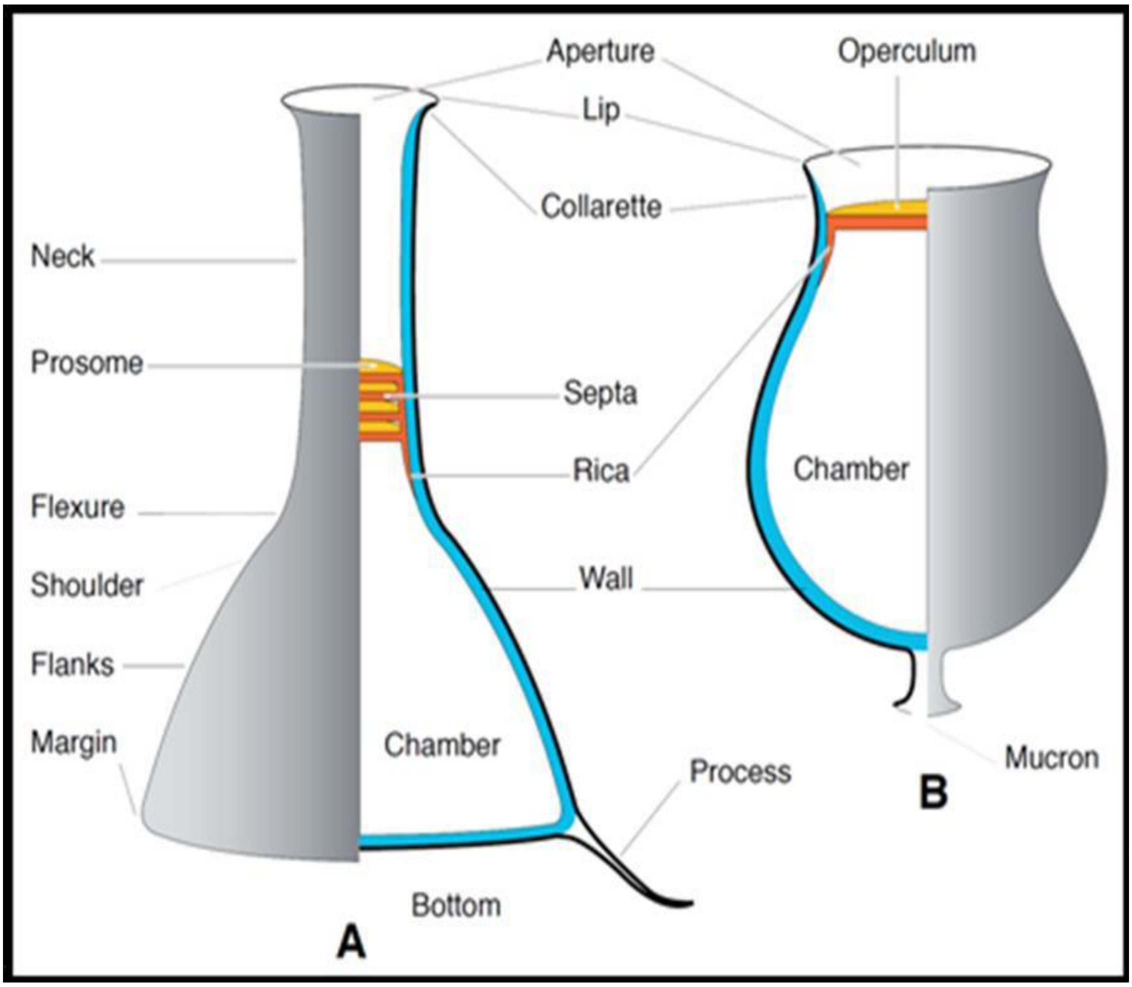


Fig. 17. The main morphological features and terminology of chitinozoans: (A) Prosomatifera, (B) Operculatifera. From Paris and Verniers (2005).

Remarks: The nature of the ornamentation (mesh like) differentiates this genus from the genus *Belonechitina* Jansonius, 1964, which is ornamented with spines randomly distributed, and the genus *Hercochitina* Jansonius, 1964, in which the spines are aligned in vertical rows or crests along the vesicle.

Acanthochitina* cf. *barbata Eisenack, 1931 emend.Jenkins, 1967
Plate 1, Figs. 1, 2

Description: *Acanthochitina* species with elongated conical to claviform chamber, neck is sub-cylindrical. The flexure and shoulders are inconspicuous.

The base is smooth, slightly concave, with a distinct basal scar and rounded basal margin. The vesicle wall is covered by complex spinose ornamentation perpendicular to the vesicle.

Dimensions: L: 275(310)345µm, Dp: 145(153) 160µm, Dc: 87(93)100µm, n = 6.

Remarks and comparison: The specimens recorded here show some degree of degradation of their ornament but clearly show the classic surface of *Acanthochitina* species. *Acanthochitina barbata* Eisenack, 1931 emend. Jenkins, 1967 differs from this species, in having elongated swollen cylindrical chamber which generally greater than two third of the vesicle length, maximum diameter midway along chamber, the base is flat and has processes on basal margin. *Acanthochitina latebrosa* Vandenbroucke, 2005, has more compacted, less elongated shape and much denser mesh like ornamentation with polygonal network.

Occurence: Bir Tlacsin Formation, late Hirnatian (Ashgillian).

Genus ***Ancyrochitina*** Eisenack, 1955a

Type species: *Conochitina ancyrea* Eisenack, 1931.

Diagnosis: "Lagenochitinidae with lenticular to conical chamber bearing a crown of nonanastomosed hollow processes on the margin." From Paris *et al.,* (1999, p. 563).

Remarks: The nature of the processes differentiates this genus from other similar genera. Genus *Clathrochitina* Eisenack, 1959b, has anastomosed processes and *Plectochitina* Cramer, 1964, has cell-like processes.

Ancyrochitina ancyrea Eisenack, 1931

Plate 1, Fig.3; Plate 11, Fig. 1

For synonymy see Costa (1971).

Additional synonymy:

1984 *Ancyrochitina ancyrea* - Nestor, pl. II, figs. 3.

1991 *Ancyrochitina ancyrea* - Grignani *et al*., pl. 6, figs. 1, 2.

2000 *Ancyrochitina ancyrea* - Grahn *et al*., p. 1. fig. 1.

2002 *Ancyrochitina ancyrea* - Jaglin and Paris, pl. 2, 13.

2003 *Ancyrochitina* gr. *ancyrea* - Grahn *et al*., p. 382; pl. II, figs 11–12.

2003 *Ancyrochitina ancyrea* - Vandenbroucke *et al*., p. 127, fig. 11 (g, h).

2005 *Ancyrochitina* ex. gr. *ancyrea* - Grahn, p. 263; Pl. I, fig. 2.

2008 *Ancyrochitina* gr. *ancyrea* - Morávek, pl. I, figs. 8, 11.

2007 *Ancyrochitina ancyrea* - Ghavidel-syooki and Vecoli, pl. II, fig. 5.

2009 *Ancyrochitina ancyrea* - Butcher, p. 604-606; pl. 4, fig. 1.

2013 *Ancyrochitina ancyrea* - Butcher, pl III. fig. 1.

Description: *Ancyrochitina* with conical to ovoid chamber, cylindrical neck and flaring collarette. The neck represents 1/2 to 2/3 of the total vesicle length. The base and flanks are convex with rounded margins carrying 2-4 long, simple and bifurcated processes. The neck and the chamber are clearly separated by conspicuous flexure and shoulders. The vesicle wall is glabrous.

Dimensions: L: 110(125)140µm, Dp: 55(73)90µm, Dc: 38(47)55µm, n = 10.

Remarks and comparison: The specimens recorded in this study confirm the original diagnosis by Eisenack (1931) in its outline and distally branched processes. *Ancyrochitina primativa* Eisenack, 1964 and *Ancyrochitina pachyderma* Laufeld, 1974, both differ by possessing simple processes. *Ancyrochitina merga* Jenkins, 1970 differs in having a greater number of processes that are generally shorter than *A. ancyrea, Ancyrochitina fragilis* Eisenack, 1955 differs from this species in having slender, more fragile appendages.

Occurrences: Tanezzuft Formation, Rhuddanian-Telychian (Llandovery).

Selected previous stratigraphic record: Llandovery, Estonia (Nestor, 1984), Paraguay (Grahn *et al*., 2000); Ashgillian, southeast Libya (Grignani *et al.,*1991); Llandovery-early Wenlock, UK (Mullins and Loydell, 2001), western Gondwana (Grahn, 2006), Brazil (Grahn, 2005), Estonia (Rubel *et al.,* 2007); Telychian, Scotland (Vandenbroucke *et al*., 2003); Pridoli, Libya (Jaglin and Paris; 2002); Ashgillian- Llandovery, Iran (Ghavidel-syooki and Vecoli, 2007); Ludlow, Czech Republic (Morávek, 2008); Telychian Sweden (Bergström *et al.,* 2008); Rhuddanian, Jordan (Butcher , 2009); southwest Libya (Butcher 2013).

***Ancyrochitina* cf. *laevaensis* Nestor, 1980a**

Plate 11, Fig. 2

Description: *Ancyrochitina* species with a conical chamber, neck is cylindrical with straight flanks and slightly widened toward the aperture. The neck represents slightly more or less than 1/2 of the total vesicle length. The base is convex with rounded basal margin carrying several short, thick processes, which are simple or branched to two times; their branching parallel to the longitudinal axis of the vesicle. The neck and the chamber are clearly separated by conspicuous flexure and shoulders. The vesicle wall is smooth.

Dimensions: L: 110(120)130µm, Dp: 60(68)75µm, Dc: 28(33)38µm, n = 4.

Remarks and comparison: *Ancyrochitina laevaensis* Nestor, 1980a differs from this species in having longer processes, which branched up to four times.

Occurrences: Tanezzuft Formation, mid Rhuddanian (Llandovery).

***Ancyrochitina merga* Jenkins, 1970**

Plate 11, Figs. 3, 4

For synonymy see Elaoud-Debbaj (1984).
Additional synonymy:
1985 *Ancyrochitina merga* - Grahn, fig. 3-15, 8, 9.
1985 *Ancyrochitina merga* - Grahn, fig. 3-15, 8, 9.
2002 *Ancyrochitina merga* - Ghavidel-syooki, pl. IV, fig. g.
2004 *Ancyrochitina merga* - Bourahrouh *et al*, pl. III, figs. 4, 8.
2005 *Ancyrochitina merga* - Vandenbroucke *et al*, fig. 12, i, j.
2005 *Ancyrochitina merga* - Vandenbroucke, p. 188; pl. 23.12- 23.14.
2006 *Ancyrochitina merga* - Ghavidel-syooki, p. 131, pl. 1, fig. 1-2.
2011 *Ancyrochitina merga* - Ghavidel-syooki *et al*., fig. 3, J.

Description: *Ancyrochitina* species with conical to ovoid wide chamber, cylindrical neck and flaring collarette. The neck represents 1/2 to 2/3 of the total vesicle length. The base and flanks are convex with rounded margins carrying 4-8 short, simple and bifurcated processes. The neck and the chamber are clearly separated by conspicuous flexure and shoulders. The vesicle wall is glabrous.

Dimensions: L: 110(125)140µm, Dp: 75(80)85µm, Dc: 28(34)40µm, n = 3.

Remarks and comparison: Only a few, sometimes broken specimens, with numerous short processes are observed in this study. It is possible that these specimens belong to the species *A. merga*. *Ancyrochitina ancyrea* Eisenack, 1931 differs from this species in having a fewer number and long processes that are generally longer than *A. merga, Ancyrochitina fragillis* Eisenack, 1955 differs also in having slender, more fragile appendages.

Occurrences: Melez Shugran Formation, late Katian (Ashgillian).

Selected previous stratigraphic record: Ashgillian, USA (Jenkins, 1970), northeast Libya (Molyneux and Paris 1985; Paris 1988), Morocco (Elaouad-Debbaj, 1984), USA (Grahn, 1985), Saudi Arabia (Al- Hajri, 1995), Iran (Ghavidel-syooki, 2000; Ghavidel-syooki and Winchester-seeto, 2004), Katian, Iran (Ghavidel-Syooki, 2002, 2006), Morocco (Bourahrouh *et al.,* 2004);

Rawtheyan stage, UK (Vandenbroucke *et al.,* 2005); Hirnantian, Iran (Ghavidel-syooki *et al*., 2011).

Ancyrochitina* cf. *porrectaspina Nestor, 1994

Plate 1, Fig. 4

Description: *Ancyrochitina* species with a conical to ovoid chamber, neck is cylindrical with straight flanks and slightly widened toward the aperture to form a straight lip. The neck represents slightly more or less than 1/2 of the total vesicle length. The base is convex with rounded basal margin carrying 4-6, simple and branching processes. The neck and the chamber are clearly separated by conspicuous flexure and shoulders. The vesicle wall is covered by granules.

Dimensions: L: 120(126)132µm, Dp: 78(81)85µm, Dc 38(41)45 µm, n = 5

Remarks and comparison: *Ancyrochitina porrectaspina* Nestor 1994 differs from this species in having longer processes and neck.

Occurrences: Tanezzuft Formation, late Rhuddanian-early Telychian (Llandovery).

Ancyrochitina ramosaspina Nestor, 1994

Plate 11, Fig. 5

1994 *Ancyrochitina ramosaspina* - Nestor, p. 99, pl. 1, figs. 1-3.

2007 *Ancyrochitina ramosaspina* -Ghavidel-syooki and Vecoli, p. 180; pl. VI, figs. 2, 3

Description: *Ancyrochitina* species with conical to ovoid chamber. The base is convex carries 4-8 processes which branched to three or four times. The flexure and shoulders are conspicuous. The neck widens towards aperture. The spines occur in the upper part of chamber and absent on the neck.

Dimensions: L: 100(113)125µm, Dp: 75(83)90µm, Dc: 35(43)50µm, n = 5.

Remarks and comparison: The specimens recorded in this study possess all morphological characteristics of *Ancyrochitina ramosaspina* Nestor, 1994, although their neck length is slightly shorter than those of the topotype material from Estonia (Nestor, 1994).

Occurrences: Tanezzuft Formation, late Rhuddanian-Aeronian (Llandovery).

Selected previous stratigraphic record: mid Llandovery, Estonia (Nestor, 1994), Iran (Ghavidel-syooki and Vecoli, 2007).

Ancyrochitina* cf. *udaynanensis Paris and Al-Hajri, 1995

Plate 11, Fig. 6

Description: *Ancyrochitina* species with conical to ovoid chamber, cylindrical neck and flaring collarette with straight or finely denticulate lips. The base is convex with rounded margins carrying short, simple or bifurcate processes. The flexure and shoulders are conspicuous. The neck represents slightly less than 1/2 of the total vesicle length. The vesicle wall is thin and ornamented with simple spines, randomly distributed on the chamber and the neck. The prosome is present in the chamber and neck contact.

Dimensions: L: 86(95)104µm, Dp: 45 (48)50µm, Dc: 32(35)39 µm, n = 7.

Remarks and comparison: This species is very similar in morphology to *Ancyrochitina udaynanensis* Paris and Al-Hajri, 1995 from the Llandovery of

Saudi Arabia, but the later possessing eight processes branched distally up to three times.

Occurence: Tanezzuft Formation, Aeronian-Telychian (Llandovery).

Ancyrochitina **sp. A**

Plate 11, Figs. 6, 7

Description: *Ancyrochitina* with conical to lenticular chamber, cylindrical neck and flaring collarette. The neck represents 1/2 to 2/3 of the total vesicle length. The base and flanks are convex with rounded margins carrying 4-8 short, simple or bifurcated processes. The neck and the chamber are clearly separated by conspicuous flexure and shoulders. The vesicle surface is ornamented with short spines. The spines occur on the chamber and the neck.

Dimensions: L: 135(140)145µm, Dp: 65(73)80µm, Dc: 32(36)40µm, n = 6.

Remarks and comparison: This species is distinguished from other *Ancyrochitina* species by possessing short, simple or bifurcate processes and the vesicle surface is ornamented with short spines, which occurs on the chamber and the neck.

Occurrences: Tanezzuft Formation, late Rhuddanian-Aeronian (Llandovery).

Genus ***Angochitina*** Eisenack, 1931

Type species: *Angochitina echinata* Eisenack, 1931.

Diagnosis: "Lagenochitinidae with ovoid chamber and randomly distributed simple or complex spine" From Paris *et al*., (1999, p. 564).

Remarks: Spiny forms with a fungiform chamber are excluded from the genus *Angochitina* and attributed to the genus *Fungochitina* Taugourdeau, 1966. Glabrous forms with ovoid chambers are attributed to the genus *Lagenochitina* Eisenack, 1931, emend. Paris *et al*., 1999, and glabrous forms with spherical chambers are attributed to the genus *Sphaerochitina* Eisenack, 1955a.

Angochitina gurupiense Grahn *et al*., 2005

Plate 1, Figs. 5, 6

For synonymy see Grahn *et al*., (2005).
Additional synonymy:
2005 *Angochitina gurupiense* - Grahn *et al*., p. 193; pl. 2, figs. 3-4.

Description: *Angochitina* species with sub-spherical to ovoid chamber, cylindrical neck and flaring collarette with straight or finely denticulate lips. The flanks and the base are convex with broadly rounded margins. The shoulders are inconspicuous, while the flexure is conspicuous or weakly developed. The vesicle is covered with randomly, sparsely distributed simple and hair-like spines.

Dimensions: L: 245(260)276µm, Dp: 75(85)95 µm, Dc: 47(51)55 µm, n = 10.

Remarks and comparison: *Angochitina longicollis* Eisenack, 1959 differs from this species in having a longer neck without any pronounced collarette, and a more elongated chamber. *Angochitina filose* Eisenack, 1955, has a more elongated chamber and short neck.

Ocurrences: Tanezzuft Formation, late Rhuddanian-mid Telychian (Llandovery).

Selected previous stratigraphic record: Aeronian-early Telychian, northeast Brazil (Grahn, 2005, 2006).

Angochitina hemeri Paris and Al-Hajri, 1995

Plate 1, Fig. 7, 8; Plate 12, Figs. 1, 2

For synonymy see Paris and Al-Hajri (1995).

Additional synonymy:

1995 *Angochitina hemeri* Paris and Al-Hajri, p. 321-322; pl.1, figs. 8-10; pl. 2, figs1, 2, 3a-b, 6.

2003 *Angochitina*? *hemeri* Vandenbroucke, fig.12-g.

Description: *Angochitina* species with sub-spherical to ovoid chamber, neck is cylindrical, long and represents about 3/4 of total vesicle length and flares in the upper third part to form large collarette with straight or finely denticulate lips. The base is convex with rounded basal margins. The shoulders are inconspicuous, while the flexure is conspicuous or weakly developed. The neck and shoulder are glabrous while the chamber is ornamented with granules to blunt cones or short spiny ornamentation restricted to and well developed in the lower part of chamber.

Dimensions: L: 270(278)285µm, Dp: 70(75)79 µm, Dc: 35(40)45 µm, n = 7.

Remarks and comparison: This species is similar to *Angochitina macclurei* Paris and Al-Hajri, 1995, but the later has a vesicle ornamented with more short and densely distributed spines. It is differentiated from *Angochitina qusaibaensis* Paris and Al-Hajri, 1995 in having a long cylindrical neck.

Occurrences: Tanezzuft Formation, early-midTelychian (Llandovery).

Selected previous stratigraphic record: Telychian, Saudi Arabia (Paris and Al-Hajri, 1995), Scotland (Vandenbroucke, 2003).

Angochitina macclurei Paris and Al-Hajri, 1995

Plate 1, Fig. 9; Plate 12, Figs. 3, 4

For synonymy see Paris and Al-Hajri (1995).

Additional synonymy:

1995 *Angochitina macclurei* Paris and Al-Hajri, p. 32-323; pl.1, figs. 1, 2a-b and 3.

2001 *Angochitina macclurei* Ghavidel-syooki, figs. 2 (D-E).

Description: *Angochitina* species with sub-spherical to ovoid chamber, neck is cylindrical and long, flares in the upper third part form a large collarette with irregular to slightly denticulate lips. The base is slightly convex with rounded basal margins. The flexure and shoulders are weakly-developed. The vesicle wall is ornamented with short and randomly distributed spines, which are better developed on the chamber than the neck.

Dimensions: L: 250(315)380 µm, Dp: 65(68)70 µm, Dc: 20(25)30 µm, n = 5.

Remarks and comparison: The specimens recorded in this study have slightly less ornamentation than the specimens illustrated by Paris and Al-Hajri (1995) from the Llandovery of Saudi Arabia.

Occurrences: Tanezzuft Formation, lateTelychian (Llandovery).

Selected previou stratigraphic record: Telychian, Saudi Arabia (Paris and Al-Hajri, 1995). Llandovery, Iran (Ghavidel-syooki, 2001).

Angochitina murzukensis Paris, Thusu, Rasul, Meinhold, Strogen, Howard, Abutarruma, Elgadry and Whitham, 2012

Plate 1, Figs. 10, 11

2012 *Angochitina murzukensis*- Paris *et al.,* p. 24, 25; pl. VIII, figs. 3, 5.

Description: *Angochitina* species with a short neck ending in a pear-shaped chamber. The flanks and base are convex with bluntly rounded margin. The flexure and shoulders are weakly developed. The chamber wall is covered by a simple, long flexible and hair like and distally simple spines. The spiny ornamentation fades away on the shoulder and on the neck.

Dimensions: L: 125 (126)127µm, Dp: 56(68)80µm; Dc: 27(29)32µm, n = 7.

Remarks and comparison: The specimens recoreded in the current study are very similar in morphology to those described by Paris *et al.,* 2012 from Tanezzuft formation of eastern Murzuq Basin, southwest Libya, but the spines are lower in density than the original. It is differentiated from the Silurian *Belonechitina* species, in having conspicuous neck and of the occurrence of spines on the chamber.

Occurrence: Tanezzuft Formation, mid Rhuddanian (Llandovery).

Selected previous stratigraphic record: Rhuddanian, southwest Libya, Paris *et al.,* 2012.

Angochitina qusaibaensis Paris and Al-Hajri, 1995

Plate 12, Fig. 5, 6

For synonymy see Paris and Al-Hajri (1995).

Additional synonymy:

1995 *Angochitina qusaibaensis* Paris and Al-Hajri, p. 323-324; pl.1, figs. 4, 5, 6a-b, 7 (a-b).

Description: *Angochitina* species with a sub-spherical to ovoid chamber, cylindrical neck widening into a collarette with straight or finely denticulate lips.

The base is slightly convex with rounded basal margin. The shoulders are inconspicuous, while the flexure is conspicuous or weakly developed. The neck and shoulder are glabrous while the chamber is ornamented with granules to blunt cones or short spiny ornamentation restricted and well developed in the lower part of the chamber, that is better developed around the margin and decreasing in density toward the neck. The prosome, with numerous conspicuous septa, occupies the whole neck end near the collarette**.**

Dimension: L: 162(168)175µm, Dp: 65(73)80µm, Dc: 27(31)35µm, n = 11.

Remarks and comaprison: This species is distinguished from other *Angochitina* species in having ornamentation that is restricted to the lower part of the chamber and well developed surrounding the margin. *Angochitina hemeri* Paris and Al-Hajri, 1995 has a more or less similar type of ornamentation but its neck is much longer. *Sphaerochitina solitudina* Paris, 1988, has an ornament of tiny granules or tubercles covering the whole vesicle.

Occurrences: Tanezzuft Formation, late Rhuddanian-Aeronian (Llandovery).

Selected previous stratigraphic record: late Rhuddanian, Saudi Arabia (Paris and Al-Hajri, 1995).

***Angochitina* sp. A**

Plate 12, Figs. 7, 8

Descriptions*:* *Angochitina* species with elongate ovoid chamber and short sub-cylindrical neck representing 1/3 of the total vesicle length. The flanks and the base are strongly convex with rounded margins. The neck and the chamber are usually clearly separated by a weakly-developed flexure and shoulders. Spiny ornamentation is observed on the chamber surface and tends to fade away towards the upper part of the chamber and then disappears on the neck. The spines are randomly-distributed, short and blunt, appearing like granules. The vesicle wall is very thin.

Dimensions: L: 110(115)120µm, Dp: 55(60)65µm, Dc: 28(32)35µm, n = 6.

Remarks and comparison: The spiny ornamentation in this species is occasionally eroded, leaving tiny scars. It is only visible at high magnification and distinguishes this species from *Lagenochitina nuayyimensis* Paris and Al-Hajri, 1995, which has glabrous vesicle wall with irregular small verrucae, occur over the whole vesicle surface.

Occurrences: Tanezzuft Formation, late Rhuddanian (Llandovery).

Genus ***Armorichitina*** Paris, 1981

Type species: *Linochitina*? c*eneratiensis* Paris, 1976.

Diagnosis: "Desmochitinidae with an ovoid chamber and membranous carina extending below the margin." From Paris et al., (1999, p. 565).

Remarks: The presence of a carina below the margin differentiates this genus from the genus *Cingulochitina* Paris, 1981, which has a complete carina on the margin. Genus *Pterochitina* Eisenack, 1955a has a lenticular to spherical glabrous chamber with a carina.

Armoricochitina nigerica Bouché, 1965.

Plate 2, Figs. 1, 2; Plate 13, Fig. 1

1965 *Armoricochitina nigerica* **-** Bouché, p. 157-158;pl 3, figs. 8, 12, 13.

1985 *Armoricochitina nigerica* **-** Paris, pl. 9, fig. 9.
1991 *Armoricochitina nigerica* **-** Grignani *et al*., , pl. 5, fig. 3, 4.
1995 *Armoricochitina nigerica* **-** Al-Hajri, pl. VII, fig. 6.
2000 *Armoricochitina nigerica* **-** Paris *et al*., pl. 1, fig. i.
2004 *Armoricochitina nigerica* **-** Bourahrouh *et al*., pl. II, fig. 2; pl III, fig. 11
2007 *Armoricochitina nigerica* **-** Paris *et al*., pl. 2, figs. 5, 9.
2008 *Armoricochitina nigerica* - Ghavidel-syooki, pl. VII, fig. 9.
2011 *Armoricochitina nigerica* - Ghavidel-syooki, pl. VII, fig. 2, 3.

Description: *Armoricochitina* species with an ovoid to conical chamber, which narrows to a short sub-cylindrical neck, and occupies approximately to 1/3 of the total length. Maximum diameter found in the middle part of chamber. The flexure and shoulders are absent and there is no collarette. A membranous carina varies in width and is present below the margin. The vesicle wall is smooth or granulate.

Dimensions: L: 140(163)185µm, Dp: 100(110)120µm, Dc: 85(92)99µm, n = 13.

Remarks and comparison: This species differs from *Armoricochitina alborzensis* Ghavidel-syooki, 2002, which has an ornamented carina and from *Armoricochitina iranica* Ghavidel-syooki, 2002, which has a spongy ornament on the chamber.

Occurence: Melez Shugran and Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian).

Selected previous stratigraphic record: Late Ordovician, Nigeria (Bouché, 1965); late Caradocian-Ashgillian, northeast Libya (Paris, 1985; Hill and Paris, 1988), (Grignani *et al.,* 1991), Algeria (Oulebsir and Paris, 1995), northern Gondwana Domain (Paris, 1990), Sauidi Arabia (Al-Hajri, 1995), western Gondwana (Grahn, 2006), UK (Van Nieuwenhove *et al*., 2006); Late Ordovician, Saudi Arabia (Paris *et al.,* 2000); Caradocian-Ashgillian, Morocco (Bourahrouh *et al*., 2004); Katian-Hirnatian, southern and southeastern Turkey (Paris *et al.,* 2007); late Katian-Hirnantian, Morocco (Le Heron *et al*., 2008); Katian, northern

Iran (Ghavidel-syooki, 2008, 2011) Late Ordovician (Hirnantian), northern Chad and southeastern Libya (Le Hérissé *et al*., 2013).

.

Armoricochitina* cf. *iranica Ghavidel-syooki, 2002

Plate 2, Figs. 3

Description: *Armoricochitina* with cylindro-conical chamber, that narrows to a short sub-cylindrical neck, which occupies less than 1/3 of the total vesicle length. The flexure and shoulders are absent and there is no collarette. The chamber flanks are sub-parallel. The base is flat to slightly concave, with a distinct basal scar, and the carina is relatively short and present below the margin. The chamber vesicle wall is covered with spongy ornament.

Dimensions: L: 180(183)185µm, Dp: 90(100)110µm, Dc: 85(87)90µm, n:5

Remarks and comparison: This species is very similar to *Armoricochitina iranica* Ghavidel-syooki, 2002 from Ashgillian of Iran, but it differs in being more cylindrical and smaller in overall size.

Occurence: Melez Shugran, Memouniat and Bir Tlacsin Formation, early late Katian-Hirnantian (Ashgillian).

***Armoricochitina* sp. A**

Plate 2, Fig. 4

Description: *Armoricochitina* species with a stocky, ovoid to conical chamber and short cylindrical neck tapering toward the aperture. The flexure and shoulders are quite marked, there is no collarette. A membranous carina is represented only by broken remnants. The vesicle wall is perfectly smooth.

Dimensions: L: 146(148)150µm, Dp: 125(129)133µm, Dc: 85(87)90µm, n = 5

Remarks and comparison: This species is very simillar to *Armoricochitina* cf. *armoricana* Elaouad-Debbaj, 1984 from the upper Ashgillian of Morocco but it is less conical in shape.

Occurence: Melez Shugran and Bir Tlacsin Formations, early late Katian-Hirnantian (Ashgillian).

Genus ***Belonechitina*** Jansonius, 1964

Type species: *Conochitina micranatha* subsp. *robusta* Eisenack, 1959.

Diagnosis: "Cononchitinidae with a conical chamber and randomly distributed spines." From Paris *et al*., (1999, p. 562).

Remarks: The random distribution of spines in this genus distinguishes it from the genus *Hercochitina* Jansonius, 1964, in which the spines are aligned in vertical rows or crests along the vesicle, and from the genus *Acanthochitina* Eisenack, 1931, which has a mesh-like ornamentation.

Belonechitina americana Taugoureau, 1965

Plate 2, Figs. 5, 6

For synonymy see Vandenbroucke *et al*., (2003).
Additional synonymy:
2005 *Belonechitina a*mericana – Vandenbroucke, p. 164-165; pl. 23.4, 23.5 and 26.2

Description: *Belonechitina* species with conical chamber, straight tapering, flat or slightly convex base and rounded basal margin. The neck is not clearly differentiated, absence of flexure and shoulders. The vesicle wall is ornamented by randomly-distributed short spines. These spines are well developed at the lower part of the chamber and a few of the spines on the remaining part of the chamber.

Dimensions: L: 140(170)200μm, Dp: chamber 65(75)85μm, Dc: 45(53)60μm, n = 4.

Remarks and comparison: This species is distinguished from other *Belonechitina* species in the absence of neck, and the chamber is ornamented with short spines. The spines are well developed at the lower part of the chamber and a few of the spines on the remaining part of the chamber. It is very similar in morphology to *Spinachitina bulmani* Jansonius, 1964, but the latter has all spines situated on the basal margin,

Occurrence: Bir Tlacsin Formation, late Hirnantian (Ashgillian).

Selected previous stratigraphic record: Ordovician, USA (Taugourdeau 1965); Late Ordovician, Anticosti Island (Achab 1977a, 1977b); Ashgillian, Anticosti Island (Achab, 1978b); Ashgillian (Cautleyan-Hirnantian), UK (Vandenbroucke, 2005); Caradocian-early Ashgillian, UK (Van Nieuwenhove *et al.,* 2006)

Belonechitina arabiensis Paris and Al-Hajri, 1995

Plate 13, Fig. 2

For synonymy see Paris and Al-Hajri (1995).

Additional synonymy:

1995 *Belonechitina arabiensis* Paris and Al-Hajri, p. 313-316; pl. 3, figs, 6-9.

Description: *Belonechitina* species with conical chamber and gently tapering flanks, with inconspicuous flexure and shoulders. The neck is sub-cylindrical and forms about 1/3 of the total vesicle length. The collarette is flaring and the lips are denticulate. The base is flat or slightly convex. A widely spaced, randomly distributed spiny ornamentation covers the chamber and fades away towards the neck. The spines are simple.

Dimensions: L: 100(105)110µm, Dp: 35(38)40µm, Dc: 20(24)28µm, n = 6.

Remarks and comparison: The spines in this species are widely-spaced whereas they are dense and closely-spaced in *Belonechitina pesudoarabiensis* Butcher, 2009. Detailed comparison between the two species is discussed by Butcher (2009).

Occurrences: Tanezzuft Formation, late Telychian (Llandovery).

Selected previous stratigraphic record: early-mid Telychian, Saudi Arabia (Paris and Al-Hajri, 1995).

Belonechitina aspera Nestor, 1980a

Plate 2, Figs. 7, 8

For synonymy see Butcher (2009).
Additional synonymy:
2009 *Belonechitina aspera* Butcher, p. 597; pl. 1, fig.1.
2010 *Belonechitina aspera* - Loydell *et al*., fig. 12 (b).

Description: *Belonechitina* species with ovoid chamber. The base is flat to slightly convex, with a rounded to inconspicuous basal margin. The flanks are convex, with inconspicuous flexure and shoulders. The neck is not easily distinguished from the chamber, and terminates in a finely denticulate aperture.

The vesicle wall is covered with a randomly distributed, spiny to granulate, blunt spines.

Dimensions: L: 174(180)185µm, Dp: 98(105)12µm, Dc: 76(80)85µm, n = 4.

Remarks and comparison: The specimens recorded in this study are similar in morphology, but bigger in overall size than the specimens illustrated by Butcher (2009) from the Llandovery of Jordan and from Latvia by Loydell *et al*., (2003). These specimens are different from the holotype illustrated by Nestor (1980a), which has a more conspicuous neck and a strongly convex base. Neither of the specimens recovered from this study, Jordan and Latvia show this feature convincingly. The specimens recorded in this study show a flat to slightly convex base.

Occurence: Tanezzuft Formation, mid Rhuddanian (Llandovery).

Selected previous stratigraphic record: Llandovery, Estonia (Nestor, 1980a), Grahn (1988); Llandovery, Estonia (Nestor, 1994), Latvia (Loydell *et al*., 2003; Loydell *et al*., 2010); Rhuddanian, Jordan (Butcher, 2009).

Belonechitina capitata Eisenack 1962

Plate 2, Fig. 9-12

For synonymy see Henri *et al*., (1973)
Additional synonymy:
1981 *Conochitina capitata* - Grahn, p. 17, fig 6 (G-J).
1981 *Belonechitina capitata* - Paris, p. 199;pl. 14, figs 16-20.
1984 *Conochitina capitata* - Grahn, p. 12; pl. 1 (C-E).
1985 *Belonechitina capitata* - Paris, pl. 6, fig. 3.
1995 *Belonechitina capitata* – Achab and Asselin, pl. II, fig. 11
1995 *pistillachitina capitata* – Al-Hajri, pl. V, fig. 11
1995 *Belonechitina capitata* - Paris, pl. II, fig. 11.

2004 *Belonechitina capitata*-Vandenbroucke pl. II, fig. 1.
2005 *Belonechitina capitata*-Vandenbroucke *et al.,* p. 166; pl. 2 (1), pl. 7 (11), pl. 27 (12) and pl. 28 (1).
2008 *Belonechitina capitata*-Vandenbroucke *et al*., fig. 14 (d).

Description: *Belonechitina* species with elongated sub-cylindrical vesicle and a conically widened basal part. The basal edge is rounded and the base is concave. The rounded basal edge is covered with simple minute spines which often continue somewhat toward the neck, but decreases in the size and density. The neck widens slightly at the aperture which is straight. The flexure and shoulders are absent.

Dimensions: L: 190(435)680µm, Dp: 50(76)102µm, Dc: 27(42)56µm, n = 8.

Remarks and comparison: This species is distinguished fom other *Belonechitina* species by having a long sub-cylindrical vesicle and conically widened basal part which is covered by minute spines. It is distinguished from *Pistillachitina pistilifrons* Eisenack, 1939 in having spines on the basal edge.

Occurence: Melez Shugran Formation, early late Katian-late Katian (Ashgillian).

Selected previous stratigraphic record: late Llanvirnian-Caradocian, Baltic (Eisenack 1962a, 1962c, 1968b); Caradocian, Sweden (Laufeld, 1967), middle-late Caradocian, Öland (Grahn, 1981); Llanvirnian-early Ashgillian, northeast Libya (Paris, 1985); Llanvirnian- early Caradocian, Saudi Arabia (Al-Hajri, 1995), Canada (Achab, 1995); Caradocian, Scandinavia (Grahn and Nõlvak, 2007), Sweden (Vandenbroucke, 2004; Grahn, 1997), UK (Vandenbroucke *et al.,* 2005, 2008); Darriwilian-Katian, Turkey (Paris, 2007); Darriwilian, Estonia (Tammekänd *et al*., 2010).

***Belonechitina* cf. *capitata* Eisenack 1962**

Plate 2, Fig. 13

Description: *Belonichitina* species with elongated sub-cylindrical vesicle and a conically widened basal part. The basal edge is rounded and the base is concave. The rounded basal edge is covered with simple minute spines. The chamber covered by simple minute spines. The neck widens slightly at the aperture which is straight. The flexure and shoulders are absent.

Dimensions: L: 180(182)184µm, Dp: 54(59)63µm, Dc: 53(56)58µm, n = 4.

Remarks and comparison: This species is is very similar in morphology to *Belonechitina capitata* Eisenack 1962 but it is smaller in the vesicle length.
Occurence: Bir Tlacsin Formation, late Hirnantian (Ashgillian).

Belonechitina micracantha Eisenack, 1931

Plate 3, Figs. 1- 3; Plate 13, Figs. 3, 4

For synonymy see Paris (1981).
Additional synonymy:
1984 *Conochitina micracantha* - Grahn and Bergström, p. I (I, J).
1985 *Belonechitina micracantha* - Molyneux and Paris, pl. 7, fig. 7.
1995 *Belonechitina* cf. *micracantha* - Achab and Asselin, pl. I, figs. 9, 10.
1995 *Belonechitina micracantha* - Al-Hajri, pl. I, figs. 7, 9.
1998 *Belonechitina micracantha* - Siesser *et al*., pl. I, figs. 1, 2.
2000 *Belonechitina* gr. *micracantha* - Samuelsson and Verniers, pl. I, figs. 9, 10, 12.
2000a *Belonechitina micracantha* - Winchester-Seeto *et al*., fig. 10, E-H.
2000b *Belonechitina micracantha* - Winchester-Seeto *et al*., pl. 2, fig. 7.
2001 *Belonechitina micracantha* - Samuelsson *et al*., fig. 3.11.
2004 *Belonechitina* e.g. *micracantha* - Bourahrouh *et al*., pl. III, figs. 14 a-b; pl. IV, figs. 3, 9.
2004 *Belonechitina micracantha* - Vandenbroucke, pl. II, figs. 1-5.
2004 *Belonechitina micracantha* -Vandenbroucke, pl. 2, figs. 2-5.
2006 *Belonechitina micracantha* - Van Nieuwenhove *et al*. pl. II, fig. 8.
2006 *Belonechitina micracantha* - Vanmeirhaeghe, pl. II, fig. 10.

2006 *Belonechitina micracantha* - Quintavalle and Playford, p. 92, 93; pl. 1, figs. 1-3, 12
2007 *Belonechitina* gr. *micracantha* - Paris *et al*., pl. 1, fig. 5.
2007 *Belonechitina micracantha* - Grahn and Nõlvack, fig. 11 (D).
2008 *Belonechitina micracantha* - Ghavidel-syooki, pl. VI, fig. 9.
2010 *Belonechitina micracantha* - Tammekänd *et al*., fig. 3 (J-L).

Description: *Belonechitina* species with sub-cylindrical to conical chamber, straight to slightly convex flanks and flat to slightly convex base. The neck is almost cylindrical with a slightly flaring collarette. The flexure and shoulders are weakly developed or absent. The chamber is ornamented by randomly-distributed tapering spines which may be simple, well-developed at the margins and may extend to the neck.

Dimensions: L: 123(231)340µm, Dp: 61(84)106µm, Dc: 31(59)88µm, n = 15.

Remarks and comparison: The spiny ornamentation, which characterizes all *Belonechitina* species, was the main character proposed by Eisenack (1931) for *Belonechitina micracantha*. Later, many other species have been excluded from this group (e.g. *Belonechitina arabiensis*, *Belonechitina pseudarabiensis* and *Belonechitina postrobusta*). However, it is still difficult to separate the numerous poorly-defined forms and they are assigned here to the inclusive taxon *Belonechitina micracantha.* This view was previously adopted by several authors (e.g. Oulebsir and Paris, 1995; Samuelsson and Verniers, 2000; Bourahrouh *et al*., 2004; Paris *et al*., 2007). *Belonechitina parvispinata* Soufiane and Achab, 2000 is differentiated from this species by its club-shaped chamber.

Occurrences: Hawaz Formation, mid–late Darrwilian (Mid Ordovician); Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian).

Selected previous stratigraphic record: Ordovician, northeast Libya **(**Molyneux and Paris, 1985); Llanvirnian-Caradocian, Canada (Achab and Asselin, 1995), Scandinavia (Grahn and Nõlvak, 2007); Arenigian-Caradocian, Saudi Arabia (Al-Hajri, 1995); Caradocian, USA (Siesser *et al*., 1998); Darriwilian, Australia (Winchester-Seeto *et al*., 2000a; Quintavalle and Playford, 2006); Ashgillian, Morocco (Bourahrouh *et al*., 2004); Darriwilian-Dapingian, Sweden (Vandenbroucke, 2004); Late Ordovician, USA (Daniel *et al*., 2004); Ashgillian, UK (Van Nieuwenhove *et al*., 2006); Caradocian-Early Ashgillian, Belgium (Vanmeirhaeghe, 2006); Darriwilian, Turkey (Paris *et al*., 2007); late Katian, Morocco (Le Heron *et al*., 2008); Katian- Hirnantian, northern Iran (Ghavidel-Syooki, 208); Caradocian, Belgium (Vanmeirhaeghe, 2007), UK (Vandenbroucke *et al*., 2008); Caradocian-Ashgillian, Morocco (Bourahrouh *et al*., 2004), Belgium (Vanmeirhaeghe, 2006); Hirnantian, Baltic (Kaljo *et al.,* 2008); Ashgillian, UK (Van Nieuwenhove *et al*., 2006) Darriwilian, Estonia (Tammekänd *et al*., 2010). Darriwilian-Hirnantian, China (Xiaofeng and Xiaohong, 2004).

Belonechitina paravitrea Paris and Al-Hajri, 1995

Plate 3, Fig 4, 5; Plate 13, Figs. 5-6

For synonymy see Paris and Al-Hajri (1995).

Additional synonymy:

1995 *Belonechitina paravitrea* - Paris and Al-Hajri, p. 316-318; pl. 2, fig. 4 and 5a-b.

2012 *Belonechitina paravitrea* - Paris *et al*, pl. VI, fig. 4a, b.

Description: Very thin, transparent walled *Belonechitina* species with a conical chamber and slightly convex base, neck is cylindrical, smooth and ending with a flaring membranous collarette. The flexure and shoulders are weakly-developed or nearly absent. The base is convex with rounded margin. The lower part of chamber bears a spiny ornamentation which are better developed on the lower part of the chamber and near the margin. The prosome includes a thick dark plug located at contact between the chamber and the neck.

Dimensions: L: 100(121)160µm, Dp: 45(52)59µm, Dc: 23(30)38µm, n = 8

Remarks and comparison: This species is characterized by its thin, traansparent walled vesicle and presence of spines on the lower part of the chamber and near the margin. *Conochitina vitrea* Taugourdeau, 1962 is very similar to this species but it lacks of spiny ornamentation.

Occurrences: Tanezzuft Formation, Aeronian-mid Telychian (Llandovery).

Selected previous stratigraphic record: late Rhuddanian-mid Telychian, Saudi Arabia (Paris and Al-Hajri, 1995; Paris *et al*., 1995). Aeronian, eastern Murzuq Basin, southwest Libya (Paris *et al*., 2012)

Belonechitina postrobusta Nestor, 1980a

Plate 3, Figs 6, 7, 8

For synonymy see Butcher (2013).

Additional synonymy:

2013 *Belonechitina postrobusta* - Butcher, p.13; Pl. II, figs.1 -9

Description. *Belonechitina* with sub-cylindrical to conical chamber, flat or weakly concave base and rounded to well-rounded basal margin. The flanks are straight to slightly convex, with inconspicuous flexure and shoulders. The aperture displays a slight degree of denticulation, and shows only very slight to no flaring. The vesicle surface is evenly covered by small, simple, randomly distributed spines. The spines are generally better developed towards the base of the vesicle, in particular around the basal margin

Dimensions: L: 175(210)245µm, Dp: 75(86)98µm, 60(63)66µm, n = 5.

Remarks and comparison: This species is very similar to *Belonechitina robusta* Eisenack, 1931, but the later differs in being more slender and conical, and the spines are longer, high-rooted, and often multi-rooted. *Belonechitina arabiensis* Paris and Al-Hajri, 1995 and *Belonechitina pseudarabiensis* Butcher, 2009 possess much longer spines, and a generally shorter vesicle length than *B. postrobusta*. *Belonechitina aspera*, Nestor, 1980a is differentiated from this species in overall size and having a convex base. Nestor (1980a) described a large range of intraspecific variation in terms of both the shape of the vesicle and the degree of ornamentation in *B. postrobusta,* with some specimens bearing only very weakly developed (or possibly degraded) verrucae, particularly in the lower part of the Juuru Stage (Nestor 1994). The spines may sometimes be coalescent on the vesicle surface (Nestor 1994). Such intraspecific variation in both vesicle shape and ornamentation were encountered in the specimens of *B. postrobusta* recovered from the well E1-NC174 core by Bucher (2012) and herein.

Occurrences: Tanezzuft Formation, early-mid Rhuddania (Llandovery)

Selected previous stratigraphic record: early Llandovery, Estonia (Nestor, 1980, 1994); early-late Rhuddanian, global (Verniers et al., 1995); late Rhuddanian, Paraguay (Grahn, 2000), western Gondwana (Grahn, 2006); Rhuddanian, Latvia (Loydell *et al*., 2003, 2009); Rhuddanian, Belgium (Van Gootel *et al*., 1998); early Rhuddanian, Jordan (Butcher, 2009), Rhuddanian, Libya (Butcher, 2013)

Belonechitina pseudarabiensis Butcher, 2009

Plate 13, Figs.7, 8

2009 *Belonechitina pseudarabiensis* - Butcher, pl. 2, figs. 1-11.
2011 *Belonechitina pseudarabiensis* - Ghavidel-syooki *et al.,* fig. 3, C-F.
2013 *Belonechitina pseudarabiensis* - Butcher, p.16; Pl. I, fig.3.

Description: *Belonechitina* species with conical chamber and gently tapering flanks, with inconspicuous flexure and shoulders. The neck is sub-cylindrical and forms about 1/3 of the vesicle total length. The base is flat or slightly convex. A densely, randomly distributed spiny ornamentation covers the chamber and fades away towards the neck. The spines are simple.

Dimensions: L: 112(136)160µm, Dp: 56(70)83µm, Dc: 39(44)52µm, n = 6.

Remarks and comparison: The spines in this species are dense and closely spaced whereas they are less dense and widely-spaced in *Belonechitina arabiensis* Paris and Al-Hajri, 1995. Detailed comparison between the two species is discussed by Butcher (2009). This species also differs from *Belonechitina ghabaensis* Al-Ghammari *et al*., 2010, which has a larger vesicle and thicker wall. Moreover, the present species lacks any bi-or multi-rooted spines which are typical in *B. ghabaensis*.

Occurrences: Tanezzuft Formation, mid Rhuddanian (Llandovery).

Selected previous stratigraphic record: Rhuddanian, Jordan (Butcher, 2009); southwest Libya; Hinantian, Iran (Ghavidel-syooki, 2011).

***Belonechitina* sp. A**

Plate 3, Figs. 9

Description: *Belonechitina* species with conical chamber, straight tapering flanks, flat to slightly concave base and rounded basal margin. The flexure and shoulders are absent, neck undifferentiated. The vesicle wall covered with randomly distributed spiny ornamentation, covering the whole vesicle but being well developed and increasing in density in the lower part of the chamber.

Dimensions: L: 227(231)235µm, Dp: 66(74)83µm, Dc: 50(53)56µm, n = 6.

Remarks and comparison: This species is distinguished from *Belonechitina cavei* Mullins and Loydell, 2001, which possesses a central button-like mucron, with a central concentric circular structure occuring across the base.

Occurrence: Tanezzuft Formation, late Rhuddanian-Aeronian (Llandovery).

***Belonechitina* sp.B**

Plate 3, Figs. 10

Description: *Belonechitina* species with conical chamber, straight tapering, slightly convex base and rounded basal margin. The flexure and shoulders are weakly-developed or absent. The neck is slightly differentiated with cylindrical to sub-cylindrical. The collarette is slightly flaring with straight to fine denticulate lips. The vesicle wall is ornamented by randomly-distributed spines. These spines are well developed at the lower part of the chamber and decrease in density toward the neck. The spines are short with rounded bulbous end.

Dimensions: L: 140(158)175 µm, Dp: 65(73)80 µm, Dc: 60(66)70 µm, n=6

Remarks and comparison: This species is distinguished from *Belonechitina arabiensis* Paris and Al-Hajri, 1995, and *Belonechitina ghabaensis* Al-Ghammari *et al*., 2010 by it is large size and having shorter bulbous ended spines, the absence of flexure and shoulders in *Belonechitina*. gr. *micracantha* distinguish it from this species.

Occurrence: Melez Shugran, Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian).

***Belonechitina* sp. C**

Plate 13, Fig. 9

Description: *Belonichitina* species with claviform to sub-cylindrical chamber, neck indistinct and inconspicuous flexure and shoulder. The base is convex with rounded basal edge. The vesicle wall covered with elongated hair like spines.

Dimensions: L: 175(212)250µm, Dp: 78(84)89 µm, Dc: 61(68)75 µm, n = 4.

Remarks and comparison: This species differs from *Belonechitina robusta* Eisenack, 1959 in having a claviform vesicle shape covered with simple and elongated hair like spines.

Occurence: Melez Shugran, Memouniat formations, early late Katian-early Hirnantian (Ashgillian).

Belonechitina sp. D

Plate 3, Figs. 11, 12

Description *Belonechitina* species with conical to sub-cylindrical chamber, straight tapering flanks, convex base and rounded basal margin. The flexure and shoulders are absent, neck undifferentiated. The whole vesicle wall covered with randomly distributed densely short spiny ornamentation.

Dimensions: L: 280(300)320μm, Dp: 85(100)114μm, n = 5.

Remarks and comparison: This species is differentiated from other *Belonichitina* species in having a conical to sub-cylindrical vesicle shape with convex base, and covered with randomly distributed, dense spines. *Belonechitina* sp. A has a vesicle wall covered with randomly distributed spiny ornamentation, covering the whole vesicle but being well developed and increasing in density in the lower part of the chamber.

Occurence: Bir Tlacsin Formation, late Hirnantian (Ashgillian).

Genus *Calpichitina* Wilson and Hedlund, 1964

Type species: *Calpichitina scabiosa* Wilson and Hedlund, 1964.

Diagnosis: "Desmochitinidae with globular lenticular chamber." From Paris *et al*., (1999, p. 564).

Remarks: Wilson and Dolly (1964) considered this genus to be a junior synonym of the genus *Hoegisphaera* Staplin, 1961. Later, Paris *et al*. (1999) retained both genera and restricted *Hoegisphaera* to species with a sub-spherical chamber. This view is adopted herein. The present definition includes the two subgenera *Calpichitina* (*Calpichitina*) and *Calpichitina* (*Densichitina*) which were erected by Paris (1981) but no longer maintained.

Calpichitina densa Eisenack, 1962a
Plate 13, Fig. 10

1985 *Calpichitina densa* – Molyneux and Paris, pl. 14, figs. 7, 14.
2001 *Calpichitina densa* - Mullins and Loydell, pl. 5, fig. 11.
2001 *Desmochitina* cf. D. *densa* – Grahn *et al*., fig. 5.

Description: *Calpichitina* species with a lenticular chamber. The chamber usually flattened, appearing like a disc and lacks of collarette. The vesicle wall is smooth

Dimensions: L: 55(82)108µm, Dc: 25(30)35µm, n = 15

Remarks and comparison: *Calpichitina lenticularis* Bouche, 1965 differs from this species in having a short membranous collarette, which appears as a circular rim and the vesicle is glabrous and frequently with slight corrugations.

Occurrences: Tanezzuft Formation, late Aeronian-Telychian (Llandovery).

Selected previous stratigraphic record: late Telychian-early Sheinwoodian, global (Verniers *et al*., 1995); Llandovery (Telychian); Llandovery-early Wenlock, northeast Libya (Molyneux and Paris, 1985); Wenlock, Estonia (Rubel *et al*., 2007); Telychian, Latvia (Loydell and Nestor, 2005), USA (Loydel *et al*., 2010); Llandovery-Wenlock, UK (Mullins and Loydel, 2001); Wenlock, UK (Mullins and Aldridge, 2004); Telychian- Sheinwoodian, western Gondwana (Grahn, 2006).

Calpichitina lenticularis Bouche, 1965

Plate 4, Figs. 1-3

For synonymy see Elaouad (1984).

Additional synonymy:

1984 *Calpichitina lenticularis* - Elaouad-Debbaj, p. 54; pl. 1, fig. 4, pl. 2, figs. 10, 19-25.

1985 *Calpichitina lenticularis* - Molyneux and Paris, pl. 6, figs. 6 (a-b).

1993 *Calpichitina lenticularis* - Soufiane and Achab, pl. 4, fig. 14.

1995 *Calpichitina lenticularis* - Al-Hajri, pl. VII, fig. 8.

1996 *Calpichitina lenticularis* - Paris, pl. 1, fig. 4.

2002 *Calpichitina lenticularis* - Ghavidel-syooki and Winchester-Seeto, pl. I, figs. 1-3.

2004 *Calpichitina lenticularis* - Bourahrouh *et al*., pl. II, fig. 8.

2008 *Calpichitina lenticularis* - Ghavidel-syooki, pl. VIII, fig. 7.

2011 *Calpichitina lenticularis* - Ghavidel-syooki, pl. VII, fig. 2.

Description: *Calpichitina* species with a flat lenticular chamber and short membranous collarette. The chamber usually flattened, appearing like a disc and the collarette appears as a circular rim, representing one third to one half of the maximum diameter. The vesicle wall is glabrous but frequently with slight corrugations.

Dimensions: L: 108(116)123µm, Dc: 45(55)65µm, n = 15

Remarks and comparison: This species differs from *Calpichitina hemsiensis* Laufeld, 1974, which is more globular. The operculum in *Calpichitina annulata* Paris, 1981, is surrounded by a thick rim which is absent in this species.

Occurrences: Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian).

Selected previous stratigraphic record: Ashgillian, Morocco (Elaouad-Debbaj, 1984) Caradocian-Ashgillian, Libya (Molyneux and Paris, 1985); Llandelio-Ashgillian, Morocco (Soufiane and Achab, 1993); Caradocian-Ashgillian, Saudi Arabia (Al-Hajri, 1995); Caradocian-Ashgillian, Algeria (Oulebsir and Paris, 1995), northern Gondwana (Paris, 1990); Ashgillian, Iran (Ghavidel-Syooki and Winchester-Seeto, 2002); Ashgillian, Morocco (Bourahrouh *et al*., 2004); Katian- Hirnantian, Turkey (Paris *et al*., 2007); Caradocian, Scandinavia (Grahn and Nõlvack, 2007); late Katian-Hirnantian, Morocco (Le Heron *et al*., 2008); Katian-Hirnantian, northern Iran (Ghavide-syooki, 2008, 2010). Ashgillian, UK (Van Nieuwenhove *et al*., 2006).

Genus ***Clavachitina*** Taugourdeau, 1966

Type species: *Rhabdochitina claviformis* Taugourdeau, 1961.

Diagnosis: "*Conochitinidae* with a glabrous claviform chamber and without mucron." From Paris *et al.,* (1999, p. 559).

Remarks: The genus *Pistillachitina* Taugourdeau, 1966 is differentiated from this genus in having a cylindrical chamber with widened base. Genus *Conochitina* Eisenack, 1931, emend. Paris, Grahn, Nestor and Lakova, 1999 has a conical to claviform chamber with a mucron.

Clavachitina* cf. *grandis Taugourdeau and de Jekhowsky, 1960

Plate 4, Fig. 4

Description: *Clavichitina* species with claviform chamber, neck is cylindrical and long represents 2/3 of the total vesicle length. The flexure and shoulders are weakly developed to absent, there is no collarette. The base is flat with a slightly rounded basal edge. The vesicle wall is glabrous.

Dimensons: L: 230(235)240µm, Dp: 65(67)68µm, Dc: 50(51)52µm, n = 3.

Remarks and comparison: This species is similar in morphology to *Clavachitina grandis* Taugourdeau and de Jekhowsky, 1960, but it is smaller in overall size.

Occurrence: Bir Tlacsin Formation, late Hirnantian (Ashgillian).

Genus ***Conochitina*** Eisenack, 1931, emend. Paris, Grahn, Nestor and Lakova, 1999

Type species: *Conochitina claviformis* Eisenack, 1931.

Diagnosis: "Cononchitinidae with a conical claviform glabrous chamber provide with a mucron." From Paris *et al.,* (1999, p. 558).

Remarks: This genus has been emended and restricted by several authors (e.g. Eisenack, 1955; Taugourdeau, 1966; Eisenack, 1968; Paris, 1981). The present diagnosis is close to the definition given by Paris (1981). Genus *Pistillachitina* Taugourdeau, 1966 is differentiated from this genus in having a cylindrical chamber with widened base. Genus *Clavachitina* Taugourdeau, 1966 has a claviform chamber without mucron.

Conochitina* cf. *alargada Cramer, 1967

Plate 4, Fig.5

Deescription: *Conochitina* species with cylindrical to sub-cylindrical chamber tapers slightly towards the straight aperture. The base is convex and the basal edge is rounded. The flanks are straight, with inconspicuous flexure and absence of shoulders. The vesicle wall is perfectly smooth.

Dimensions: L: 240 (243) 245µm, Dp: 63 (67) 70µm, n = 4

Remarks and comparison: *Conochitina alargada* Cramer, 1967 differs from this species in having a vesicle which tapers from a maximum diameter near the basal margin to a constriction along the vesicle and then increases in width towards the aperture.

Occurrence: Tanezzuft Formation, Aeronian (Llandovery).

Conochitina* cf. *armillata Taugourdeau and Jekhowsky (1960)

Plate 4, Fig. 6; Plate 13, Fig. 11

Description: *Conochitina* species with a conical to cylindro-conical chamber, neck is cylindrical, equal or slightly longer than the chamber and becomes wider towards the straight aperture. Chamber flanks slightly convex with the maximum diameter at or near the middle part of the chamber.The flexure and shoulders are Incospicuous or weakly developed. The base is flat to slightly convex with rounded margins and thickened mucron often present. The vesicle wall is perfectly smooth.

Dimensions: L: 275(285)295µm, Dp: 85(88)92µm, Dc: 62(64)67µm, n = 7

Remarks and comparison: *Conochitina armillata* Taugourdeau and Jekhowsky, 1960 has a clear protruding mucron and its basal margin is not developed. *Conochitina pumilio* Verniers *et al.,* 2002 is smaller and without a mucron. *Conochitina subcyatha* Nestor 1982 has a conical chamber, the basal edge is better developed and the neck is longer than the chamber.

Occurrences: Tanezzuft Formation, late Rhuddanian-early Telychian (Llandovery).

Conochitina edjelensis Taugourdeau, 1963

Plate 14, Fig. 1

1963 *Conochitina edjelensis* - Taugourdeau, p. 137; pl. 3, figs.55-58.
1985 *Conochitina edjelensis* - *elongate* Hill *et al*., pl. 13, fig. 6, 11.
1995 *Conochitina edjelensis* - Paris *et al*., 1995, pl. I, fig. 9.
2003 *Conochitina edjelensis* - Loydell *et al*., fig. 16-m.
2005 *Conochitina edjelensis* - Grahn *et al*, pl. 1, fig. 3.
2006 *Conochitina edjelensis* - Grahn, pl. V, fig. 9, 14.
2006 *Conochitina edjelensis* - Hints *et al*., pl. 1, fig. 7.
2007*Conochitina edjelensis* - Ghavidel-syooki, pl. 1, fig. 6
2010 *Conochitina edjelensis* - Loydell *et al*.,fig. 12 (n).

Description: *Conochitina* species with conical to sub-cylindrical chamber has straight flanks but swollen at the base taper toward the aperture, has a short cylindrical neck, not clearly differentiated, but slightly widened toward the straight aperture. The flexure and shoulders are inconspicuous, there is no collarette. The base is straight to slightly convex. The vesicle wall is perfectly smooth.

Dimensions: L: 145(160)176µm, Dp: 67(73)79µm, Dc: 52(55)58µm, n = 7

Remarks and comparison: This species is distiguished from other *Conochitina* species in having a straight flanks but swollen at the base and tapers towards the aperture. *Conochitina intermedia* Eisenack, 1955 has a simple conical vesicle with short neck. *Conochitina simplex* Eisenack, 1939, which contain a few indviduals whose bases extend broadly in inverted cones.

Occurrences: Tanezzuft Formation, late Rhuddanian-Telychian (Llandovery).

Selected previous stratigraphic record: Early Silurian, Algeria (Taugourdeau, 1963), Spain (Cramer 1966) Saudi Arabia (Paris *et al*., 1995), northeast Libya (Hill *et al.,* 1985; Paris, 1988), Spain (Cramer, 1967), Estonia (Nestor, 1994); Aeronian-Telychian, global (Verniers *et al.,* 1995), Brazil (Grahn *et al*., 2005); Llandovery, Iran (Ghavidel-Syooki, 2006), Estonia (Hint *et al*., 2006) Telychian-Sheinwoodian, Brazil (Grahn, 2005); Aeronian, Latvia (Loydell *et al*. 2003); Rhuddanian to late Telychian, Iran (Ghavidel-syooki, 2006); Aeronian, Latvia (Loydell *et al.,* 2009).

Conochitina* cf. *electa Nestor, 1980

Plate 4, Fig. 7; Plate 14, Fig. 2

Description: *Conochitina* species with a cylindro-conical chamber. The neck is short, sub-cylindrical and slightly widened towards the aperture, with weakly or inconspicuous flexure and shoulders. The base is slightly flat, the basal part has funnel shape extension and the basal edge is bluntly rounded. The vesicle wall is smooth.

Dimensions: L: 180(182)186µm, Dp: 96(101)106µm, n = 3.

Remarks and comparison: This species differs from *Conochitina electa* Nestor, 1980 in that the basal edge is less pronounced and in not having a constriction above the base. It is very similar in morphology to *Conochitina* cf. *C. electa* reported from Llandovey of Estonia by Achab (1981)

Occurrences: Tanezzuft Formation, Aeronian (Llandovery).

Conochitina elegans Eisenack, 1931

Plate 4, Fig. 8

For synonymy see Grhan (1982).

Additional synonymy:

1984 *Conochitina elegans* – Grahn, p. 13; pl. I (A-B).

1998 *Conochitina elegans* – Siesser *et al.,* pl. 1, fig 13.

2005 *Conochitina elegans* – Vandenbroucke *et al.,* fig 13 (o).

2010 *Conochitina elegans* – Butcher, p. 85; pl. 1, fig. 1,2.

Description: *Conochitina* species with an elongated sub-cylindrical to conical chamber tapers gradually towards the straight aperture. The base is slightly convex and the basal edge is rounded. The flanks are straight, with an inconspicuous flexure and absence of shoulders, absence of collarette. The vesicle wall is perfectly smooth.

Dimensions: L: 540(517)585µm, Dp: 65(78)90µm, Dc: 54(57)60µm, n = 8.

Remarks and comparison: Eisenack (1934) differentiated *Rhabdochitina conocephala* from *Conochitina elegans* Eisenack, 1931 based on the shape of vesicle. In general *Rhabdochitina* species has a cylindrical vesicle and *Conochitina* species has a conical to sub-cylindrical vesicle. The specimens recorded in this study were assigned to *Conochitina elegans*, as the proportion of specimens displaying a sub-cylindrical to conical vesicle was greater than those displaying a cylindrical one.

Occurrences: Melez Shugran Formation, early late Katian-Late Ktaian (Ashgillian).

Selected previous stratigraphic record: late Arenigian-early Llanvirnian, Sweden (Grahn 1980, 1981a); late Arenigian-late Ashgillian, Estonia (Eisenack 1962b, 1965; Nolvak 1980); early Ashgillian, Sweden (Grahn, 1981b); early Caradocian, USA (Stauffer, 1933), Sweden (Laufeld 1967); Caradoc?, west Germany (Eisenack 1939); late Caradocian-lower Ashgill, USA (Jenkins 1969), Baltic (Grahn 1981a); Late Ordovician, Estonia (Grahn, 1984); Caradocian, USA (Siesser *et al.*, 1998); Ashgillian, UK (Vandenbroucke *et al.,* 2005), China (Wang and Chen, 2004); Llanvirnian, Scandinavia (Grahn and Nõlvak, 2007); Llanvirinian-Caradocian, Turkey (Paris *et al.,* 2007); Late Ordovician, USA (Butcher *et al.,* 2010).

Conochitina* cf. *elegans Eisenack, 1931

Plate 4, Fig. 9

Description: *Conochitina* species with an elongated sub-cylindrical to conical chamber tapers gradually towards the aperture. The base is flat and the basal edge is slightly rounded. The flanks are straight, with an inconspicuous flexure and absence shoulders, there is no collarette. The vesicle wall is perfectly smooth.

Dimensions: L: 200(274)349µm, Dp: 65(75)85µm, Dc: 49 (60)70µm, n = 8.

Remarks and comparison: The specimens recorded here are shorter than the typical *C. elegans* as described by Eisenack (1931). The mean length of typical *C. elegans* described by Eisenack (1931; 1959; 1965) and Jenkins (1967; 1970) is over 388µm which is significantly longer than the mean length recorded for this species.

Occurrences: Bir Tlacsin Formation, late Hirnantian (Ashgillian).

Conochitina* cf. *minnesotensis Stauffer, 1933

Plate 4, Figs. 10, 11

Description: *Conochitina* species with elongated sub-cylindrical chamber. The neck is undifferentiated and absence of shoulders and flexure. The flanks are straight and taper towards the aperture. The base is convex with broadly rounded basal margin and possesses a short copula or mucron at its centre. The vesicle wall covered with dense grana.

Dimensions: L: 426(428)430µm, Dp: 70(85)100µm, n = 3.

Remarks and comparison: *Conochitina minnesotensis* Stauffer, 1933 differs from this species in having smooth vesicle wall.

Occurrences: Hawaz Formation, mid-late Darrwilian (Llanvirnian).

Conochitina proboscifera Eisenack, 1937

Plat 4, Fig. 12; Plate 14, Fig. 3

1937 *Conochitina proboscifera* - Eisenack, p. 225; pl. 15, figs, 4, 5.
1955 *Conochitina proboscifera* - Eisenack, p. 5; pl. 3, figs, 1,2.
1964 *Conochitina proboscifera* - Taugourdeau and Jekhowsky p. 859; pl. I, figs, 10,13; pl. II, figs. 13-19; pl. III, fig. 23-25; pl, IV, fig. 39.
1974 *Conochitina proboscifera* forma truncata - Laufeld, p. 72, fig. 34 (D,E).
1985 *Conochitina proboscifera* - Hill *et al*., pl. 14, figs. 1 (a-b).
2003 *Conochitina proboscifera* - Loydell *et al*., fig. 16 (ab)
2005 *Conochitina proboscifera* - Grahn *et al*., pl. 1, fig. 5.
2005 *Conochitina proboscifera* - Grahn, pl. III, fig. 13.
2006 *Conochitina proboscifera* - Hints *et al*., pl. 1, fig. 13.

Description: *Conochitina* species with claviform chamber, neck undifferentiated and absence of shoulders and flexure, there is no collarette. The base is convex and possesses a short, circular mucron at its centre. The basal margin broadly rounded and the flanks are straight and taper toward the aperture and slight or weak flexure in the vesicle flanks. The vesicle wall is perfectly smooth.

Dimensions: L: 224(450)676µm; Dp: 88(120)152µm, n = 6.

Remarks and comparison: This species is very similar to *Conochitina praeproboscifera* Nestor, 1994, which is distinguished by its thinner vesicle wall and its base is flat with slightly rounded basal margin. *Rhabdochitina magna* Eisenack, 1931, has a cylindrical vesicle with straight flanks and thinner vesicle wall. *Conochitina claviformis* Eisenack, 1931, has a gentle constriction in the vesicle approximately half way along its length.

Occurrences: Tanezzuft Formation, Llandovery (late Telychian).

Selected previous stratigraphic record: Wenlock, UK (Eisenack 1959, 1962b, 1968, 1970, 1972b; Taugourdeau and de Jekhowsky 1964; Laufeld 1974, 1979), Telychian- Aeronian, Belgium (Verniers and Rickards, 1978; Verniers, 1981); Llandovery-Wenlock, Britain and Ireland (Aldridge *et al*., 1979); Silurian, Canada (Achab 1981), Welsh Basin (Aldridge *et al.,* 1981), Estonia and North Latvia (Nestor 1982b, 1982c, 1990, 1993, 1994, 1997); Wenlock, Shropshire, UK (Dorning, 1981); Llandovery-Wenlock, UK (Mabillard and Aldridge, 1985), USA (Grahn, 1985); late Llandovery-early Wenlock, Saudi Arabia (Hill *et al.,* 1985); Llandovery, Libya (Paris, 1988); Wenlock-Ludlow, northeast England (Barron, 1989); late Telychian-Wenlock, Canada (Asselin *et al*., 1989), Bohemia (Dufka, 1995), Gotland (Grahn, 1995); late Telychian-Sheinwoodian, global (Verniers *et al*., 1995); Llandovery-Wenlock, Gotland (Nestor and Einasto, 1997); Sweden (Grahn, 1998); Telychian-Sheinwoodian, Norway (Nestor, 1999); early Wenlock, Wales (Verniers, 1999); late Llandovery, Wales (Gary *et al*., 2000); Telychian, Sweden (Bergström *et al.,* 2008), Latvia (Loydell *et al*., 2003); Aeronian-Telychian, Brazil (Grahn *et al*., 2005); Llandovery-Wenlock, Estonia (Hint *et al.,* 2006).

Conochitina* cf. *subcyatha* *Nestor, 1982

Plate 14, Fig. 4

Description: *Conochitina* species with sub-conical chamber, neck is long, cylindrical and represents about 1/3 to 1/2 of the total vesicle length, flexure and shoulders are weakly developed or absent, there is no collarette. The base is flat and slightly rounded basal edge. A prosome is present and located at the base of the neck. The vesicle wall is perfectly smooth.

Dimensions: L: 264(276)289µm, Dp: 86(100)115µm: Dc: 67(73)78µm, n = 5.

Remarks and comparison: This species is similar in morphology to *Conochitina subcyatha* Nestor, 1982*,* but the later has a longer neck and the base commonly provided with low callus and small mucron which is not clearly seen in the specimens recorded herein.

Occurrence: Tanezzuft Formation, Aeronian (Llandovery).

***Conochitina* sp. A**

Plate 4, Fig. 13

Description: *Conochitina* species with a cylindro-conical chamber. The neck is short, sub-cylindrical and slightly widened toward the aperture, with weakly or inconspicuous flexure and shoulders. The base is flat to slightly convex bears a discrete apex mark and the margins are rounded. The vesicle wall is smooth.

Dimensions: L: 214(217)220µm, Dp: 71(75)78µm: Dc: 68(70)72µm, n = 5.

Remarks and comparison: This species is distinguished from other *Conochitina* species in having a discrete apex mark at the base of chamber.

Occurrence: Tanezzuft Formation, Telychian (Llandovery).

***Conochitina* sp. B**

Plate 4, Fig. 14

Description: *Conochitina* species with a cylindro-conical chamber with straight flanks and absence of flexure and shoulders. The base is flat to slightly concave with rounded basal margins. The vesicle wall is perfectly smooth.

Dimensions: L: 240(248)255µm, Dp: 67(77)87µm, n = 5.

Remarks and comparison: *Conochitina edjelensis* Taugourdeau, 1963 differs from this species in having a straight flanks which are swollen at the base and tapers towards the aperture.

Occurrence: Tanezzuft Formation, Telychian (Llandovery).

Genus ***Cyathochitina*** Eisenack, 1955, emended. Paris, Grahn, Nestor and Lakova, 1999

Type species: *Conochitina campanulaeformis* Eisenack, 1931.

Diagnosis: "Lagenochitinidae with a conical to hemispherical glabrous chamber and with a complete membranous carina on a sharp margin" From Paris *et al*., (1999. P. 563).

Remarks: Paris *et al*. (1999) emended this genus to exclude conical forms without a conspicuous flexure which are transferred to *Hyalochitina* Paris and Grahn in Paris *et al*. (1999). Species with a carina located below margin are accommodated in *Tanuchitina* Jansonius, 1964 emend. Paris *et al*., 1999.

Cyathochitina campanulaeformis Eisenack, 1931

Plate 5, Figs. 1, 2

For synonymy see Butcher (2009).
Additional synonymy:
2009 *Cyathochitina campanulaeformis* - Butcher, p. 611-614; pl. 5, fig. 1-10.
2010 *Cyathochitina campanulaeformis* - Tammekänd *et al*., fig. 3 (Y).
2013 *Cyathochitina campanulaeformis* - Butcher., P. 32, 33; pl. V, fig.3 .

Description: *Cyathochitina* species with a conical chamber and distinct flexure and inconspicuous shoulders. The neck is cylindrical and represents 1/3 of total vesicle length, and does not flare towards the aperture, there is no collarette. The basal margin is sharp to rounded, with a flat to concave base, and the flanks may be straight to slightly convex. A longitudinal ribbing is often observed on the neck and flexure, strengthening this part of the vesicle. A carina occurs at the basal margin, and varies from being distinct to a simple thickening of the basal margin. The vesicle wall is smooth to granulate and wrinkles or corrugations may develop at the lower part of the chamber.

Dimensions: L: 154(243)288µm, Dp: 145(132)165µm, Dc: 54(73)85µm, n = 18.

Remarks and comparison: This species is distinguished from other *Cyathochitina* species by its bell-like shape, slightly convex flanks and the presence of a very small carina, more often observed as a thickening of the basal edge. *Cyathochitina kuckersiana* Eisenack, 1934 differs from *C. campanulaeformis*, in having a wide, thin carina. *Cyathochitina calix* Eisenack, 1931 is differentiated through its more elongate vesicle.

Occurrences: Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian); Tanezzuft Formation, mid Rhuddanian-Telychian (Llandovery).

Selected previous stratigraphic record: late Arenigian-late Ashgillian, Estonia (Eisenack 1962a, 1968a, 1968b; Nõlvak 1980); early Llanvirnian-early Llandeilo, Welsh Borderland (Jenkins, 1967), France (Paris, 1980); late Llanvirnian-early Ashgillian, Sweden (Grahn 1981b); late Llanvirnian-middle Llandovery, Sweden (Laufeld 1971; Laufeld 1967); Mid Ordovician in Bohemia (Eisenack 1948); Early-Mid Ordovician, USA (Grahn and Bergström, 1984b); late Caradocian-early Ashgillian, U.S.S.R. (Laufeld, 1971). Early Llandovery, Sweden (Grahn 1978); late Arenigian-early Llanvirnian, Sweden (Grahn 1980, 1981a); Ordovician, Estonia (Grahn, 1984a); Katian, Saudi Arabia (McClure, 1988); Llanvirnian-Caradocian, Saudi Arabia (Al-Hajri, 1995); Mid Ordovician, Germany (Samuelsson *et al*., 2000); Silurian, Canada (Soufian and Achab, 2000); Late Ordovician, Iran (Ghavidel-syooki and Winchester-Seeto, 2002); Rhuddanian, Latvia (Loydell, 2003); Late Ordovician, Sweden (Vandenbroucke, 2004); Aeronian-Sheinwoodian, western Gondwana (Grahn, 2006); Llandovery, Iran (Ghavidel-syooki, 2006; Ghavidel-syooki and Vecoli; 2007); Llanvirnian-Caradocian, southeastern Turkey (Paris *et al*., 2007); Rhuddanian, Jordan (Butcher, 2009) Darriwilian, Estonia (Tammekänd *et al*., 2010).

Cyathochitina costata Grahn, 1982

Plate 5, Figs. 3, 4

1982 *Cyathochitina costata* - Grahn, p. 35; fig. 14 G

2002 *Cyathochitina* cf. C. *costata* - Ghavidel-syooki and Winchester-Seeto, p. 94; pl. IV, figs. 3, 4.

Description: *Cyathochitina* species with sub-conical chamber, neck is cylindrical and tapering towards the straight aperture. The flexure is distinct and the flanks are convex. The base is flat and the basal edge is provided with a short carina. The vesicle wall is covered with long distinct ridges from the aperture to the basal edge.

Dimensions: L: 130(200)270µm, Dp: 130(158)185µm, Dc: 50(68)85µm, n = 7.

Remarks and comparison: *Cyathochitina dispar* Benoit and Taugourdeau 1961 has an overall morphology similar to *C. costata,* but it has faintly concentric striations instead of longitudinal ridges.

Occurence: Bir Tlacsin Formation, late Hirnantian (Ashgillian).

Selected previous stratigraphic record: late Caradocian, Gotland (Grahn, 1982); Hirnantian, Latvia (Hints *et al*., 2010); Caradocian-early Ashgillian (Ghavidel-syooki and Winchester-Seeto, 2002).

Cyathochitina kuckersiana Eisenack, 1934

Plate 5, Figs. 5-7

For synonymy see Butcher (2009).

Additional synonymy:

2009 *Cyathochitina kuckersiana* - Butcher, p. 614-615; pl. 5, fig. 11.
2010 *Cyathochitina kuckersiana*- Tammekänd *et al*., fig. 3 (AC).
2013 *Cyathochitina kuckersiana* – Le Hérissé *et al*., fig. 7, E.
2013 *Cyathochitina kuckersiana* - Butcher, P. 33, 34; pl. V, fig.4 .
2013 *Cyathochitina kuckersiana* – De la Puent and Rubinstine, pl. 2, fig.5 .

Description: *Cyathochitina* species with conical chamber, neck is cylindrical and comprises 1/3 to 1/2 of the total vesicle length and flares slightly towards the straight aperture. The basal margin is sharp, with a flat base and shows concentric structures. The flexure is distinct and the shoulders are inconspicuous, the flanks are straight to slightly concave. The surface is smooth to weakly granulate. A wide thin carina occurs at the basal margin.

Dimensions: L: 165(217)270µm, Dp: 150(167)185µm, Dc: 75(80)85µm, n = 17

Remarks and comparison: This species differs from *Cyathochitina campanulaeformis* Eisenack, 1931 in the presence of a wide carina, *Cyathochitina calix,* Eisenack, 1931 lacks the wide carina, and displays a much more elongate chamber. Jenkins (1969) proposed two subspecies of *C. kuckersiana* (*C. kuckersiana latipatagium* Jenkins, 1969; and *C. kuckersiana patagiata* Jenkins, 1969); with the assignation of typical specimens of *C. kuckersiana* (sensu Eisenack, 1931) to the subspecies *C. kuckersiana kuckersiana*. The differentiation of these subspecies was based upon the width of the carina. However, Nestor (1994) questioned the erection of the subspecies on the basis that shorter and longer vesicles. *C. kuckersiana* with the carina of variable width occur together in almost all studied samples, and suggested that the width and carina are independently variables in a large population. This view was adopted by Butcher (2009) and accepted herein.

Occurrences: Tanezzuft Formation, early Rhuddanian-late Telychian (Llandovery).

Selected previous stratigraphic record: late Llanvirnian, Sweden (Grahn 1981a); Llanvirnian, Sweden (Laufeld 1967); early Ashgillian, Sweden (Grahn 198Ib), Estonia (Eisenack 1962a). late Caradocian-early Ashgillian, U.S.S.R (Laufeld, 1971), Baltic (Grahn, 1981b); Early-Mid Ordovician, USA (Grahn and Bergström, 1984b) Ordovician, Estonia (Grahn, 1984a); Llandelio-Ashgillian, Morocco (Soufian and Achab, ?1993); Llandovery, northeast Libya (Hill *et al.,* 1985); Caradocian, USA (Siesser et al., 1998); Silurian, Canada (Soufian and Achab, 2000); Llandovery, Wales (Mullins and Loydell, 2001, 2002); Rhuddanian, Latvia (Loydell, 2003), Jordan (Butcher, 2009), southwest Libya (Butcher 2013); Late Katian, Morocco (Le Heron *et al*., 2008); Darrwilian, Estonia (Tammekänd *et al*., 2010), Late Ordovician (latest Hirnantian)-Early Silurian (Rhuddanian), northern Chad and southeastern Libya (Le Hérissé *et al*., 2013); late Katian, Argentina (De la Puent and Rubinstine, 2013).

Cyathochitina* cf. *regnelli Eisenack, 1955

Plate 4, Figs. 8, 9

Description: *Cyathochitina* species with a conical chamber, neck is short and represents 1/3 of the total vesicle length. The flexure and shoulders are inconspicuous and does not flare towards the aperture. The base is concave to almost flat, with concentric circular structures. The basal edge has a transparent carina. The carina varies from being distinct to a simple thickening.

Dimensions: L: 155(182)210µm, Dp: 100(124)148µm, Dc: 60(70)80µm, n = 6

Remarks and comparison: This species is similar in morphology to *Cyathochitina regnelli* Eisenack, 1955, but the later has a cylindrical neck representing 1/2 to 3/4 of the total length, which become wider towards the aperture, the aperture is straight and very wide compared to the base.

Occurence: Melez Shugran, late Katian (Ashgillian).

Genus ***Desmochitina*** Eisenack, 1931

Type species: *Desmochitina nodosa* Eisenack, 1931.

Diagnosis: "Desmochitinidae with an ovoid, glabrous chamber." From Paris *et al.*, (1999, p. 564).

Remarks: This definition includes the two subgenera: *Desmochitina* (*Desmochitina*) and *Desmochitina* (*Pseudodesmochitina*) erected by Paris (1981) but no longer maintained.

Desmochitina minor Eisenack, 1931

Plate 6, Fig. 1; Plate 14, Figs. 5-7

For synonymy see Paris (1981).

Additional synonymy:

1984 *Desmochitina minor* - Elaoud-Debbaj, p. 57; pl.1, fig. 3, 16, 20; pl. 2, fig. 9, 14, 18.

1988 *Desmochitina minor* - McClure, pl. V, figs. 9-11.

1991 *Desmochitina minor* - Grignani *et al.*, , pl. 5, fig. 7.

1995 *Desmochitina minor* - Al-Hajri, pl. IV, fig. 5; pl. V, figs. 9, 10.

1998 *Desmochitina minor* - Siesser *et al.*, pl. II, figs. 1-3.

2000 *Desmochitina minor* - Paris *et al.*, pl. 1, fig. f.

2002 *Desmochitina minor* - Ghavidel-Syooki and Winchester-Seeto, pl. I, fig. 6.

2004 *Desmochitina minor* - Vandenbroucke*,* pl. III, fig. 22.

2006 *Desmochitina minor* - Van Nieuwenhove *et al.*, pl. I, fig. 3.

2007 *Desmochitina* gr. *minor* - Paris *et al.*, pl. 1, fig. 8.

2008 *Desmochitina minor* - Ghavidel-syooki, pl. VI, fig. 4.
2010 *Desmochitina minor* - Ghavidel-syooki, pl. VII, fig. 1.
2010 *Desmochitina minor* - Tammekänd *et al*., fig. 3 (E)

Description: *Desmochitina* species with a cylindrical to ovoid chamber. The flanks are convex with a rounded base. The collarette is flaring and occasionally folded outside. The vesicle wall is thick, glabrous or rough except the collarette which lacks any ornamentation. The ornamentation is usually consistent through the entire vesicle.

Dimensions: L: 70(98)125µm, Dp: 55(68)91µm, n = 16.

Remarks and comparison: *Desmochitina omanensis* Al-Ghammari *et al*., 2010 is distinguished from this species in having an elongate collarette. *Desmochitina mortoni* Al-Ghammari *et al*., 2010 is smaller in overall size than *D. minor. Desmochitina ovulum* Eisenack, 1962 is distinguished also from this species in having cylindrical to ovoid chamber and smooth vesicle wall.

Occurrences: Melez Shugra and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian).

Selected previous stratigraphic record: Ashgillian, Morocco (Elaoud-Debbaj, 1984; Bourahrouh *et al*., 2004), Saudi Arabia (Al-Hajri, 1995), southeast Libya (Grignani *et al.,* 1991), Iran (Ghavidel-syooki and Winchester-seeto, 2002); Caradocian, USA (Siesser *et al*., 1998), Saudi Arabia (McClure, 1988); Late Ordovician, Saudi Arabia (Paris *et al*., 2000); Darriwilian-Ashgillian, Sweden (Vandenbroucke, 2004); Caradocian-Ashgillian, UK (Van Nieuwenhove *et al*., 2006) Tremadocian-Arenigian, western Gondwana (Grahn, 2006); Darriwilian-Hirnantian, Turkey (Paris *et al*., 2007); Katian-Hirnantian, northern Iran (Ghavidel-Syooki, 2008, 2010); Caradocian, Scandinavia (Grahn and Nõlvak, 2007); Caradocian-Ashgillian, Scotland (Vandenbroucke *et al.*, 2003); Late Ordovician, Sweden (Vandenbroucke, 2004); Caradocian, UK (Vandenbroucke *et al*., 2008); Hirnantian, UK (Vandenbroucke *et al*., 2008); Caradocian, Belgium (Vanmeirhaeghe, 2007); Caradocian-Ashgillian, Morocco (Bourahrouh *et al*., 2004); Katian, Estonia (Hint *et al.,* 2007); Hirnantian, western Latvia (Hint *et al.,* 2010), Baltic (Kaljo *et al.,* 2008) Ashgillian, UK (Van Nieuwenhove *et al*., 2006) Darriwilian, Estonia (Tammekänd *et al*., 2010); Ashgillian, China (Wang and Chen, 2004); late Katian. Morocco (Le Heron *et al*., 2008).

Desmochitina* cf. *piriformis Laufeld, 1967

Plate 14, Fig. 8

Description: *Desmochitina* species with a cylindrical to ovoid chamber, neck is absent. The flanks are convex with rounded base. The collarette is damaged or absent and the aperture is wide and rounded. The vesicle surface is smooth.

Dimensions: L: 80(88)95µm, n = 4.

Remarks and comoparison: *Desmochitina piriformis* Laufeld, 1967 differs from this species in having a short collarete and thin vesicle wall. This species is very similar in size and shape to *Desmochitina* (*Psudodesmochitina)* sp. aff. *piriformis* from Portugal, described by Paris (1981).

Occurrences: Melez Shugran Formation, early late Katian - late Katian (Ashgillian).

Genus ***Euconochitina*** Taugourdeau, 1966 emend. Paris, Grahn, Nestor and Lakova, 1999.

Type species: *Conochitina conulus* Eisenack, 1955b.

Diagnosis: “Conochitinidae with a conical glabrous chamber and without mucron.” From Paris *et al*. (1999, p. 559).

Remarks: Paris *et al*. (1999) emended the genus to exclude the forms with ornamented vesicles. Conical forms of the genus *Conochitina* are distinguished from this genus in having a mucron. Following Paris *et al*. (1999), the genus *Jenkinochitina* Paris, 1981, is considered as a junior synonym of this genus.

Euconochitina lepta Jenkins, 1970

Plate 6, Fig. 2; Plate 14, Fig. 9

1970 *Sphaerochitina lepta* sp. nov.; Jenkins, pl. 51, figs. 11-13, 16-20.
1984 *Jenkinochitina lepta* - Elaoud-Debbaj, p. 57; pl. 2, fig. 24; pl. 3, figs. 20-23.
1991 *Sphaerochitina lepta* - Grignani *et al*., pl. 5, fig. 8, 9; pl. 6, fig.14.
2002 *Jenkinochitina lepta* - Ghavidel-syooki and Winchester-Seeto, pl. III, figs. 1, 4.
2004 *Euconochitina lepta* - Bourahrouh *et al*., pl. II, fig. 7.
2005 *Euconochitina lepta* - Vandenbroucke *et al*., fig. 13 (K).
2007 *Euconochitina lepta* - Paris *et al*., pl. 2, fig. 2.
2007 *Euconochitina lepta* - Ghavidel-syooki, pl. IV, fig. 5.

Description: *Euconochitina* species with a conical chamber, cylindrical neck tapering towards the aperture, usually ending by a flaring collarette. The flexure is inconspicuous and shoulders are absent. The base is flat to slightly convex and the basal margin is rounded. The vesicle surface is perfectly smooth.
Dimensions: L: 82 (93) 105µm, Dp: 89 (92) 95µm, Dc: 36 (43) 50µm, n = 13

Remarks and comparison: Jenkins (1970) reported individuals with a spiny ornamentation. The specimens recorded here are glabrous with no ornamentation developed. Ghavidel-syooki and Winchester-Seeto (2002) assigned similar but spiny individuals to *Jenkinochitina* Paris, 1981 which is considered as a junior synonym of *Euconochitina* in the recent reorganization of the systematics of chitinozoans (Paris *et al*., 1999). Adopting the view of Paris *et al*. (1999), such spiny individuals should be assigned to *Fungochitina* Taugourdeau, 1966 rather than *Jenkinochitina*.

Occurrences: Melez Shugran Formation, late Katian (Ashgillian).

Selected previous stratigraphic rcord: Ashgillian, USA (Jenkins, 1970), Morocco (Elaouad-Debbaj, 1984), northern Gondwana Domain (Paris, 1990); Ashgillian, southeast Libya (Grignani *et al.,* 1991), Algeria (Oulebsir and Paris, 1995), Saudi Arabia (Al-Hajri, 1995), Turkey (Steemans *et al*., 1996), Iran (Ghavidel syooki, 2000; Ghavidel-syooki and Winchester-Seeto, 2002); Late Ordovician, Morocco (Bourahrouh *et al*., 2004); Katian-Hirnantian, southeastern Turkey (Paris *et al*., 2007), Iran (Ghavidel-syooki 2008) late Katian-Hirnantian, eastern Morocco (Le Heron *et al*., 2008); Ashgillian, UK (Vandenbroucke *et al.,* 2005; Van Nieuwenhove *et al*., 2006).

Euconochitina brevis Taugourdeau and de Jekhowsky, 1960

Plate 14, Fig. 10

For synonymy see Chen *et al* (2009).
Additional synonymy:
2009 *Euconochitina brevis* **-** Chen *et al.,* p318; pl. II, figs. 1–4.

Description: *Euconochitina* species with stocky, tapered sub-cylindrical chamber has straight flanks but swollen at the lower portion of chamber. The neck is not clearly differentiated. The flexure and shoulders are inconspicuous, there is no collarette. The base is convex with rounded basal margin. The vesicle wall is perfectly smooth.

Dimensions: L: 185(188)190 µm, Dp: 76(79)82 µm, Dc: 52(55)58 µm, n = 3

Remarks and comparison: This species is distinguished from other *Euconochitina* species by having a stocky, tapered sub-cylindrical vesicle with straight flanks. Wang and Chen (1992) discussed the intraspecific variation of *Euconochitina brevis* based on the Silurian specimens and found that the shape of this species varies from squat to slender. The stouter specimens have an outline recalling the silhouette of species of *Eisenachitina* Jansonius, 1964 restrict. Paris, 1981, but differs from it by the lack of spiny ornamentation.

Occurrences: Hawaz Formation, middle-late Darriwilian (Llanvirnian).

Selected previous stratigraphic record: Ordovician-Llandovery, Algeria (Taugourdeau and de Jekhowsky, 1960); Middle Ordovician of SW France (Taugourdeau, 1961); Silurian of Spain (Cramer, 1967); Llandovery, China (Wang and Chen, 1992)·Arenigian, China (Chen and Zhang, 2005), Canada (Achab, 1986b); late Floian–Dapingian (Arenigian), China (Chen *et al.,* 2009).

Euconochitina vitrea Taugourdeau, 1962

Plate 15, Fig. 1

1961 *Conochitina vitrea* - Taugourdeau, p. 234-235; pl. 1, fig. 18

2012 E*uconochitina vitrea* - Paris *et al*., pl. VI, fig. 5 .

.

Description: A thin, transparent walled *Euconochitina* species with a conical chamber, neck is cylindrical, smooth and ending with a flaring membranous collarette. The flexure and shoulders are weakly-developed or nearly absent. The base is convex with rounded margin. The prosome includes a thick dark plug located at contact between the chamber and the neck. The vesicle wall is perfectly smooth.

Dimensions: L: 100(121)160µm, Dp: 45(50)55µm, Dc: 23(29)35µm, n = 7

Remarks and comparison: This species is characterized by its thin and smooth walled vesicle. *Belonechitina paraviterea* Paris and Al-Hajri, 1995 is very similar in morphology to this species but it differs in having a spines on the lower part of the chamber and near the margin.

Occurrence: Tanezzuft Formation, late Rhuddanian - early Telychian (Llandovery)

Selected previous stratigraphic record: middle and upper Llandovery, Algeria, Sahara (Taugourdeau, 1962); Aeronian-Telychian, globally (Verniers *et al*., 1995); Rhuddanian, southwest Libya (Paris *et al*., 2012).

Genus ***Fungochitina***Taugourdeau*, 1966*

Type species: *Conochitina fungiformis* Eisenack*,* 1931.

Diagnosis: "Lagenochitinidae with conical to lenticular chamber and randomly distributed spines." From Paris *et al*., (1999, p. 564).

Remarks and comparison: Paris, 1999 include the spiny forms with a conical to lenticular chamber to this genus.

Fungochitina actonica Jenkins, 1967

Plate 6, Fig. 3, 4

1967 *Sphaerochitina actonica* - Jenkins, p. 476; pl. 75, figs. 20, 23 and 24, text. Fig 12.
1981 *Jenkinochitina actonica* - Paris, pl. 16, fig. 21.
1984 *Jenkinochitina actonica* - Elaouad-Debbaj, p. 57; pl. 2, fig. 20; pl. 3, figs. 15-17.

Description: *Fungochitina* species with a conical chamber, cylindrical neck tapering towards the aperture, usually ending by a flaring collarette. The flexure is inconspicuous and shoulders are absent. The base is flat to slightly convex and the basal margin is rounded. The vesicle surface is ornamented with short spines.

Dimensions: L: 135(136)160µm, Dp: 62(79)95µm, Dc: 40(43)46µm, n = 5.

Remarks and comparison: This species attributed to *Fungochitina* based on the vesicle shape and the spiny ornamentation.

Selected previous stratigraphic record: Caradocian, Shropshire (Jenkins, 1967), southwest Europe (Paris, 1981); Late Ordovician, Morocco (Elaouad-Debbaj, 1984).

Occurrences: Bir Tlacsin Formation, late Hirnantian (Ashgillian).

Fungochitina spinifera Eisenack, 1931

Plate 6, Fig. 5, 6

1962a *Conochitina fungiformis* subsp. *spinifera* - Eisenack, p. 310; Pl. 14:15

Description: *Fungochitina* species with a sub-conical chamber, cylindrical neck that widens slightly towards the straight aperture.The flexure is distinct and absence of shoulders. The base is concave and the basal edge gently rounded, provided with minute, spinose thickenings. The vesicle wall is covered with spinose thickenings.

Dimensions: l: 145(157)168, Dp: 82(88)94, Dc: 33(40)46, n = 5.

Remarks and comparison: Eisenack (1968b) subdivided *Fungochitina fungiformis* into two subspecies. *Fungochitina fungiformis fungiformis* and *Fungochitina fungiformis spinifera.* The former is defined as a smooth form and the latter as a form with minute spines on the basal edge and along the flanks. However, in the revision of *Fungochitina* by Paris *et al.* (1999) these subspecies were elevated to species rank and assigned to different genera; the smooth *fungiformis* to *Saharochitina*, and the spiny *spinifera* to *Fungochitina.*

Occurrences: Bir Tlacsin Formation, late Hirnantian (Ashgillian).

Selected previous stratigraphic record: late Caradocian, Gotland (Eisenack, 1931); Ashgillian (Pushgilian-Cautleyan), UK (Van Nieuwenhove *et al.*, 2006).

Genus *Lagenochitina* Eisenack, 1931 emend. Paris *et al*., 1999

Type species: *Lagenochitina baltica* Eisenack, 1931

Diagnosis: "Lagenochitinidae with an ovoid to cylindrical glabrous chamber" From Paris *et al*., (1999, p. 562).

Remarks: This genus emended by Paris *et al*., (1999) to exclude forms with spherical chambers and transferred to the genus *Sphaerochitina* Eiesnack, 1955a.

Lagenochitina* cf. *avelinoi Lange, 1952

Plate 7, Fig. 1

Description: *Laginochitina* species with elongated ovoid to claviform chamber, cylindrical neck represent about 1/2 to 2/3 of the total vesicle length. The flexure is weakly developed, but the shoulders are absent. The flanks are slightly convex and the base is convex with rounded margins. The vesicle wall is glabrous.

Dimensions: L: 267(271)276µm, Dp: 86(88)90µm, Dc: 52(53)54µm, n = 4.

Remarka and comparison: This species is very similar in morphology to *Lagenochitina avelinoi* Lange, 1952, but it differs in having a much shorter neck and also is smaller in overall size. *Lagenochitina elegans* Beju and Danet 1962 has ovoid chamber and long neck.

Occurrences: Tanezzuft Formation, mid Rhuddanian (Llandovery).

Lagenochitina baltica Eisenack, 1931

Plate 6, Fig. 7

1931 *Lagenochitina baltica* - Eisenack, p. 80; pl. 1, figs. 1-3.
1959 *Lagenochitina baltica* - Eisenack, p. 2; pl. 9, figs. 6, 7.
1965 *Lagenochitina baltica* - Eisenack, p. 121; pl. 9, fig. 1.
1967 *Lagenochitina baltica* - Laufeld, p. 337; fig. 30.
1967 *Lagenochitina baltica* - Jenkins, p. 462; pl. 73, figs. 6-7.
1968 *Lagenochitina baltica* - Eisenack, p. 156; pl. 24, fig. 8.
1984 *Lagenochitina baltica* - Grahn and Bergström, pl. III (H, I).
1985 *Lagenochitina baltica* - Molyneux and Paris, pl. 7, figs. 4.
2005 *Lagenochitina baltica* - Vanmeirhaeghe *et al.,* pl. 2 (A-C)
2005 *Lagenochitina baltica* - Vandenbroucke, p.183, figs. 22 (6, 7, 15), 23(18), 27(9), 29(12, 14, 23)
2005 *Lagenochitina baltica* - Vandenbroucke, figs. 12 (h); fig. 13 (h).
2005 *Lagenochitina baltica* - Vandenbroucke *et al*., fig. 26(h).
2006 *Lagenochitina baltica* Vanmeirhaeghe, pl. II, fig. 16.
2006 *Lagenochitina baltica* Van Nieuwenhove, pl. 1, fig. 5.
2008 *Lagenochitina baltica* - Ghavidel-syooki, pl. VII, fig. 8.

Description: *Lagenochitina* species with flask-shaped vesicle, ovoid chamber and cylindrical neck clearly differentiated from the chamber. The flexure is distinct, but the shoulders are inconspicuous. The base and flanks are convex with rounded basal margin. The vesicle wall is smooth to finely granulate.

Dimensions: L: 160(166)172μm, Dp: 87(98)110μm, Dc: 50(51)52μm, n = 7.

Remarks and comparison: *Lagenochitina capax* Jenkins, 1967 is distinguished in having a greater degree of flexure between the neck and the body of chamber than *Lagenochitina baltica. Lagenochitina prussica* Eisenack, 1931 differs also from *L. baltica* in having a very distinctive flexure and ornamented vesicle wall.

Occurrences: Melez Shugran Formation, late Katian (Ashgillian).

Selected previous stratigraphic record: Caradocian-Ashgillian, Baltoscandia (Grahn, 1982a), UK (Jenkins, 1967), Portugal (Paris, 1979), Canada (Achab, 1977a); Llanvirinian, Newfoundland (Neville 1974; Martin, 1978); Middle Ordovician, USA (Carter and Laufeld, 1975; Grahn and Bergström, 1985); Caradocian, Sweden (Laufeld, 1967); late Caradocian-early Ashgillian, northeast Libya (Molyneux and Paris, 1985); Caradocian-Ashgillian, northern Gondwana domain (Paris, 1990) Cradocian-Ashgillian, Scandinavia (Grahn and Nõlvak, 2007); Katian-Hirnantian, northern Iran (Ghavidel-syooki, 2008), Belgium (Vanmeirhaeghe *et al*., 2005), North England (Vandenbroucke, 2005); Katian-Hirnantian, Turkey (Paris *et al*., 2007); Caradocian, UK (Vandenbroucke *et al.*, 2003, 2005, 2008); Caradocian-Ashgillian, Belgium (Vanmeirhaeghe, 2006); Caradocian-Ashgillian, Morocco (Bourahrouh *et al*., 2004); Katian, Estonia (Hints *et al.,* 2007); Ashgillian, UK (Van Nieuwenhove *et al*., 2006) Ashgillian, UK (Van Nieuwenhove *et al*., 2006) Darrwilian-Ashgillian, China (Wang and Chen, 2004); Hirnantian, Morocco (Le Heron *et al*., 2008).

Lagenochitina* cf. *dalbyensis Laufeld, 1967

Plate 7, Fig. 2

Description: *Lagenochitina* species with ovoid chamber, cylindrlcal neck. The flexure is distinct and the shoulders are inconspicuous. The flanks are convex and the base is flat, has a short and thick mucron. The vesicle wall is perfectly smooth.

Dimensions: L: 171(1178)185µm, Dp: 64(71)78µm, Dc: 48(51)55µm, n = 4.

Remarks and comparison: This species is simillar in morphology to *Lagenochitina dalbyensis* Laufeld, 1967 but it is smaller in overall size and has shorter neck. It is very similar to *Lagenochitina* aff. *dalbyensis* Vandenbroucke, 2005 from the Upper Ordovician of England.

Occurrences: Melez Shugran Formation, early late Katian-late Katian (Ashgillian).

Lagenochitina* cf. *navicula Taugourdeau and Jekhowsky, 1960

Plate 15, Fig. 2

Description: *Lagenochitina* species with a sub-spherical to ovoid chamber, short cylindrical neck. The flexure is weakly developed, but the shoulders are absent. The base and flanks are convex with rounded basal margin. The prosome is present at the base of neck. The vesicle surface is glabrous.

Dimensions: L: 126(151)177µm, Dp: 88(89)91µm, Dc: 44(45)47µm, n = 9.

Remarka and comparison: This species is very similar to *Lagenochitina navicula* Taugourdeau and Jekhowsky 1960, but it differs in having a much shorter neck and almost sub-spherical to ovoid chamber. *Lagenochitina elegans* Beju and Danet 1962 has elongated ovoid chamber and long neck. *Lagenochitina* aff. *navicula* Taugourdeau and Jekhowsky, 1960 reported by Grahn *et al*., (2010) from the Llandovery of northeast Brazil is very similar to this species but it has spherical chamber and well developed of flexure.

Occurence: Tanezzuft Formation, mid Rhuddanian (Llandovery).

Lagenochitina* cf. *nuayyimensis Paris and Al-Hajri, 1995

Plate 15, Figs. 3, 4

Description: *Lagenochitina* species with bell-shaped vesicle, sigmoid flanks tapering towards the aperture. The neck is sub-cylindrical, shorter than the chamber length and gently flaring towards the aperture which has straight to finely denticulate edges. The chamber bottom is conical to oval with rounded basal margins. The vesicle wall is glabrous but irregular, small verrucae occur over the whole vesicle surface.

Dimensions: L: 130(135)140µm, Dp: 55(58)60µm, Dc: 28(30)32µm, n = 3.

Remarks and comparison: The specimens recorded here possess the same morphological characteristics of *Lagenochitina nuayyimensis* Paris and Al-Hajri, 1995, but their neck is shorter and the chamber length is bigger than the topotype material from Rhuddanian of Saudi Arabia (Paris, 1995)

Occurrences: Tanezzuft Formation, Telychian (Llandovery).

Lagenochitina prussica Eisenack, 1931

Plate 6, Figs. 8-10

For synonymy see Elaouad-Debbaj, 1984.
Additional synonymy:
1988 *Lagenochitina prussica* - Grahn, fig. 2-12, 8.
2004 *Lagenochitina prussica* - Bourahouh *et al*., pl. III, figs. 10, 13.
2005 *Lagenochitina prussica* - Vanderbrouke *et al.,* fig. 12, g

Description: *Lagenochitina* species with sub-spherical chamber, neck is sub-cylindrical and clearly differentiated from the chamber. The flexure is distinct and the shoulders are inconspicuous. The base is slightly convex and the flanks are convex with rounded basal margin. The vesicle wall is ornamented with grana.

Dimensions: L: 160(210)260µm, Dp: 130(158)185µm, Dc: 50(63)75µm, n = 8.

Remarks and comparison: *L. prussica* is distinguieshed from *Lagenochitina baltica* Eisenack, 1931 emend. Paris *et al*., 1999 in having a very distinctive flexure and the vesicle wall is ornamented with well developed grana. In addition *Lagenochitina baltica* has more elongated vesicle.

Occurrences: Bir Tlacsin Formation, late Hirnantian (Ashgillian).

Selected previous stratigraphic record: Ashgillian, Baltic (Nölvak, 1980); late Caradocian, Sweden (Laufeld, 1967); Caradocian-early Ashgillian, U.S.S.R (Laufeld, 1971); Caradocian-Ashgillian, Gotland (Grahn, 1982); Ashgillian Morocco (Elaouad-Debbaj, 1984); Onnian-Pushgilian, UK (Vanderbrouk *et al*., 2005); ?late Cautleyan-early Rawtheyan, Belgium (Vanmeirhaeghe, 2006); late Hirnantian, Morocco (Bourahouh *et al.,* 2004), Algeria (Paris *et al*, 2000); late Katian-Hirnantian, Turkey (Paris et al., 2007); mid Katian, Iran (Ghavidel-syooki, 2008); Ashgillian, western Gondwana (Grahn, 2006); Ashgillian, northern Gondwana domain (Paris, 1990); late Katian, Morocco (Le Heron *et al*., 2008); Rawtheyan- Hirnantian, northeast Libya (Paris, 1988); Hirnantian, Latvia (Hints *et al*., 2010).

***Lagenochitina* sp.A**

Plate 7, Fig. 3

Description: *Lagenochitina* species with a sub-spherical to ovoid chamber, neck is cylindrical and comprises more the 1/2 of the total length and slightly widens toward the straight aperture. The flexure is conspicous, but the shoulders are weakly developed. The flanks are convex and the base is flat, which has a short and thick mucron. The vesicle wall is perfectly smooth

Dimensions: L: 160(166)172μm, Dp: 80(93)106μm, Dc: 50(54)58μm, n = 5

Remarks and comparison: *Lagenochitina tumida* Umnova, 1969 differs from this species in having the neck comprising up to the third of total length. *Lagenochitina dalbyensis* Laufeld, 1967 also differs from this species in having an ovoid chamber.

Occurrences: Melez Shugran Formation, early late Katian-late Katian (Ashgillian).

***Lagenochitina* sp.B**

Plate 7, Figs. 4-6

Description: *Lagenochitina* species with sub-spherical chamber and sub-cylindrical neck clearly differentiated from the chamber. The flexure is distinct, and the shoulders are inconspicuous. The base is slightly convex and the flanks are convex with rounded basal margin. The vesicle wall is foveolate.

Dimensions: L: 230(242)253µm, Dp: 170(186)202µm, Dc: 80(83)85µm, n = 8

Remarks and comparison: This species is distinguished from *Lagenochitina prussica* Eisenack, 1931, and *Lagenochitina baltica* Eisenack, 1931 emend. Paris *et al*., 1999 in having a foveolate vesicle wall rather than smooth to finely granulate in *Lagenochitina baltica*, and well developed grana in *Lagenochitina prussica. Lagenochitina deunffi* Henry *et al.* 1974 has no real ornamentation on the surface but it has small cups.

Occurrences: Bir Tlacsin Formation, late Hirnantian (Ashgillian).

Genus ***Laufeldochitina*** Paris, 1981

Type species: *Cyathochitina stentor* Eisenack, 1937.

Diagnosis: "Conochitinidae with a claviform, glabrous chamber and a complete, flaring membranous carina, below the margin." Diagnosis of Paris *et al*. (1999).

Discussion: This genus is characterized by its claviform chamber. Similar forms with cylindrical chamber are accommodated in the genus *Tanuchitina* Jansonius, 1964 emend. Paris *et al*., 1999.

***Laufeldochitina* sp. A**

Plate 7, Fig. 7

Description: *Laufeldochitina* species with claviform chamber, inconspicuous flexure and slightly convex flanks. The neck is short and cylindrical. A membranous carina is developed below the margin. The vesicle wall is glabrous with small folds.

Dimensions: L: 165(173)180µm, Dp: 50 (55)60µm, Dc: 30(33)35µm, n = 4.

Remarks and comparison: This species is attributed to *Laufeldochitina* Paris, 1981 based on the chamber shape. The species of *Tanuchitina* Jansonius, 1964 emend. Paris *et al*., 1999 differentiated from this species in having a cylindrical chamber.

Occurrences: Bir Tlacsin Formation, late Hirnantian (Ashgillian).

Genus ***Pistillachitina*** Taugourdeau, 1966

Type species: *Rhabdochitina pistillifrons* Eisenack, 1939.

Diagnosis: "Conochitinidae with a glabrous cylindrical chamber ended by a lenticular to hemispherical widening " Paris *et al*., (1999, p. 559).

Remarks: The presence of a widened base differentiates this genus from the genus *Rhabdochitina*. Genus *Euchonochitina* differs in having conical chamber and the genus C*honochitina* has conical to claviform chamber with a mucron.

***Pistillachitina* cf. *pistilifrons* Eisenack, 1939**

Plate 8, Fig. 1

Description: *Pistillachitina* species with sub-cylindrical vesicle with a conically widened basal part. The neck is cylindrical and becomes wider towards the aperture, with inconspicuous flexure and shoulders. The vesicle wall is perfectly smooth.

Dimensions: L: 168(189)210μm, Dp: 45(61)78μm, Dc: 42(47)53μm, n = 5.

Remarks and comparison: The specimens recorded here are very similar in morphology and size to *Pistillachitina* cf. *pistillifrons* from Portugal illustrated by Paris (1981) and from Iran illustrated by Ghavidel-syooki and Winchester-Seeto (2002). It differs from *Pistillachitina pistilifrons* Eisenack, 1939 in having smaller size and proportionally shorter neck. *Belonechitina capitata* Eisenack, 1962 has spines in the basal edge.

Occurrences: Melez Shugran Formation, early late katian-late Katian (Ashgillian).

Genus ***Plectochitina*** Cramer, 1964

Type Species: *Plectochitina carminae* Cramer 1964.

Diagnosis: "Lagenochitinidae with a conical to ovoid chamber provided with a crown of cell like processes" Paris *et al*., (1999, p. 563).

Remarks: The nature of the processes differentiates this genus from other similar genera. Genus *Clathrochitina* Eisenack, 1959b, has anastomosed processes and the genus *Ancyrochitina* Eisenack, 1955a, has a crown of non anastomosed hollow processes.

***Plectochitina* cf. *carminae* Cramer, 1964**

Plate 15, Fig. 9

Description: *Plectochitina* species with cylindro-conical chamber with a concave base. The flexure is conspicuous, but the shoulders are weakly developed or slightly conspicuous. The basal margin is rounded with spongy anastomosing processes at the edge. The neck is cylindrical and slightly widens towards the aperture, and represents about 1/2 of the total vesicle length. The vesicle wall is covered by simple spines and hair like spine ornamentation. The anastomosing processes has a network pattern which varies from species to species.

Dimensions: L: 82(88)94 µm, Dp: 68(70)72 µm, Dc: 32(36)41 µm, n = 5.

Remarks and comparison: This species is similar in morphology to *Plectochitina carmina* Cramer, 1964, but it differs in having shorter neck and the vesicle wall covered by simple and hair like spine ornamentation. The later differs also in having processes at basal margin that are long, intricately anastomosing and forming a star-like net. *Plectochitina* cf. *carmina* reported by Ghavidel-syooki (2004) from the Llandovery of southeast Iran differs from this species in having longer neck ornamented with simple spines.

Occurrence: Tanezzuft Formation, late Rhuddanian-Aeronian (Llandovery).

Plectochitina* cf. *kazhdumiensis Ghavidel-Syooki and Winchester-Seeto, 2004

Plate 7, Fig. 10

Description: *Plectochitina* species with conical-ovoid chamber with convex base. The basal margin is rounded, providing with 2-4 long and simple processes tapering distally. The neck is cylindrical, widens slightly towards the aperture. The flexure is conspicuous, but the shoulders are weakly-developed. The vesicle wall is covered with small granules.

Dimensions: L: 128(130)132µm, Dp: 82(86)89µm, Dc: 40(41)42µm, n = 5.

Remarks and Comparison: This species is very similar to *Plectochitina kazhdumiensis.* Ghavidel-syooki and Winchester-Seeto, 2004, but the later has longer processes with nodular structure.

Occurrence: Tanezzuft Formation, Aeronian (Llandovery).

Plectochitina* cf. *nodifera Nestor, 1980a

Plate 15, Fig. 5

Description: *Plectochitina* species with conical chamber, neck is cylindrical to sub-cylindrical and become slightly wider towards the aperture, with indistinct collarette. The base is flat to convex and rounded basal edge carrying numerous nodular processes. The processes ends cannot be established due to poor preservation. The flexure is conspicuous, but the shoulders are inconspicuous to absent. The vesicle wall is smooth.

Dimensions: L: 134(136)138µm, Dp: 65(72)78µm, Dc: 38(42)45µm, n = 5.

Remarks and comparison: This species is very similar to *Plectochitina nodifera* Nestor, 1994, but the later has numerous nodular processes, which curve away from the aperture, they are narrow distally to a simple point or may be branched.

Occurrences: Tanezzuft Formation, mid Rhuddanian (Llandovery).

Plectochitina paraguayensis Wood and Miller, 1991

Plate 7, Fig. 8; Plate 15, Figs. 6

1991 *Plectochitina paraguayensis* - Wood and Miller, p. 186-188; pl. 1, figs1-5; pl. 2, figs. 1-5
1995 *Plectochitina paraguayensis* - Paris *et al.,* pl. 1, fig. 11.
2002 *Plectochitina paraguayensis* - Ghavidel-syooki, pl. 2, figs. A-C, H.
2006 *Plectochitina paraguayensis* - Ghavidel-syooki, pl. 3, fig. 1
2007 *Plectochitina paraguayensis* - Ghavidel-syooki and Vecoli, P. 180; pl. II, fig. 3; pl. III, fig.1.

Description: *Plectochitina* species with conical to ovoid chamber, neck is cylindrical to sub-cylindrical and become wider towards the aperture. The collarette is distinct and provided with small simple spines. The base is convex and broadly rounded basal edge carrying 2-4 long spongy processes. The flexure is conspicuous, but the shoulders are weakly developed. The prosome is present at the neck base. The vesicle wall is smooth or finely granulate.

Dimensions: L: 119(142)165µm, Dp: 60(72)85µm; Dc: 40(58)69µm, n = 9.

Remarks and comparison: This species differs from *Plectochitina nodosa* (Taugourdeau and de Jekhowsky) Cramer, 1964 in lacking nodose processes. *Plectochitina spongiosa* (Achab) Molyneux and Paris, 1985 their processes have multiple bases and anastomose distally. *Plectochitina pseudoagglutinans* (Taugourdeau) Cramer, 1964 has more processes that are similar in shape to those in *P. paraguayensis.*

Occurrences: Tanezzuft Formation, mid Rhuddanian- early Aeronian (Llandovery).

Selected previous stratigraphic record: early and mid Llandovery, Saudi Arabia (Paris *et al*., 1995), Aeronian–Telychian, Paraguay (Wood and Miller, 1991), Rhuddanian-Aeronian, Iran (Ghavidel-Syooki, 2000a; Ghavidel-syooki, 2002; Ghavidel-syooki and Winchester- Seeto, 2004; Ghavidel-syooki, 2006; Ghavidel-syooki and Vecoli, 2007), early and middle Llandovery, global (Verniers *et al*., 1995); Aeronia-Telychian, western Gondwana (Grahn, 2006).

Plectochitina pseudoagglutinans Taugourdeau, 1963

Plate 7, Fig. 9; Plate 15, Fig. 7

1963 *Ancyrochitina fragilis pseudoagglutinans* - Taugourdeau, pl. I, fig. 5-6
1967 *Plectochitina pseudoagglutinans* - Cramer, p. 125-127; pl. V., figs 145-146
1985 *Plectochitina pseudoagglutinans* - Hill *et al*., pl. 12, figs. 5a-b; pl. 13, fig 8
2001 *Plectochitina pseudoagglutinans* - Ghavidel-syooki, fig. 3 (A-B), (D-F).
2006 *Plectochitina pseudoagglutinnans* - Ghavidel-syooki, pl. 1 fig. 5; pl. 3, figs.1, 3-4 and 6.
2007 *Plectochitina pseudoagglutinans* - Ghavidel-syooki and Vecoli, pl. II, fig. 1, 2 and 4.
2013 *Plectochitina pseudoagglutinans* - Butcher, p. 25, 26; pl. III, fig. 7.

Description: *Plectochitina* species with conical to cylindro-conical chamber, neck is cylindrical to sub-cylindrical and becomes slightly wider towards the aperture, with indistinct collarette. The base is convex with rounded basal edge carrying 4-8 long spongy processes frequently broken and distally resemble knobs or tiny expansions. The flexure is conspicuous, but the shoulders are weakly developed. The vesicle wall is smooth to finely granulate.

Dimensions: L, 108(127)145μm, Dp: 43(56)68μm; Dc: 35(53)70μm, n = 8

Remarks and comparison: *Plectochitina nodifera* Nestor, 1994 has processes with irregular thickening, which are nodular in proximal part and bifurcate in distal end.

Occurrence: Tanezzuft Formation, late Rhuddanian- early Telychian (Llandovery).

Selected previous stratigraphic record: Llandovery, northern Africa (Taugourdeau *et al.* 1967), Spain (Cramer 1966, Preiwalder 1997), late Aeronian-mid Telychian, global (Verniers *et al.* 1995); late Aeronian-early Telychian Saudi Arabia (Paris *et al.* 1995), mid-late Llandovery, Libya (Hill and Paris 1985; Paris, 1988), Aeronian-Telychian, Iran (Ghavidel-Syooki 2001, 2006; Ghavidel-syooki and Vecoli, 2007); Rhuddanian, southwest Libya (Butcher, 2013).

Plectochitina* cf. *sylvanica Jenkins 1970

Plate 15, Fig. 8

Description: *Plectochitina* species with cylindrical-conical chamber, neck is cylindrical to sub-cylindrical and become slightly wider towards the aperture. The collarette is indistinct. The base is convex and broadly rounded basal edge carrying 2-4 long spongy processes, of uniform thickness and texture. The flexure and the shoulders are weakly developed. The prosome is present at the neck base. The vesicle wall is smooth.

Dimensions: L: 120(123)125**,** Dp: 45(53)60µm; Dc: 25(26)28µm, n = 3.

Remarks and comparison: The specimens recorded here possess the same morphological characteristics of *P. sylvanica* Jenkins 1970 Paris and Al-Hajri, 1995, but it differs in having few processes. *P. sylvanica* Jenkins 1970 has 8-16 long processes that are commonly anastomosing, occasionally discrete for their full length and connected at their tips by a continuous ring.

Occurrence: Melez Shugran Formation, late Katian (Ashgillan).

***Plectochitina* spp.**

Plate 8, Fig. 2

Description: *Plectochitina* species with conical-ovoid chamber with flat or slightly convex base. The basal margin is rounded, with 6-8 simple, not branched, irregular processes and frequently broken. The neck is cylindrical, slightly wider towards the aperture provided with small simple spines or straight lips, flexure is conspicuous, but the shoulders are weakly-developed. The vesicle wall is granulate.

Dimensions: L: 86(103)120µm, Dp: 86(92)98µm, Dc: 40(42)44µm, n = 12.

Remaarks and comparison: The specimens recorded here are attributed to *Plectochitina* based on the occurrence of more or less cell-like processes which have a spongy appearance. It is distinguished from *Plectochitina nodifera* Nestor, 1994, which has processes with irregular thickening; they are nodular in the proximal part and bifurcate at their distal end.

Occurrences: Tanezzuft Formation, late Rhuddanian-early Telychian (Llandovery).

Genus ***Pterochitina*** Eisenack, 1955

Type species: *Bion perivelatum* Eisenack, 1937 (holotype lost, neotype; Eisenack 1955).

Diagnosis: "Desmochitinidae with a lenticular to spherical, glabrous chamber with membranous carinae." From Paris *et al*., (1999, p. 565).

Remarks: The genus *Cutichitina* Achab, Asselin and Soufiane, 1993 is distinguished from this genus in having an ovoid chamber enveloped by a membranous sleeve. Also the genus *Elatachitina* Poumot, 1968 is distinguished in having larger size and conical vesicle.

Pterochitina deichaii Taugourdeau, 1963

Plate 8, Fig. 3; Plate 16, Figs. 1, 2

1963 *Pterochitina deichaii* Taugourdeau, p. 138;pl. 2, figs. 37-38.

1985 *Pterochitina deichaii* Hill *et al*., pl.13, fig. f.

2005 *Pterochitina deichaii* Grahn, pl.VII, fig. 13.

Description: *Pterochitina* species with a flat lenticular to spherical chamber and short membranous collarette.The vesicle wall is smooth with membranous carinae is situated below the equatorial plane of the vesicle.

Dimensions: L: 85 (118) 150µm including membranous carinae, n = 13

Remarks and comparison: *P. deichaii* is distinguished from *Pterochitina perivelata* Eisenack, 1937 in having a membranous carina situated below the equatorial plane of the vesicle, while the later has a membranous carinae situated above the equatorial plane of the vesicle,

Occurrence: Tanezzuft Formation, late Rhuddanian- Telychian (Llandovery).

Selected previous stratigraphic record: Llandovery, northeast Libya (Hill *et al*., 1985); Telychian Sheinwoodian, Brazil (Grahn, 2005), western Gondwana (Grahn, 2006) Rhuddanian-Telychian, Saudi Arabia (Paris *et al.,* 1995).

Genus ***Rhabdochitina*** Eisenack, 1931

Type species: *Rhabdochitina magna* Eisenack, 1931.

Diagnosis: “Conochitinidae with a glabrous elongate cylindrical vesicle.” From Paris *et al*., (1999, p. 561).

Remarks: A mucron may occur in this genus (Paris *et al*., 1999). Genus *Pistillachitina* Taugourdeau, 1966 is differentiated from this genus in having a widened base. Genus *Clavachitina* Taugourdeau, 1966 has a claviform chamber.

Rhabdochitina gracilis Eisenack, 1962

Plate 8, Figs. 4, 5

For synonymy see Grahn (1982a).
Additional synonymy:
1984 *Rhabdochitina gracilis* - Elaouad-Debbaj, p. 60; pl. 2, fig. 1, 2 and 5.
2008 *Rhabdochitina gracilis* - Ghavidel-syooki, pl. VII, fig. 3.

Description: *Rhabdochitina* species with a long sub-cylindrical vesicle, which has straight flanks tapering slightly towards the straight aperture. The flexure and shoulders are absent. The base is convex with a broadly rounded basal margin and has a short and thick mucron.The vesicle wall is perfectly smooth.

Dimensions: L: 545(567)590µm, Dp: 45(49)54µm, n = 10

Remarks and comparison: *Rhabdochitina magna* Eisenack, 1931 differs from *R. gracilis*, in having more cylindrical vesicle and the base is generally flat.

Occurrence: Melez Shugran, Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian).

Selected previous stratigraphic record: Ashgillian, Morocco (Elaoud-Debbaj, 1984), western Gondwana (Grahn, 2006); Katian, northern Iran (Ghavidel-syooki, 2008) Caradocian, Sweden (Grahn, 1997); Llanvirnian- Hirnantian, Scandinavia (Grahn and Nõlvak, 2007); Caradocian, Belgium (Vanmeirhaeghe, 2007); Caradocian-Ashgillian, Morocco (Bourahrouh *et al*., 2004); Katian, Estonia (Hint *et al.,* 2007); Hirnantian, western Latvia (Hints *et al.,* 2010) Hirnantian, Baltic (Kaljo *et al.,* 2008). Ashgillian, UK (Van Nieuwenhove *et al*., 2006) Darriwilian, Estonia (Tammekänd *et al*., 2010). Darriwilian-Ashgillian, China (Wang and Chen, 2004).

Rhabdochitina magna Eisenack, 1931

Plate 7, Fig. 6

For synonymy see Grahn (1980).

Additional synonymy:

1981 *Rhabdochitina magna* - Paris, p. 197; pl. 13, fig. 19.
1981 *Rhabdochitina magna* - Grahn, p. 45; fig. 16 (A, B).
1982 *Rhabdochitina magna* - Grahn, p. 45; fig. 16 (A, B).
1984 *Rhabdochitina magna* - Elaouad-Debbaj, p. 61; pl. 1, fig. 24.
1988 *Rhabdochitina magna* - McClure, pl. II, figs. 9-11.
1995 *Rhabdochitina magna* - Achab and Asselin, pl. IV, fig. 8.
1998 *Rhabdochitina magna* - Siesser *et al*., pl. I, figs. 12.
2004 *Rhabdochitina magna* - Vandenbroucke , pl. I, figs. 12, 13
2006 *Rhabdochitina magna* - Quintavalle and Playford, p. 104, 105; pl. , fig. 8; pl. 3, fig. 6.
2007 *Rhabdochitina magna* Vanmeirhaeghe, pl.1, fig. 17.
2010 *Rhabdochitina magna* - Tammekänd *et al*., fig. 3,(v)

Description: *Rhabdochitina* species with a long cylindrical vesicle, which has straight flanks widened slightly at the straight aperture. The flexure and shoulders are absent. The base is general flat with a rounded basal margin.The vesicle wall is perfectly smooth.

Dimensions: L: 460(472)485µm, Dp: 65(86)107µm, n = 15.

Remarks and comparison: *Rhabdochitina gracilis* Eisenack, 1962 differs from *R. magna* Eisenack, 1931 in having a sub-cylindrlcal vesicle and convex base, which has a short and thick mucron with a broadly rounded basal edge

Occurrence: Melez Shugran, Bir Tlacsin formations early late Katian-Hirnantian (Ashgillian).

Selected previous stratigraphic record: early Llanvirian-late Ashgillian, Estonia (Eisenack 1962a, 1965, 1968a, 1968b); early Llandello, UK (Jenkins 1967); Ashgillian, Canada (Achab 1977, 1978, 1995); late Arenigian- Ashgillian, Sweden (Grahn , 1980, 1981, 1982); Llanvirinian, Saudi Arabia (McClure, 1988); Ashgillian, Morocco (Elaouad-Debbaj, 1984); Late Ordovician, USA (Siesser *et al*., 1995); Darrwillian, Newfoundland (Albani, 2001); Mid Ordovician, Australia (Quintavalle and Playford, 2006); Llanvirnian- Hirnantian, Scandinavia (Grahn and Nõlvak, 2007) Hirnantian, Turkey (Paris *et al*., 2007); Ashgillian, UK (Vandenbroucke *et al,* 2005); Late Ordovician, Sweden (Vandenbroucke*,* 2004); Caradocian, UK (Vandenbroucke *et al*., 2008); Caradocian, Belgium (Vanmeirhaeghe, 2007); Caradocian-Ashgillian, Morocco (Bourahrouh *et al*., 2004); Katian, Estonia (Hint *et al.,* 2007); Hirnantian, western Latvia (Hint *et al.,* 2010) Ashgillian, UK (Van Nieuwenhove *et al*., 2006) Darriwilian, Estonia (Tammekänd *et al*., 2010).

Rhabdochitina turgida Jenkins, 1967.

Plate 8, Fig. 7

1967 *Rhabdochitina turgida* - Jenkins, p. 467, pl. 74, figs.16–19.
1974 *Rhabdochitina turgida* - Neville, p. 202, pl. 7, fig. 1–11, 15.
1985 *Rhabdochitina turgida* - Zhen, p. 378–379, pl. 1, figs. 20, 21.
1986a *Rhabdochitina turgida* - Achab, p. 289, pl. 2, figs. 9–11.
1996 *Rhabdochitina turgida* - Chen *et al*., p. 206, pl. 1, figs.11

1998 *Rhabdochitina turgida* – Siesser *et al*., pl. 2, figs.4.
2009 *Rhabdochitina turgida* - Chen *et al.,* p. 320; pl. III, figs.1, 6–7; pl. IV, fig. 6.

Description:- *Rhabdochitina* species with stout, swollen cylindrical vesicle, neck undifferentiated, absence of flexure and shoulder. The base is convex to flat with a rounded basal edge. The vesicle wall is perfectly smooth.

Dimensions: L: 231(241)252µm, Dp: 68(70)72µm, Dc: 62(65)68µm, n = 8.

Remarks and comparison: *Rhabdochitina striata* Eisenack, 1958b differs from this species in having longitudinal striation. *Rhabdochitina usitata* Jenkins, 1967 differs also in having hemispherical base with a rounded basal edge and it shows a scar of attachement seen as a stout process in the center of the base.

Occurrence: Melez Shugran and Bir Tlachine formations, early late Katian-Hirnantian (Ashgillian).

Selected previous stratigraphic record: Llanvirnian-Caradocian, Shropshire (Jenkins, 1967); Llanvirnian, western Newfoundland (Neville, 1974), Canada (Achab, 1986a); Caradocian, USA (Siesser *et al.,* 1998). Darriwilian, China (Chen *et al*., 1996, 2009).

Rhabdochitina usitata Jenkins, 1967

Plate 16, Fig. 3

1967 *Rhabdochitina - usitata* - Jenkins, p. 469; pl. 74, figs. 13-15, 20; pl. 75, fig. 1
1988 *Rhabdochitina - usitata* - McClure, pl. IV, figs. 4.
1998 *Rhabdochitina - usitata* - Siesser *et al*., pl. 2, figs.10, 11.
1984 *Rhabdochitina - usitata* - Achab, p.138, pl. 4, Figs. 1, 2, 5.
2001 *Rhabdochitina - usitata* - Albani *et al*., pl. 2, Fig. 8.

2006 *Rhabdochitina - usitata* - Quintavalle and Playford, p. 104, pl. 3, Fig. 9.
2006 *Rhabdochitina - usitata* - Ghavidel-syooki, pl. V, fig. 9.
2009 *Rhabdochitina - usitata* - Chen *et al.,* p. 320; pl. III, fig. 4.

Description:- *Rhabdochitina* species with stout, swollen cylindrical vesicle, neck undifferentiated and absence of flexure and shoulders. The base is hemispherical with a rounded basal edge and it shows scar of attachment of remaining stout process in the centre of the base. The aperture is straight. The vesicle wall is perfectly smooth.

Dimensions: L: 262(420)578µm, Dp: 85(107)130µm, Dc: 42(67)93µm, n = 10.

Remarks and comparison: *Rhabdochitina gallica* Taugourdeau*,* 1961 differs from this species in having flat base. *Rhabdochitina turgida* Jenkins, 1967 also differs in having a flat to concave base. It differs from *Rhabdochitina magna* in having a stout, swollen cylindrical vesicle and smaller in overall size.

Occurrence: Melez Shugran and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian).

Selected previous stratigraphic record: Caradocian-Ashgillian, Saudi Arabia (McClure, 1988); Llanvirnian-Caradocian, Shropshire (Jenkins, 1967), Anticosti Island (Achab, 1984); Caradocian, USA (Siesser *et al.,* 1998); Llanvirnian, Newfoundland (Neville, 1974; Albani *et al*., 2001), Australia (Quintavalle and Playford, 2006), Katian, northern Iran (Ghavidel-Syooki, 2008); Dapingian–Darriwillian, China (Chen *et al.*, 2009).

Genus ***Siphonochitina*** Jenkins, 1967

Type species: *Siphonochitina formosa* Jenkins, 1967

Diagnosis: "Conochitinidae with a claviform to cylindrical chamber with membranous bulb." From Paris *et al*., (1999, p. 561).

Discussion: The genus *Eremochitina* Taugourdeau and de Jekhowsky, 1960 differs from this genus in having a claviform chamber and is characterized by a tubular copula.

Siphonochitina* cf. *formosa Jenkins, 1967

Plate 16, Fig. 4

Description: *Siphonochitina* species with conical to claviform chamber, tapering flanks and convex base. The neck is sub-cylindrical with flaring collarette and straight aperture. A thin, broken and short membranous bulb is developed at the base of the chamber. The vesicle wall is smooth.

Dimensions: L: 300(305)310µm, Dp: 55(58)60µm, Dc: 40(43)45µm, n=4

Remarks and comparison: The membranous bulb may be twisted and broken. Species recorded by Jenkins (1967) have a longer membranous bulb than these recorded in this study.

Occurrences: Hawaz Formation, mid-late Darriwilian (Llanvirnian).

Genus ***Sphaerochitina*** Eisenack 1955 emended.

Paris, Grahn, Nestor and Lakova, 1999

Type species: *Lagenochitina sphaerocephala* Eisenack 1932.

Diagnosis: "Lagenochitinidae with a glabrous chamber." From Paris *et al*., (1999, p. 562).

Remarks: Paris *et al*., (1999) emended this genus to exclude spiny forms (spines exceeding two microns) as well as the forms with conical or lenticular chambers.

Sphaerochitina* cf. *palestinaense Grahn *et al*., 2005

Plate 16, Fig. 5

Description: *Sphaerochitina* species with spherical to sub-spherical chamber, neck is cylindrical, long and represents about 2/3 of the total vesicle length and flares in the upper third part to form large collarette with straight lips. The flanks and the base are broadly convex with rounded basal margins. The flexure is conspicuous, but the shoulders are weakly-developed. The neck and shoulder are glabrous while the chamber is ornamented with minute tubercles. The prosome is present.

Dimensions: L: 172(181)190µm, Dp: 72(75)78µm, Dc: 42(45)48µm, n = 6.

Remarks and comparison: *Sphaerochitina palestinaense* Grahn, De Melo and Steemans, 2005 differs from this species in having a longer neck and pronounced collarette.

Occurrence: Melez Shugran, early late Katian-late Katian (Ashgillian).

Sphaerochitina* cf. *silurica Grahn *et al.,* 2000

Plate 8, Fig. 8

Description: *Sphaerochitina* species with a spherical to ovoid chamber, cylindrical neck and flaring collarette with straight or finely denticulate lips. The neck represents more than 1/2 of the total vesicle length. The flanks and the base are convex with broadly rounded margins. The shoulders are inconspicuous, while the flexure is conspicuous or weakly developed. The vesicle surface is perfectly smooth.

Dimensions: L: 167(188) 210µm. Dp: 75(78) 82µm, Dc: 44(48)52µm, n = 8.

Remarks and comparison: *Sphaerochitinas silurica* Grahn *et al.,* 2000, has a vesicle wall provided with well developed tubercles. *Sphaerochitina sphaerocephala* Eisenack, 1932 differs from this species in having a chamber wall covered with minute tuberules. *Sphaerochitina solutidina* Paris, 1988 has a vesicle wall provided with tuberules and has a shorter neck.

Occurrence: Tanezzuft Formation, late Rhuddanian-late Telychian (Llandovery).

***Sphaerochitina* sp. A**

Plate 16, Fig. 6

Description: *Sphaerochitina* species with spherical to ovoid chamber, cylindrical neck represents about 1/2 of the total vesicle length, and does not flare towards the aperture. The flanks and the base are convex with rounded margins; flexure and shoulders are weakly-developed.The vesicle surface is glabrous.

Dimensions: L: 142(148)154 µm, Dp: 68(75)83 µm, 34(36)38 µm, n = 4.

Remarks and comparison: The chamber shape and broadly rounded base distinguishes this species from *Lagenochitina.* It differs from other *Sphaerochitina* species in a having straight collarette.

Occurrence: Tanezzuft Formation, late Rhuddanian-Aeronian (Llandovery).

Sphaerochitina **sp. B**

Plate 16, Fig. 7

Description: *Sphaerochitina* species with a spherical to ovoid chamber. The neck is sub-cylindrical, represents about 1/2 of the total vesicle length and flares in the upper third part to form a large collarette with straight or finely denticulate lips. The flexure is conspicuous, but the shoulders are weakly developed. The vesicle surface is covered with minute densely distributed tubercles increasing in density towards the aperture. The prosome is present closes the neck near the chamber-neck contact.

Dimensions: L: 158(160)162µm, Dp: 78(80)83µm, Dc: 58(61)64µm, n = 8

Remarks and comparison: *Sphaerochitina sphaerocephala* Eisenack, 1932 differs from this species in having a more elongated neck and glabrous vesicle wall.

Occurrence: Melez Shugran Formation, early late Katian-late Katian (Ashgillian).

Genus ***Spinachitina*** Schallreuter, 1963 emend. Paris, Grahn, Nestor and Lakova, 1999

Type species: *Conochitina cervicornis* Eisenack, 1931.

Diagnosis: "conochitinidae with a conical to cylindrical chamber bearing a crown of processes."From Paris (1999, p. 562).

Remarks: This genus has been emended by several authors (e.g. Eisenack, 1955; Taugourdeau, 1966; Eisenack, 1968; Paris, 1981). Later Paris *et al*., 1999, restrict this genus to the forms without a conspicuous flexure.

Spinachitina bulmani Jansonius, 1964

Plate 16 , Fig. 8

For synonymy see Elaouad-Debbaj (1984).

Additional synonymy:

1985 *Spinachitina bulmani* - Molyneux and Paris, pl. 5, fig. 1a-b.

2002 *Spinachitina bulmani* - Ghavidel-syooki and Winchester-Seeto, p. 92; pl. IV, figs. 7, 8.

2005 *Spinachitina bulmani* - Vandenbroucke, p. 174; pl. 10, 4; pl. 11, 7-18, 20, 22; pl. 13, 7-13, 9; pl. 28, 17; pl 30, 3.

2007 *Spinachitina bulmani* - Vanmeirhaeghe, pl. 1, figs. 14.

2008 *Spinachitina bulmani* - Ghavidel-syooki, pl. IV, figs. 7.

2011 *Spinachitina bulmani* - Ghavidel-syooki, pl. VII, figs. 7.

Description: *Spinachitina* species with sub-conical chamber, with a weakly developed flexure and sometimes distinct but usually inconspicuous shoulders. The neck is sub-cylindrical and widening slightly towards the aperture which is straight. The flanks are straight, slightly convex and the base is flat with slightly rounded basal margin bearing numerous small, simple spines and fewer large spines, but most are poorly preserved. The prosome is generally contracted at the base of the neck. The vesicle wall is smooth.

Dimensions: L: 120(136)152µm; Dp: 50(60)70µm, Dc: 40(44)48 µm, n = 5.

Remarks and comparison: *Spinachitina oulebsiri* Paris *et al*., 2000 differs from this species in having a longer conical vesicle, straighter flanks and it has only 20 spines attached to its margin. *Spinachitina fossensis* Vanmeirhaeghe and Verniers, 2004 differs in overall size and in having an aperture surrounded by a flaring collarette and lips that can be denticulate or bearing spines. *Spinachitina multiradiata,* Eisenack, 1959, has concave flanks below the neck and has a longer neck.

Occurrence: Memouniat Formation, early Hirnantian (Ashgillian).

Selected previous stratigraphic record: early Caradocian, Scotland and Shropshire (Jansonius, 1964; Jenkins, 1967); Ashgillian, Morocco (Elaouad-Debbaj, 1984), Anticosti (Achab, 1978), Norway (Grahn *et al*., 1994), Libya (Molyneux and Paris, 1985; Paris, 1988) , UK (Vandenbroucke, 2005); Caradocian- early Ashgillian, Iran (Ghavidel-syooki and Winchester-Seeto, 2002); Sandbian-Katian, Belgium (Vanmeirhaeghe, 2007); Katian-Hirnantian, Iran (Ghavidel-syooki, 2008, 2011).

Spinachitina fossensis Vanmeirhaeghe, 2004

Plate 9, Figs. 11, 12

2004 *Spinachitina fossensis* - Vanmeirhaeghe, p. 263; pl. I(a–d, j, k), pl, II (k).
2005 *Spinachitina fossensis* - Vanmeirhaeghe, p. 178; pl. 24(9), pl, 24(15).

Description: *Spinachitina* species with sub-conical chamber, with a weakly developed flexure and sometimes distinct but usually inconspicuous shoulders. The neck is sub-cylindrical and widening slightly towards the aperture which surrounded with a flaring collarette and lips that can be denticulate or bear spines. The flanks are slightly convex and the base is flat with rounded basal margin bearing a numerous small, simple spines. The wall is smooth to fine granulate.

Dimension: L: 140(149)158µm, Dp: 65(73)82µm, Dc: 42(46)50µm, n = 2.

Remarks and comparison: This species differs from *Spinachitina bulmani* Jansonius, 1964 in having an aperture surrounded by a flaring collarette and lips that can be denticulate or spinose. *Spinachitina multiradiata* Eisenack, 1959, has concave flanks below the neck and a longer neck. *Spinachitina oulebsiri* Paris *et al*., 2000, has straighter flanks and has only twenty spines attached to its margin.

Occurrence: Melez Shugran Formation, late Katian (Ashgillian).

Selected previous stratigraphic record: Ashgillian, Belgium (Vandenbroucke, 2004), UK (Vandenbroucke, 2005).

Spinachitina fragilis Nestor, 1980a

Plate 9, Fig. 1, 2

For synonymy see Butcher (2009).

Additional synonymy:

2009 *Spinachitina fragilis* – Butcher, p. 86; pl. I, figs. 3-6.

2012 *Spinachitina fragilis* – Paris *et al*., pl. X, figs. 1a-b, 3, 4, 5a-b.

Description: *Spinachitina* species with conical chamber, sub-cylindrical neck. The flexure is inconspicuous to slightly weakly developed, absence of shoulders. The flanks are slightly convex and the base is flat to concave with rounded to sub-rounded basal margin bearing a crown of around twenty or more short, simple spines, which are fragile and often broken. The wall is smooth or glabrous.

Dimensions: L: 260(275)289µm, Dp: 86(93)101µm, Dc: 53(57)61µm, n = 10.

Remarks and comparison: Butcher (2009) discussed in detail the systematic position and synonymy of *Spinachitina fragilis*, and included within the synonymy *Spinachitina oulebsiri* Paris *et al*., 2000, on the basis of a detailed biometric study of the type material and previous records of both species in the literature. However, this synonymy creates biostratigraphical difficulties, as both species are index species for chitinozoan biozones, the former being regarded as latest Ordovician (Hirnantian), and the latter as earlist Silurian (Rhuddanian). Both biozones are commonly cited in the literature (e.g. Gradstein *et al.,* 2004). According to Paris *et al*., (2000) *Spinachitina oulebsiri* could represent an early stage of the *Spinachitina fragilis* lineage. This lineage is characterised by the increase of the vesicle’s length, by a progressive differentiation of the flexure, and by the development of a crown of spines on the margin whilst the diameter remains more or less stable. Vandenbroucke *et al*. (2009) also recognized the objective difficulties in differentiating species within the *Spinachitina oulebsiri - Spinachitina fragilis* lineage and decided to retain the two species separately, pending more comprehensive analyses. They considered the split between the two morphotypes as being supported by subtle differences *S. oulebsiri* has conical spines, whereas *Spinachitina fragilis* has more cylindrical spines. Another difference concerns the width of the chamber and the vesicle length: the holotype of *Spinachitina fragilis* is more slender than specimens assigned to *Spinachitina oulebsiri* here, which has a more conical chamber and a stouter general appearance. As stated by Butcher (2010), Delabroye and Vecoli (2010) and Ghavidel-syooki *et al.,* (2011), that the taxonomy of *Spinachitina* around the Ordovician–Silurian boundary is in urgent need of revision. The author herein strongly agrees with this statement and follows the discussions and definition of *Spinachitina fragilis* as presented by Butcher (2009), until such taxonomic matters can be conclusively resolved.

Occurrence: Tanezzuft Formation, early Rhuddanian (Llandovery).

Selected previous stratigraphic record: early Llandovery, Estonia (Nestor, 1980, 1994); early Rhuddanian, Saudi Arabia (Paris *et al*., 1995), global (Verniers *et al*.,), Iran (Ghavidel-syooki and Winchester-Seeto, 2004), Jordan (Butcher, 2009), eastern Murzuq Basin, southwest Libya (Paris *et al.,* 2012).

Spinachitina* cf. *fragilis Nestor, 1980a

Plate 10, Fig. 1, 2

Describtion: *Spinachitina* species with a conical chamber and a weakly developed flexure and absence of shoulders. The neck is sub-cylindrical, almost parallel towards the straight aperture. A crown of 15-25 simple spines on the basal margin, and the vesicle wall is smooth or glabrous**.**

Dimensions: L: 310(355)400µm, Dp: 70(90)110µm, Dc: 50(53)55µm, n = 3.

Remarks and Comparison: This species is very similar in morphology to *Spinachitina fragilis* Nestor, 1980a but it differs in having bigger vesicle size. *Spinachitina wolfarti* Grahn and Bergamaschi, 2000 from mid Llandovery (Aeronian) of Paraguay and Brazil has a less conical vesicle and the basal margin has fewer spines. *Spinachitina harringtoni* Grahn and Bergamaschi, 2000 has elongated vesicle and the basal margin has fewer spines

Occurrence: Tanezzuft Formation, early Rhuddanian (Llandovery).

Spinachitina oulebsiri Paris *et al*., 2000

Plate 9, Figs. 3-8

For synonymy see Vandenbroucke *et la*., 2009.

Additional synonymy:

2009 *Spinachitina oulebsiri* - Ghavidel- syooki, pl. VII, flgs. 5, 6.

2013 *Spinachitina oulebsiri* – Le Hérissé *et al*., fig. 6, K.

Description: *Spinachitina* species with cylindro-conical chamber with straight flanks, tapering gently towards the aperture. The neck is poorly differentiated, slightly flaring collarette. The flexure is inconspicuous and absence of shoulders. The base is flat or concave and surrounded with a rounded margin bearing about twenty short and closely spaced conical and simple spines, but usually broken. The vesicle surface is smooth or glabrous.

Dimensions: L: 118(135)152µm, Dp: 52(73)94µm, Dc: 40(55)69 µm, n = 8.

Remarks and comparison: Butcher (2009) demonstrated that it is impossible to find quantitative criteria to clearly distinguish *Spinachitina oulebsiri* Paris *et al.,* 2000a from *Spinachitina fragilis* Nestor, 1980 and considered the later as a senior synonym of the former. According to Paris *et al*., (2000) *Spinachitina oulebsiri* could represent an early stage of the *Spinachitina fragilis* lineage. This lineage is characterised by the increase of the vesicle's length, by a progressive differentiation of the flexure, and by the development of a crown of spines on the margin whilst the diameter remains more or less stable. Vandenbroucke *et al*. (2009) also recognized the difficulties in differentiating species within the *Spinachitina oulebsiri-Spinachitina fragilis* lineage and decided to retain the two species separately, pending more comprehensive analyses. They considered the split between the two morphotypes as being supported by subtle differences *S. oulebsiri* has conical spines, whereas *S. fragilis* has more cylindrical spines. Another difference concerns the width of the chamber and the vesicle length, the holotype of *S. fragilis* is more slender than specimens assigned to *S. oulebsiri,* which has a more conical chamber and a stouter general appearance. This study is not a basis for taxonomical revision and the view of Vandenbroucke *et al*. (2009) is adopted herein. This view also adopted by Ghavidel-syooki (2011). However, based on the overall morphological aspect the specimens recorded here are attributed to *Spinachitina oulebsiri,* but in fact they are smaller in length of the vesicle.

Occurrence: Bir Tlacsin Formation, late Hirnantian (Ashgillian).

Selected previous stratigraphic record: Hirnantian, Algeria (Paris, 2000), Morocco (Le Heron *et al*., 2008), Iran (Ghavidel-syooki, 2008; Ghavidel-syooki *et al*., 2010), LateOrdovician (latest Hirnantian)-Early Silurian (Rhuddanian), northern Chad and southeastern Libya (Le Hérissé *et al*., 2013).

Spinachitina* cf. *oulebsiri Paris, 2001

Plate 9, Figs. 9, 10

Description: *Spinachitina* species with cylindro-conical chamber has smooth straight flanks, tapers gently towards the aperture. The neck is poorly differentiated. The flexure is inconspicuous and absence of shoulders. The base is flat or concave and surrounded with a rounded margin bearing more than 40 short and closely spaced conical and simple spines. The vesicle surface is smooth.

Dimensions: L: 150(160)170µm, Dp: 56(67)78µm, Dc: 40(43)46µm, n = 3.

Remarks and comparison: This species differs slightly from *Spinachitina oulebsiri* Paris *et al.,* 2000, in having more than 40 spines in the rounded basal margin and less pronounced flexure and shoulders. *Spinachitina verniersi* Vandenbroucke *et al*., 2009, has a crown of about 40 and poorly separated spines.

Occurrence: Bir Tlacsin Formation, late Hirnantian (Ashgillian).

Genus ***Tanuchitina*** Jansonius, 1964 emanded. Paris, Grahn, Nestor, and Lakova, 1999

Type species: *Tanuchitina ontariensis* Jansonius, 1964.

Diagnosis: "*Conochitinidae* with cylindrical chamber and a complete membranous carina below the margin." From Paris *et al*., (1999, p. 561).

Remarks: Paris *et al*., (1999) emended this genus to exclude forms with a carina on the margin, transferred them into the genus *Hyalochitina* Paris and Grahn, 1996, and claviform forms with a carina below the margin that are accommodated in the genus *Laufeldochitina* Paris, 1981.

Tanuchitina anticostiensis Achab, 1977a

Plate 10, Figs. 3-5

1977 *Cyathochitina anticostiensis* - Achab, pl. 4, figs 1, 2, 5.
1985 *Tanuchitina anticostiensis* - Molyneux and Paris, pl. 6, figs 7.
1995 *Tanuchitina anticostiensis* - Achab and Asselin, pl. IV, fig. 16.
2006 *Tanuchitina anticostiensis* – Grahn, fig. 5 (C).

Description: *Tanuchitina* species with cylindrical to sub-cylindrical vesicle, slightly swollen in lower part, the greatest width being approximately in the middle part of the vesicle. The neck is neck is poorly differentiated. The flexure and shoulders are absent, membranous carina below the margin. The vesicle wall is smooth.

Dimensions: L: 270(315)360µm, Dp: 90(100)110µm, Dc: 78(89)100µm, n = 6.

Remarks and comparison: This species is distinguished from *Tanuchitina laurentiana* Soufiane and Achab, 2000 by its much greater size, its cylindrical vesicle and well developed carina. *Tanuchitina ontariensis* Jansonius, 1964 has long flaring neck of about half the total length of the vesicle. *Tanuchitina bergstroemi* Laufeld, 1967 is greater in size and bears an elongated vesicle tapering in both poles.

Occurrence: Melez Shugran and Menouniat formations, late Katian-early Hirnanitian (Ashgillian).

Selected previous stratigraphic record: Late Ordovician, Canada (Achab, 1977); Ashgillian, northeast Libya (Molyneux and Paris, 1985); Caradocian-Ashgillian, Canada (Achab, 1995), Ashgillian, western Gondwana (Grahn, 2006).

Tanuchitina elongata Bouche, 1965

Plate 10, Fig. 6; Plate 16, Fig. 9

1965 *Tanuchitina elongata* - Bouche, p. 157; pl. 3, fig. 6

1995 *Tanuchitina elongata* - Achab and Asselin, pl. IV, 5

1995 *Tanuchitina elongata* - Al-Hajri, pl. VII, fig. 4.

2004*Tanuchitina elongata* - Bourahrouh *et al*., pl. III, figs 5, 6a, 7; pl. IV., figs. 4 (a, b)

2008 *Tanuchitina elongate* - Ghavidel-syooki, pl. VII, fig.. 1; pl. VI, fig 7.

Deescription: *Tanuchitina* species with long cylindrical vesicle has straight flanks, neck is poorly differentiated, but the flexure and shoulders are absent. A membranous flaring collarette surrounds the aperture. The basal edge is narrow carina is developed below the margin. The vesicle wall is smooth.

Dimensions: L: 450(562)675µm, Dp: 65(80)90µm, n = 9.

Remarks and comparison: *Tanuchitina fistulosa* Taugourdeau and Jekhowsky, 1960 is stockier than *T. elongata* Bouche and posseses a well develop carina. *Tanuchitina bergstroemi* Laufeld, 1867 is greater in size and bears an elongated vesicle tapering in both poles.

Occurrence: Melez Shugran Formation, late Katian-early Hirnanitian (Ashgillian).

Selected previous stratigraphic record: Ashgillian, Canada (Achab and Asselin, 1995), northern Gondwana domain (Paris, 1990), Saudi Arabia (Al-Hajri, 1995); Hirnantian, Turkey (Paris *et al.*, 2007), northern Iran (Ghavidel-Syooki, 2008); Ashgillian, Morocco (Bourahrouh *et al*., 2004) Ashgillian, UK (Van Nieuwenhove *et al*., 2006).

***Tanuchitina* sp.A**

Plate 10, Figs. 7, 8

Description: *Tanuchitina* species with cylindrical to sub-cylindrical chamber has slightly straight flanks, neck is poorly differentiated. The flexure and shoulder are absent, maximum diameter occurring just above the basal edge. Short membranous carinae extend below the rounded margin. The vesicle wall is perfectly smooth.

Dimensions: L 285(297)310µm, Dp: 83(92)100µm, Dc: 80(89)97µm, n=6

Remarks and comparison: This species is very similar in morphology to *Tanuchitina* sp. Al-Hajri, 1995 from the Ashgillian of Saudi Arabia. It is distinguished from *Tanuchitina anticostiensis* by its smaller size and having thin short carina

Occurrence: Melez Shugra Formation, early late Katian- late Katian-early (Ashgillian).

***Tanuchitiuna* sp. B**

Plate 10, Fig. 9

Description: *Tanuchitiuna* species with long conical to claviform chamber has slightly convex flanks, with a maximum diameter occurring approximately one third of the length of vesicle from the base, the vesicle then narrows slightly toward the straight aperture. The flexure and shoulders are absent. The base is flat to slightly convex. A membranous carina is well developed below the margin. The vesicle wall is smooth.

Dimensions: L: 260(268)277µm, Dp: 100(106)112µm, Dc: 72(73)74µm, n = 5.

Remarks and comparison: This species is very similar in morphology to *Tanuchitina* sp. aff. *fistulosa* reported by Al-Hajri (1995) from the Caradocian-lower Ashgillian of Saudi Arabia but it differs in having a shorter carina. It differs from *Tanuchitina fistulosa* in having a less elongate vesicle and a shorter carina.

Occurrence: Melez Shugra Formation, early late Katian- late Katian-early (Ashgillian).

***Tanuchitina* sp. C**

Plate 10, Figs. 10, 11

Description: *Tanuchitina* species with long cylindrical vesicle, has straight flanks, which increase in wider toward the straight aperture, with absence of flexure and shoulders. The basal edge is narrow and a short membranous carina is developed below the margin. The vesicle wall is smooth.

Dimensions: L: 280 (295) 310µm, Dp: 58 (60) 62µm, n=9

Remarks and comparison: *Tanuchitna elongata* Bouche, 1965 has a membranous flaring collarette surrounds the aperture and larger in size. *Tanuchitina bergstroemi* Laufeld, 1867 is greater in size and bears an elongated vesicle tapering in both poles. *Tanuchitina fistulosa* Taugourdeau and Jekhowsky, 1960 posses will develop carina.

Occurrence: Bir Tlacsin Formation, late Hirnanitian (Ashgillian).

Genus ***Velatachitina*** Poumot, 1968

Type species: *Velatachitina nebulosa* Poumot, 1968.

Diagnosis: "Conochitinidae with a claviform chamber enveloped within a membranous sleeve. " From Paris *et al*., (1999, p. 562).

Remarks: The membranous sleeve may extend beyond the margin.

***Velatachitina* sp.A**

Plate 10, Fig. 12

Description: *Velatachitina* species with sub-cylindrical chamber. The neck is undifferentiated. The vesicle is entirely enclosed within a thin, membranous sleeve which usually extends below the base of the chamber.
Dimensions: L: 265(268)272, Dp: 90(95)100, n = 2.

Remarks and comparison: This species differs from *Velatachitina nebulosa* Poumot, 1968 by lacking of tubular membranous structure which has not been observed in the specimens recorded here. *Velatachitina veligera* poumot, 1968 has a claviform chamber and cylindrical neck.

Occurrence: Hawaz Formation, mid-late Darrwilian (Llanvirnian).

4.4 SPORE SYSTEMATIC

4.4.1 Introduction

The Cryptospores described herein are treated under provisions of the International Code of Botanical nomenclature (e.g. Traverse and Strother, 1994). Their classification has been discussed by Strother (1991) and Richardson (1996). However, for easy reference, the genera are arranged alphabetically in the systematic section. The descriptions of cryptospores provided here are based on examination of taxa under transmitted light microscope. The morphological terminology follows that previously discussed and illustrated by Richardson (1996).

4.4.1.1 Systematic description

4.4.1.1.1 Cryptospores:

Genus ***Acontotetras*** Richardson, 1996a

Type species: *Acontotetras inconspicuis* Richardson, 1996a

Diagnosis: “Permanent tetrahedral tetrads composed of sub-triangular to sub-circular, closely adhering. Eucryptospore units separated from each other by distinct lines of attachment; exine with a sculpture of grana, coni or microconi.” From Richardson (1996a, p 14).

Remarks: The presence of grana and coni distinguishes this genus from the genus *Tetrahedraletes* Strother and Traverse, 1979, emend. Wellman and Richardson, 1993, which has a laevigate exine. The genus *Rimosotetras* Burgess, 1991 also has laevigate exine A and consists of loose tetrads.

Acontotetras inconspicuis Richardson, 1996a

Plate 1, Fig. 1

1996a *Acontotetras inconspicuis* - Richardson, p. 14; pl. 9, figs. 6-8; pl. 10, figs. 3, 6-7.

2002 *Acontotetras inconspicuis* - Burden *et al*., p. 203; pl. 3, fig. 8.

Description: Naked, unfused sub-triangular to sub-spherical spore-like palynomorphs adhered tightly in permanent tetrahedral configuration or cross tetrad arrangement. The distal wall of each spore is relatively thin and thickens near the edges forming rounded crassitudes which are 1-3 µm in width. Each individual spore is distinguishable from the adjacent spores by a plane of attachment. Distal exine sculptured with closely spaced fine grana.

Dimensions: L**:** 25(30)35µm, n = 4

Remarks and comparison: *Acontotetras* sp. A Richardson, 1996a has a thinner, less rigid exine with more widely spaced grana. *Acontotetras* sp. B Richardson, 1996a has a thicker, rigid, exine with more widely spaced grana.

Occurrences: Bir Tlacsin Formation, late Hirnantian (Ashgillian).

Selected previous stratigraphic record: late Pridoli- early mid Gedinnian, England (Richardson, 1996a); Early Devonian, Canada (Burden *et al.,* 2002); Lochkovian, Saudi Arabia (Steemans *et al.,* 2007).

Genus ***Chelinohilates*** Richardson, 1996a

Type species: *Chelinohilates erraticus* - Richardson, 1996a

Diagnosis: "Eucryptospore or paracryptospores with an exine differentiated into at least two layers; outer layer sculptured, diaphanous, variably appressed to the inner exinal layer (inner exoexine), and does not extend over the well marked contact area (hilum); the inner exoexine may be folded over the contact area, or collapsed; outer exinal layer (outer 'exoexine') sculptured consist of muri, mural folds, or rugulae, muri forming irregular, convolute or reticulate pattern." From Richardson (1996, p. 34, 35).

Remarks: The genus *Hispanaediscus* Cramer emend. Burgess and Richardson, 1991 is distally sculptured with dominant verrucate or verrucate-muronate ornament, but the contact area is not thin and diaphanous. *Cymbohilates* Richardson, 1996a has similar structure but a distal sculpture of grana, coni or spinae. The genus *Artemopyra* Burgess and Richardson, 1991 emend. Richardson, 1996a has proximal radial muri over part of the contact area, but distally is laevigate and *Segestrespora* Burgess, 1991 has a similar wall construction with a variably adherent envelope, sometimes sculptured with muri.

Chelinohilates maculatus Steemans, Higgs and Wellman, 2000

Plate 1, Fig. 2

2000 *Chelinohilates maculatus* - Steemans, Higgs and Wellman, p. 94; pl. 1., figs. e, f, g, h.

2000 *Chelinohilates maculatus* - Wellman, Higgs and Steemans, p. 126; pl. 4, figs. l.

Description: Amb sub-circular circular sub-equatorial crassitude 1-3 µm wide delimites a more or less circular laEvigate hilum, distal surface thicker than the proximal one, ornamented by an irregular to regular rounded to subpolygonal reticulum.

Dimensions: L: 42(47)51µm, n = 8.

Remarks and comparison: The specimens recorded in the current study are simillar in morphology to the specimens described and illustrated by Steemans *et al*., (2000) from late Rhuddanian of Saudia Arabia but it is bigger in overall size. *Chelinohilates lornensis* Wellman and Richardson, 1996 is ornamented by a more regular and polygonal reticulum formed by thinner muri.

Occurrences: Hawaz Formation, mid–late Darriwilian (Llanvirnian); Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian); Tanezzuft Formation, late Rhuddanian-Telychian (Llandovery).

Selected previous stratigraphic record: Llandovery, Saudi Arabia (Steemans, Higgs and Wellman, 2000); Silurian, Saudi Arabia (Wellman, Higgs and Steemans, 2000).

Genus ***Dyadospora*** Strother and Traverse, 1979 emend. Burgess and Richardson, 1991

Type species: *Dyadospora murusattenuata* Strother and Traverse, 1979.

Diagnosis: “Palynomorphs consisting of two inaperaturate spores or spore-like palynomorphs occurring in a dyad configuration; individual spores spherical to sub-spherical to hemispherical in outline; walls psilate; overall length of flattened dyad body 25 to 50 μm.” From Burgess and Richardson (1991, p. 614).

Remarks: The dyads in this genus are naked, unfused dyads tightly or loosely adhered with a clear line of attachment are placed in this genus. The dyads may separate into two hilate cryptospores. Naked fused dyads with no obvious line of attachment are placed in the genus *Pseudodyadospora* Johnson, 1985.

Dyadospora murusattenuata Strother and Traverse, 1979 *sensu* Steemans, Le Hérissé and Bozdogan, 1996

Plate 1, Figs. 3, 4, 5

For synonymy see Steemans *et al*. (1996).

Additional synonymy:

1996 *Dyadospora murusattenuata* Morphon; Steemans *et al*., p. 63-64; pl. VI, figs. 1, 2.
1996 *Dyadospora murusdensa* - Wellman, pl. 1, figs. 16-20, 25; pl. 2, figs. 11-16, 20.
1996 *Dyadospora murusattenuata* - Wellman and Richardson, pl. 5, figs. 11.
1996 *Dyadospora murusdensa* - Wellman and Richardson, pl. 2, fig. 4.
1997 *Dyadospora murusattenuata* - Wang *et al*., pl. II, fig. 3.
1997 *Dyadospora murusdensa* - Wang *et al*., pl. 2, figs. 4-7.
2000 Morphan *Dyadospora murusattenuata* - Steemans *et al*., pl. 2, figs. a, b.
2000 Morphan *Dyadospora murusattenuata* - Wellman *et al*., pl. 1, figs. g-i.
2001 *Dyadospora murusattenuata* - Steemans, fig. 4.1.
2001 *Dyadospora murusdensa* - Beck and Strother, pl. 4, fig. 5.
2002 *Dyadospora murusattenuata* - Lavender and Wellman, pl. II, fig. 1.
2002 *Dyadospora murusdensa* - Lavender and Wellman, pl. II, fig. 2.
2002 *Dyadospora murusdensa* - Mizusaki *et al*., fig. 3, b, c. .
2004 Morphon *Dyadospora murusdensa* - Rubenstein *et al.,* p. 1042, pl. 1, fig. 10.
2004 *Dyadospora murusdensa* - Mauller *et al*., fig. 4 (9).
2004 *Dyadospora murusattenuata* - Mauller *et al*., fig. 4 (8).
2005 *Dyadospora murusattenuata* - Wang *et al*., pl. I, figs. 4-6.
2005 *Dyadospora murusdensa* - Wang *et al*., pl. 1, figs. 12.
2006 *Dyadospora murusattenuata* - Rubinstein and Toro, fig. 3.14.
2009 *Dyadospora murusattenuata* - Spina and Vecoli, pl. 1, figs. 4,14, 18.
2011 *Dyadospora murusattenuata* - Vecoli *et al*., p. 88; pl. IV, figs. 5, 7.
2013 *Dyadospora murusattenuata* - Le Hérissé *et al*., fig. 10, B, C.

Description: Naked, unfused dyads with isomorphic or anisomorphic circular to sub-circular spores. An equatorial crassitude surrounds the contact areas between the two spores with a plane of attachment between the crassitudes indicated by a line of attachment. The spores are usually loosely adhered or partially separated. Distal exine is laevigate.

Dimensions: L**:** 24(36)50µm, n = 10.

Remarks and comparison: Burgess and Richardson (1991) differentiated *Dyadospora murusattenuata* Strother and Traverse, 1979, from *Dyadospora murusdensa* Strother and Traverse, 1979, in that the former is characterized by a thinner more folded wall than the latter. Their very similar morphologies and the occurrence of all intermediate forms make it difficult to separate the two species. Thus, and in agreement with Steemans *et al*. (1996), *Dyadospora murusattenuata* is adopted herein to include both *Dyadospora murusattenuata* and *Dyadospora murusdensa*. This view was also adopted by Steemans *et al*. (2000), Wellman *et al*. (2000), Steemans (2001) and Rubinstein and Toro (2006). *Pseudodyadospora laevigata* Johnson, 1985 is fused and normally elongate with unfolded, thicker walls.

Occurrences: Hawaz Formation, mid–late Darriwilian (Llanvirnian); Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian); Tanezzuft Formation, mid Rhuddanian-Telychian (Llandovery).

Selected previous stratigraphic record: Rhuddanian-early Telychian, northeast Libya (Richardson, 1988); Wenlock, England (Burgess and Richardson, 1991); Silurian, Scotland (Wellman and Richardson, 1993); Ordovician-Silurian, southeast Turkey (Steemans *et al*., 1996); Caradocian, United Kingdom (Wellman, 1996); Lochkovian, Scotland (Wellman and Richardson, 1996); latest Ordovician, China (Wang *et al*., 1997); Llandovery, Saudi Arabia (Steemans *et al*., 2000); Llandovery, Saudi Arabia (Wellman *et al*., 2000); Pridoli, Canada (Beck and Strother, 2001); Caradocian-Ashgillian, Belgium (Steemans, 2001); Early Devonian, Scotland (Lavender and Wellman, 2002); Rhuddanian–early Aeronian, Brazil (Misuzaki *et al.,*2002); Hirnantian-Llandovery, Argentina (Rubinstein *et al*., 2004); Llandovery, east Paraguay (Mauller *et al*., 2004); Late Silurian, China (Wang *et al*., 2005); Llandovery, northwest Argentina (Rubinstein and Toro, 2006); Llandovery-Wenlock, Scotland, UK (Molyneux *et al.,* 2008); Silurian-Devonian, North Africa (Spina and Vecoli, 2009); Katian-Hirnantian, Anticosti Island, Québec, Canada, and Estonia (Vecoli., et al., 2011), Late Ordovician (Hirnantian)-Early Silurian (Rhuddanian), northern Chad and southeastern Libya (Le Hérissé *et al*., 2013).

Genus ***Hispanaediscus*** Cramer emended Burgess and Richardson, 1991

Type species: *Hispanaediscus verrucatus* Cramer emended Burgess and Richardson, 1991

Diagnosis: “Alete proximally hilate cryptospores; originally elliptical to hemispherical in equatorial view; equatorial to subequatorial crassitude surrounding the helum. Hilum laevigate, or with radial and/or randomly orientated muri/folds. Distal exine ornamented with verrucae or muri.” From Burgess and Richardson (1991, p. 610).

Remarks: The genus *Artemopyra* Burgess and Richardson (1991), has the same structure and often radial proximal muri/folds, but is distally laevigate, apiculate or spinose.

Hispanaediscus verrucatus Cramer emend. Burgess and Richardson, 1991

Plate 1, Fig. 6

1991 *Hispanaediscus verrucatus* - Cramer emend. Burgess and Richardson, p. 610 ;pl. 2, figs. 12, 13

2001 *Hispanaediscus verrucatus* – Beck and Strother, p. 164; pl 10, figs. 10-14; pl. 11, fig. 14.

2005 *Hispanaediscus verrucatus* - Wang *et al*., pl. 1, fig. 15.

Description: Monad cryptospore with sub-circular or circular amb, sub-equatorial to equatorial crassitude 1-2 µm wide. Proximal hilum laevigate and distal surface ornamented with elongated verrucae. At the equator verrucae are produced by local thickening of the crassitude.

Dimensions: L: 20(25)28µm, n = 4.

Remarks and comparison: *Hispanaediscus rugulatus* Cramer emend. Burgess and Richardson, 1995 is similar but has murornate/rugulate proximal walls. *Hispanaediscus wenlockensis* Cramer emend. Burgess and Richardson, 1991 is larger.

Occurrences: Hawaz Formation, mid–late Darriwilian (Llanvirnian); Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian); Tanezzuft Formation, late Rhuddanian-early Telychian (Llandovery).

Selected previous stratigraphic record: early Pridoli, Britain (Burgess and Richardson, 1991); Silurian, Canada (Beck and Strother, 2001); Lochkovian, Saudi Arabia (Steemans *et al.,* 2007); Silurian, China (Wang *et al*., 2005); early pridoli, Brazil (Steemans et al., 2008); Silurian-Devonian, North Africa (Spain and Vecoli, 2009).

Hispanaediscus* cf. *wenlockensis Burgess and Richardson, 1991

Plate 1, Fig. 7

Description: Monad cryptospore with sub-circular or circular amb, crassitude equatorial to sub-equatorial. Proximal hilum laevigate. Distal surface ornamented with densely and closely packed verrucae.

Dimensions: L: 45(48)50µm, n = 4.

Remarks and comparison: The specimens recorded here are similar in distal ornamentation to *Hispanaediscus wenlockensis* Burgess and Richardson, 1991, but it differs in that the proximal hilum is laevigate and lacks the proximal radial folds or muri. It is very similar to *Hispanaediscus* cf. *wenlockensis* recorded by Wellman *et al.,* (2000) from the Ordovician-Silurian of Saudi Arabia but it is larger in over all size.

Occurrences: Hawaz Formation, mid–late Darrwilian (Llanvirnian); Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian); Tanezzuft Formation, late Rhuddanian-mid Telychian (Llandovery).

Genus ***Imperfectotriletes*** Steemans, Higgs and Wellman, 2000

Type species: *Imperfectotriletes patinatus* Steemans, Higgs and Wellman, 2000.

Diagnosis: "A subcircular to subtriangular monad with a thin disrupted proximal exine which shows irregular trilete tracks." From Steemans *et al*. (2000, p. 98).

Remarks: This genus accommodates monads with an equatorial crassitude that resemble *Ambitisporites* Hoffmeister, 1959, and patinate forms that resemble *Archaeozonotriletes* (Naumova) Allen, 1965. However, this genus differs from both in the lack of a true trilete mark (Steemans *et al*., 2000).

Imperfectotriletes vavrdovae (Richardson, 1988) Steemans, Higgs and Wellman, 2000

Plate 1, Fig. 8

For synonymy see Steemans *et al*. (2000)

Additional synonymy:

2000 *Imperfectotriletes vavrdovae* - Steemans *et al*., pl. 2, figs. i-m.

2000 *Imperfectotriletes vavrdovae* - Wellman *et al*., pl. 5, figs. c-e.

2001 *Imperfectotriletes* (*? Ambitisporites) vavrdovae* - Steemans, p. 7, figs. 4. 6

2001 *Imperfectotrilete* - Le Hérissé *et al,* pl. 4, fig.2.

2002 *Imperfectotriletes vavrdovae* - Mizusaki *et al*., fig. 3 (e).

2004 *Imperfectotriletes vavrdovae* - Rubinstein *et al*., p. 1044; pl/ 1, figs. 1, 6.

2004 *Imperfectotriletes vavrdovae* - Mauller *et al.,* fig. 4 (15).

2013 *Imperfectotriletes vavrdovae* - Le Hérissé *et al*., fig. 10, D, E.

Description: Sub-circular to sub-triangular crassitate monad, proximal face thin, frequently torn, with irregular trilete cracks, laevigate.

Dimensions: L**:** 38(39)40µm, n = 3.

Remarks and comparison: *Imperfectotriletes* of patinate form are accommodated in *Imperfectotriletes patinatus* Steemans, Higgs and Wellman, 2000.

Occurrences: Melez Shugran, Memouniat and Bir Tlacsin formations, late Katian-Hirnantian (Ashgillian); Tanezzuft Formation, late Rhuddanian-early Telychian (Llandovery).

Selected previous stratigraphic record: Llandovery, Saudi Arabia (Steemans *et al*., 2000); Llandovery, Saudi Arabia (Wellman *et al*., 2000); Ordovician, Belgium (Steemans, 2001); Rhuddanian-early Aeronian, Brazil (Misusaki *et al.,*2002); Hirnantian-Llandovery, Argentina (Rubinstein *et al*., 2004); Llandoverian, Paraguay (Mauller *et al.,* 2004) Upper Ordovician (latest Hirnantian)-Early Silurian (Rhuddanian), northern Chad and southeastern Libya (Le Hérissé *et al*., 2013).

Genus ***Laevolancis*** Burgess and Richardson, 1991

Type species: *Laevolancis divellomedium* (Chibrikova, 1959) Burgess and Richardson, 1991.

Diagnosis: “Alete proximally hilate spores, originally elliptical to hemispherical in equatorial view with an equatorial to subequatorial crassitude surrounding the hilum; exine laevigate.” Diagnosis of Burgess and Richardson (1991, p. 606, 607).

Remarks: This genus accommodates alete forms which are derived from dissociation of loosely attached dyads.

Laevolancis chibrikovae Steemans, Higgs and Wellman, 2000
Plate 1, Fig. 9

For synonymy see Steemans *et al*. (2000)
Additional synonymy:
2000 *Laevolancis chibrikovae* - Steemans *et al*., pl. 2, figs. n, o; pl. 3, fig. a.
2004 *Laevolancis chibrikovae* - Rubinstein et al., pl. 1, fig. 11.
2010 *Laevolancis chibrikovae* - Wang and Zhang, fig. 5f.

Description: Amb circular to sub-circular with equatorial to sub-equatorial crassitude surrounds a circular to sub-circular contact area (hilum). The hilum is thinner than the distal exine and generally collapsed, distal surface entirely laevigate.

Dimensions: L**:** 30(32)34µm, n = 8.

Remarks and comparison: This species is similar to *Laevolancis divellomedium,* but the border of the hilum is sometimes partially torn, indicating that the hilate cryptospores are physically separated from permanent dayads. *Imperfectotriletes vavrdovae* (Richardson) Steemans, Higgs and Wellman, 2000, differs by having an irregular trilete crack.

Occurrences: Hawaz Formation, mid–late Darriwilian (Llanvirnian); Melez Shugran Formation, early late Katian-late Katian (Ashgillian); Tanezzuft Formation, late Rhuddanian (Llandovery).

Selected previous stratigraphic record: Caradocian, UK (Wellman, 1996); Late Ordovician, China (Wang *et al*., 1997); Llandovery, Saudi Arabia (Steemans *et al*., 2000; Wellman *et al*., 2000); Hirnantian-Rhuddanian, Argentina (Rubinstein *et al*., 2004); Llandovery, China (Wang and Zhang, 2010).

Laevolancis divellomedia-plicata *sensu* Steemans, Le Hérissé and Bozdogan, 1996

Plate 2, Fig. 1, 2

For synonymy see Burgess and Richardson (1991); Wellman and Richardson (1993); Steemans *et al*. (1996)

Additional synonymy:

1996 *Laevolancis divellomedium* - Steemans *et al*., p. 65, 66;pl. VI, figs. 3, 4.
1996 *Laevolancis divellomedium* - Wellman and Richardson, pl. 1, figs. 4, 7.
2000 *Laevolancis divellomedium* - Steemans *et al*., pl. 3, figs. b-e.
2000 *Laevolancis divellomedia-plicata sensu* - Wellman *et al*., pl. 2, figs. k, l.
2001 *Laevolancis divellomedium* - Beck and Strother, pl. 4, figs. 3, 4.
2001 *Laevolancis divellomedium* **-** Le Hérissé *et al,* pl. 4, fig.2, 3.
2002 *Laevolancis divellomedium* - Lavender and Wellman, pl. 1, fig. 1.
2002 *Laevolancis plicata* - Lavender and Wellman, pl. 1, fig. 2.
2002 *Laevolancis divellomedium* - Rubinstein and Steemans, pl. IV, fig. 19.
2002 *Laevolancis divellomedium* - Misusaki *et al.*, fig. 3 f, g.
2004 *Laevolancis divellomedium* - Mauller *et al.,* fig. 4 (18).
2005 *Laevolancis divellomedium* - Wang *et al*., pl. 1, figs. 7, 8; pl. 2, fig. 6.
2006 *Laevolancis divellomedium* - Rubinstein and Toro, fig. 3.13.
2008 *Laevolancis divellomedium* - Steemans *et al*., fig. 8.17.

Description: Amb circular to sub-circular with equatorial to sub-equatorial crassitude surrounds a circular to sub-circular contact area (hilum). Entirely laevigate.

Dimensions: L**:** 20(30)39µm, n = 8.

Remarks and comparison: Burgess and Richardson (1991) differentiated *Laevolancis divellomedium* from *Laevolancis plicata* in that the former has a thicker, folded wall. Their very similar morphologies and the occurrence of all intermediate forms make it difficult to separate the two species. Thus, the two species are included herein under *Laevolancis divellomedia-plicata*, the view which was previously adopted by Steemans *et al*. (1996) and Wellman *et al*. (2000). As noted by Burgess and Richardson (1991) and Wellman and Richardson (1993), this species is most likely derived from dissociation of *Dyadospora murusattenuata* Strother and Traverse, 1979, *sensu* Steemans, Le Hérissé and Bozdogan, 1996.

Occurrences: Hawaz Formation, mid–late Darriwilian (Llanvirnian); Melez Shugran, Memouniat and Bir Tlacsin formations, early late Katian-Hirnantian (Ashgillian); Tanezzuft Formation, mid Rhuddanian-early Telychian (Llandovery).

Selected previous stratigraphic record: Wenlock, England (Burgess and Richardson, 1991); Silurian, Scotland (Wellman and Richardson, 1993); Ordovician-Silurian, southeast Turkey (Steemans *et al*., 1996); Lochkovian, Scotland (Wellman and Richardson, 1996); Llandovery, Saudi Arabia (Steemans *et al*., 2000); Silurian, Saudi Arabia (Wellman *et al*., 2000); late Aeronian-early mid Telychian, Brazil (Le Hérissé *et al.,* 2001); latest Llandovery-Pridoli, Canada (Beck and Strother, 2001); Rhuddanian-early Aeronian, Brazil (Misusaki *et al.,*2002); Lochkovian, Scotland (Lavender and Wellman, 2002); Silurian-Devonian boundary, Libya (Rubinstein and Steemans, 2002); Lochkovian, southwest Wales (Higgs *et al.,* 2004); Llandovery, Paraguay (Mauller *et al.,* 2004); Late Silurian, China (Wang *et al*., 2005); Llandovery, northwest Argentina (Rubinstein and Toro, 2006); late Ludlow-Pridoli, northern

Brazil (Steemans *et al*., 2008); Llandovery-Wenlock, Scotland, UK (Molyneux *et al.,* 2008).

Genus ***Pseudodyadospora*** Johnson, 1985

Type species: *Pseudodyadospora laevigata* Johnson, 1985.

Diagnosis: "A single elongate oval or elliptical vesicle; bipolar; usually symmetrical but often asymmetrical. A transverse thickening encircles the vesicle wall, dividing it into two equal or unequal parts. Cross wall between the two parts usually absent, but may be present. Sutures generally absent; when present on psilate forms they appear to be produced artificially by oblique compression of the vesicle." Diagnosis of Johnson (1985, p. 337).

Remarks: The dyads in this genus are naked and fused with no obvious line of attachment. The genus *Dyadospora* Strother and Traverse, 1979 emended Burgess and Richardson, 1991 accommodates naked unfused dyads tightly or loosely adhered with a clear line of attachment. The genus *Segestrespora* Burgess, 1991 accommodates envelope-enclosed fused dyads.

Pseudodyadospora laevigata Johnson, 1985.

Plate 2, Figs. 3, 4, 5

For synonymy see Steemans *et al*. (1996)

Additional synonymy:

1996 *Pseudodyadospora laevigata* - Steemans *et al*., p. 51-53; pl. III, figs. 11, 12.

1996 *Pseudodyadospora laevigata* - Wellman, pl. 1, figs. 11-15; pl. 2, figs. 1-10.

1997 *Pseudodyadospora laevigata* - Wang *et al*., pl. II, figs. 8, 9.

2000 *Pseudodyadospora laevigata* - Steemans *et al*., pl. 3, fig. g. 192
2000 *Pseudodyadospora laevigata* - Wellman *et al*., pl. 1, figs. a-c.
2000 *Pseudodyadospora laevigata* - Steemans, fig. 4.14.
2002 *Pseudodyadospora laevigata* - 1985; Misusaki *et al.,*2002, fig. 3, i.
2005 *Pseudodyadospora laevigata* - Wang *et al*., pl. 1, fig. 13.

Description: Naked fused dyads of elliptical to subcircular outline. The two spores are of similar or variable sizes and joined tightly by a traverse encircling dark crassitude. The wall is thick and laevigate.

Dimensions: L**:** 35(40)45µm, n = 8.

Remarks and Comparison: This species is distinguished by the absence of spore separation and an enclosing membrane. Dyads in *Segestrespora* are enclosed within an envelope and dyads in *Dyadospora* are usually of equal size with a well developed line of attachment and usually observed separated. *Pseudodyadospora petasus* is distally invaginated, with a thin distal wall.

Occurrences: Hawaz Formation, mid–late Darriwilian (Llanvirnian); Melez Shugran, Memouniat and Bir Tlacsin formations, late Katian-Hirnantian (Ashgillian); Tanezzuft Formation, late Rhuddanian-Telychian (Llandovery).

Selected previous stratigraphic record: Ordovician-Silurian, southeast Turkey (Steemans *et al*., 1996); Caradocian, southern Britain (Wellman, 1996); latest Ordovician, China (Wang *et al*., 1997); Llandovery, Saudi Arabia (Steemans *et al*., 2000); Silurian, Saudi Arabia (Wellman *et al*., 2000); Caradocian-Ashgillian, Belgium (Steemans, 2001); Rhuddanian-early Aeronian, Brazil (Misusaki *et al.,*2002); Late Silurian, China (Wang *et al*., 2005); Silurian-Devonian, North Africa (Spina and Vecoli, 2009).

Pseudodyadospora petasus Wellman and Richardson, 1993

Plate 2, Figs. 6, 7

For synonymy see Steemans *et al*. (1996)

Additional synonymy:

1996 *Pseudodyadospora petasus* - Steemans *et al.*, pl. III, figs, 13, 14; pl. IV, fig. 1.

1996 *Pseudodyadospora petasus* - Wellman and Richardson, pl. 5, fig, 9, pl. 13, fig. 2.

1997 *Pseudodyadospora petasus* - Wang *et al.*, pl. II, fig. 16.

2000 *Pseudodyadospora petasus* - Steemans *et al.*, pl. 3, figs. h, i.

2000 *Pseudodyadospora petasus* - Wellman *et al.*, pl. 1, figs. a-c.

2002 *Pseudodyadospora petasus* - Lavender and Wellman, pl. II, fig. 3.

2002 *Pseudodyadospora petasus* - Rubinstein and Steemans, pl. IV, fig. 20.

2002 *Pseudodyadospora petasus* - Misusaki *et al.,* fig. 3, j.

2004 *Pseudodyadospora petasus* - Rubinstein *et al*., p. 1045; pl. 1, fig. 7.

2005 *Pseudodyadospora petasus* - Wang *et al.*, pl. 1, fig. 14.

Description: Isomorphic fused dyads normally of oval outline in polar view. The two spores are distally invaginated and attached forming an equatorial constriction. They are preserved in polar compression. The spores are laevigate with no line of attachment.

Dimensions: L**:** 25(33)45µm, n = 10.

Remarks and comparison: This species distinguished from other *Pseudodyadospora* species by its shape and thin distal wall. *Pseudodyadospora laevigata* Johnson, 1985 is distally inflated with no equatorial constriction.

Occurrences: Hawaz Formation, mid–late Darriwilian (Llanvirnian); Melez Shugran, Memouniat and Bir Tlacsin formations, late Katian-Hirnantian (Ashgillian); Tanezzuft Formation, late Rhuddanian- Aeronian (Llandovery).

Selected previous stratigraphic record: Silurian, Scotland (Wellman and Richardson, 1993); Ordovician-Silurian, southeast Turkey (Steemans *et al*., 1996); Lower Devonian, Scotland (Wellman and Richardson, 1996); latest Ordovician, China (Wang *et al*., 1997); Llandovery, Saudi Arabia (Steemans *et* *al*., 2000); Silurian, Saudi Arabia (Wellman *et al*., 2000); Rhuddanian–early Aeronian, Brazil (Misusaki *et al.,*2002); Silurian-Devonian boundary, Libya (Rubinstein and Steemans, 2002); Early Devonian, Scotland (Lavender and Wellman, 2002); Hirnantian-Llandovery, Argentina (Rubinstein *et al*., 2004); Late Silurian, China (Wang *et al*., 2005); Lochkovian, Saudi Arabia (Steemans *et al*., 2007); Llandovery-Wenlock, Scotland, UK (Molyneux *et al.,* 2008); Silurian-Devonian, North Africa (Spina and Vecoli, 2009).

Genus ***Rimosotetras*** Burgess, 1991

Type species: *Rimosotetras problematica*, Burgess, 1991

Diagnosis: "Adherent, but usually partially separating, tetrahedral tetrads composed of alete, laevigate, sub-triangular to circular, ± crassitate spores or spore like units." From Burgess, 1991 (1979, p. 586).

Remarks: In *Tetrahedraletes* Strother and Traverse, 1979 emend. Wellman and Richardson, 1993 the spores comprising the tetrad are much more tightly adherent.

Rimosotetras problematica, Burgess, 1991
Plate 2, Figs. 8, 9

For synonymy see Burgess, 1991
Additional synonymy:
1991 *Rimosotetras problematica* - Burgess, p. 586; pl. 1, figs. 12, 14, 15.
1996 *Rimosotetras problematica* - Steemans *et al*., p. 55; pl IV, figs. 5-6.
2000 *Rimosotetras problematica* - Steemans *et al.,* p. 100; pl. 3 , figs. j, k.
2000 *Rimosotetras problematica* - Wellman *et al.,* p. 117; pl. 1 , fig. d.

2001 *Rimosotetras problematica* - Le Hérissé *et al* , pl. 4, fig. 7, 8.
2004 *Rimosotetras problematica* - Rubinstein *et al*., p. 1045; pl. 1, fig. 8.
2002 *Rimosotetras problematica* - Misusaki *et al.,* fig. 3, k.
2011 *Rimosotetras problematica* - Vecoli *et al.,* p. 83; pl. I, 9; pl. II, 19, 20; pl. III, 11,12; pl. IV, 13,20.
2013 *Rimosotetras problematica* – Le Hérissé *et al*., fig. 10, G.

Description: Tetrad composed of loosely attached, sometimes partially separated lavigate sub-triangular to sub-circular spore with a narrow equatorial crassitude 1-2 µm wide. Spores laevigate.

Dimensions: L: 32(41)45µm, n = 6.

Remarks and comparison: This species is composed of similar distally inflated, laevigate spores to *Tetrahedraletes medinensis* Strother and Traverse, 1979, emend. Wellman and Richardson, 1993, but they are loosely attached.

Occurene: Hawaz Formation, mid–late Darriwilian (Llanvirnian); Melez Shugran, Memouniat and Bir Tlacsin formations, late Katian-Hirnantian (Ashgillian); Tanezzuft Formation, mid Rhuddanian- Telychian (Llandovery).

Selected previous stratigraphic record: Early Silurian, USA (Gray and Boucot, 1971); late Asgillian-late Aeronian or early Telychian, northeast Libya (Hill *et al*., 1985; Richardson, 1988); late Caradocian, Wales, UK (Richardson, 1988); Ashgillian-Rhuddanian, southwest wales, UK (Burgess, 1991); early Wenlock, Scotland, UK (Wellman and Richardson, 1993); Late Ordovician-Late Silurian, southeast Turkey (Steemans et al., 1996); Ordovician-Silurian, Saudi Arabia (Wellman *et al.,* 2000); Llandovery, Saudi Arabia (Steemans *et al.,*2000); late Aeronian-early mid Telychian, Brazil (Le Hérissé *et al,* 2001); Caradocian-Ashgillian, Belgium (Steemans, 2001); Rhuddanian-early Aeronian, Brazil (Misusaki *et al.,*2002); Lochkovian, southwest Wales, UK (Higgs, 2004); Hirnantian-Llandovery, Argentina (Rubinstein *et al*., 2004); Lochckovian, Saudi Arabia (Steemans *et al.,* 2007); Llandovery-Wenlock, Scotland, UK (Molyneux *et al.,* 2008); Silurian-Devonian, North Africa (Spina and Vecoli, 2009); Katian-

Hirnantian, Anticosti Island, Québec, Canada, and Estonia (Vecoli., *et al*., 2011), Late Ordovician (Hirnantian)-Early Silurian (Rhuddanian), northern Chad and southeastern Libya (Le Hérissé *et al*., 2013).

Genus ***Segesterospora*** Burgess 1991, emed. Steemans *et al*., 1996

Type species: *Segesterospora* (Dayadspora) *membranifera* Burgess, 1991

Diagnosis: "Bipolar, laevigate and permanently fused peudodyas, divided by a single central to slightly off-centred thickened encircling band, and totally enclosed within a closely adherent to completly separated envelope which either lacks ornamentation, or has apiculi, muri, regulate or verrucate" From Burgess (1991, p. 588).

Remarks: This genus *Segesterospora* diagnosed by Burgess, 1991 then emended by Steemans *et al*., 1996 to indude the dyads and not only the pseudodyads

***Segesterospora* sp. A**

Plate 3, Fig. 1. 2

Description: Dayad/pseudosyad with sub-circular to elliptic amb entirely enclosed with an envelope ornamented with muri.

Dimensions: L: 55(60)65µm, n = 6.

Remarks and comparison: *Segestrespora membranifera* Burgess, 1991 has envelope sculptured with a low regulary sized and ambed reticulum, *Segestrespora rugosa* (Johnson) Burgess, 1991 has envelope sulptured with closely spaced sinuous rugulae and *Segesterspora burgessii* Steemans *et al.,* 1996 possessing a thin envelope heavily ornamened with small grana

Occurene: Tanezzuft Formation, late Rhuddanian (Llandovery).

Genus ***Sphaerasaccus*** Steemans, Higgs and Wellman, 2000

Type species: *Sphaerasaccus glabellus* Steemans, Higgs and Wellman, 2000

Diagnosis: "A sub-circular to sub-triangular laevigate monad enclosed within a laevigate envelope." From Steemans *et al*., (2000, p. 102).

Remarks: The genus *Rugosphaera* Strother and Traverse, 1979 is enclosed within a rugulate envelope.

Sphaerasaccus glabellus Steemans, Higgs and Wellman, 2000

Plate 3, Fig. 3

1996 Laevigate monads enclosed with a laevigate envelope – Wellman, p. 118; pl. 3, figs. 18-20

2000 *Sphaerasaccus glabellus* - Steemans, Higgs and Wellman, p. 102; pl. 4, figs. a-b

2004 *Sphaerasaccus glabellus* - Rubinstein p. 1047, text-figure 4c.

2005 *Sphaerasaccus glabellus* - Rubinstein *et al*., pl. 1, fig. 13.

2010 *Sphaerasaccus glabellus* - Rubinstein *et al*., fig. 2 (e, f).

Description: Monad cryptospore with circular to sub-circular amb, thick laevigate wall. Enclosed within a thin tight, laevigate and loosely adherent envelope, no contact feature observed.

Dimensios: L: 25(30)35µm, n = 5.

Remarks and Comparison: This species is distinguished in having a laevigate monad enclosed within a laevigate envelope.

Occurence: Hawaz Formation, mid–late Darriwilian (Llanvirnian); Melez Shugran, Memouniat and Bir Tlacsin formations, late Katian-Hirnantian (Ashgillian); Tanezzuft Formation, late Rhuddanian-mid Aeronian (Llandovery).

Selected previous stratigraphic record: Caradocian, southern Britain (Wellman, 1996); Rhuddanian, Saudi Arabia (Steemans *et al*, 2000); Hirnantian-Llandovery, Argentina (Rubinstein *et al*., 2004); Llandovery, east Paraguay (Mauller *et al*., 2004); Early and Mid Ordovician, Argentina (Rubinstein *et al*., 2010).

Genus ***Tetrahedraletes*** Strother and Traverse, 1979 emend. Wellman and Richardson, 1993

Type species: *Tetrahedraletes medinensis* Strother and Traverse, 1979.

Diagnosis: “Permanent tetrahedral tetrads composed of subtriangular to subcircular spore-like units. The spores are crassitate and have a laevigate invaginated distal wall. The spores are discrete and the plane of attachment between adjoining spores forms a distinct line of attachment at the junction between the crassitudes.” From Wellman and Richardson (1993, p. 164).

Remarks: Strother and Traverse (1979) proposed *Tetrahedraletes* for permanent tetrads of tetrahedral configuration and *Nodospora* for permanent tetrads of cross-tetrad arrangement. Several previous studies concluded that the type specimens of *Tetrahedraletes* (*T. medinensis*) and *Nodospora* (*N. burnhamensis*) were synonyms and they were identical tetrads with different compressional morphologies (e.g. Gray *et al*., 1982; Duffield, 1985; Burgess, 1991; Gray, 1991). Accordingly, Burgess (1991) emended *Tetrahedraletes* to accommodate naked, laevigate, fused or unfused permanent tetrads. This view was accepted by Traverse and Strother (1994). Wellman and Richardson (1993) considered the nature of the junction between the spores, i.e. fused or unfused, as a generically diagnostic character. To account for this, they emended *Tetrahedraletes* to accommodate unfused tetrads and proposed a new genus *Cheilotetras* to accommodate fused tetrads. *Acontotetras* Richardson, 1996a differs from *Terahedraletes* in having exine sculptured with grana, coni or micro-coni.

Tetrahedraletes medinensis Strother and Traverse, 1979,
emend. Wellman and Richardson, 1993.

Plate 3, Figs. 4, 5, 6

For synonymy see Steemans *et al.* (1996).

Additional synonymy:

1996 *Tetrahedraletes medinensis* - Steemans *et al.*, p. 57-59; pl. V, figs. 1, 2.
1996 *Tetrahedraletes medinensis* - Wellman, pl. 1, figs. 6-10.
1996 *Tetrahedraletes medinensis* - Wellman and Richardson, pl. 5, figs. 3, 4, 7.
1997 *Tetrahedraletes medinensis* - Wang *et al.,* pl. 1, figs. 1-8.
2000 *Tetrahedraletes medinensis* - Maziane-Serraj *et al.*, pl. II, fig. 13.
2000 *Tetrahedraletes medinensis* - Steemans *et al.*, pl. 4, figs. c, d.
2000 *Tetrahedraletes medinensis* - Wellman *et al.*, pl. 1, figs. a-c.
2001 *Tetrahedraletes medinensis* - Steemans, figs. 6.3-6.5.
2001 *Tetrahedraletes medinensis* - Le Hérissé *et al,* p. 4, fig. 15.
2002 *Tetrahedraletes medinensis* - Lavender and Wellman, pl. 2, fig. 4.
2002 *Tetrahedraletes medinensis* - Rubinstein and Steemans, pl. 2, fig. 25.
2004 *Tetrahedraletes medinensis* - Rubinstein *et al*., p. 1047, text-figure 4B.
2007 *Tetrahedraletes medinensis* - Breuer *et al.*, pl. 3, fig. 17.
2008 *Tetrahedraletes medinensis* - Steemans *et al.*, figs. 10.1-10.2.

2011 *Tetrahedraletes medinensis* - Vecoli *et al.*, p. 83; pl. I, 1; pl II, 2, 5, 6–9, 13–15; pl. III, 1–3, 5; pl. IV, 4,12,14.

2013 *Tetrahedraletes medinensis* - Le Hérissé *et al*., fig. 8, O.

Description: Naked, unfused subtriangular to subspherical spore-like palynomorphs adhered tightly in permanent tetrahedral configuration or cross tetrad arrangement. The distal wall of each spore is relatively thin and thickens near the edges forming rounded crassitudes which are 2-5 µm in width. Each individual spore is distinguishable from the adjacent spores by a plane of attachment. The distal surfaces are rigid with none observed folded. The exine is laevigate.

Dimensions: L: 25(36)45µm, n = 15.

Remarks and comparison: *Acontotetras* species are distinguished from *T. medinensis*, in having exine sculptured with grana, coni or micro-coni, closely and widely spaced. *Cheilotetras caledonica* Wellman and Richardson, 1993 comprises fused spores. *Rimosotetras problematica* Burgess 1991 is composed of similar distally inflated, laevigate spores, but they are loosely adherent.

Occurrences: Hawaz Formation, mid–late Darriwilian (Llanvirnian); Melez Shugran, Memouniat and Bir Tlacsin formations, late Katian-Hirnantian (Ashgillian); Tanezzuft Formation, Rhuddanian- Telychian (Llandovery).

Selected previous stratigraphic record: Llandovery-Wenlock, USA (Strother and Traverse, 1979); Wenlock, England (Burgess and Richardson, 1991); Llandovery, Wales (Burgess, 1991); Silurian, Scotland (Wellman and Richardson, 1993); Ordovician-Silurian, southeast Turkey (Steemans *et al*., 1996); Caradocian, United Kingdom (Wellman, 1996); Early Devonian, Scotland (Wellman and Richardson, 1996); Late Ordovician, China (Wang *et al*., 1997); Llandovery-Wenlock, Ireland (Maziane-Serraj *et al.*, 2000); Llandovery, Saudi Arabia (Steemans *et al*., 2000); Silurian, Saudi Arabia (Wellman *et al*., 2000); late Aeronian-early mid Telychian, Brazil (Le Hérissé *et al,* 2001); Caradocian-Ashgillian, Belgium (Steemans, 2001); Early Devonian, Scotland (Lavender and

Wellman, 2002); Lochkovian, southwest Wales (Higgs *et al.,* 2004); Hirnantian-Llandovery, Argentina (Rubinstein *et al*., 2004); Silurian-Devonian boundary, Libya (Rubinstein and Steemans, 2002); Darrwilian-Llandovery, Oman (Molyneux *et al*., 2006); Early Devonian, northern Saudi Arabia (Al-Ghazi, 2007); Early-Mid Devonian, northern Saudi Arabia (Breuer *et al*., 2007); late Ludlow-Pridoli, northern Brazil (Steemans *et al*., 2008); Llandovery-Wenlock, Scotland, UK (Molyneux *et al.,* 2008); Silurian-Devonian, North Africa (Spina and Vecoli, 2009); Katian-Hirnantian, Anticosti Island, Québec, Canada, and Estonia (Vecoli., *et al*., 2011), Upper Ordovician (Hirnantian)-Early Silurian (Rhuddanian), northern Chad and southeastern Libya (Le Hérissé *et al*., 2013).

Genus ***Velatiteras*** Burgess, 1991

Type species: *Velatiteras laevigata* Burgess, 1991.

Diagnosis: “Obligate cryptospore tetrads composed of tightly-adherent laevigate sub-triangular to sub-circular spores with low and rounded ± fused equatorial crassitude. Tetrads enclosed within a closely adherent to completely separated, ± ornamented envelope; when envelope tightly-adpressed any ornamentation passes over spore contacts uninterrupted.” Diagnosis of Burgess (1991, p. 583).

Remarks: This genus erected by Burgess (1991) to accommodate all fused and unfused envelope-enclosed tetrads in this genus. Wellman (1996) accepted this view but highlighted the chance of separating the fused from unfused tetrads. However, the envelope restricts the possibility of distinguishing between the two forms. The genus *Stegambiquadrella* Johnson, 1985 accommodates loosely adhered cryptospores enclosed with an envelope. The genus *Tetrahedraletes* Strother and Traverse, 1979, emend. Wellman and Richardson, 1993 accommodates naked unfused tetrads. The genus *Cheilotetras* Wellman and Richardson, 1993 accommodates naked fused tetrads.

Velatiteras laevigata Burgess, 1991

Plate 4, Fig. 1

For synonymy see Burgess (1991).
Additional synonymy:
1991 *Velatiteras laevigata* - Burgess, pl. 1, figs. 5, 6.
1996 *Velatiteras laevigata* - Burgess, 1991; Steemans *et al*., pl. V, figs. 5- 7.
1996 *Velatiteras laevigata* - Burgess, 1991; Wellman, pl. 3, figs. 5-7.
2000 *Velatiteras laevigata* - Burgess, 1991; Steemans *et al*., pl. 4, figs. e, f.
2001 *Velatiteras laevigata* - Le Hérissé *et al* , pl. 4, figs. 19.
2011 *Velatiteras laevigata* - Vecoli *et al.*, p. 84; pl. I, 12; pl. III, 13–19; pl. IV, 8.
2013 *Velatiteras laevigata* - Le Hérissé *et al*, fig. 8, M.

Description: Tetrads of sub-circular outline enclosed within a thin, transparent laevigate envelope, varies from completely separated to closely adpressed. The tetrads are composed of unfused laevigate sub-triangular spores with rounded equatorial crassitude.

Dimensions: L: 35(38)40µm, n = 4.

Remarks and comparison: The envelope in *Velatiteras reticulata* Burgess, 1991 is ornamented with muri forming a reticulum and the envelope in *Velatiteras rugulata* Burgess, 1991 is ornamented with sinuous to convolute and anastomosing rugulae.

Occurrences: Hawaz Formation, mid–late Darrwilian (Llanvirnian); Memouniat Formation, late Hirnantian (Ashgillian); Tanezzuft Formation, late Rhuddanian-Telychian (Llandovery).

Selected previous stratigraphic record: Llandovery, Wales (Burgess, 1991); Ordovician-Silurian, southeast Turkey (Steemans *et al*., 1996); Caradocian, UK (Wellman, 1996); Llandovery, Saudi Arabia (Steemans *et al*., 2000); Katian-Hirnantian, Anticosti Island, Québec, Canada and Estonia (Vecoli., *et al*., 2011), Upper Ordovician (latest Hirnantian)-Early Silurian (Rhuddanian), northern Chad and southeastern Libya (Le Hérissé *et al*., 2013).

.

Tetrad sp.A

Plate 3, Fig. 7

Description: Tetrad cryptospore with sub-circular to circular amb, wall surface ornamented by closely spaced angular rugulae. A thin membrane is not clearly visible at the margin.

Dimensions: L: 40(45)50, n = 4.

Remarks and comparison: *Velatitetras rugosa* (Strother and Traverse) Le Hérissé and Bozdogan, 1996 differs from this species in having tetrad or tetrahedral tetrad entirely enclosed with an envelope, However, the ornamentation in this species is similar to it.

Occurene: Hawaz Formation, mid–late Darriwilian (Llanvirnian).

Tetrad spp.

Plate 3, Figs. 8, 9

Description: Tetrad with sub-circular to sub-triangular amb. Distally patinate. Proximal surface with irregular trilete cracks, laevigate or ornamented with rounded verrucae.

Dimensions: L**:** 25(27)28µm, n = 2.

Remarks and comparison: *Imperfectotriletes vavrdovae* (Richardson, 1988) Steemans *et al.,* 2000 is crassitate.

Occurrences: Hawaz Formation, mid–late Darriwilian (Llanvirnian).

Incertae sedis

Genus ***Quadrisporites*** Hennelly, 1958 emend. Potonié and Lele, 1961

Type species: *Quadrisporites horridus* Hennelly, 1958.

Diagnosis: "Four bodies together in rhomboidal or square position; flattened in the bedding plane and perhaps originally more or less globular; bodies not bean shaped, germinal aperture not seen; ornamentation shows grana, pilae or bacula." Emended diagnosis of Potonié and Lele (1961, P. 25).

Remarks: Cramer and Díez (1972) considered *Tetraletes* Cramer, 1966b as a junior synonym of *Quadrisporites.* Segroves, 1967. Le Hérissé (2002) suggested an algal origin of this genus.

Quadrisporites granulatus (Cramer, 1966b) Cramer and Díez, 1972.

Plate 4, Figs. 2, 3, 4

For synonymy see Steemans *et al.,* (1996).
2008 *Quadrisporites granulatus* - Pasquo and Noetinger, fig. 7 (B, C)

Description: Tetrad cryptospore with sub-circular to rectangular outline, consisting of four laevigate spore-like cells, arranged in a square to rhomboidal configuration. The spore-like cells are surrounded with thick rings, creating a cross at the centre of the tetrad.

Dimensions: L: 31(39)46µm, n = 8.

Remarks and Comparison: *Quadrisporites variabilis* (Cramer, 1966b) Cramer and Díez, 1972, has spore like cells that are sculptured with randomly-distributed cone-like spines

Occurence: Hawaz Formation, mid–late Darriwilian (Llanvirnian); Melez Shugran, Memouniat and Bir Tlacsin formations, late Katian-Hirnantian (Ashgillian); Tanezzuft Formation, late Rhuddanian- early Telychian (Llandovery).

Selected previous stratigraphic record: Late Silurian-Early Devonian, Spain (Cramer, 1966a); Silurian, Libya (Richardson and Ioannides, 1973; Richardson and McGregor, 1986); Silurian-Devonian (Rauscher, 1973; Rauscher and Robardet, 1975; early Pragian-early Emsian, Massif Armoricain (Le Hérrisé, 1983); Late Ordovician, Turkey (Steemans et al., 1996) Early Devonian (Lochkovian), Bolivia (Pasquo and Noetinger, 2008).

Genus A. Steemans, Higgs and Wellman, 2000

Description: "Ornamented and permanently fused pseudodyads, divided by a single more or less central thickened encircling band, and totally enclosed within a closely adherent to completely separated laevigate envelope." From Steemans, Higgs and Wellman (2000, p. 106, 107).

Remarks: The genus *Segestrespora* Burgess, 1991 differs from this genus, in having a laevigate dyad enclosed with a laevigate or ornamented envelope.

Genus A. Sp. A. Steemans, Higgs and Wellman, 2000

Plate 4, Fig. 5

For synonymy see Steemans, Higgs and Wellman, 2000
Additional synonymy:
2000 Genus A. Sp. A **-** Steemans, Higgs and Wellman, p. 107; pl., 5 (g, h)

Description: Pseudodyad elliptical to sub-circular in outline. The two spores are of similar or variable sizes and joined tightly by a single darkened encircling band. The wall is ornamented with irregular distributed verrucae that are irregular in shape.

Dimensios: L: 45(48)50 µm, n = 2.

Remarks and Comparison: This species is similar in morphology to the species described by Steemans *et al.,* (2000) from the Llandovery of Saudi Arabia but it bigger in size. *Pseudodyadospora* sp. B Richardson, 1988 has the dyads wall ornamented with small grana.

Occurence: Hawaz Formation, mid–late Darriwilian (Llanvirnian); Bir Tlacsin Formation, late Hirnantian (Ashgillian); Tanezzuft Formation, late Rhuddanian-ealy Aeronian (Llandovery).

Selected previous stratigraphic record: Llandovery, Saudi Arabia (Steemans, Higgs and Wellman, 2000).

Micro-ornamented monads

Plate 4, Fig. 6

Description: Monad cryptospore oval to sub-circular in outline, with equatorial to sub-equatorial crassitude. Exine ornamented with fine grana.

Dimensions: L: 24(26)28µm, n = 4.

Remarks and comparision: The naked laevigate monad described by Wellman (1996) is very similar but is described as laevigate.

Occurrence: Hawaz Formation, mid–late Darriwilian (Llanvirnian); Melez Shugran, Memouniat and Bir Tlacsin formations, late Katian-Hirnantian (Ashgillian); Tanezzuft Formation, late Rhuddanian- early Telychian (Llandovery).

4.4.1.1.2 Spores

For the systematic description of trilete spores the terminology of Grebe (1971) is adopted and followed in this study.

Anterurma **SPORITES** Potonié 1893
Turma **TRILETES** Reinsh, 1891
Subtratum **ZONOTRILETES** Waltz 1935

Infratum **CRASSITI** Bharadwaj and Venkatachala 1961

Genus ***Ambitisporites*** Hoffmeister, 1959

Type species: *Ambitisporites avitus* Hoffmeister, 1959.
Diagnosis: “Trilete, radial miospore, sub-circular to roundly triangular in equatorial outline, and possessing a well defined, simple trilete and an equatorial crassitudo.” From Hoffmeister (1959, p. 331).

Ambitisporites dilutus (Hoffmeister, 1959) Richardson and Lister, 1969
Plate 4, Fig. 7

1959 *Punctatisporites?dilutus* - Hoffmeister, p. 334; pl. 1, figs. 9-13.
1969 *Ambitisporites dilutus* - Lister, p. 229; pl. 40, fig. 3.
1973 *Ambitisporites dilutus* – Richardson and Ioannides, p. 277; pl. 5, figs. 1-8.
1985 *Ambitisporites dilutus* – Hill *et al*., pl. 16, figs. 5, 6.

1986 *Ambitisporites dilutus* – Richardson and Mc Gregor, pl. 1, fig. 2.

1991 *Ambitisporites dilutus* – Burgess and Richardson, pl. 615, Text-fig. 3 (D, H).

1996 Morphon *Ambitisporites avitus–dilutus senus* - Steemans *et al*., p.47; pl II, figs. 11-14.

1996 *Ambitisporites dilutus* – Wellman and Richardson, p.76; pl. 7, fig. 9.

2000 Morphon *Ambitisporites avitus–dilutus senus* - Steemans *et al.,* p.128; pl. 5 (g, h, i)

2001 *Ambitisporites dilutus* – Beck and Strother, p.136, 140; pl. 1, fig. 14.

2002 *Ambitisporites dilutus* – Burden *et al*., , p208; pl. 5, fig. 14.

2003 *Ambitisporites dilutus* – Ghavidel-Syooki, pl. I, fig. 12.

2004 *Ambitisporites dilutus* – Higg, fig. 7 (R,T).

2005 *Ambitisporites dilutus* – Wang *et al*., pl. II, figs. 11, 12.

2010 Morphon *Ambitisporites avitus–dilutus senus* - Steemans *et al., ;*Wang and Zhang, fig. 5 (m-o).

Description: Trilete spore sub-triangular with broadly convex sides with a well defined trilete laesura extending the full length of spore radius and sometimes accompanied by distinct lip. The exine is about 1-2µm thick, smooth, thickest at the equator where it forms a narrow crassitude and the curvaturae perfecta usually confluent with the equator.

Dimensions: L: 40(45)50µm, n = 4.

Remarks and Comparison: *Ambitisporites avitus* Hoffmeister, 1959 has a more prominent crassitude than *Ambitisporites dilutus. Imperpectotriletes vavrdovae* (Richardson) Steemans *et al*., 2000 has a trilete mark that is a simple split without predefined laesurae.

Occurence: Tanezzuft Formation, mid Rhuddanian-Telychian (Llandovery).

Selected previous stratigraphic record: Silurian, Libya (Hoffmeister, 1959; Richardson and Ioannides, 1973; Al Ameri, 1984 unpublished thesis); Llandovery southwest Wales, UK (Burgess and Richardson, 1991), northeast Libya (Hill *et al*., 1985); Lochkovian, Scotland (Wellman and Richardson, 1996), southwest Wales (Higg, 2004); Silurian, Saudi Arabia (Wellman et al, 2000), Canada (Burden *et al.,* 2002); Devonian, Iran (Ghavidel-syooki, 2003); Silurian, China (Wang *et al.,* 2005); Llandovery, China (Wang and Zhang, 2010).

CHAPTER 5. REVIEW OF ORDOVICIAN-SILURIAN PALYNOLOGY

5.1. Introduction

Acritarchs and chitinozoans are diverse and abundant in marine sediments from Early Palaeozoic times. Cryptospores appeared in the Mid Ordovician and occur in non-marine and marine deposits. The three groups are widely used for biostratigraphical purposes in different parts of the world. The palynology review provided here concerns the three groups reported only from Gondwana and only from the Mid-Late Ordovician and the Early Silurian (Llandovery).

5.1.1. Acritarchs

5.1.1.1. Libya

Several papers have been devoted to Mid Ordovician-Early Silurian acritarch-based palynostratigraphy of Libya. Deunff and Massa (1975) published acritarch data from the Tremadocian, the Arenigian and the Llanvirnian-Caradocian of Libya. Late Ordovician-Early Silurian acritarch and chitinozoan from the northeast Libya subsurface have been described by Molyneux and Paris (1985) and Hill *et al*., (1985). In particular Hill and Molyneux (1988) defined three Late Ordovician biozones ranging from the Caradocian-Ashgillian and four Llandovery assemblage biozones ranging from the Rhuddanian-Telychian.These assemblage biozones were compared with the acritarch assemblages from the type area of Great Britain (Hill and Dorning, 1984). Grignani *et al*. (1991) defined nineteen palynological assemblages ranging in age from Ordovician to Late Triassic from the Al Kufra Basin, southeast Libya. Two assemblages from the Late Ordovician were recognized and one assemblage from the Early Silurian based on acritarch and chitinozoan. Vecoli, *et al.*, (2003) synthesized the palynostratigraphic data from the Ghadames Basin, northwest Libya and adjoining area in southern Tunisia and confirmed the applicability of the zonation proposed in Vecoli (1999) and Vecoli *et al*., (1999a) over the studied data from the Ghadames Basin, with the addition of one further acritarch biozone of Mid Cambrian age. The study also showed that variation in the diversity of the phytoplankton indicates that the depositional environment was restricted to marine conditions during the Early-Mid Cambrian through the early Tremadocian, with evidence for a regression event near the Cambrian-Ordovician transition. The late Tremadocian - early Arenigian was a period of erosion which resulted in a stratigraphic gap in the sedimentary record. A major transgression took place in the late Arenigian-early Llanvirnian. During the Ashgillian there was a relatively shallow water environment. More palynological data from northwest and southwest Libya studies are contained in an unpublished thesis (Al Ameri, 1983) and unpublished reports of the National Oil Corporation, Libya (lithology, biostratigraphy and paleoenvironments of fifty-six wells drilled in the Ghadames and Murzuq Basin of western Libya; Mesozoic and Palaeozoic biostratigraphy of concession blocks NC186, NC187 and NC190, Murzuq Basin).

5.1.1.2. Northern Chad and southeast Libya

Two acritarch assemblage zones associated with two chitinozoan assemblage zones and one cryptospore assemblage zone were identified recently by Le Hérissé *et al*., (2013) from 23 core samples selected from Late Ordovician-earliest Silurian sediments of the Moussegouda core hole in the Erdi Basin, northern Chad, and from two samples from well KW-2 in Kufra Basin, southeastern Libya. Two new palynomorphs of biostratigraphical interest were described and illustrated. The recovered palynomorph assemblages are compared and correlated with contemporaneous assemblages recorded in other northern Gondwana localities (Mauritania, Morocco, Algeria, Libya, Africa, Saudi Arabia, Jordan), and in South Africa, in order to evaluate possible effects of the ice cap melting on palynomorph assemblages and sedimentation. This suggests that the topmost Ordovician (Hirnantian) or earliest Silurian (early Rhuddanian) in northern Chad and southeastern Libya, reflects near shore conditions, with obvious fresh water influences. The lack of black shale or grey shale in the uppermost Ordovician and of “hot shale” in the lower Silurian in these areas, and their replacement by siltstones, are probably related to an isostatic readjustment that rapidly starved the marine sedimentation in the areas previously overlain by a thick ice cover during the climax of the Hirnantian glaciation.

5.1.1.3. Algeria and Tunisia

Acritarch data from subsurface sections in Algeria and southern Tunisia have been published by Vecoli (1999) and Vecoli *et al.* (2003). In the Mid-Late Ordovician, three zones were recognized and assigned to the late Arenigian, Llanvirnian and Ashgillian. The study also showed that the early Tremadocian and Llanvirnian were times of maximum microphytoplankton diversity in North Africa. Late Arenigian-Llanvirnian assemblages overall showed peri-Gondwanan affinities. Hirnantian and Llandovery acritarch species associated with chitinozoan are also reported by Vecoli *et al*. (2009) from southern Tunisia. Paris *et al*. (2000b) investigated the effects of the final stages of the Late Ordovician glaciations on acritarchs and leiospheres from the northeastern, Algerian Sahara. The study concluded that some species survived the glaciation (e.g. *Eupoikilofusa striata*, *Villosacapsula setosapellicula*), while other pre-existing taxa, especially those with the most complex morphology, disappeared (e.g. *Ordovicidium elegantulum*, *Orthosphaeridium octospinosum*). After glacial events, the survivors were mainly small and of simple morphology (e.g. *Evittia*, *Michrystridium*, *Multiplicisphaeridium*, *Veryhachium*). Other contributions on Algerian acritarch materials are those of Deunff (1961, 1964), Jardiné *et al.* (1974) and Baudelot and Géry (1979).

5.1.1.4. Morocco

Many acritarch data, including new taxa, were described from late Arenigian to Llanvirnian subsurface deposit from Morocco (e.g. Cramer, 1974; Cramer *et al*., 1974; Cramer and Díez, 1976, 1977; Elaouad-Debbaj, 1984, 1988). The Ashgillian Moroccan assemblages are of low abundance and poor preservation. In North Africa, early Ashgillian acritarch assemblages are reported only from Moroccan localities (Vecoli, 2008). Bourahrouh *et al*. (2004) investigated the abundance and diversity of acritarchs in an integrated study with chitinozoans to interpret the palaeoenvironments of the Late Ordovician of Morocco. Acritarch assemblages were used to date Late Ordovician-Silurian successions in eastern Morocco by Le Heron *et al*. (2008).

5.1.1.5. Jordan

Basha (1987, 1990) briefly reported a few Ordovician acritarchs from southern and eastern Jordan. Detailed acritarch biostratigraphy of Jordan has been investigated by Keegan *et al*. (1990). Three assemblages were recognized in the Mid-Late Ordovician, dated as Llanvirnian, Caradocian and Ashgillian, and two assemblages were recognized in the Llandovery- Wenlock. Noting a decline in overall acritarch diversity, Loydell *et al*. (2009) briefly referred to acritarch abundance and diversity from the Llandovery Batra Formation.

5.1.1.6. Saudi Arabia

Most acritarch data from the Arabian Plate are from Saudi Arabia. Ordovician-Silurian acritarch studies were initiated in Saudi Arabia by Hemer (1968). McClure (1988) briefly reported the occurrence of a few acritarch species from the Ordovician but did not provide any illustrations. Jachowicz (1995) investigated acritarch assemblages from the Ordovician of central and northwestern Saudi Arabia. Four acritarch assemblages were documented and dated as Tremadocian-Arenigian, early Caradocian, late Caradocian and early Ashgillian. These palynological units are generally broad-based. This acritarch based Ordovician palynostratigraphy has been further improved by Molyneux and Al-Hajri (2000) who conducted a detailed study on biostratigraphy and palynofacies from the sub-surface of central Saudi Arabia. They documented several acritarch assemblages ranging in age from Early or Mid Cambrian, through Early, Mid and Late Ordovician to Llandovery. They suggested near shore, marginal-marine conditions for low diversity assemblages. For infrequent occurrences of more diverse assemblages, they suggested open marine shelf sea environments. Le Hérissé *et al*. (2007) investigated acritarch occurrences and environmental changes in the early Mid Ordovician of Saudi Arabia. Based on acritarch recovery combined with detailed sedimentology, Miller and Al-

Ruwaili (2007) identified Hirnantian Gondwanan glacial sediments in the Late Ordovician Sarah Formation in central Saudi Arabia. Le Hérissé *et al*. (1995) discussed the stratigraphic and palaeogeographic significance of acritarch assemblages from the Silurian subsurface of central and northern Saudi Arabia. They described eleven new acritarch species and proposed several informal acritarch assemblage zones in the Llandovery. The same assemblages have been recognized later by Le Hérissé (2000) in a study investigating acritarch recovery from the Llandovery subsurface of central Saudi Arabia. Le Hérissé (2000) correlated the newly proposed acritarch zonation with the Saudi acritarch zonation of Le Hérissé *et al*. (1995), the Saudi Arabia chitinozoan zonation of Paris *et al*. (1995) and Paris and Al-Hajri (1995) and the global Silurian chitinozoan zonation of Verniers *et al*. (1995). Seven acritarch assemblages ranging in age from earliest Rhuddanian to mid to late Telychian have been recognized. The first three assemblages are assigned to the Rhuddanian and corresponds to zones 1, 2 and 3 of Le Hérissé *et al*. (1995). Zones 4 and 5 of Le Hérissé *et al*. (1995) have also been recognized and assigned to the Aeronian and early Telychian respectively. Taking into account data from chitinozoan occurrences, the age assignment of zones 6 and 7 has been readjusted to the Llandovery or Llandovery-Wenlock boundary. In a taxonomic publication, Al-Ruwaili (2000) described new acritarch species from the Llandovery-Ludlow Qalibah Formation in northwestern Saudi Arabia. The acritarch-based palynostratigraphic understanding of the Ordovician and Silurian of Saudi Arabia has been summarized by Al-Hajri and Owens (2000).

5.1.1.7. Oman

A few papers report acritarchs from Oman. Lovelock *et al*. (1981) briefly recorded acritarch assemblages from the Early and Mid Ordovician of Oman. Droste (1997) published a biozonation scheme based mainly on acritarchs and to a lesser extent on chitinozoans and cryptospores. Four broad biozones, the Furongian (Late Cambrian)-Tremadocian (Zone 1108), the Mid Ordovician (Zone 1098), the Late Ordovician (Zone 1005 including an informal Assemblage Unit 1012) and the Llandovery 1003, were recognized in the Haima Supergroup. Molyneux *et al*. (2006) considered this scheme to be of low resolution and incorporating misconceptions over the ranges of key taxa. Similarly to Droste (1997), the biozonation scheme is based mainly on acritarchs and to a lesser extent on chitinozoans. The biozones were correlated with maximum flooding surfaces proposed by Sharland *et al*. (2001) for the Arabian Plate.

5.1.1.8. Iraq

Al-Ameri (2009) proposed four biozones in the Mid-Late Ordovician and a single biozone in the Llandovery sediments of western Iraq based on acritarchs and the presence of a few chitinozoans and spores.

5.1.1.9. Iran

Several papers have been published on Ordovician-Llandovery acritarch palynostratigraphy from Iran. Bozorgnia (1973) first reported a few acritarchs from northern Iran. Ghavidel-syooki (1995) recorded three acritarch assemblage biozones in Tremadocian-Arenigian strata in the Lashkarak Formation in northern Iran. Later, six assemblages in the Ordovician and two assemblages in the Llandovery were identified in the Zagros Basin in southern Iran (Ghavidel-syooki, 1996). In eastern central Iran, Ghavidel-syooki (2003) identified three acritarch assemblage biozones in the Middle-Late Ordovician (Llanvirnian-Ashgillian) and a broad single biozone in the Llandovery-early Wenlock. Ghavidel-syooki (2006) identified two acritarch zones in the Late Ordovician (Caradocian-Ashgillian) in northern Iran. Most of these studies concluded that the Iranian acritarch assemblages indicate broad similarity with those from southern Europe, northern Africa, southwestern China and Saudi Arabia. Ghavidel-syooki (2008) described the acritarch assemblages associated with the recognized chitinozoan formal biozones from the Late Ordovician of the Gorgan Schists, northern Iran. These chitinozoan biozones ranging from late Katian-Hirnantian.

5.1.1.10. Turkey

Erkmen (1979) began acritarch investigations from Turkey, indicating a Caradocian-Arenigian age for the Badinan Formation in the southeastern part of Turkey. Erkmen and Bozdoğan (1979) recorded abundant and well preserved acritarchs, chitinozoans, tasmanites and scolecodonts from the Dada Formation of southeast Turkey, suggesting a Upper Llandovery-Ludlow age for this Formation based on acritarchs, which resemble mid Silurian assemblages from Tunisia and Libya. Other acritarch data from poorly preserved palynological materials are reported by Dean and Martin (1992) and Dean *et al*. (1993), reporting Tremadocian, Arenigian and Ashgillian acritarchs from southern Turkey. Acritarch assemblages of Ashgillian age have been documented by Steemans *et al*. (1996) from southeastern Turkey. The most detailed acritarch-based study is the investigation of the Ordovician of southern and southeastern Turkey by Paris *et al*. (2007). Eight local assemblage biozones have been recognized; two in the Arenig, one in the Llanvirn, two in the Caradoc and three in the Ashgillian.

5.1.1.11. India and Pakistan

Acritarch studies from Peninsular India are fairly rare. Khanna *et al*. (1985) reported the occurrence of Ordovician acritarchs from the Late Ordovician Yong Limestone from India. Sinha *et al*. (1996a, 1996b) reported diverse species of acritarchs from the Late Ordovician Shiala and Yong Formations. The only detailed investigation of Indian Ordovician–Silurian acritarchs was by Sinha *et al*. (1998). Four local acritarch assemblage zones were proposed, two of them are Late Ordovician-Llandovery in age. From Pakistan, Tongiorgi *et al*. (1994) recognized two acritarch assemblages from the Arenigian sedimentary sequence overlying the Ishkarwaz Granite.

5.1.1.12. South China

Most Asian Ordovician acritarch data are from China. A complete review of Chinese acritarch studies, listing over 100 articles published in the last three decades, was compiled by Li *et al.* (2002). More than half of all publications concerned Ordovician acritarchs of South China, including descriptions of approximately 100 new species. Acritarch studies from Early and Mid Ordovician sections in South China were conducted by Li (1987, 1989) and Li *et al*. (2000). The studies concluded that the Arenigian and Llanvirnian acritarchs from South China show strong affinities to the Mediterranean palaeobiogeographical acritarch province. This suggest that during the Arenigian-Llanvirnian, South China should be included in the peri-Gondwanan palaeobiogeographical acritarch province (Li *et al*., 2002). Brocke *et al*. (2000) distinguished four acritarch assemblages from the late Arenigian to early Llanvirnian of South China. Tongiorgi *et al*. (1995; 1998) and Yin (1995) proposed changing palaeobiogeographical affinities of acritarch assemblages throughout the early to late Arenigian, attributing this change to oceanic current changes and sea level fluctuations. Palynomorphs from the transitional sequences between the Ordovician and Silurian have been investigated by Yin and He (2000). Taxonomical discussions on Chinese taxa have been published by several authors (Servais *et al*., 1996; Brocke *et al*., 1997; Fatka and Brocke, 1999). Yan and Li (2010) investigated the palaeoenvironmental implication of Lower-Middle Ordovician acritarch communities from four sections in South China. They recognized ten acritarch ecological assemblages with their distributions controlled by environmental changes. The South Chinese acritarch distribution and diversity curves have been illustrated and discussed by Yan *et al*. (2005) and Li *et al*. (2004, 2007). From the Silurian, acritarchs have been reported from the Wenlock and younger sediments, while no investigations have been published on the Llandovery acritarchs of South China (Li *et al*., 2002).

5.1.1.13. Australia

Only a few published papers concern acritarch data from Australia. Very briefly, Combaz (1965) and Combaz and Péniguel (1972) reported the occurrence of acritarchs from the eastern Australian Georgiana and the western Australian Canning Basins, respectively. Detailed descriptions of assemblages from the Arenig-Llanvirn sections were published by Playford and Martin (1984) from the Canning Basin, Western Australia. From the same basin, Quintavalle and Playford (2006a,b) published Ordovician acritarchs and chitinozoans taxonomical and biostratigraphical data. They recognized five acritarch zones and four chitinozoan zones, ranging from early Arenigian through late Llanvirnian. Also from the Canning Basin in Western Australia, Quintavalle and Playford (2008) investigated acritarch distribution from the Early and Mid Ordovician subsurface. Eight morphologically distinctive acritarch species have been selected to characterize the Dapingian and Darriwilian stages of Western Australia.

5.1.1.14. South America

Few papers have been published from the Mid-Late Ordovician-Llandovery of South America. Rubinstein and Toro (2006) reviewed the publications on South American acritarchs of the Eastern Cordillera and northwestern Argentina. Playford *et al*. (1995) created the "South America" acritarch subprovince. From Brazil, Padilha de Quadros (1986, 1988) described a poorly diversified assemblage attributed to the Arenig-Llanvirn. Théry (1985) and Théry *et al*. (1986) published Ordovician acritarch assemblages from Colombia. Acritarch data from Bolivia was published by Gagnier *et al*. (1996). In Argentina, Ottone *et al*. (1999) and Vergel *et al*. (2002) considered acritarchs in integrated studies of the Ordovician palynomorphs of Argentina. Rubinstein (2003) conducted an acritarch-based study of Ordovician biostratigraphy and palaeoenvironment of northwestern Argentina. The Aeronian (Llandovery) acritarchs from northwestern Argentina have been investigated by Rubinstein and Toro (2006).

5.1.1.15. Regional and global investigations

The Ordovician acritarch distribution from different parts of Gondwana has been discussed in detail by Servais *et al*. (2003), mostly based on original investigations and on revision of published works. Vecoli and Le Hérissé (2004) compiled a taxonomically consistent and chronostratigraphically well constrained dataset of Ordovician acritarchs from the northern Gondwana margin. They analyzed the diversity and biodynamic patterns of acritarch communities during latest Cambrian through latest Ordovician times. In addition, the stratigraphic ranges of the acritarch species are precisely established based on cross-correlation with the chitinozoan biozonation. Vecoli (2008) investigated acritarch dynamics across the Ordovician–Silurian boundary. Based on stratigraphic occurrences of morphologically well-defined and palaeogeographically well distributed taxa, the study resulted in an updated, informal acritarch biozonation of the latest Ordovician–earliest Silurian stratigraphic interval. The study concluded that there was not a mass-extinction event among acritarchs connected with the Late Ordovician glaciations.

5.1.2. Chitinozoans

5.1.2.1. Libya

Late Ordovician-Lower Silurian acritarchs and chitinozoans from northeast Libya subsurface have been investigated by Molyneux and Paris (1985) and Hill *et al*., (1985). In particular, Paris (1988) defined three Late Ordovician chitinozoan biozones ranging from Caradocian-Ashgillian and four Llandovery chitinozoan biozones ranging from Rhuddanian–Telychian. New Late Ordovician and Llandovery species were also described. Grignani *et al*. (1991) defined nineteen palynological assemblages ranging in age from Ordovician to Late Triassic from the Al Kufra Basin southeast Libya. Two assemblages within the Late Ordovician were recognized based on chitinozoans. These assemblages were compared with the Late Ordovician chitinozoans assemblages defined from northeast Libya by Molyneux and Paris (1985), and one assemblage from the Early Llandovery was also recognized based on chitinozoan, associated acritarch and graptolites. Based on palynological and palynofacies analysis, Paris *et al*., (2012) defined two chitinozoan biozones associated with acritarchs in the Tanezzuft sequence of well CDEG-2a drilled in Dor el Gussa, eastern Murzuq Basin, dated to Rhuddanian-early Aeronian in age and assigned to the *S. fragilis* and *L. nuayyimensis* biozones. This sequence was correlated with other sequences of northern Gondwana. Recently, Butcher (2013) studied the chitinozoans in Well E1-NC174 core, and suggested that the entire core is to be of Rhuddanian age, with the hot shale constrained to the upper part of the range of *Belonechitina postrobusta* and assigned to the mid Rhuddanian.

5.1.1.2. Northern Chad and southeast Libya

Two chitinozoan assemblages associated with two acritarch assemblage zones zone and one cryptospore assemblage zone have been identified recently by Le Hérissé *et al*., (2013) from 23 core samples selected from Late Ordovician-earliest Silurian sediments of the Moussegouda core hole in the Erdi Basin, northern Chad, and from two samples from well KW-2 in Kufra Basin, South East Libya. These assemblages range from Hirnantian-Rhuddanian.

5.1.2.3. Algeria and Tunisia

Chitinozoans from Algeria have been investigated extensively by Oulebsir and Paris (1993, 1995) and Paris *et al*. (2000b). Nine new species have been described from the Early and Mid Ordovician of the northwestern Algerian Sahara by Oulebsir and Paris (1993). Oulebsir and Paris (1995) recognized most northern Gondwana chitinozoan zones from the late Arenigian-mid Caradocian strata from the Algerian Sahara. Paris *et al*. (2000b) investigated the effects of the final stages of the Late Ordovician glaciations on Algerian chitinozoans. The study concluded that the glaciation did not cause a mass extinction of the chitinozoans, and taxa that were well represented in the pre-glacial deposits survived the Late Ordovician glaciation. However, fairly low diversity and abundance was recorded. Hirnantian and Llandovery chitinozoan species are also reported from southern Tunisia by Vecoli *et al*. (2009).

5.1.2.4. Morocco

Many chitinozoan data were described from Tremadocian, Arenigian and Llanvirnian subsurface materials from Morocco (e.g. Elaouad-Debbaj, 1984a, 1988). Ashgillian chitinozoan assemblages from Morocco were also investigated by Elaouad-Debbaj (1984b) who identified thirty species of chitinozoan in the upper Kataoua Formation and in the lower Deuxierne Bani Formation. Low abundances of poorly preserved chitinozoans, acritarchs and miospores were also reported from Morocco by Bahmani (1978). Soufiane and Achab (1993) described two new species and identified five chitinozoan assemblages from Ordovician rocks of the Tedla Basin in Morocco. The assemblages were dated as late Arenigian, latest Arenigian, late Llanvirnian, early Caradocian and late Ashgillian. Bourahrouh *et al*. (2004) investigated the biostratigraphy, biodiversity and palaeoenvironments of the Late Ordovician of Morocco. Five late Caradocian-Ashgillian chitinozoan biozones belonging to the North Gondwana zonation were identified and no significant environmental changes were recorded in late Caradocian and early Ashgillian chitinozoan assemblages. Late Katian-Hirnantian chitinozoan assemblages were used to date Upper Ordovician - Silurian successions in eastern Morocco by Le Heron *et al*. (2008).

5.1.2.5. Mauritania

Only one record of Mauritanian chitinozoa has been published by Paris *et al*. (1998). A high resolution biostratigraphy for the late Hirnantian-early Rhuddanian deposits was documented in southeastern Mauritania where four local chitinozoan assemblages were recognized.

5.1.2.6. South Africa

Chitinozoan were recovered for the first time from South Africa by Cramer *et al*., (1974), who listed a fauna that is not highly age diagnostic. They were only able to date the deposit to the Late Ordovician. No systematic descriptions were provided and no scanning electron microscope (SEM) photographs were shown. Chitinozoan from South Africa were also described and illustrated by Gabbott *et al*. (1998) from the Soom Shale. Their specimens, mainly of the genus *Cyathochitina*, occurred on bedding planes as scattered individuals, linked chains and aggregated masses, sometimes associated with organic envelopes. Vandenbroucke *et al.* (2009) in their study of the Soom Shale Member (latest Hirnantian–earliest Rhuddanian) in South Africa considered *Sphaerochitina oulebsiri* and *Sphaerochitina fragilis* as separate species, and erected a new species, *Spinachitina verniersi*, which they synonymise with a subset of the *Spinachitina fragilis* specimens studied by Butcher (2009).

5.1.2.7. Jordan

Keegan *et al*. (1990) and Loydell *et al*. (2009) briefly referred to chitinozoan taxa and their abundance and diversity from the Ordovician and Llandovery of Jordan. More detailed investigation of the Jordanian Llandovery chitinozoans was conducted recently by Bucher (2009). In this study, a new species were erected and two Rhuddanian local biozones recognized and correlated with local and global chitinozoan and graptolite biozonations.

5.1.2.8. Saudi Arabia

Chitinozoan studies from Saudi Arabia contribute very significantly to current understanding of chitinozoan biostratigraphy and zonation on both a regional and global scale. The occurrence of chitinozoan in the Lower Palaeozoic of Saudi Arabia has been known since the early investigations of Hemer (1968). The specific diversity of Ordovician and Llandovery chitinozoan assemblages from northern parts of Saudi Arabia has been illustrated by McClure (1988). Detailed biostratigraphic study, including a detailed zonation scheme, on Ordovician chitinozoan from northwestern Saudi Arabia has been published by Al-Hajri (1995). Ten chitinozoan biozones have been recognized, ranging from mid Arenig to mid Ashgillian, and correlated with biozones of northern Gondwana (Paris, 1990). Later, four chitinozoan assemblages were documented by Paris *et al*. (2000a) in several wells penetrating the Mid-Late Ordovician Qasim Formation from central Saudi Arabia. They established local biostratigraphic subdivisions correlated with the northern Gondwana biozones of Paris (1990). Furthermore, they selected *Tanuchitina fistulosa* Taugourdeau and de Jekhowsky, 1960 as the index species of a new late Caradocian zone within the previously undefined interval between the *robusta* and *nigerica* biozones in the northern Gondwana biozonation of Paris (1990). In their study, Assemblage 1 was reported from post-Quwarah to pre-Qusaiba strata (Sarah Formation) and was assigned to the late Ashgillian. Assemblage 2 from the Quwarah member is characterized by diagnostic species of the Ashgillian Assemblage 3 from the Ra′an member has been assigned to the late

Caradocian with a possible earliest Ashgillian age. Assemblage 4 is recorded from the middle part of the Hanadir Member and is characterized with the diagnostic taxa of the Llanvirnian. Assemblages 2, 3 and 4 of Paris *et al*. (2000a) are, respectively, correlated with the *A. merga - A. nigerica*, the *A*. n. sp. aff. *fistulosa* and *L. pissotensis* biozones of Al-Hajri (1995). Chitinozoan of Darriwilian (Llanvirnian) age from the Hanadir Member of the Qasim Formation has been reported and illustrated by Le Hérissé *et al*. (2007). From the Llandovery, Paris *et al*. (1995) distinguished eight local chitinozoan biozones in the sub-surface of Saudi Arabia. The study also concluded that Saudi chitinozoan populations have a great similarity with North Gondwana and moderate to fairly low similarities with Baltica. Some affinities between the Saudi and the Chinese material are reported. New chitinozoan species from the Llandovery of central Saudi Arabia have been described by Paris and Al-Hajri (1995).

5.1.2.9. Oman

Chitinozoan studies in Oman have been begun recently. Al-Ghammari *et al*. (2010) described four new Darriwilian chitinozoan species from the Mid Ordovician Saih Nihayda Formation. Dapingian and Darriwilian chitinozoan assemblages have also been used by Sansom *et al*. (2009) to date fish-bearing outcrops from the Mid Ordovician of Oman. Molyneux *et al*. (2006) referred briefly to chitinozoans from the Mid Ordovician-Llandovery Safiq Group.

5.1.2.10. Iran

The Ordovician-Silurian chitinozoan biozonation schemes from Saudi Arabia developed by Al-Hajri (1995), Paris *et al*. (1995) and Paris *et al*. (2000a) provide a basis for comparison and correlation with Iranian chitinozoan palynostratigraphy. Ghavidel-syooki (2000) identified six successive assemblage zones in the Zagros Basin in southern Iran. Four assemblages ranged from the early Caradocian to late Ashgillian and the upper two assemblages were recorded in the Llandovery. From the Late Ordovician of northeastern Iran, Ghavidel-syooki and Winchester-Seeto (2002) recognized four chitinozoan biozones correlated with northern Gondwana biozones (Paris, 1990; Paris *et al*., 2000a), ranging from late Caradocian to mid Ashgillian. These assemblages are reported to show great similarities with assemblages from northern Gondwana and Arabia. Ghavidel-syooki and Winchester-Seeto (2004) investigated chitinozoan biostratigraphy and palaeogeography of Llandovery strata from southern Iran. They described eight new species and identified five biozones, ranging from the earliest Rhuddanian to late Telychian. The assemblages recorded in this study are also noted to be similar to those recorded in Arabia and northern Gondwana (e.g. Libya and Algeria). Ghavidel-Syooki and Vecoli (2007) investigated Latest Ordovician–Early Silurian chitinozoan biostratigraphy and palaeobiogeography from northeastern Iran. They described five new chitinozoan species and established six local biozones, one in the mid Ashgillian and four in the Llandovery. They conclude that the Llandovery strata in northeastern Iran are age-equivalent to those in the Zagros Basin in southern Iran. They also concluded that only a minor component of the Iranian chitinozoan fauna is shared with typical North Gondwanan assemblages. A significant proportion of this fauna is shared with typical Baltican assemblages, suggesting palaeobiogeographical affinities between Iran and Baltica. Ghavidel-syooki (2008) recognized five chitinozoan biozones from the Late Ordovician Gorgan Schists of northern Iran. These biozones are quite similar to those of the North Gondwana Domain (Paris, 1990; Oulebsir and Paris, 1995; Paris *et al.,* 2000b; Paris *et al.,* 2007), ranging from late Katian-Hirnantian. Acritarch assemblages associated with the recognized chitinozoan biozones were also described. Later Ghavidel-syooki *et al.* (2011) investigated Latest Ordovician - Early Silurian outcrop samples from the Ghelli and Soltan Maidan formations of northern Iran. They concluded that the chitinozoan assemblages identified from the Ghelli Formation reflected a palaeobiogeographic affinity with the North Gondwana Domain, but they noted that the absence of the *T. elongata* biozone, which is normally recorded in the North Gondwana Domain between the *A. merga* and *S. oulebsiri* biozones and generally attributed to the early Hirnantian, possibly indicates the presence of a hiatus encompassing part of the Hirnantian stage. Acritarch assemblages associated with the recognized chitinozoan biozones were also described, they are consistent with newly proposed hypotheses of a Late Ordovician phytoplanktonic biogeographical differentiation between a Laurentian/Baltica realm and a Gondwanan realm.

5.1.2.11. Turkey

Ordovician-Silurian investigations on chitinozoans from Turkey are limited. Steemans *et al*. (1996) briefly refer to Ordovician and Silurian chitinozoans from southeastern Turkey. Many Ordovician chitinozoan biozones from the northern Gondwana zonation have been identified in southern Turkey by Paris *et al*. (2007). The biozones range from the Darriwilian to the Katian.

5.1.2.12. India and Pakistan

Chitinozoan studies from Peninsular India are rare. Khanna *et al*. (1985) and Sinha *et al*. (1996b) reported the occurrence of chitinozoan species from the Late Ordovician Yong Limestone. Tongiorgi *et al*. (1994) recorded index chitinozoan species from the middle Arenigian from Pakistan.

5.1.2.13. China

A correlative study of the Ordovician chitinozoan biostratigraphy from different parts of China has been conducted by Wang and Chen (2004). They recognized 17 chitinozoan zones and 5 main chitinozoan diversification events. Tang *et al*., (2007) identified three chitinozoan assemblages from the Mid Ordovician (Dapingian-Darriwilian) and described five new species. An association of three chitinozoan species has been proposed as an auxiliary tool for locating the base of the Darriwilian Stage. Early and Mid Ordovician chitinozoans from the Dapingian (base of the Mid Ordovician) type sections in China have been investigated by Chen *et al*. (2009). Four chitinozoan biozones, ranging in age from the Floian to the early Darriwilian, have been recognized. Three new chitinozoan species have been described. For global correlation purposes three genera have been suggested to have their first appearance datum in the Dapingian.

5.1.2.14. Australia

Early investigations on chitinozoans from eastern and western Australia were published by Combaz (1965) and Combaz and Péniguel (1972), respectively. Further investigations from the Canning Basin in Western Australia were conducted by Winchester-Seeto *et al*. (2000a) who recognised three Middle Ordovician assemblages. Winchester-Seeto *et al*. (2000a) stated that there are no definite links to contemporaneous faunas from North Gondwana and the assemblages can be correlated with the Laurentian biozonation scheme. Chitinozoan abundance and diversity in this study are discussed by Winchester-Seeto *et al*. (2000b).

5.1.2.15. South America

A detailed review of chitinozoan literature from South America has been published by Grahn (2006). Ordovician and Silurian chitinozoans from Brazil have been investigated by Grahn (1992a, 1992b) and Grahn and Paris (1992). Llandovery chitinozoan have been recorded by Costa (1974). From Argentina, Vergel *et al*. (2002) studied chitinozoan in an integrated study with acritarch from the Ordovician of Argentina. Further studies on Argentina are by Ottone *et al*. (2001), who recognized a late Llanvirnian and an early Caradocian chitinozoan biozone, and by Grahn and Gutíerrez (2001) who recognized mid Llandovery-early Wenlock chitinozoans. Late Hirnantian-early Rhuddanian acritarchs have been reported from northwestern Argentina by Rubinstein and Vaccari (2004). No chitinozoan have been reported from the Mid and Late Ordovician of Bolivia. Early Silurian chitinozoan taxa from southern Bolivia have been reported by Díaz-Martínez and Grahn, 2007.

5.1.2.16. Regional and global investigations

Using data from southwestern Europe, central Europe, the Middle East, northern Africa and Florida, Paris (1990) proposed a formal Ordovician chitinozoan biozonation for the Northern Gondwana Domain. This scheme has been further updated after new biozones were introduced by Paris *et al*.

(2000a). A similar regional scheme for the Ordovician–Silurian of western Gondwana was proposed by Grahn (2006), based on chitinozoan data from northern Argentina, southern Bolivia, southern Peru and Brazil. Grahn (2006) proposed a formal Ordovician-Silurian chitinozoan biozonation for western Gondwana. Five biozones were defined in the Ordovician and nine biozones in the Silurian. Including data from Gondwana, Verniers *et al*. (1995) proposed a global chitinozoan biozonation for the Silurian. Seven biozones were recognized in the Llandovery. The diversity of chitinozoan in Gondwana and worldwide has been discussed in detail by Paris *et al*. (2004) and Achab and Paris (2007).

5.1.3. Cryptospores and spores

5.1.3.1. Libya

Most cryptospore and spore studies in Africa are from Libya. Early Silurian plant spores were reported from Libya by Hoffmeister (1959). Silurian spores associated with acritarchs from the sediments of the Ghadames Basin were studied and illustrated by Richardson and Ioannides (1973) and Tekbali and Wood (1991). Cryptospores and spores from the Upper Ordovician and Llandovery of northeast Libya have been investigated by Richardson (1988). The oldest assemblage of Richardson (1988) is divided into three subzones indicating late Caradocian, late Ashgillian and Rhuddanian-early Aeronian ages. The youngest assemblage is of late Aeronian - early Telychian age. Gray *et al*. (1982) reported cryptospores from the Caradocian - Ashgillian of Libya.

5.1.3.2. Northern Chad and southeast Libya

One cryptospore assemblage zone, associated with two chitinozoan and acritarch assemblages zones, was identified recently by Le Hérissé *et al*., 2013 from 23 core samples selected from Late Ordovician-earliest Silurian sediments of the Moussegouda core hole in the Erdi Basin, northern Chad, and from two samples from well KW-2 in Kufra Basin, South East Libya. This assemblage ranges from Hirnantian-Rhuddanian.

5.1.3.3. Saudi Arabia

Cryptospores from Saudi Arabia have been the focus of several papers. Firstly, a brief documentation of cryptospores was published by McClure (1988), who reported tetrahedral tetrads from the Llanvirnian. Detailed investigations of cryptospores from Saudi Arabia have been published by Strother *et al*. (1996), Steemans *et al*. (2000) and Wellman *et al*. (2000). Strother *et al*. (1996) reported a moderately diverse Llanvirn assemblage. Steemans *et al*. (2000) investigated cryptospores and trilete spores from the Llandovery of central Saudi Arabia. Four new genera and six new species were described. Based on first occurrences of taxa and on relative abundance of envelope-enclosed cryptospores, a new biostratigraphic scheme for strata near the Ashgillian-Llandovery boundary was proposed. The scheme is represented by a single assemblage biozone which is divided into two interval biozones that are both further subdivided into two subzones. The third detailed investigation was by Wellman *et al*. (2000) who described three Llandovery-Ludlow spore assemblages from central Saudi Arabia. The assemblages are correlated with the biostratigraphic scheme established by Steemans *et al*. (2000). Spores and cryptospores are also briefly reported from Ordovician and Silurian subsurface strata from different parts of Saudi Arabia by several authors (e.g. Le Hérissé *et al*., 1995; Le Hérissé, 2000; Molyneux and Al-Hajri, 2000). Le Hérissé *et al*. (2007) reported well-preserved and abundant cryptospores from the Darriwilian. In a recent investigation, Steemans *et al*. (2009) reported an earlier emergence of hilate and trilete spores from the Katian-Hirnantian age.

5.1.3.4. Oman

A few papers from Oman have briefly referred to cryptospores. Droste (1997) and Molyneux *et al*. (2006) reported dyads and tetrads from the Middle Ordovician-Llandovery Safiq Group. Wellman *et al*. (2003) described spore-containing plant fragments from Caradoc terrestrial deposits.

5.1.3.5. Turkey

Spore/cryptospore investigations have been published from Turkey by Steemans e*t al*. (1996), who studied Ordovician, and Silurian cryptospores and miospores from southeastern Turkey. The study resulted in recognition of two Late Ordovician zones, a single Llandovery zone and a single Ludlow zone. Cryptospores also have been reported recently by Paris *et al*. (2007) from the Mid-Late Ordovician of southeastern Turkey.

5.1.3.6. China

Wang *et al*. (1997) described a sporomorph assemblage of Latest Ordovician (Hirnantian) age. The authors stated that the assemblage is similar to what has been previously recorded from Libya, the Czech Republic and southwestern Wales. Llandovery (Telychian) sporomorphs and graptolites have been recovered from China by Wang and Zhang (2010). The sporomorph assemblage included four genera and six species of cryptospores and one genus and one species of trilete spore.

5.1.3.7. South America

Several papers have been published on cryptospores from South America. A late Hirnantian-early Rhuddanian assemblage from the Ordovician-Silurian boundary of northwestern Argentina has been investigated by Rubinstein and Vaccari (2004). The assemblages are similar in composition to those described from coeval deposits worldwide. Rhuddanian-early Aeronian cryptospore assemblages from central-western Brazil were investigated by Misuzaki *et al*. (2002). Llandovery miospore biostratigraphy from Paraguay has been investigated by Steemans and Pereira (2002). Three spore assemblages have been recognized and a uniformity of vegetation from South America, Avalonia, Gondwana and Laurentia is confirmed.

5.1.3.8. Regional and global investigations

The diversity and zonation of cryptospores have been discussed in several publications. Noting the absence of Hirnantian glacial influence on cryptospore biodiversity, Steemans (2000) investigated cryptospore diversity during the Ordovician-Llandovery. A detailed review and discussion of cryptospore stratigraphical distribution and zonation is given by Wellman (1996). Gray (1985) proposed a sporomorph zonation scheme from the Ordovician and Silurian. The oldest zone is defined by the first appearance of cryptospores in the lower Llanvirnian and its top is defined by the first appearance of miospores in late Llandovery. Gray *et al*. (1992) redefined the top boundary to the mid Telychian where trilete spores first begin to dominate assemblages. Richardson and Edwards (1989) proposed an assemblage zone of similar lower and upper boundary as proposed by Gray (1985). However, this zone is subdivided into lower and upper units based on the increase in diversity in the upper part. Richardson (1988) modified this zone and divided it into three subzones which are dated as Caradocian (based on materials from southern Britain), late Ashgillian (based on materials from northeast Libya) and Rhuddanian-early Aeronian (based on Llandovery materials).

CHAPTER 6. PALYNOSTRATIGRAPHY AND CORRELATION

6.1. Introduction

This chapter outlines biostratigraphical interpretation of acritarch, chitinozoan and spore assemblages recovered from detailed palynological analysis of 167 core and cutting samples selected from five wells drilled in the Murzuq basin of southwest Libya. These wells penetrate Ordovician-Early Silurian strata belonging to the As Shabiyat, Hawaz, Melez Shugran, Memouniat, Bir Tlacsin and Tanezzuft formations. The vertical distribution of acritarch, chitinozoan and cryptospore in the studied wells enables recognition of several biozones and assemblage zones. These biozones and assemblage zones are discussed below in ascending stratigraphic order. The characteristic and associated taxa are identified, the occurrences of the assemblage zones and biozones are provided. The species chronostratigraphic significance and the ages are discussed on the basis of comparison with previously established palynological schemes in north Gondwana and elsewhere (see Fig. 22). The ranges of selected taxa are summarized in Figs (18, 19, 20 and21).

6.2 Chitinozoan palynozones

6.2.1 Introduction

The chitinozoan biozones recovered in this study are referred to the regional Ordovician and Silurian chitinozoan biozones previously defined in north Gondwana (Paris, 1990; Webby *et al*. 2004), in Saudi Arabia (Al-Hajri, 1995; Paris *et al*. 1995, 2000), in Morocco (Bourahrouh *et. al.,* 2004), in Jordan (Butcher, 2009), in northeast Libya (Molyneux and Paris, 1985; Hill *et al*., 1985; Paris, 1988), in Dor el Gussa, eastern Murzuq Basin, southwest Libya (Paris *et al*., 2012), in the Murzuq Basin, southwest Libya (Butcher 2013), in Iran (Ghavidel-syooki 2000, 2006, 2008; Ghavidel-syooki and Winchester-Seeto 2002, 2004; Ghavidel-syooki and Vecoli, 2007; Ghavidel-syooki *et al.,* 2011a, b), and globally (Verniers *et al.,* 1995), these provided the basis for correlation and age assignment for the present biozones. The early Silurian Saudi Arabian biozones are slightly different from the global Silurian chitinozoan biozonation proposed by Verniers *et al*. (1995) but seem usable in most of the northern Gondwana regions. The chitinozoan assmemblage zone and biozones recorded are documented and described here from the oldest to the youngest.

6.2.1.1. Assemblage Zone 1

Composition: This assemblage zone is characterized by the occurrence of *Siphonochitina*. cf. *formosa, Velatochitina* sp. A*, Conochitina* cf. *minnesotensis* and *Euconochitina brevis,* associated with a few poorly preserved specimens of chitinozoan*.* Long ranging taxa also occurs (e.g *Belonechitina micracantha*).

Occurence: Hawaz Formation, Well H2-NC186 (core, cutting interval 4605 ft.-5200 ft.) and well A28i-NC186 (core interval depth 4518 ft-4723 ft), D1-200 (cutting interval 5150 ft- 5700 ft)

Age assessment and correlation: The chitinozoan recorded in this assemblage do not provide a firm age assignment as no classical components of Darriwilian chitinozoan assemblage biozone have been recorded. However, the presence of acritarchs indicates this assemblage extends at least into the middle Ordovician, and most likely into the middle-late Darriwilian age (Llanvirinian). This finding is consistent with previous studies on the Hawaz Formation using graptolites, brachiopods and trilobites (Mamgain, 1980), and by using acritarchs (Aziz, 2000), but it is inconsistent with Seilacher *et al*. (2002) who considered the Hawaz Formation to be Arenigian based on the occurrence of certain ichnospecies of the trace fossil *Cruziana* in the Al Kufrah Basin (Seilacher *et al*. 2002).

6.2.1.2. *Armoricochitina nigerica* Biozone

Composition: This biozone is characterised by the occurrence of *Armoricochitina nigerica* and other associated taxa such as *Lagenochitina baltica,* C*alpichitina lenticularis, Belonechitina micracantha*, *B. capitata,* *Conochitina elegans*, *Cyathochitina campanulaeformis*, *Desmochitina minor, D.* cf. *piriformis, Belonechitina capitata, Pistillachitina* cf. *pistilifrons, Rhabdochitina magna, R. gracilis, Sphaerochitina* sp. B *Tanuchitina* sp. A and *Tanuchitina* sp.B*.*

Occurrence: Melez Shugran Formation, Well D1-200 (core, cutting interval 4878 ft - cutting interval 5130 ft); I3- NC186 (cutting interval 4810 ft – 5240 ft).

Age assessment and correlation: According to Paris (1990, 1996), Bourahrouh *et al*. (2004) and Webby *et al*. (2004), the *A. nigerica* Biozone is defined as a partial-range biozone corresponding to the stratigraphic interval from the first occurence of *A. nigerica* up to the first occurence of *Ancyrochitina merga*, the index species of the succeeding biozone. This biozone is correlated to the upper part of the *complanatus graptolite* zone of the British Standard (Paris, 1990, 1996; Webby *et al*., 2004), corresponding to an early-late Katian age.

Based on the presence of *A. nigerica,* occurrence of other associated taxa and absence of *Ancyrochitina merga*, the index species of the succeeding biozone, this part of the Melez Shugran Formation is assigned to an early late Katian age and corresponds to the *A. nigerica* Biozone (Paris, 1990, 1996; Webby *et al*., 2004). This biozone has been described by Bourahrouh *et al*. (2004) from Morocco, Ghavidel-syooki and Winchester-Seeto (2002), Ghavidel-syooki (2008) and Ghavidel-syooki *et al.* (2011) from north and northeast Iran, Al-Hajiri (1995) from Saudi Arabia and Paris (2007) from Turkey.

6.2.1.3. *Ancyrochitina merga* Biozone

Composition: This biozone is characterised by the first occurrence of *Ancyrochitina merga.* Taxa that first appear in this biozone include *Tanuchitina anticostiensi* and *Euoconochitina lepta.* Other taxa continuing into this biozone from preceding biozones are: *Armorichitina nigerica*, C*alpichitina lenticularis*, *Lagenochitina baltica, Conochitina elegans*, *Desmochitina* cf. *piriformis, Belonechitina capitata, Pistillachitina* cf. *pistilifrons, Rhabdochitina magna, R.*

gracilis, Sphaerochitina sp. B*, Tanuchitina sp.* A and *Tanuchitina* sp*.* B. Long ranging species also occur (e.g. *Belonechitina micracantha, Cyathochitina campanulaeformis* and *Desmochitina minor.*

Occurence: Melez Shugran Formation, Well D1-200 (core interval 4831.5 ft.-4878 ft.).

Age assessment and correlation: In this study, the *A. merga* Biozone directly overlies the *A. nigerica* Biozone, which is assigned an early late Katian age. This biozone was defined by Paris (1990, 1996), Bourahrouh *et al.* (2004) and Webby *et al*. (2004) as the interval-range biozone corresponding to the stratigraphic interval from the first occurrence of *A. merga* up to the first occurrence of *Tanuchitina elongata*, the index species of the succeeding biozone. The other important taxa characterizing this biozone are *E. lepta, T. anticostiensi* and *L. baltica.* However*, L. baltica* is a well known species reported in the Ashgillian of Libya (Molyneux and Paris 1985; Paris 1988), Algeria (Oulebsir and Paris, 1995) and north and northeast Iran (Ghavidel-syooki and Winchester-Seeto, 2002; Ghavidel-syooki, 2008). Paris *et al*. (1999a, b) used *L. baltica* as a species linking the chitinozoan biozonation of Laurentia and north Gondwana. Also in north Gondwana, *L. baltica* ranges from the base of the *Acanthochitina barbata* biozone to the lower part of the *T. elongate* Biozone (Paris *et al*., 1999, 2000), and from top of the *A. nigerica*-lower part of the *T. elongata* Biozone in Morocco (Bourahrouh *et al.,* 2004). In addition *E. lepta* is also well known in the Ashgillian and Hirnantian of Morocco (Elaouad-Debbaj, 1984), Algeria (Oulebsir and Paris, 1995), Saudi Arabia (Al-Hajri, 1995; Paris *et al.,* 2000a), Turkey (Steemans *et al*., 1996), northern Iran (Ghavidel-syooki and Winchester-Seeto 2002; Ghavidel-syooki, 2008) and Turkey (Paris *et al.,* 2007). Paris (1990) cites *E. lepta* as part of the *A. merga* and *T. elongate* Biozones in the northern Gondwana domain.

Accordingly, and based on the first occurrence of *A. merga* and other associated taxa, this part of the Melez Shugran Formation is assigned a late Katian age and considered to correspond to the *A. merga* biozone (Paris, 1990; Webby *et al*., 2004), the same biozone was described by Bourahrouh *et al*.

(2004) from Morocco, Ghavidel-syooki and Winchester-Seeto (2002), Ghavidel-Syooki (2008) and Ghavidel-syooki *et al*. (2011) from northern and northeast Iran. In addition, and based on the occurrence *A. nigerica, T. anticostiensi, E. lepta* and C. *lenticularis*, this biozone is comparable with the unnamed strata of north-eastern Libya (=*P. sylvanica - S. debbaje* Biozone), Zone 2 from the Ashgillian of northeast Libya (Paris, 1988), Ashgillian zone JO-1 of Jordan (Keegan *et al*., 1990) and the *A. merga* biozone from Saudi Arabia described by Al Hajri (1995). Paris *et al*. (2000a), recorded a very similar chitinozoan association (including *A. nigerica, A. merga*, *C.lenticularis* and *D.* gr. *minor*) from the Late Ashgillian (Ass.2) recorded in the Ra′an Member of the Qasim Formation in Saudi Arabia. However, the authors stated that accurate stratigraphic assignment for this assemblage is difficult due to the poor preservation of the index species.

6.2.1.4. *Tanuchitina elongata* Biozone

Composition: This biozone is characterised by the first occurrence of *Tanuchitina elongata* in the upper part of the Melez Shugran Formation in well D1-200 (core sample depth 4831.5 ft.). *Tanuchitina anticostiensi, Euoconochitina lepta, Ancyrochitina* cf. *sylvanica* are the most important taxa associated with the index taxa in this biozone. Other taxa continuing into this biozone from preceding biozones are: *Armorichitina nigerica*, C*alpichitina lenticularis*, *Lagenochitina baltica, Conochitina elegans*, *Desmochitina* cf. *piriformis, Belonechitina capitata, Pistillachitina* cf. *pistilifrons, Rhabdochitina magna, R. gracilis, Sphaerochitina* sp. *B, Tanuchitina sp.* A*, Tanuchitina* sp. B. Long ranging taxa also occur (e.g *Belonechitina micracantha, Cyathochitina campanulaeformis* and *Desmochitina minor*).

We should point out here that the chitinozoan recorded in the Memouniat Formation are only from the lower part of this Formation in core samples 4782ft. - 4799ft. of well I3-NC186. These samples do not contain the index taxa of the *T. elongata* biozone, but they are characterized by the occurrence of *Tanuchitina anticostiensis, Armorichitina nigerica* and *Euoconochitina lepta*. Other long ranging taxa also occur (e.g., *Desmochitina minor*, *Calpichitina* *lenticularis*). However, the core and cutting samples from the upper part of the Memouniat Formation represented in well B2-NC186 were barren of palynomorphs.

Occurence: Melez Shugran Formation, Well D1-200 (core interval 4778 ft-4831.5 ft). lower Memouniat Formation, Well I3-NC186 (core interval 4782 ft-4799 ft), Upper Memouniat Formation Well B2-NC186 (core, cutting interval 4000 ft-4700 ft)

Age assessment and correlation: *T. elongata* Biozone was defined by Paris (1990) and regarded as the last Ordovician chitinozoan biozone in the northern Gondwana domain. Later Paris *et al.* (2000) carried out research work on the Late Ordovician marine glacial sediments in well NI-2 (northeast Algerian Sahara) that resulted in creation of a new chitinozoan species *Spinachitina oulebsiri* from the M' Kratta Formation, suggesting a latest Hirnantian age. The *T*. *elongata* Biozone is now restricted to the interval-range biozone between the first occurance of *T. elongata* and the first occurrence of *Spinachitina oulebsiri*, the index species of the succeeding biozone, and is attributed an early Hirnantian age in north Gondwana (Paris *et al*., 2000; Webby *et al*., 2004).

In this study this biozone directly overlies the *A. merga* Biozone, which is assigned to the late Katian. The base of this biozone is defined by the first occurrence of *T. elongata,* defined in the upper part of the Melez Shugran Formation in core sample (4831.5ft) of Well D1-200. The top is defined by the first occurrence of S. o*ulebsiri* in Well A28i-Nc186 core. However, the chitinozoan taxa recorded in the lower part of the Memouniat Formation of Well I3-NC186 (core interval 4782 ft. – 4799 ft.) do not contain the index taxa of the *T. elongata* biozone*,* which occurs in the upper part of the Melez Shugran Formation. However, the occurrence *of T. anticostiensis* and *E. Lepta* is important as these species does not extend higher than the *T. elongata* biozone (Paris, 1990, 1996). *T. anticostiensis* occurrs in the unnamed strata of northeastern Libya (= *A. nigerica* Biozone), zone 3 of Paris (1988) which corresponds to the *T. elongata* Biozone. Paris (1996) show that the total ranges of *T. anticostiensis* in northern Gondwana and Laurantia represents the late

Ashgillian (late Rawtheyan-early Hrnantian in the British scale). In addition, *E. lepta* is a well known species in the Ashgillian and Hirnantian age in Morocco (Elaouad-Debbaj 1984), Algeria (Oulebsir and Paris 1995), Saudi Arabia (Al-Hajri, 1995; Paris *et al.,* 2000), Turkey (Steemans *et al*., 1996), Iran (Ghavidel-syooki and Winchester-Seeto, 2002; Ghavidel-syooki, 2008) and Turkey (Paris *et al.,* 2007). Paris (1990) cites *E. lepta* as part of the *A. merga* and *T. elongata* Biozones in the northern Gondwana domain.

Accordingly, and based on the first occurrence of *T. elongata* in the upper part of Melez Shugran Formation, the occurrence of *T. anticostiensis* and *E. lepta* in the lower part of the Memouniat Formation, and the age assignment proposed by Paris *et al*., (2000), adopted by Webby *et al*. (2004) for the T. *elongata* Biozone, the upper part of the Melez Shugran Formation and the lower Memouniat Formation is attributed an early Hirnantian age and considered to correspond to the *T. elongata* biozone (Paris, 1990 Paris, 1996; Webby *et al*., 2004). The same biozone is described by Bourahrouh *et al*., (2004) from Morocco and Ghavidel-syooki (2008) from northern Iran.

However, the upper sandy level of the upper part of the Memouniat Formation represented in Well B2-NC186 (core, cutting interval 4000 ft.-4700ft.) was barren of palynomorphs (medium to coarse sand). This is possible evidence of major glacio-eustatic sea level fall (maximum glacial advance). This sandy body is assigned to the early Hirnantian within the *T. elongata* Biozone, based on the chitinozoan taxa recorded in the lower Memouniat Formation of Well I3-NC186 (core interval 4774.5 ft.- 4782 ft.) which indicates an age assessment that the Memouniat Fromation lies within the *T. elongata* Biozone. The overlying shale bed of the Bir Tlachin Formation of well A28i-NC186 (core interval 4482 ft.-4515 ft.) is assigned a late Hirnantian age and considered to correspond to the *S. oulebsiri* Biozone. This finding is consistent with previous studies on the Melez Shugran and the Memouniat Formations using brachiopods and trilobites by Havlicek and Massa (1973), Gundobin (1985) and Sutcliffe *et al.* (2000), who assigned these Formations to the Late Ordovician (Hirnantian)

6.2.1.5. *Spinachitina oulebsiri* Biozone

Composition: This biozone is characterized by the occurence of *Spinachitina oulebsiri,* associated with *Spinachitina* cf. *oulebsiri, Taunochitina* cf. *elongata, Lagenochitina prussica, Cyathochithia costata, Fungochitina spinifera***,** *Belonechitina* cf. *capitata* and *Acanthochitina* cf. *barbata.* Other taxa continuing into this biozone from the preceding biozones are: *Desmochitina minor*, *Belonechitina micracantha* and *Calpichitina lenticularis.*

Occurrence: Bir Tlacsin Formation, Well A28i-NC186 (core interval 4482 ft-4517 ft), Well H2-NC186 (cutting interval 4550 ft. 4590 ft) and Well I3-NC186 (cutting interval 4680 ft-4740 ft)

Age assessment and correlation: In this study, this biozone is characterized by the occurrence of *S. oulebsiri* in core sample 4517ft. of Well A28i-NC186. This species was originally established from records in the upper Member of the M' Kratta Formation, northeast Algerian Sahara by Paris *et al*. (2000), and was indirectly correlated with the *persculptus* graptolite Zone of latest Hirnantian age (Webby *et al*., 2004). Accordingly, the *S. oulebsiri* chitinozoan biozone is of particular interest for correlation of latest Ordovician strata and for the identification of the Ordovician – Silurian boundary. Recently, Butcher (2009) who studied Llandovery chitinozoans from Jordan suggested that *Spinachitina oulebsiri* represents a junior synonym of *Spinachitina fragilis,* and as a consequence, potentially lowers the base of the *Spinachitina fragilis* Biozone into the Hirnantian. Alternatively, Vandenbroucke *et al*. (2009) in their study of the Soom Shale Member (latest Hirnantian–earliest Rhuddanian) of South Africa, suggest that the Ordovician–Silurian boundary interval may contain several morphologically similar *Spinachitina* species and suggest that *S. verniersi* and *S. oulebsiri* appear during the late Hirnantian and cross the Ordovician–Silurian boundary, whereas *S. fragilis* would be restricted to the Rhuddanian. Nevertheless, the same authors state that the taxonomy of *Spinachitina* around the Ordovician–Silurian boundary requires substantial revision. This was also stated by Butcher (2010), Delabroye and Vecoli (2010), Ghavidel-syooki *et al.* (2011) and Paris *et al*., (2012). This author strongly agrees with this statement and follows the discussions and definition as presented by Vandenbroucke *et al*. (2009) until such taxonomic matters can be conclusively resolved.

Based on the previous discussion, the occurrence of *S*. *oulebsiri* and other associated taxa indictes that the Bir Tlacsin Formation should be attributed a late Hirnantian age and considered to correspond to the *S. oulebsiri* Biozone of north Gondwana (Paris *et al*., 2000a; Webby *et al*., 2004). The same biozone is described by Ghavidel-syooki (2008) and Ghavidel-syooki *et al.,*(2011) from northern Iran.

6.2.1.6. *Spinachitina fragilis* Biozone

Composition: This biozone is characterized by the occurrence of *Spinachitina fragilis.* Other associated taxa also occur very rarely such as *Cyathochitina kuckersiana, Belonechitina postrobusta,*

Occurrence: Lower part of Tanezzuft Formation Well B2-NC186 (cutting sample 3950 ft-4000 ft.)

Age assessment and correlation: In this study this biozone is defined by the occurrence of *S. fragilis* and occurs only in one cutting sample (3950-4000ft.) of Well B2-NC186. It occurs in association with other species such as *Cyathochitina kuckersiana, Belonechitina postrobusta***.** Ghavidel-syooki (2000) and Ghavidel-syooki and Winchester-Seeto (2004) documented that *S. fragilis* was recognized within the uppermost *Normalograptus persculptus* Zone in Iran and has been reconfirmed also in Iran, again across the Ordovician–Silurian by Ghavidel-syooki *et al*. (2011). They suggest that the first occurence of *S. fragilis* is in the late Hirnantian. However, Butcher (2009) correlated the *S. fragilis* Biozone with the upper *ascensus- acuminatus* graptolite Biozone based upon a characteristic graptolite assemblage and showed that the first appearance of *B. postrobusta* species occurs within the *S. fragilis* biozone and increases in abundance in the *vesiculosus* graptolite Biozone of core BG-14 from Jordan. Therefore, the specimens of *Spinachitina* recovered in this study are identified according to the definition of Vandenbroucke *et al*. (2009), until the taxonomic situation concerning *Spinachitina* straddling the Ordovician–Silurian boundary can be conclusively resolved (see discussion on the preceding assemblage).

According to the graptolite data of Butcher (2009) and Paris (1995), the occurrence of *S. fragilis,* which is recorded in the present assemblage biozone, indicates an early Rhuddanian age for this part of the Tanezzuft Formation. It is considered to correspond to the *S. fragilis* zone of the global biozones (Verniers *et al.,* 1995) and the same biozone from central Saudi Arabia (Paris, 1995), Jordan (Butcher, 2009) and the Tanezzuft Formation of the eastern Murzuq Basin, Libya (Paris *et al*., 2012).

Based on the occurrence of *A. laevaensis, A. ancyrea,* other *Spinachitina* and *Sphaerochitina* species, Grignani *et al.* (1991) established assemblage biozone C from the Tanezzuft Formation of Well KW2 in the Kufra Basin, southeast Libya and assigned an early Llandovery age. The correlation of this assemblage biozone with the *Spinachitina fragilis* Biozone is possible, but is still questionable because the authors do not provide more evidence indicative of a Rhuddanian age. Also no early Silurian acritarchs were observed in the assemblage.

6.2.1.7. *Belonechitina postrobusta* Biozone

Composition: This top of this biozone is defined by the last occurrence of *Belonechitina postrobusta.* Important associated taxa occur such as *Plectochitina paraguayensis Cyathochitina kuckersiana, Angochitina murzukensis, Belonechitina aspera, Lagenochitina* cf. *navicula, Cyathochitina campanulaeformis* and *Ancyrochitina ancyrea.*

Occurrence: Tanezzuft Formation (Hot shale) Well E1-NC174 (core interval 7246 ft.-7287 ft) and Well I3- NC186 (cutting intervals 4600 ft-4650 ft)

Age assessment and correlation: In this study the top of this biozone is defined by the last occurrence of the biozone *Belonechitina postrobusta*. Paris (in Hill *et al.* 1985) recorded the occurrence of *B. postrobusta*? in north-eastern

Libya, but no data were provided for its occurrence. They show only that *Belonechitina postrobusta* is restricted to the early Llandovery. Butcher (2009) demonstrated that the first appearance of *B. postrobusta* species occurs within the *S. fragilis* biozone and increases in abundance in the *vesiculosus* graptolite Biozone of core BG-14 from Jordan. This allows correlation of the *B. postrobusta* Local Abundance biozone with many of the previously proposed biozones based upon this taxon from Baltica, northern and western Gondwana, South China, Laurentia and Avalonia.

It is interesting to note that in his recent chitnozoan study of the well E1NC-174 core, Butcher (2013) suggested that the entire core is Rhuddanian age, with the Hot Shale constrained to the upper part of the range of *Belonechitina postrobusta* and assigned to the mid Rhuddanian in age as none of the characteristic earlist Silurian taxa (e.g. S. *fragilis, P. nodifera A. laevaensis*) were recorded below the Hot Shale. Although, these taxa were recorded below the Hot Shale in the BG-14 core southern Jordan (Butcher, 2009). This result agreed with the Loydell's (2012) detailed study of the graptolites from well E1-NC174 core. The chitinozoan data recorded from the same well in the current study and contradict the suggestion of Lüning *et al.,* (2003), in that the base of the core may lie within the latest Ordovician.

Accordingly, and based on the age adopted for the *B. postrobusta* Biozone by Verniers *et al.* (1995), and the same biozone described by Paris *et al.* (1995) from Saudi Arabia, Butcher (2009) from Jordan and by Butcher (2013) from the same well studied herein (E1-NC174 core, Murzuq Basin, southwest Libya), the age of this biozone is restricted to the mid Rhuddanian (early Llandovery) and most probably the *acuminatus*-lower *vesiculosus* graptolite biozone.

Therefore, a mid Rhuddanian age is attributed for this part of the Tanezzuft Formation and it is considered to correspond to the global *B. postrobusta* Biozone (Verniers *et al.,* 1995), and the same biozone from central Saudi Arabia (Paris 1995), Jordan (Butcher 2009) and Murzuq Basin, southwest Libya (Butcher 2013).

6.2.1.8. *Angochitina qusaibaensis* Biozone

Composition: The base of this assemblage biozone is characterized by the first occurrence of *Angochitina qusaibaensis* associated with *Belonechitina paraviterea, Euconochitina viterea* and *Pterochitina dechai.* Other Species continuing into this biozone from preceding biozones are: *Plectochitina paraguayensis, Cyathochitina campanulaeformis, Cyathochitina kuckersiana* and *Ancyrochitina ancyrea*. The occurrence of *Plectochitina pseudoagglutinanis* in this biozone is questionable.

Occurrence: Tanezzuft Formation, Well E1-NC174 (cutting interval 6550 ft-7246 ft) and D1-200 (4650 ft- 4700 ft), Well B2-NC186 (cutting interval 3700 ft-3950 ft).

Age assessment and correlation: This biozone was defined by Paris *et al.,* (1995). It corresponds to the interval-range biozone between the last occurrence of *Lagenochitina nuayyimensis* (Total Range Biozone) and the first occurrence of *Conochitna alargada-Plectochitina paraguayensis* (Concurrent Range Biozone). The base of this biozone was poorly defined in Saudi Arabia (Paris *et al*., 1995). Recent investigation on the chitinozoan of well CDEG-2a in Dor el Gussa, eastern Murzuq Basin (Paris *et al*., 2012) have shown that *A. qusaibaensis* is not associated with *L. nuayyimensis,* at least in the main part of the range biozone of *L. nuayyimensis*. In this study the base of this biozone is defined by the first occurrence of *A. qusaibaensis* in association with *P. dechai.* The occurrence of these species is important as the former does not extend below the middle part of the *Cononchitina electea* Biozone according to Verniers *et al.* (1995), and the later does not extend below the *A. qusaibaensis* Biozone (Paris *et al.,* 2012). The top of this biozone is defined by the first occurence of *Conochitina* cf. *alagada* in the succeeding biozone. However, this biozone directly overlies the *B. postrobusta* Biozone. However, the *L. nuayyimensis* Biozone has not been recognized in this study.

Although the present assemblage does not contain a global diagnostic species, such as *Conochitina electea* of Verniers *et al*. (1995), the first occurrence of *A.*

qusaibaensis in this biozone and the occurrence of *C. viterea* in the upper part of this biozone allows it to be correlated it with at least the upper part of the *C. electea* and *S. maennili* global Biozones (Verniers *et al.,* 1995), the *A. quasibaensis* Interval Range Biozone from central Saudi Arabia (Paris 1995) and the *A. udayanensis - P. dechai* Biozone from Iran (Ghavidel-syooki and Winchester-Seeto, 2004). However, species *P. pseudoagglutinanis* has been recorded in this assemblage in the cutting sample 6750ft.-6950ft. of Well E1-NC174. This could be due to caving from the sediments above. However, Paris (1988) recorded this species in side-wall core samples of Well I1c-81 in unnamed strata (=*C. vitrea-S. libyensis* Biozone) of northeast Libya and attributed it to the Rhudanian. Generally, this species has previously been recorded as a first appearance in the Aeronian-Telychian (mid-late Llandovery) strata in the Algerian Sahara (Taugourdeau and de Jekhowsky, 1960), northeast Libya (Paris, in Hill *et al*., 1985), Saudi Arabia (Paris *et al*., 1995), southern Iran (Ghavidel-syooki, 2000) and globally (Verniers *et al.,* 1995).

Accordingly, and based on the occurrence of *A. qusaibaensis* and other important associated taxa, this biozone is attributed a late Rhuddanian-early Aeronian (early Llandovery) age and considered to correspond to the *A. qusaibaensis* Biozone (Paris *et al.,* 1995). Correlation with unnamed strata of northeastern Libya (= A*. seurat- P. pseudoagglutinanas* Biozone) *Z*one 5 from the Rhuddanian of northeast Libya described by Paris *et al*., (1988) with this assemblage biozone is possible. However, Paris (1988) suggested that this biozone is provisional.

6.2.1.9. *Conochitina* cf. *alargada - Plectochitina paraguayensis* Biozone

Composition: This biozone is characterized by the first occurrence of *Conochitina* cf. *alargada,* the occurrence of *Plectochitina pseudoagglutinans* and *Euconochitina viterea,* and the last occurence of *Plectochitina paraguayensis* and *Angochitina qusaibaensis.* Other taxa continuing into this biozone from preceding biozones are: *Pterochitina dechai, Cyathochitina campanulaeformis, Cyathochitina kuckersiana* and *Ancyrochitina ancyrea.*

Occurrence: Tanezzuft Formation, Well I3-NC186 (cutting interval 3950 ft 4600), Well D1-200 (cutting interval 4250 ft.-4650 ft), Well H2-NC186 (cutting interval 4160 ft. 4500 ft), Well E1-NC174 (cutting interval 6350ft.-6550ft).

Age assessment and correlation: In this study, this biozone is defined based on the first occurrence of *C.* cf. *alargada* and *E. vitrea,* the last occurrence of *P. paraguayensis* and the occurrence of *P. pseudoagglutinans.* However, *P. pseudoagglutinans* has been previously recorded with a first appearance in the Aeronian (mid Llandovery) strata in the Algerian Sahara (Taugourdeau and de Jekhowsky 1960), Libya (Paris in Hill *et al*., 1985; Paris, 1988), Saudi Arabia (Paris *et al*., 1995), Iran (Ghavidel-syooki, 2000a,b; 2006; Ghavidel-syooki and Winchester-Seeto, 2004; Ghavidel-syooki and Vecoli, 2007). In addition the occurrence of *P. paraguayensis* is important as it appears in this assemblage biozone and does not range upwards into the succeeding biozone. *P. paraguayensis* has previously been recorded from Early-Mid Silurian strata in the Qalibah Formation of Saudi Arabia (Paris *et al*., 1995), the Sarchahan Formation of Iran (Ghavidel-syooki, 2000a, 2006; Ghavidel-syooki and Winchester-Seeto, 2004; Ghavidel-syooki and Vecoli, 2007). Moreover, Verniers *et al.* (1995) and Paris (1995) considered this species to be characteristic of the early and middle Llandovery. Also the first occurrence of *E. viterea* in this biozone is important as this species occurs globally close to the base of the *C. alargada* Biozone (Verniers *et al.,* 1995).

Based on the occurrence of *C.* cf. *alargada* and *E. viterea,* the last occurrence of *P. paraguayensis,* and the occurrence of *P. pseudoagglutinans*, a mid-late Aeronian age is assigned to this part of the Tanezzuft Formation and probably corresponds at least in part to the global *C. alargada* Biozone (Verniers *et al*., 1995) and *C. alargada – P. paraguayensis* Concurrent Range Biozone of Saudi Arabia (Paris *et al*., 1995). It also can be compared with the *C. alargada- A. convexa* Biozone (Ghavidel-syooki and Winchester-Seeto, 2004), *C. alargada* Biozone (Ghavidel-syooki, 2006) and *C. alargada – P. saharica local* Biozone (Ghavidel-syooki and Vecoli, 2007) from Iran.

6.2.1.10. *Angochitina hemeri* Biozone

Composition: This biozone is characterized by the first occurrence of *Angochitina hemeri, Calpichitina densa, Conochitina edjelensis, Belonochitina arabiensis* and *Conochitina proboscifera*. Other taxa continuing into this biozone from preceding biozones are: *Plectochitina pseudoagglutinanas, Belonochitina paravitrea, Euconochitina viterea, Cyathochitina campanulaeformis, Cyathochitina kuckersiana* and *Ancyrochitina ancyrea.*

Occurrence: Tanezzuft Formation, Well I3-NC186 (cutting interval 3750 ft-3950 ft) and Well D1-200 (3850 ft – 4250 ft).

Age assessment and correlation: This biozone was defined by Paris *et al.,* (1995). It corresponds to the interval-range biozone between the first significant occurrence of *Angochitina hemeri* and the first occurence of *Angochitina macclurei,* the index species of the succeeding biozone of Paris *et al*., (1995). In this study, this biozone corresponds to the two former regional biozones defined by Paris *et al.,* (1995) and respectively labelled (Concurrent Range Biozone of *S. solitudina* and *A. hemeri*) and (interval range zone of *A. hemeri*) from Saudi Arabia, based on the first occurrence of *Angochitina hemeri* and other associated taxa such as *C. desna* and *C. edjelensis.*

Although the present biozone does not contain the globaly diagnostic taxon *Eisenackitina dolioliforms* of Verniers *et al.* (1995), these authors suggest that *P. pseudoagglutinanas, C. edijlensis* and *E. vitrea* as diagnostic taxa of the *E. dolioliforms* global Biozone. Furthermore, the first occurence of *A. hemeri* and other associated taxa in this assemblage biozone suggest a possible correlative with the mid-late Llandovery *E. dolioliformis* Biozone in the global chitinozoan biozonation scheme of Verniers *et al*. (1995) and the *S. solitudina* - *Angochitina hemeri* and *A. hemeri* (Concurrent Range Biozones) from Saudi Arabia (Paris 1995). Based on the above discussion and correlation, this part of the Tanezzuft Formation is assigned a mid late Aeronian- early Telychian (Llandovery) age.

6.2.1.11. *Angochitina macclurei* Biozone

Composition: This biozone is defined by the first occurrence of *Angochitina macclurei.* Other taxa continuing into this biozone from preceding biozones are *Conochitina proboscifera, Calpichitina densa, Conochitina edjelensis, Euconochitina viterea* and *Ancyrochitina ancyrea.*

Occurrence: Tanezzuft Formation, Well I3-NC186 (cutting interval 3700 ft.-3750 ft.)

Age assessment and correlation: This biozone was defined by Paris *et al.,* (1995). It corresponds to the acme biozone of *Angochitina macclurei*. In this study the base of this biozone is identified by the first occurrence of *A. macclurei* and the last appearance of *A. hemeri.* However, Verniers *et al*., (1995) suggest that *Angochitina macclurei* is a diagnostic species of the *A. longicolis* global Biozone.

Accordingly, based on previously discussed occurrences, this part of the Tanezzuft Formation is attributed a late Telychian (late Llandovery) age and considered to correspond to the *A. longicolis* global Biozone (Verniers *et al.*, 1995), *A. macclurei* (Acme Range Biozone) from Saudi Arabia (Paris *et al*., 1995) and Iran (Ghavidel-syooki and Winchester-Seeto 2004). This is supported by the absence of important Llandovery-Wenlock chitinozoan species well known worldwide such as *Margachitina margaritana*. Also, and based on the occurrence of *C. proboscifera* and *D. densa,* the correlation of this biozone with unnamed strata of northeastern Libya (=*C. armillata - Cyathochitina* sp.B Biozone) Zone 6 from the late Aeronian-Telychian described by Paris (1988) is possible. Although he suggests this biozones is temporary.

6.3. Acritarch palynozones

6.3.1. Introduction

In this study eight acritarch Assemblage Zones were recognized including: Ac-1 in the mid-late Darriwilian (Llanvirnian), Ac-2, Ac-3 and Ac-4 in the early late Katian - Hirnantian (Ashgillian) and Ac-5, Ac-6, Ac-7 and Ac-8 in the Rhuddanian-Telychian (Llandovery). Selected acritarchs species ranges are shown in Fig. 19. The most relevant and biostratigraphically-significant study of Ordovician acritarchs was published recently by Vecoli and Le Hérissé (2004). It provides comprehensive and refined biostratigraphical ranges of acritarchs from the northern Gondwana margin. It is used here to provide age constrain for the Late Ordovician assemblage biozones. In addition correlation with other previous biozones established in North Africa (Algeria, Tunisia, northwest and northeast Libya), Saudi Arabia and Jordan is used herein. For Silurian acritarchs the most significant study established assemblage zones from Saudi Arabia (Le Hérissé et al, 1995; Le Hérissé, 2000), northeast Libya (Hill and Molyneux 1988) that are used here to provide age constraints for the Early Silurian assemblage biozones

6.2.1.1. Assemblage A

Composition: This assemblage is essentially barren of palynomorphs.

Occurence: As Shabiyat Formation, Well H2-NC186 (cutting interval 5250 ft-5450 ft) and well I3-NC186 (cutting interval 5250 ft-5400 ft).

Age assessment and correlation: All the examined samples from the As Shabiyat Formation are barren of palynomorphs except some cutting samples from well I3-NC186 (5250ft.-5340ft.) that contains only a few acritarchs such as *Leiosphaeridia* spp. and *Veryhachium* species, which could be caving from the sediments above. There is no other diagnostic species of acritarch and chitinozoan found. Therefore, in this study no age can be given for this assemblage zone. A Tremadocian age is assigned for this part of As Shabiyat

Formation based on the lithostratigraphical correlation with the fossiliferous Sanrhar Formation by Massa *et al*. (1977).

6.3.1.2. Assemblage Zone Ac-1

Composition: This assemblage is defined by the occurrence of *Baltisphaeridium klabavense*, *Poikilofusa ciliaris*, *Stellechinatum celestum*, *Stelliferidium striatulum*, *S. philippoti, S. stelligerum*, *Tectitheca* sp. A, *Uncinisphaera fusticula*, *Ampulala suetica, Lophosphaeridium fuscipetiolatum, Pterospermella colbathii, Frankea breviuscula. F. longiuscula, F. hamata* and *Leiofusa* cf. *fusiformis*. Other associated taxa include *Micrhystridium* cf. *acuminosum, Polygonium gracile*, *Dictyotidium* sp. A, *Electoriskos* sp. A*, Helosphaeridium* sp. A*, Solisphaeridium* cf. *solare*, *Rhopaliophora* sp., A, *Stelliferidium simplex* and *Virgatasporites* sp. A. Long ranging taxa also occur (e.g. *Veryhachium lairdii, V. trispinosum* and *Leiosphaeridia* spp.).

Occurence: Hawaz formation, Well H2-NC186 (core, cutting interval 4605ft.-5200ft.), Well A28i-NC186 (core interval depth 4518ft.-4723ft.) and Well D1-200 (cutting interval 5150ft.- 5750ft.)

Age assessment and correlation: The acritarch association in this assemblage is indicative of a mid-late Darriwilian (Llanvirnian) age. *B. klabavense*, *S. celestum*, *T.* sp. A and *U. fusticula* are recorded from the mid-late Darriwilian of Saudi Arabia (Molyneux and Al-Hajri, 2000; Le Hérissé *et al*., 2007). In Oman *S. striatulum* is recorded from the mid-late Darriwilian (Molyneux *et al*., 2006). Characteristic species recorded by Keegan *et al*. (1990) in Zone JO-3 of the mid-late Darriwilian in Jordan (e.g. *B. klabavense* and *S. striatulum*) are documented in this assemblage. Vecoli (1999) and Vecoli *et al*. (2003) documented *P. ciliaris, A. suetica, L. fuscipetiolatum, P. colbathii, S. philippoti, F. sartbernardensis, F. breviscula,* and *F. Longiscula* in zone (E), (F) from the mid-late Darriwilian (Llanvirnian) of Algeria, Tunisia and northwest Libya. In addition *B. klabavense* has been recorded from the mid-late Darriwilian of Turkey (Paris *et al.,* 2007). However, all these previously cited taxa from Saudi Arabia, Jordan, Iraq, Iran, Turkey, North Africa (Libya, Algeria and Tunisia), except *Tectitheca* sp. A, are reported to span the Darriwilian of northern Gondwana (Vecoli and Le Hérissé, 2004). In addition to these taxa, the latter authors documented further acritarchs that span the Darriwilian of northern Gondwana such as *F. hamata, S. celestum* and *Leiofusa* cf*. fusiformis,* which are also recorded in the present assemblage.

The occurrences of *P. cillaris, A. suetica, S. philippoti, Leiofusa* cf. *fusiformis,* and *P. colbathii* indicate that this assemblage is not older than mid-late Darriwilian (Llanvirnian) as these species are unknown from pre-Llanvirnian strata in northern Gondwana (Vecoli and Le Hérissé, 2004). The upper boundary of this assemblage is restricted to the Darriwilian by the occurrence of the above taxa and *L. fusticula* which has not been recorded from post-Darriwilian strata (Vecoli and Le Hérissé, 2004).

Based on previously-discussed occurrences, the present assemblage is considered to be of mid-late Darriwilian (Llanvirnian) age. The chitinozoans recovered in this zone do not provide a firm age assignment as no classical components of Darriwilian chitinozoan biozones have been observed. A middle-late Darriwilian age is proposed here for this assemblage based on acritarchs and comparison with the assemblages described in Oman (Molyneux *et al*. 2006), Saudi Arabia (Molyneux and Al-Hajri, 2000; Le Hérissé *et al*., 2007), Jordan (Keegan *et al*. 1990), Iran (Ghavidel-syooki 1996), Zones E and F of North Africa (Vecoli, 1999; Vecoli *et al.,* 2003) and North Gondwana (Vecoli and Le Hérissé 2004). This age assignment is supported also by the absence of typical Later Ordovician Katian-Hirnantian species.

6.3.1.3. Assemblage Zone Ac-2

Composition: This assemblage is characterised by the occurrence of *Poikilofusa spinata, Leiofusa* cf. *litotes, Orthosphaeridium rectangulare, Veryhachium subglobosum* and last occurrence of *Orthosphaeridium bispinosum*. Other associated taxa include *Multiplicisphaeridium irregulare*, *M. bifurcatum, Neoveryhachium carminae*, *Ordovicidium elegantulum*, *Orthosphaeridium octospinosum*, *O. insculptum, Baltisphaeridium* *longispinosum, B. longispinosum delcatum, B. christoferi, Villosacapsula setosapellicula, Leiofusa fusiformis*, *Veryhachium reductum, V. oklahomense, Acanthodiacrodium crassus, Eupoikilofusa platynetrella, E. striata, Polygonium gracile, Villosacapsula irroratum, Dilatisphaera* cf. *wimanii, Lophosphaeridium* sp. B.*, L. acinatum, Leprotolypa evexa* and *Aremoricanium squarrosum.* Long ranging taxa also occur (e.g. *Veryhachium lairdii, V. trispinosum* and *Leiosphaeridia* spp.).

Occurrence: Melez Shugran Formation, Well D1-200 (core interval 4778 ft - cutting interval 5130 ft) and Well I3- NC186 (cutting interval 4810 ft – 5240 ft).

Age assessment and correlation: Most of the acritarch species recorded in this assemblage indicate an early late Katian age. Hill and Molyneux (1988) reported several taxa (e.g. *M. irregulare*, *V. reductum, B. christoferi*) in an unnamed Formation assigned to the Late Ordovician (Rawtheyan in the British scale) based on chitinozoans. Vecoli and Le Hérissé (2004) reported several taxa (e.g. *A. squarrosum*, *M. irregulare*, *O. bispinosum,* V. *setosapellicula O. insculptum, A. crassus, L. evexa* and *B. longispinosum,*) that span the early-late Katian of northern Gondwana. A similar association, including *A. squarrosum* (as *A. syringosage*), *M. irregulare* and *O. bispinosum*, is recorded from the early-mid Katian (late Caradocian) of northwest Saudi Arabia by Jachowicz (1995). *O. bispinosum* is also reported to characterise the Zone JO2 Sandbian-Katian of Jordan (Keegan *et al*., 1990). *A. squarrosum*, *M. irregulare*, *O. elegantulum* and *V. setosapellicula* are documented from the Katian in Oman by Molyneux *et al*. (2006). In northern Iran Ghavidel-syooki (2006, 2008) recorded acritarch assemblages, including *M. irregulare, M, bifurcatum, B. longispinosum delicatum, V. lairdi O. elegantulum, O. insculptum, O. rectangulare, V. subglobosum* and *V. setosapellicula*, these assemblages are assigned to the Katian- Hirnantian (Late Ordovician), but he recorded that the range of species *N. carminae, Dactylofusa striata, D. playnetrella,* and *A. crassus* does not extend higher than the Katian. Al-Ameri (2010) recorded *M. irregulare*, *O. elegantulum*, and *O. bispinosum* from the Sandbian-mid Katian (Caradocian) of Iraq. In Turkey, Steemans *et al*. (1996) reported several species (e.g. *M. irregulare* and *V. setosapellicula*) assigned to the Sandbian-mid Katian (Late Ordovician).

However, in this study the base of this assemblage is defined by the occurrence of *M. irregulare, P. spinata, O. rectangulare, Leiofusa* cf. *litotes* and *V. subglobosum*. In northern Gondwana all of these species have not been reported before the early late Katian. This is older than the *A. nigerica* chitinozoan Biozone. The top is defined by the last occurrence of *O. bispinosum* which has not been recognised from the late Katian meaning it is younger than the *A. nigerca* chitinozoan Biozone according to Vecoli and Le Hérissé, (2004). The occurrence of these taxa in this assemblage suggests it is possibly comparable with zone JO-2 of Jordan (Keegan *et al*., 1990).

Accordingly, and based on age assignment using chitinozoa, the present assemblage is attributed to an early late Katian age and considered to correspond to the *A. nigerica* Biozone (Paris, 1990; Webby *et al*., 2004).

6.3.1.4. Assemblage Zone Ac-3

Composition: This assemblage is characterised by the occurrence of *Leiofusa estrecha* and *Dactylofusa cucurbita*. Other associated taxa include *Multiplicisphaeridium irregulare*, *M. bifurcatum, Neoveryhachium carminae*, *Ordovicidium elegantulum*, *Orthosphaeridium rectangulare, O. octospinosum*, *O. insculptum, Baltisphaeridium longispinosum, B. longispinosum delcatum, B. christoferi, Villosacapsula setosapellicula, Leiofusa fusiformis, Veryhachium reductum, V. oklahomense, Eupoikilofusa platynetrella, E. striata, Polygonium gracile, Villosacapsula irrorata* and *Aremoricanium squarrosum, Lophosphaeridium* sp. B., *L. acinatum* and *Leprotolypa evexa* . Long ranging taxa also occur (e.g., *Veryhachium lairdii, V. trispinosum* and *Leiosphaeridia* spp.).

Occurrence: Melez Shugran Formation, Well D1-200 (core interval 4831.5 ft – 4878 ft).

Age assessment and correlation: Most of the acritarchs recorded in this assemblage are present in the preceding assemblage. The base of this assemblage is defined by the absence of *O. bispinosum* and first appearance of *Leiofusa estrecha* and *Dactylofusa cucurbita.* The top is defined by the first appearance of *Leiofusa* cf. *tumida*, *Eupokilofusa ctenista, Dactylofusa striatogranulata* and *Moyeria cabotti* in the succeeding assemblage zone*.* In northern Gondwana *O. bispinosum* has not been reported from the post- early late Katian meaning it is not younger than the *A. nigerica* chitinozoan Biozone of northern Gondwana (Vecoli and Le Hérissé, 2004).

However, we should mention here that the species *Eupoikilofusa playnetrella* has been recorded from core samples containing this assemblage and in the preceding Assemblage Zone AC-2. The same species is recorded in northern Iran in the early Kataian (Ghavidel-syooki, 2008). Also, the species *D. cucurbita* has been recorded from the core samples containing this assemblage zone. Grignani *et al.* (1991) recorded *D. cucurbita* in his Assemblage Zone B, which is correlated with the chitinozoan-based *A. merga* Biozone in the current study. Vecoli and Le Hérissé, (2004) considered those species to be characteristic of the Hirnantian in northern Gondwana.

Accordingly, this assemblage is attributed a late Katian age based on the age assignment based on chitinozoa, which is considered to correspond to the *A. merga-* Biozone of (Paris, 1990; Webby *et al*., 2004). This is supported by the occurrence of *Leiofusa estrecha* and absence of *O. bispinosum* according to Vecoli and Le Hérissé, (2004). Based on the presence of some taxa mentioned above, this assemblage may be comparable with unnamed strata (Biozone As 1) from the Ashgillian of northeast Libya of Hill and Molyneux (1988) which was assigned a late Katian age (Rawtheyan in the British scale) based on chitinozoa (Paris 1988) and correlated with the *A. merga* Biozone in this study. It is also correlated with the Ashgillian Zone JO-1 of Jordan (Keegan *et al*. 1990), the Moroccan Ashgillian succession (Elaouad-Debbaj 1988a) and Assemblage Biozones A, B from the Late Ashgillian of the Kufra Basin of southeast Libya (Grignani *et al.,* 1991).

6.3.1.5. Assemblage Zone Ac-4

Composition: This assemblage is characterised by the occurrence of *Epoikilofusa ctenista, Leiofusa* cf. *tumida*, *Dactylofusa striatogranulata, Visbysphaera pirifera, Moyeria cabotti* and *Baltisphaeridiun aliquigranulum.* Other associated taxa occur such as *Multiplicisphaeridium irregulare*, *M. bifurcatum, Neoveryhachium carminae*, *Ordovicidium elegantulum*, *Villosacapsula Orthosphaeridium rectangulare, O. octospinosum*, *O. insculptum, Eupokilofusa striata, Villosacapsula setosapellicula, Veryhachium oklahomense, Cheleutochroa* cf. *diaphorosa* and *Polygonium gracile, Lophosphaeridium sp*. B.*, L. acinatum, Leprotolypa evexa* and *Villosacapsula irrorata.* Long ranging taxa also occur (e.g. *Veryhachium lairdii, V. trispinosum* and *Leiosphaeridia spp.*).

Occurrence: Memouniat Formation, Well I3-NC-186 (cutting, core interval (4782 ft.- 4799 ft), Bir Tlacsin Formation, Well A28i-NC186 (core interval 4482 ft.-4517 ft) and Well H2-NC186 (cutting interval 4550 ft. 4590 ft).

Age assessment and correlation: This assemblage is defined by the first occurence of *Leiofusa cf. tumida*, *Eupokilofusa ctenista, Dactylofusa striatogranulata, Baltisphaeridiun aliquigranulum* and *Visbysphaera pirifera*. A similar association, including *V. setosapellicula* and *E. ctenista,* has been recorded previously in the early Ashgillian of northwest Saudi Arabia by Jachowicz (1995) and in the unnamed Ashgillian strata (Biozone As 2) of northeast Libya by Hill and Molyneux (1988). Moreover Vecoli and Le Hérissé, (2004) considered those species to be characteristic of the Hirnantian in north Gondwana. Their ranges extend from the upper part of the *T. elongata- S. ouelbsiri* chitinozoan Biozones. The presence of the taxa cited above suggest that correlation of this assemblage with zone G from Libya, Algeria and Tunisia (Vecoli, 1999; Vecoli *et al.,* 2003) is possible.

The present assemblage is equivalent to the chitinozoan-based *T. elongata* and *S. oulebsiri* Biozones and confirms a Hirnantian age for this assemblage and provides a more precise age assignment. Accordingly the present assemblage is attributed a Hirnantian age and considered to correspond to the upper *T. elongate- S. ouelbsiri* biozones (Paris *et al*., 2000a; Webby *et al.,* 2004).

Vecoli and Le Hérissé (2004) show that the acritarch assemblages associated with post-glacial sediments are well characterized by the presence of reworked specimens of various ages from the Tremadocian up to the pre-Hirnantian and the first occurrence of distinct morphotypes of Silurian ‘‘affinity’’ such as *Visbysphaera* spp.

Generally, the acritarchs recorded in this assemblage zone coexist with some questionable reworked early Ashgillian taxa such as *L. evexa, Orthosphaeridium insculptum* and *Baltisphaeridium* cf. *druggi. A. crassus* also exists in this assemblage in the core and cuting samples of the Bir Tlacsin Formation in Wells A28i-NC186 and H2-NC186.

6.3.1.6. Assemblage Zone Ac-5

Composition: This assemblage is characterised by the relative abundance of sphaeromorph acritarchs (*Leiosphaeridia* spp.) and the occurrence of a few specimens of *Evittia*. sp.1 and *Veryhachium wenlockianum.* Long ranging taxa also occur (e.g. *Veryhachium trispinosum, Evittia denticulate* and *Neoveryhachium carminae*)

Occurrence: Tanezzuft Formation, Well B2-NC186 (cutting sample 3950 ft-4000 ft.).

Age assessment and correlation: This assemblage shows very close similarities with the earliest Rhuddanian acritarch assemblage zone recorded by Le Hérissé (2000) from Saudi Arabia. This assemblage is equivalent to the chitinozoan-based *S. fragilis* Biozone and confirms an early Rhuddanian age and provides a more precise age assignment. Accordingly, the present assemblage is attributed an early Rhuddanian age and is considered to correspond to the *S. fragilis* Biozone (Verniers *et al*., 1995; Paris *et al* .,1995).

6.3.1.7. Assemblage Zone Ac-6

Composition: This assemblage is characterised by the occurrence of *Eupoikilofusa striatifera, Multiplicisphaeridium circumscriptum, M. fermosum, M.* cf. *brazusdesnodem, Tylotopalla caelamenicutis*, *T.* cf. *deerlijkianum, Cymatiosphaera* cf. *densisepta*, *Deunffia brevispinosa*, *Dictyotidium dictyotum*, *Polygonium* .sp. A, *Evittia* sp. 1, *E. remota*, *E. sanpetrensis*, *Veryhachium valiente*, *V. wenlockianum* and *Domasia limaciforme.* Long ranging taxa also occur (e.g. *Leiofusa* estrecha, *Neoveryhachium* carminae, *Veryhachium trispinosum* and *Evittia denticulata*).

The acritarchs recorded in this assemblage zone coexist with some reworked Late Ordovician taxa such as *Orthosphaeridium rectangulare.*

Occurrence: Lower part of the Tanezzuft Formation Well E1-NC174 (core interval 7246 ft-7270 ft) and Well I3- NC186 (cutting intervals 4600 ft-4650 ft).

Age assessment and correlation: The occurrence of *Polygonium* sp. A, *V. valiente, Cymatiosphaera* cf. *densisepta* and other associated taxa indicate that this assemblage is very similar to the early Rhuddanian assemblage from Saudi Arabia (Le Hérissé et al., 1995; Le Hérissé 2000) which corresponds to the *B. postabusta* Biozone. However, in this study this assemblage is equivalent to the chitinozoan-based *B. postabusta* Biozone and confirms an middle Rhuddanian age and provides a more precise age assignment. Accordingly the present assemblage is attributed an early Rhuddanian age and is considered to correspond to the *B. postabusta* Biozone (Verniers *et al*., 1995; Paris *et al* 1995).

6.3.1.8. Assemblage Zone Ac-7

Composition: This assemblage is characterised by the occurrence of *Tunisphaeridium tentaculiferum, Eupoikilofusa saetosa, Carminella maplewoodensis, Neoveryhachium carminae constricta, Cymbosphaeridium* sp. 1, *Visbysphaera microspinosum, V. gotlandica, Baiomeniscus camurus,* *Micrhystridium stellatum, Geron* sp.1 and *Eupoikilofusa catabrica.* Other associated taxa include *Veryhachium wenlockianum, Evittia* sp. 1*, V. valiente, Eupokilofusa rhikne, Evittia sanpetrensis, E. remota podolica, E. remota* and *Eupoikilofusa striatifera* Long ranging taxa occur also (e.g. *Veryhachium trispinosum*, *Leiofusa estrecha, Neoveryhachium carminae* and *Evittia denticulata*).

Occurrence: Tanezzuft Formation, Well E1-NC174 (cutting interval 6550 ft – 7246 ft) and Well D1-200 (cutting interval 4650 ft-4700 ft) and Well B2-NC186 (3700 ft – 3950 ft).

Age assessment and correlation: This assemblage is defined by the occurrence of *T. tentaculiferum, N. carminae constricta* and *Micrhystridium stellatum. T. tentaculiferum* characterises the Mid Silurian worldwide, and has been recorded from the late Llandovery-Ludlow of Turkey (Erkmen and Bozdoğan, 1979) and assemblage Ll2 (Aeronian) in northeast Libya (Hill and Molyneux, 1988). However, the chitinozoa evidence suggests the assemblage is of Rhuddanian age (Paris 1988). In Saudi Arabia *Tunisphaeridium tentaculiferum* and *Neoveryhachium carminae constricta* are not reported before than Zone 2, which is assigned to the mid Rhuddanian, and their ranges extend to the early Aeronian (Le Hérissé 1995). Subsequently, Le Hérissé (2000) documented both species associated with other taxa (e.g. *Eupoikilofusa saetosa*) attributed to the mid Rhuddanian and considered to correspond to the *L. mayyimensis* chitinozoan Biozone. Therefore, the presence of the above cited taxa support at least a late Rhuddanian- early Aeronian age for this assemblage.

Based on the occurrence of some acritarch species (e.g. *Tunisphaeridium tentaculiferum, Micrhystridium stellatum, Carminella maplewoodensis, Neoveryhachium carminae constricta* and *Geron* sp. 1) the comparison of this assemblage with the Zone Ll2 of northeast Libya (Hill and Molenuex, 1988), Zones 1 2, 3, and 4 of Saudi Arabia (Le Hérissé *et al*., 1995) and mid-late Rhuddanian acritarchs of Saudi Arabia (Le Hérissé, 2000) is possible.

However, in this study this assemblage zone is equivalent to the chitinozoan-based *A. qusaibaensis* Biozones which confirms the late Rhauddanian-early Aeronian age for this assemblage and provides a more precise age assignment.

6.3.1.9. Assemblage Zone Ac-8

Composition: This assemblage is characterised by the occurrence of *Ammonidium microladium, Pteroverricatus occuliformis, P. zonocylindrus, Tylotopalla aniae, Circinatisphaera enigma* and *Tunisphaeridium caudatum.* Other associated taxa occur include *Tunisphaeridium tentaculaferum, Visbysphaera microspinosum, V. gotlandica, Eupoikilofusa striata, Cymbosphaeridium* sp. A, *Cymbosphaeridium* sp. 1, *Eupoikilofusa catabrica, E. striatifera*, *Neoveryhachium carminae constricta, Evittia* sp. 1, *E. sanpetrensis, E. remota podolica* and *Leiofusa estrecha, Neoveryhachium carminae, Veryhachium valiente, V. wenlockianum* and *E. rhikne.* Long ranging taxa also occur (e.g., *Veryhachium trispinosum*, *Evittia denticulata* and *Leiofusa estrecha*).

Occurrence: Tanezzuft Formation, Well I3-NC186 (cutting interval 3700-ft 4600 ft), Well D1-200 (cutting interval 3850 ft-4650 ft), Well E1-NC174 (cutting interval 6350 ft-6650 ft), Well H2-NC186 (cutting interval 4160 ft-4550 ft).

Age assessment and correlation: Most of the acritachs recorded here are present in the preceding assemblage. However, this assemblage is defined by the occurrence of *A. microladium*, *P. occuliformis, P. zonocylindrus* and *C. enigma.* Hill and Molyneux (1988) defined Zone Ll3 based on the occurrence of *A. microladium* and other associated taxa such as *E. catabrica, V. gotlandica* and *V. microspinosum,* which also exist in the subsequent Zone Ll4. They assigned Zone Ll3 an Aeronian age and Zone Ll4 an uppermost Aeronian-Telychian age. This is supported by chitinozoa evidence of Paris (1988). Le Hérissé (1995) defined Zone 5 based on the first occurrence of *Pteroverricatus zonocylindrus* and other associated taxa, which are not recorded in the current study. They suggested a late Aeronian-early Telychian age. Zone 6 is defined based on the occurrence of *A. microladium* and other associate taxa such as *V.*

microspinosum and is assigned a late Telychian-early Sheinwoodian age. Le Hérissé (2000) assigned *Circinatisphaera enigma* and *Carminella mapplewoodensis* to the early-mid Telychian and considered them to correspond to the *S. solitudina-A. hemeri* Concurrent Range Biozone and assigned *P. occuliformis* and *P. zonocylindrus* to the early - middle Telychian and considered them to correspond to the *S. solitudina-A. hemeri* and *A. hemeri* Interval Range Biozone. They also considered that *A. microladum* and *Cymbosphaeridium* sp. 1 belong to the mid to late Telychian and are equivalent to the interval between the *S. solitudina, A. hemeri* and *A. macculeri* Biozone of Paris (1995). However, in this study the occurrences of these species in the upper part of the chitinozoan-based biozone *C.* cf. *alargada-P. paraguayensis*, which is assigned a mid-late Aeronian age, could be due to caving from the above sediment.

Based on the above discussion, comparison of this assemblage zone with the Zones Ll3, Ll4 from northeast Libya (Hill and Molyneux, 1988), Zones 5, 6 from Saudi Arabia (Le Hérissé *et al*., 1995) and the Zones described by Le Hérissé (2000) is possible. However, in this study the present assemblage is equivalent to the chitinozoan-based *C.* cf. *alargada- P. paraguayensis, A. hemeri* and *A. macclurei* Biozones, which confirms a mid-late Aeronian-Telychian age for this assemblage and provides a more precise age assignment.

6.4. Cryptospore palynozones

6.4.1. Introduction

Four cryptospore Assemblage Zones were recognised: Cr-1 in the mid-late Darriwilian, Llanvirnian (Mid Ordovician), Cr-2 in the mid to late Katian and Hirnantian, Ashgillian (Late Ordovician), Cr-3 and Cr-4 in the Rhuddanian-Telychian (Llandovery) Early Silurian. These assemblages are very similar to those described from the Mid Ordovician-Llandovery of different areas in Gondwana and the world (e.g. Gray, 1985; Richardson, 1988, 1996; Strother *et al*., 1996; Wellman, 1996; Wang *et al*., 1997; Steemans *et al*., 2000). This uniformity suggests a cosmopolitan distribution of cryptospore producing plants (e.g. Wellman *et al*., 2003; Steemans *et al*., 2009). Selected cryptospore stratigraphical ranges are shown in Fig. (20). Most of the cryptospores recovered in this study consist of tetrads and dyads (fused or unfused) which are either naked or enclosed within a laevigate or an ornamented envelope. Hilate monads, physically separated spores and laevigate trilete spores also occur. In comparison with acritarchs and chitinozoans, the existing biostratigraphic schemes of cryptospores (e.g. Steemans *et al*., 2000) are of lower biostratigraphic value with broader zones and with most known species long ranging and non-age diagnostic. The age of the present assemblages is based on the occurrences of chitinozoans and acritarchs.

6.4.1.1. Assemblage Zone Cr-1

Composition: The most important cryptospores recognized in this assemblage are *Dyadospora murusattenuata*, *Laevolancis chibrikovae*, *Pseudodyadospora petasus*, *Tetrahedraletes medinensis, Velatiteras laevigata, Chelinotriletes maculatus, Rimosotetras problematica, Hispanaediscus* cf. *wenlockensis, Hispanaediscus verrucatus, Laevolancis divellomedia-plicata, Laevolancis chibrikovae Sphaerasaccus glabellus, Quadrisporites granulatus, Pseudodyadospora laevigata,* Tetrad spp., Micro-ornamented monads and Genus sp. A

Occurrences: Hawaz Formation, Well H2-NC186 (core, cutting interval 4605 ft-5200 ft), well A28i-NC186 (core interval depth 4518 ft-4723 ft) and Well D1-200 (cutting interval 5150ft- 5750ft).

Age assessment and correlation: Strother *et al*. (1996) recorded similar taxa regarded here as synonyms of *D. murusattenuata*, *P. laevigata* and *T. medinensis*. In their assemblage, recorded from the Mid Ordovician in Saudi Arabia, they noted that envelope-enclosed tetrads are rare. This is also observed herein by the relatively low abundance of *S. glabellus* and *V. laevigata.* Newly reported work has documented spores from Early-Mid Ordovician strata (Rubinstein *et al*., 2010), reporting a diverse cryptospore assemblage, including naked and envelope-enclosed monads and tetrads in Argentina (e.g. *Laevolancis divellomedia* or *Laevolancis chibrikovae* and *Sphaerasacus glabellus*). These taxa are also recorded in this assemblage zone. Wellman (2010) discussed this finding within a framework of evolutionary transformation. Molyneux *et al*. (2006) reported cryptospores from the mid-late Darriwilian Saih Nihayda Formation in Oman such as *P. laevigata* and *T. medinensis.*

It should point out here that this Assemblage Zone is equivalent to acritarch Assemblage Zone (Ac-1) which is attributed to the mid-late Darriwilian based on the occurrences of diagnostic acritarch species as no classical components of Darriwilian chitinozoan biozones have been recorded in this study.

6.4.1.2. Assemblage Zone Cr-2

Composition: This assemblage is characterized by the occurrence of *Imperfectotriletes vavrdovae* and *Acontotetras inconspicuis.* Other associated taxa include *Dyadospora murusattenuata*, *Laevolancis chibrikovae*, *Tetrahedraletes medinensis, Chelinotriletes maculatus, Rimosotetras problematica, Hispanaediscus* cf. *wenlockensis, H. verrucatus, Laevolancis divellomedia plicata, Sphaerasaccus glabellus, Quadrisporites granulatus, Pseudodyadospora petasus, Pseudodyadospora laevigata* and Micro-ornamented monads

Occurence: Melez Shugran Formation, Well D1-200 (core interval 4778 ft - cutting interval 5130 ft), Bir Tlacsin and Memouniat Formation, Well I3-NC-186 (cutting interval 4680 ft- core interval 4799 ft), Well A28i-NC186 (core interval 4482 ft-4517 ft) and Well H2-NC186 (cutting interval 4550 ft 4590 ft).

Age assessment and correlation: This assemblage is characterised by the occurrence of *Imperfectotriletes vavrdovae* and *Acontotetras inconspicuis.* Most of the cryptospore species in the preceding Cr-1 Assemblage Zones are also recognized here. However, due to the occurrence of *Imperfectotriletes vavrdovae,* this assemblage is comparable with the *Imperfectotriletes* spp. Interval Bizones (subzone) of the *Imperfectotriletes spp. Laevolancis divellomedia* Assemblage Biozone recorded in Saudi Arabia (Steemans *et al*., 2000), and also with the Latest Ordovician (Late Ashgillian) assemblage in northeast Libya reported by Richardson(1988), which included tetrads, pseudodyads, dyads and *A*? *vavrdovii,* some of which are identical to those recorded in this assemblage such as *Tetrahedraletes medinensis* and *Pseudodyadospora laevigata.* Therefore, this Assemblage Zone is believed to correspond to the Late Ordovician and is characterised by the incoming of *Imperfectotriletes* and the absence of true trilete spores. This is supported by the Upper Ordovician chitinozoan biozones (*A. nigerica, A, merga, T. elongate* and *S. oulebsiri*) and acritarch assemblage zones (Ac-2, Ac-3, and Ac-4) established in this study, which provide a more precise age assignment. Thus this assemblage is attributed an early late Katian-Hirnantian age.

6.4.1.3. Assemblage Zone Cr-3

Composition: This assemblage is characterised by the presence of very few specimens of cryptospores such as *Dyadospora murusattenuata*, *Laevolancis divellomedia-plicata*, *Tetrahedraletes medinensis, Rimosotetras problematica, Pseudodyadospora laevigata, Imperfectotriletes vavrdovae* and one specimen of *Ambitisporites dilutus* that occurred in a core sample in Well E1-NC174 (7287ft.).

Occurence: Lower part of the Tanezzuft Formation Well E1-NC174 (core interval 7246 ft–7287 ft), Well I3-NC-186 (cutting intervals 4600 ft-4640 ft) and Well B2-NC186 (cutting interval 3950 ft-4000 ft).

Age assessment and correlation: Most of the cryptospores species recorded in the preceding assemblages are absent here. The assemblage is characterised by the presence of very rare cryptospores such as *D. murusattenuata*, *L. divellomedia-plicata*, *T. medinensis, R. problematica* and *P. laevigata*. In addition only one true trilete spore (*Ambitisporites dilutus*) is recorded. Again the occurrence of *Imperfectotriletes vavrdovae,* and incoming of very rare true trilete spores, indicate that this assemblage can be correlated with the Ashgillian and Rhuddanian *Imperfectotriletes* spp. and *Laevolancis divellomedia* Interval Bizones (subzones) of the *Imperfectotriletes spp. Laevolancis divellomedia* Assemblage Biozone recorded in Saudi Arabia (Steemans *et al*., 2000). This zone is attributed to an early Rhuddanian age based on occurrences of diagnostic chitinozoan species of (*S. fragilis, B. postrobusta* Biozones) and acritarch assemblage zones (Ac-5, Ac-6), which provides a more precise age assignment. Thus this assemblage is attributed an early Rhuddanian age.

6.4.1.4. Assemblage Zone Cr-4

Composition: The main components of this assemblage zone include *Ambitisporites dilutus, Dyadospora murusattenuata*, *Laevolancis chibrikovae*, *Pseudodyadospora petasus*, *Tetrahedraletes medinensis, Velatiteras laevigata, Chelinotriletes maculatus,* cf. *Artemopyra, Rimosotetras problematica, Hispanaediscus* cf. *wenlockensis, H. verrucatus, Laevolancis divellomedia-plicata, Sphaerasaccus glabellus, Quadrisporites granulates, Segesterospora* sp. A, *Pseudodyadospora laevigata,* Micro-ornamented monads and Genus sp. A

Occurence: Tanezzuft Formation, Well D1-200 (cutting interval 3850 ft-4700ft.), Well I3-NC186 (cutting interval 3700ft 4600ft), Well E1-Nc174 (core and cutting interval 6350 ft – 7246 ft), Well H2-NC186 (Cutting interval 4150ft – 4500ft) and Well B2-NC186 (cutting interval 3700 ft-3950 ft)

Age assessment and correlation: This assemblage is characterised by the presence of the above cited cryptospores, associated with moderately abundant specimens of the true trilete spore (e.g *A. dilutus*). However, the occurrence of envelope-enclosed taxa such as *S. glabellus* and *V. laevigata* in this assemblage zone is very rare. This observation is in accordance with the general decrease in envelope-enclosed cryptospores throughout the Llandovery (Steemans *et al*., 2000). The abundant occurrence of hilate spores (e.g. *L. divellomedia-plicata*) and moderately abundant true trilete spore (e.g *A. dilutus*) characterises this zone from the older Cr-3 Assemblage Zone. This zone is comparable with the Ashgillian and Rhuddanian *Laevolancis divellomedia* Interval Biozone (subzone) of the *Imperfectotriletes spp. Laevolancis divellomedia* Assemblage Biozone recorded in Saudi Arabia (Steemans *et al*., 2000).

This assemblage is equivalent to chitinozoan biozones (*A. qusaibaensis, C.* cf. *alargada – P. paraguayensis, A. hemeri* and *A. macclurei*) and acritarch Assemblage Zones (Ac-7, Ac-8), which confirms the late Rhuddanian-Telychian age. The chitinozoans biozones provides a more precise age assignment. Thus this assemblage is attributed a late Rhuddanian- Telychian age.

6.5. Conclusion

In this study no age can be given for the Ashbiyat Formation because it is barren of palynomorphs, but a Tremadocian age is assigned based on the lithostratigraphical correlation with the fossiliferous Sanrhar Formation by Massa *et al*. (1977). A mid-late Darriwilian (Llanvirnian) age is suggested for the Hawaz Formation based on the occurrence of the age-diagnostic acritarch based Ac- 1 Assemblage Zone. However, the chitinozoa recovered in this zone do not provide a firm age assignment as no classical components of Darriwilian chitinozoan biozones have been recorded. The cryptospore-based Cr-1 Assemblage Zone occurs in the Hawaz Formation and is defined and correlated with the Ac-1 Assemblage Zone and chitinozoan Assemblage Zone 1.

The Melez Shugran Formation is assigned to the early late Katian- early Hirnantian (Ashgillian) based on the occurrence of chitinozoan Biozones *A. nigerica, A. merga, T. elongata* and the diagnostic acritarch-based Ac-2, Ac-3 and Ac-4 Assemblage Zones. The Memouniat Formation is also assigned to the early Hirnantian (Ashgillian) and corresponds to the *T. elongata* Biozone based on the occurrence of important chitinozoan taxa in the lower part of this Formation. A late Hirnatian age is assigned to the Bir Tlacsin Formation based on the occurrence of the chitinozoan Biozone *S. oulebsiri*. The acritarch-based Assemblage Zone Ac-4 occurs in both Formations and is correlated with chitinozoan-based biozones. In addition the cryptospore Assemblage Zone Cr-2 occurs in the Melez Shugran, Memouniat and Bir Tlacsin Formations and is correlated with the early late Katian-Hirnantian chitinozoan biozones and acritarch-based Assemblage Zones Ac-2, Ac-3, and Ac-4.

The lower part of Tanezzuft Formation is assigned to the early-mid Rhuddanian (Llandovery), based on the occurrence of chitinozoan-Biozones *S. fragils* and *B. postrobusta* and the diagnostic acritarch-based Assemblage Zones Ac-5, Ac-6, with the hot shale constrained to the upper part of the range of *Belonechitina postrobusta*. The middle and upper part of the Tanezzuft Formation is assigned to the late Rhuddanian-Telychian (Llandovery) based on the occurrence of chitinozoan Biozones *A. qusaibaensis, C.* cf. *alargada* - *P. paraguayensis, A.*

hemeri and *A. macclurei* and the diagnostic acritarch-based Assemblage Zones Ac-7 and Ac-8. Two cryptospore-based Assemblge Zones Cr-3, Cr-4 occur in the Tanezzuft Formation. Assemblage zone Cr-3 is correlated with the chitinozoan Biozones *S. fragilis* and *B. postrobusta* and acritarch-based Assemblage Zones Ac-5, Ac-6 and Assemblage Zone Cr-4 is correlated with the chitinozoan-based *A. qusaibaensis, C.* cf. *alargada-P. paraguayensis, A. hemeri* and *A. macclurei* Biozones and acritarch-based Assemblage Zones Ac-7, Ac-8.

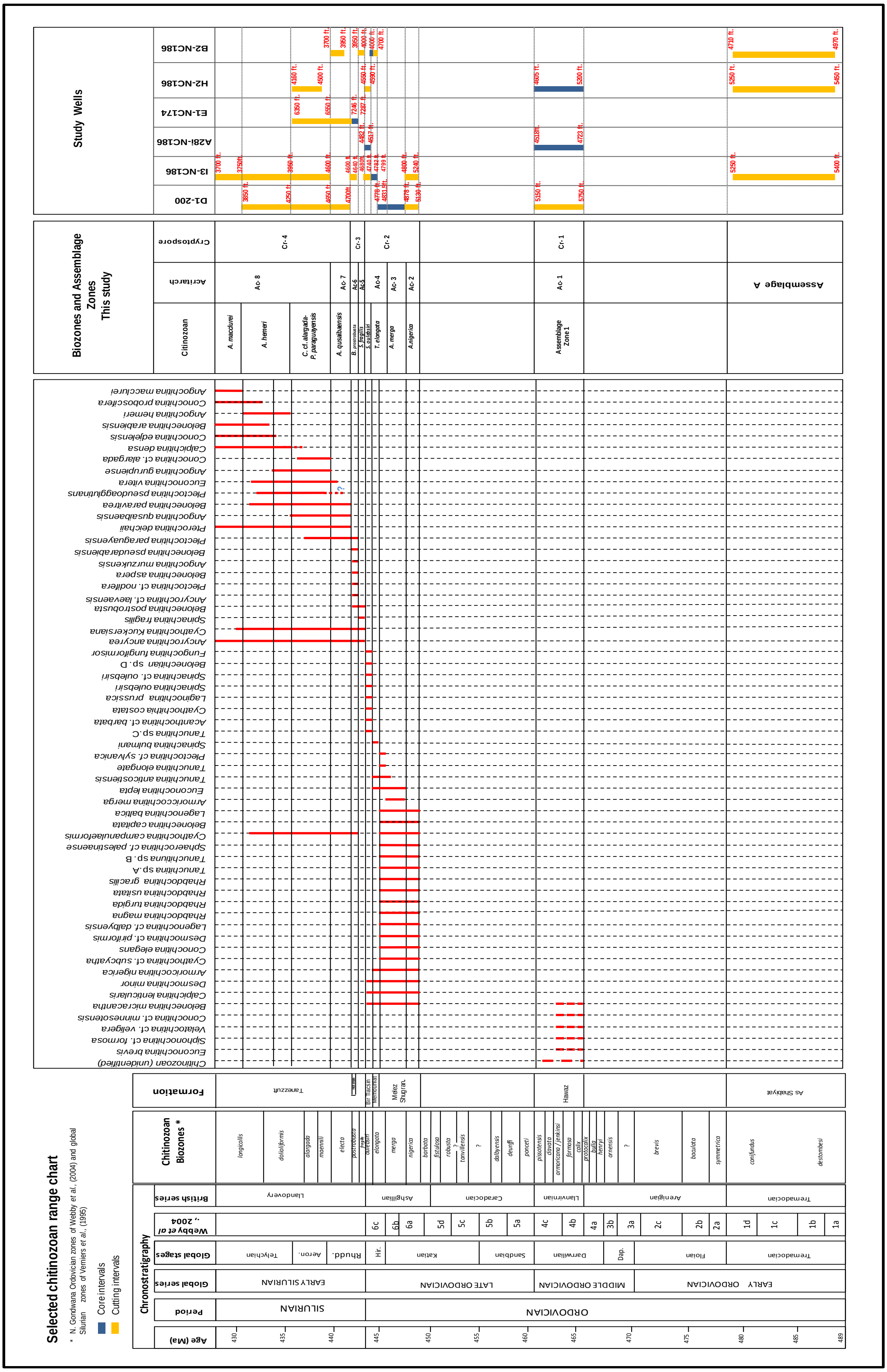


Fig.18. Selected chitinozoan range chart

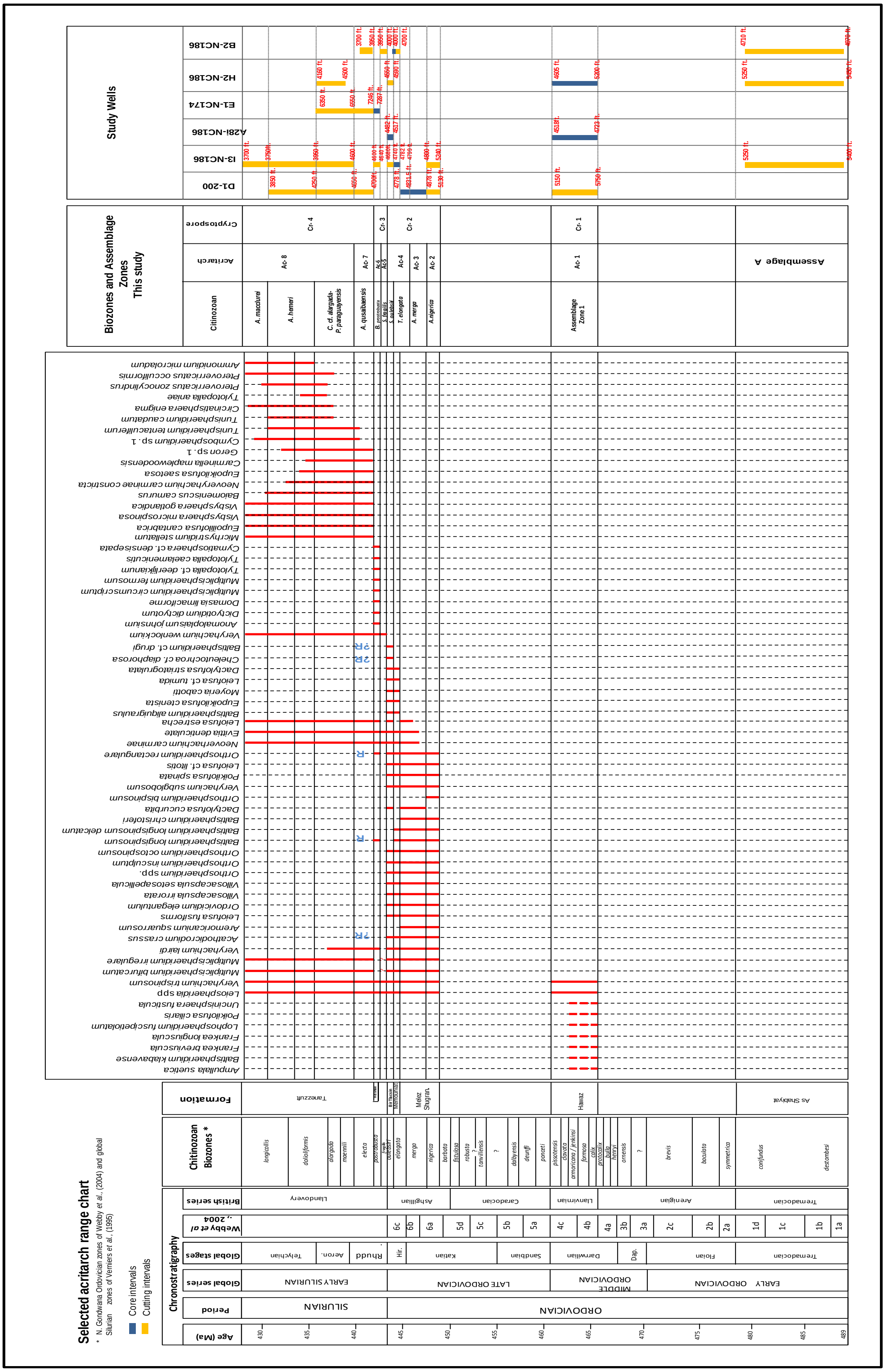


Fig.19. Selected acritarch range chart

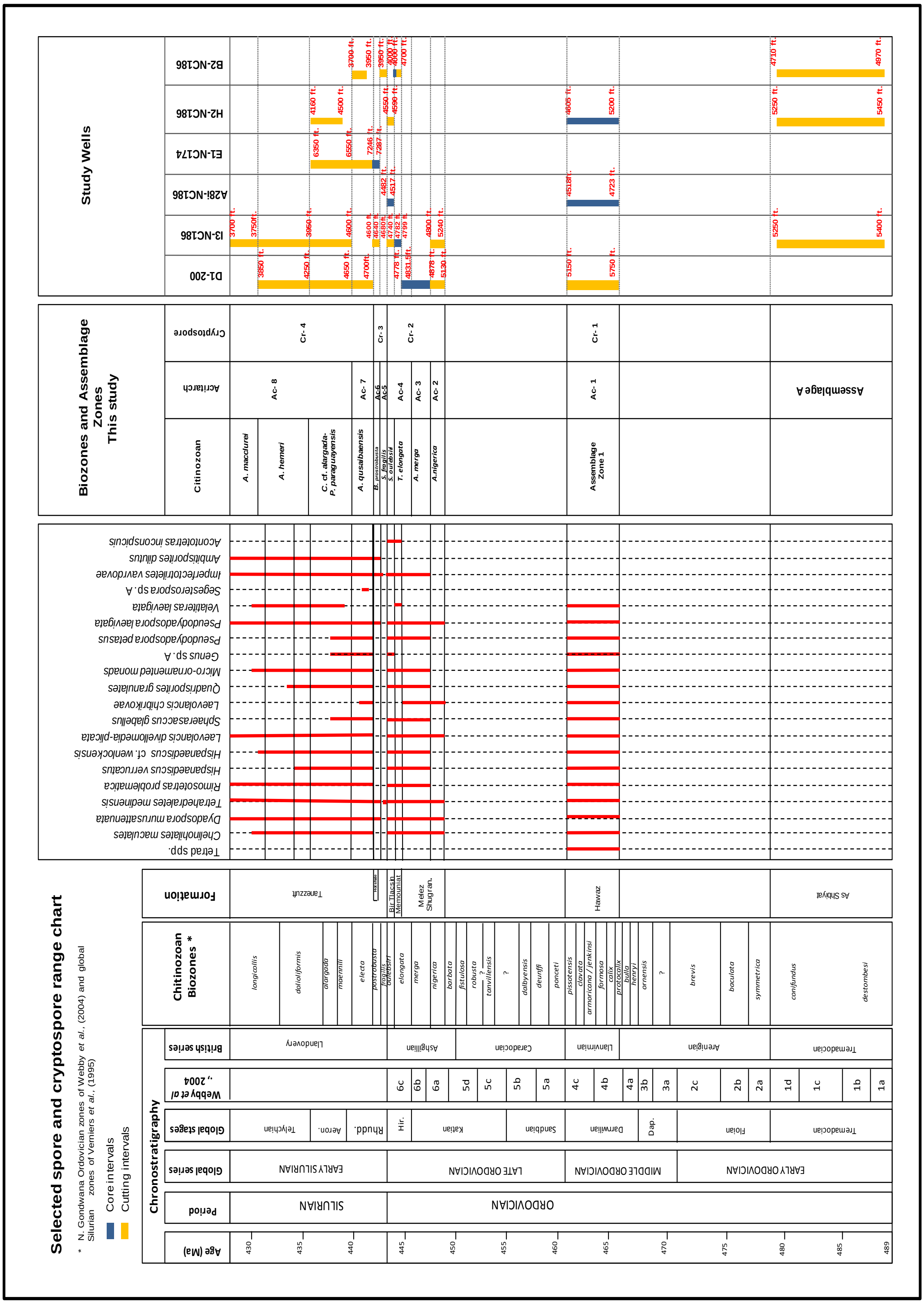


Fig. 20. Selected cryptospore range chart

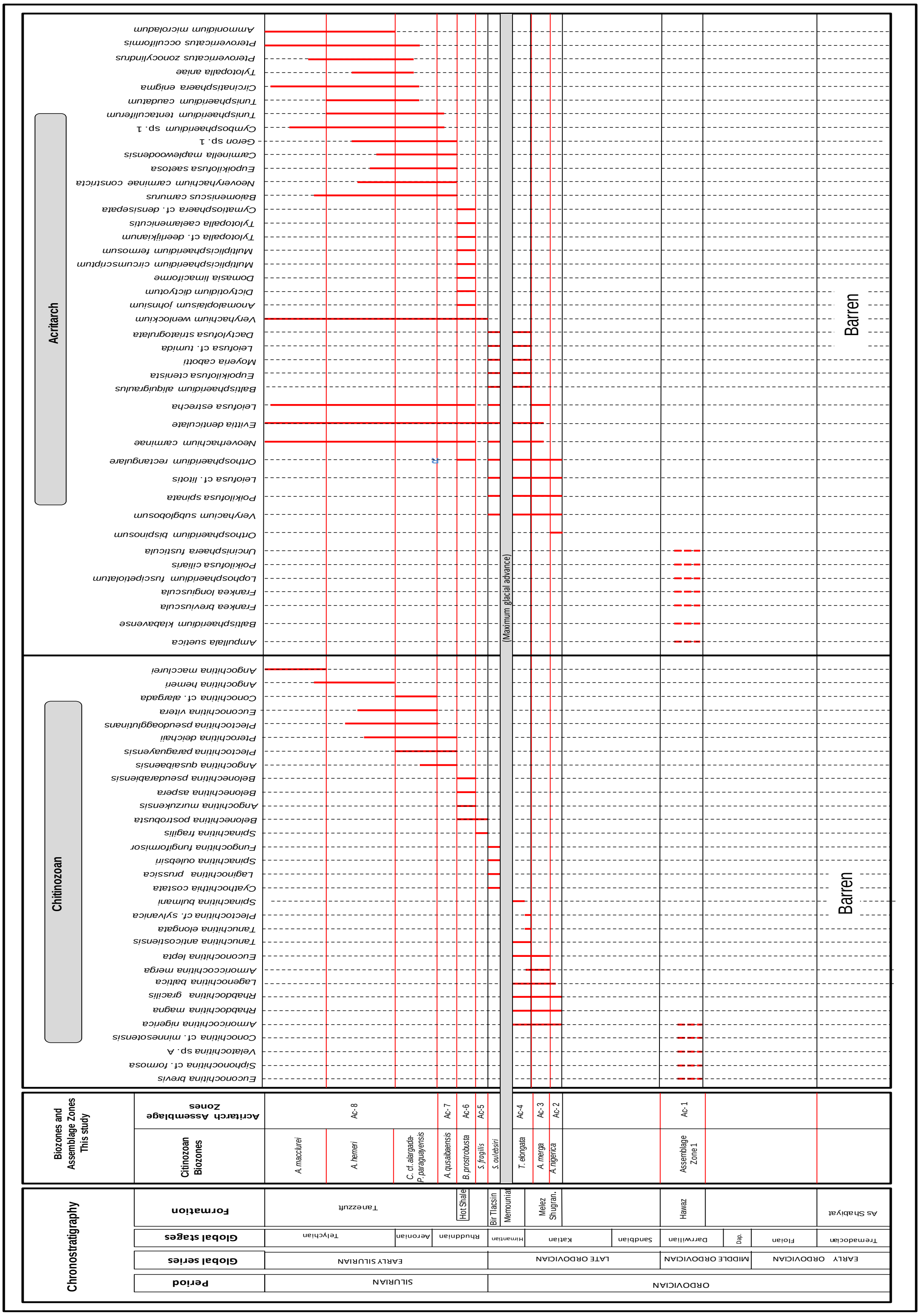


Fig. 21. Stratigraphi range chart of selected taxa (acritarch and chitinozoan) in the studied sections of Wells D1-200, H2-NC186, I-3NC186, B2-NC186, A28i-NC186 and E1-NC174

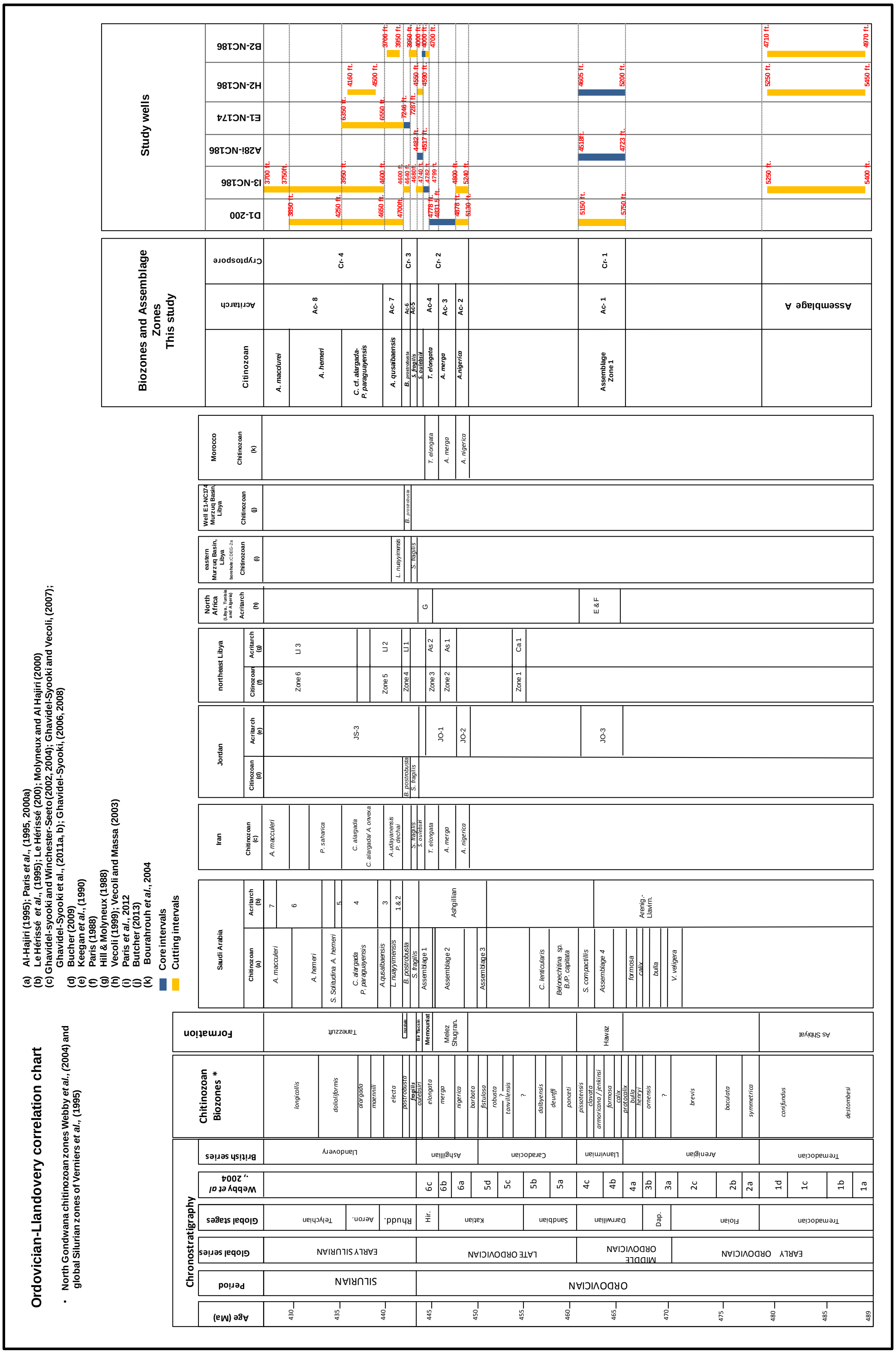


Fig. 22. Ordovician-Llandovery correlation chart

CHAPTER 7. PALYNOFACIES AND PALAEOENVIRONMENT

7.1. Introduction

This chapter concerns palynofacies analysis of the core and cutting samples from Ordovician-Lower Silurian strata belonging to the As Shabiyat, Hawaz, Melez Shugran, Memouniat, Bir Tlacsin and Tanezzuft formations. In the last few decades palynofacies studies have become widely used, particularly in the hydrocarbon industries as well as in academic studies, to understand past palaeoenvironment. The present study focuses on palynofacies in the academic context (e.g. palaeoenvironmental interpretation).

The term palynofacies was originally defined by Combaz (1964) to encompass the total complement of acid-resistant organic matter recovered from a sediment or sedimentary rock by palynological processing techniques, using hydrochloric acid and hydrofluoric acid, as seen under a microscope. Tyson (1995) defined palynofacies as “a body of sediment containing a distinctive assemblage of palynological organic matter thought to reflect a specific set of environmental conditions or to be associated with characteristic range of hydrocarbon generating potential”. Traverse (1988, 2007) defined palynofacies as “association of palynological matter in sediments. Generally, all three definitions refer to palynomorph content in a body of sediment of a specific character that represent a particular depositional environment.

7.2. Previous studies

For palaeoenvironmental reconstructions, a consistent pattern of Early Palaeozoic palynomorph distribution, related to onshore-offshore gradient, has emerged from a number of palynological studies. Where both marine and terrestrial assemblages co-occur, palaeoenvironmental approach is mainly based on the ratio between marine and terrestrial taxa to determine the transgressive/regressive cycles that occurred during sediment deposition. Examples of palynofacies studies following this approach were conducted by

Richardson and Rasul (1990) and Wicander and Wood (1997). Where terrestrial taxa are absent, differences in marine palynomorph composition and diversification provide an alternative approach to palaeoenvironmental reconstructions. Such an approach had been highlighted by several authors (e.g. Staplin, 1961; Jacobson, 1979; Al-Ameri, 1983; Dorning, 1987, Dorning and Bell, 1987; Hill and Molyneux, 1988; Richardson and Rasul, 1990; Stricanne *et al*., 2004). In a sequence stratigraphy context, Molyneux *et al*. (2006) used the ratio between low or highly diverse marine and terrestrial taxa to determine the transgressive/regressive cycles of the Lower Palaeozoic Haima Supergroup in Oman. More recently, and in a palaeoenvironmental context, Vecoli *et al*. (2009) combined palynofacies and palynostratigraphic investigations together with organic carbon isotope measurements of terminal Ordovician through Silurian shaly sediments from the northern Ghadamis Basin in the subsurface of southern Tunisia.

7.3. Classification of palynofacies

Palynofacies classification schemes change according to the nature and aims of a certain study. These schemes and the associated terminology have been the subject of discussion in many publications (e.g. Boulter and Riddick, 1986; Van Bergen *et al*., 1990; Van der Zwan, 1990; Tyson, 1995; Batten, 1996; Batten and Stead, 2005; Traverse, 1994, 2007).

In this study, the classification schemes of Van Begren *et al*. (1990), Tyson (1995) and Batten (1996) are used with some modifications. For effective interpretations of palaeoenvironments, palynofacies particles are divided into three categories: palynomorphs, structured organic matter and structureless organic matter. However, in this study most palaeoenvironmental interpretations will mainly depend on onshore-offshore gradient which is determined by relative abundances of palynomorphs and their specific diversities, in association with AOM. A count was made by counting 200 particle of organic matter in each sample for palynofacies analysis. Palynofacies particles and sections are illustrated photographically in three plates (pages 602-607). Palynofacies distribution charts for each well have been produced. These charts include stratigraphy, chronostratigraphy, palynostratigraphy (Biozones and Assemblage Zones).

7.3.1. Palynomorphs

The term palynomorphs refers to all acid resistant, organic walled microfossils that are found in the palynological preparation. This group comprises both marine (acritarch, chitinozoa and scolecodonts) and terrestrial (spore and cryptospore) elements. For palynofacies analysis, in this study, the palynomorphs are divided into four groups: sphaeromorph acritarchs, other acritarchs including Prasinophyceae algae (e.g. *Pterospermella*, *Tasmanites*, *Cymatiosphaera*, *Dictyotidium, Pteroverricatus*), chitinozoans and cryptospores. Sphaeromorph acritarchs include all spherical palynomorphs with neither processes nor ornamentation (e.g. *Leiosphaeridia* spp.). Process-bearing and/or ornamented acritarchs are termed as other acritarchs. The sphaeromorph acritarchs are distinguished as separate categories because the difference in their position along an onshore-offshore gradient (e.g. Al-Ameri, 1983; Dorning; 1987). Such distinction between acritarchs in palynofacies analysis was previously followed by several authors (e.g. Hill and Molyneux, 1988; Stricanne *et al*., 2004; Molyneux *et al*., 2006). In this study *Incertae sedis* (e.g. *Quadrisporites granulatus,* Genus A. sp. A. and Micro-ornamented monads are included in the cryptospore as suggested by Steemans *et al.* (2000).

High percentages of cryptospores and sphaeromorph acritarchs, indicate a proximity to terrestrial sources (Steemans and Wellman, 2004; Molyneux *et al*., 2006). Middle Ordovician-Llandovery proximal-marine sections might be expected to contain more diverse and abundant cryptospores than their correlative distal sections. The abundance of cryptospores is inversely related to that of acritarchs and chitinozoans, which indicate offshore shelf environments (e.g. Al-Ameri, 1983; Dorning, 1987; Tyson, 1995; Molyneux *et al*., 2006). Samples from offshore shelf facies contain the most abundant and diverse assemblages of acritarchs and chitinozoans which are likely to reach a maximum at, or close to, a marine-flooding surface in offshore shelf settings.

Assemblages from nearshore and deep-water basinal facies are generally of lower diversity and are dominated by sphaeromorph acritarchs and other widely occurring species such as *Veryhachium trispinosum* (Dorning, 1981; Strother, 1996; Vecoli, 2000; Molyneux *et al*., 2006).

7.3.2. Structured organic matter

This group includes all structured, taxonomically unassignable particles (Van Bergen *et al*., 1990). Three groups are recognised in this category: animal remains, cuticles and plant tissues. In their classification, Van Bergen *et al*. (1990) and Traverse (2007) considered scolecodonts and fragments of graptolite periderm are included under the animal remains group. Cuticles are resistant cellular layer covering the epidermis of land plants. They are generally yellow to light-yellow or light brown under light microscope. The plant tissue group includes yellow-brown to dark-brown plant materials characterised by cell outlines (Van Bergen *et al*., 1990). Cuticles and plant tissues are usually associated with cryptospores, indicating terrestrial environments (Tyson, 1995). Scolecodonts and graptolites are indicators of marine environments (Szaniawski, 1996; Rickards, 2005) with high percentages of graptolite fragments indicating offshore distal marine conditions.

7.3.3. Structureless organic matter

This group includes amorphous organic matter (AOM). AOM refers to the fluffy or membranous structure-less organic matter with little or no preserved cellular structure preserved (Tyson, 1995; Batten, 1996; Batten and Stead, 2005). Detailed discussion on its origin and nature is given by Tyson (1995). Its colour is variable, ranging from yellow to brown to dark brown or black. Its characters are affected by origin, environment of deposition and degree of thermal alteration (Batten, 1996).

Classifications of AOM have been attempted by several authors (e.g. Combaz, 1980; Masran and Pocock, 1981; Masran, 1984). Batten (1983) preferred to describe the general appearance of amorphous matter without formally categorizing them from the point of view of either morphology or biological origin. In this study the AOM is divided herein into yellowish brown and dark brown AOM. The AOM is usually the dominant organic component of sediments that accumulated in dysoxic-anoxic (deficiency of oxygen) marine conditions (Tyson, 1987; 1995), especially in areas removed from any significant influence of terrestrial input (Batten, 1996). This type of organic matter may also dominate the organic content of non-marine successions (Batten, 1983; Duncan and Hamilton, 1988; Stemmerik *et al*., 1990). In this study, 10 µm is considered as the minimum diameter for counting AOM.

7.4. Paleoenvironmental interpretation based on the palynological and palynofacies analysis

For palynofacies analysis the abundance terminology used in this study are: rare (0-5%), relatively common (6-10%), common (11- 25%), abundant (26-50%) and dominant (>50%).

7.4. 1. Formation: As Shabiyat

7.4. 1. 1. Wells: H2-NC186 (cutting interval 5250 ft-5300 ft), I3-NC186 (cutting interval 5250 ft-5400 ft) and B2-NC186 (cutting interval 4710 ft-4970 ft).

7.4. 1. 2. Palynofacies and palaeoenvironment:

In this study, the studied sections of the As Shabiyat Formation were barren of palynomorphs and palynodebris. Therefore, no age and depositional environment can be determined.

7.4. 2. Formation: Hawaz Formation

7.4. 2. 1. Wells: A28i-NC-186 (core interval 4518 ft- 4723 ft), H2-NC186 **(**core interval 4605 ft-4842 ft.; cutting interval 4930 ft 5200 ft) and D1-200 (cutting interval 5550 ft- 5750 ft).

7.4. 2. 2. Palynofacies

In the studied sections of the Hawaz Formation, the palynofacies display two distinct parts (lower and upper). The lower part is characterized by abundant to dominant sphaeromorph acritachs (35-60%). Other acritarchs are present to common in abundance (not more than 32%) throughout this part with low diversity and while chitinozoa are rare. Yellowish brown, dark brown AOM occurs with varying abundances, but is generally common to abundant. Also this interval shows the abundance of cryptospores decreases and cuticle is rare to absent. However, the abundance of spheromorphs acritarchs, present to common occurrence of other acritarchs, together with commom to abundant AOM indicates that this part of the Hawaz Formation accumulated under condition of lower oxygenation (Tappan, 1980; Tyson, 1995; Traverse, 2007). In general sphaeromorph acritarchs are the most abundant acritarchs through the whole sections of Hawaz Formation.

The upper part is marked by the highest relative abundance and diversty of cryptospores (20-44%). This is associated with abundant sphaeromorph acritachs (50% or more). The plant tissues also exist in rare abundance (1% or less), the other acritarchs are rare to absent and represent not more than (5%) while chitinozoans are absent.

Generally, the abundance of other acritarchs shows an increasing trend downwards and a dramatic decrease in abundance is observed in the upper part. This is accompanied by an increase in abundance of cryptospores, sphaeromorph acritarchs (*Leiosphaeridia* spp.) in the upper part. This indicates upward shallowing towards more proximal marginal marine conditions.

7. 4. 2. 3. Palaeoenvironment

The low diversity of marine palynomorphs (acritarchs and chitinozoans) with common to abundant sphaeromorph acritarchs (e.g *Leiospohaeridia* spp.), abundance of cryptospores decreases and cuticle are rare to absent, associated with varying abundances of yellowish brown and dark-brown AOM in the lower part, the highest abundance of cryptospores associated with abundant sphaermorph acritarchs in the upper part of the Hawaz Formation suggests that the depositional environment is generally (shallow marine) inner shelf marine to marginal marine. Such interpretations are consistent with lithology- and sedimentology-based study of Romas *et al*. (2006) and de Gibert *et al.* (2011) who suggested that the whole Hawaz Formation was deposited in a shallow marine environment.

Vecoli (1999) and Vecoli *et la*. (2003) obtained very similar palynological and palaeoenvironmental results for the late Arenigian-early Llanvirnian strata sequences from the Hassi- R'Mel area, north-central Algeria (Well N1 2) and northern Rhadames Basin, southern Tunisia (Wells St1, Sn1) and northwest Libya (Well A1-70). Their acritarch assemblage zones are correlated in this study with the acritach assemblage zone AC-1 of the Hawaz Formation. Based on microphytoplankton diversity and abundance, both studies interpreted the late Arenigian–Llanvirnian sequences as an open marine, offshore setting in southern Tunisia but with more proximal marine conditions in the Algerian area. Also they recorded a major transgression event in the late Arenigian-early Llanvirnian.

Overall, the Hawaz Formation represents a major transgressive-regressive cycle with sea-level change reflected stratigraphically by acritarch and chitinozoan abundance, deposited in inner shelf marine environments, and abundant sphaeromorph acritarchs and cryptospores deposited in proximal nearshore environments. Such interpretations are also consistent with the lithology- and sedimentology-based study of Anfray and Rubino (2003) who suggested that the Hawaz Formation represents a major transgressive-regressive cycle.

7. 4. 3. Formation: Melez Shugran

7. 4. 3. 1. Wells: D1-200 (core interval 4778 ft- 4878 ft; cutting interval 4900 ft- 5130 ft), I3-NC186 (cutting interval 4810 ft- 5230 ft).

7. 4. 3. 2. Palynofacies

In general, the palynofacies of the studied sections of the Melez Shugran Formation are dominated by well preserved palynomorphs represented by abundant and diverse marine acritarchs (more than 50%) and common chitinozoans (9-24%). Sphaeromorph acritachs are common to abundant throughout the whole section (generally common but not more than 29%) and cryptospores are rare to present in abundance (not more than 8%). AOM is subordinate, light in colour, and badly preserved. Cuticle occurs with (less than 2%). animal remains (e. g. scolecodonts) also occur, but are generally rare (not more than 3%).

7. 4. 3. 3. Palaeoenvironment

The relatively high abundance and diversity of marine palynomorphs (acritarchs and chitinozoans) and low abundance of cryptospores, indicates that the depositional environment for the Melez Shugran Formation is inner shelf marine. This is supported by the concurrent existence of animal remains (e.g. scolecodonts) through the whole section. Such interpretation is consistent with the lithology- and sedimentology-based study of El-Ghali (2005), who suggests that the Melez Shugran Formation was deposited during a period of overall transgression related to relative sea level rise during glacial advance and loading of the continental shelf and subsequent glacial retreat. Beuf *et al*. (1971), Massa (1988) and Paris *et al*. (2000) suggests a relatively shallow marine environment was established associated with the onset of peri-glacial condition during the entire Ashgillian.

7. 4. 4. Formation: Memouniat

7. 4. 4. 1. Wells: I3-NC186 (core interval 4782 ft. - 4799 ft.), B2-NC186 (core interval 4400 ft.- cutting interval 4700 ft.)

7. 4. 4. 2. Palynofacies

In the studied sections of the Memouniat Formation, the palynofacies display two distinct parts (lower and upper). The lower part is represented in the shale intercalations unit of well I3-NC186. It is characterized by well preserved, dominant and diverse marine acritarchs (not more than 60%) and a rare to present low diversity of chitinozoans (5% or less). Sphaeromorph acritachs are generally abundant throughout the whole section (but not more than 35%). The cryptospores are present (with less than 5%) in abundance and AOM is subordinate, light in colour and badly preserved. Cuticle also occurs but is rare (less than 1%). The upper part is represented in Well B2-NC186. This part is barren of palynomorphs.

7. 4. 4. 3. Palaeoenvironment

The relatively high abundance and diversity of marine palynomorphs (acritarchs) and rare and low diversity of chitinozoans and cryptospores, indicates a inner shelf marine environment for the lower part of the Memouniat Formation. However, the upper part of the Memouniat Formation, represented in Well B2-NC186, was barren of palynomorphs (coarse sand). This may possibly be regarded as evidence of major glacio-eustatic sea level fall (maximum glacial advance). This sand body is assigned to the early Hirnantian based on the chitinozoans assemblage established in this study from the intercalation shale unit of Well I3-NC186 (core interval 4774.5 ft.- 4782 ft.) which allow one to assign the age of the Memouniat Formation to be within the *T. elongata* Biozone. The overlying shale bed of the Bir Tlachin Formation of well A28i-NC186 (core interval 4482 ft.- 4515 ft.) is assigned a late Hirnantian age and corresponds to the *S. oulebsiri* Biozone. Bourahrouh *et al.,* (2004) obtained very similar palynological and palaeoenvironmental results for the upper sandy level of the Lower Second Bani Formation from Morocco, and interpreted the depositioal environment of this sandy level as the result of a dramatic fall of the sea level due to the development of the Hirnantian ice cap on Gondwana. Such interpretations are consistent with the lithology- and sedimentology based study of El-Ghali (2005) who suggested the lower and middle Memouniat Formation represents a glacial depositional system and the upper part of the Mamuniyat Formation was formed as a result of isostatic rebound, associated with relative sea-level fall. In the northwest Murzuq Basin Fello and Lita (2003) suggests that the lower and middle unit of the Memouniat Formation was deposited in shallow to marginal marine environment and the upper unit is a fluvial system.

7. 4. 5. Formation: Bir Tlacsin

7. 4. 5. 1. Wells: A28i-NC186 (core interval 4482 ft- 4517 ft), I3-NC-186 (cutting interval (4680 ft- 4740 ft)

7. 4. 5. 2. Palynofacies

The palynofacies of the Bir Tlacsin Formation is characterized by abundant, well preserved and diverse acritarchs (more than 50%), present to common and diverse chitinozoans (9-25%). Sphaeromorph acritarchs are present to common throughout the whole section (generally not more than 19%) and AOM is subordinate, light in colour, and badly preserved. Cuticle occurs with (less than 2%) and the cryptospores are present with low diversity (not more than 8%). Animal remains (e.g. Scolecodonts) also occurs, but generally rare (not more than 1%).

7. 4. 5. 3. Palaeoenvironment

In previous studies no age dating nor detailed depositional environment interpretation was determined for the Bir Tlacsin Formaion. Echikh and Sola (2000) described the Bir Tlacsin Formation as a transitional lithofacies, between the Memouniat Formation Sandstones and the Silurian Tanezzuft Shales. They concluded that the age of the Bir Tlacsin Formation is uncertain and may vary locally. Lithologically it consists of shale with abundant coarse sand grains. Hallet (2002) concluded that the Bir Tlacsin Formation is important from a petroleum systems point of view, because it acts as a barrier between the Memouniat reservoir and the Hot Shale source rock. Recently McDougall and Gruenwald (2011) conclude that the Bir Tlacsin represents the final Upper Ordovician package. Sedimentologically it is similar to the Melaz Shugran

Formation, composed of interbedded silty mudstones or muddy heterolithics and undisturbed laminated mudstones, and the top of the Bir Tlacsin is often marked by a condensed horizon, rich in mudchips and locally iron-rich sandstones. These are sharply overlain by the graptolitic shales of the Lower Silurian Tanezzuft Formation.

In this study, based on the occurrence of diagnostic species of chitinozoans and acritarchs, the Bir Tlacsin Formation is assigned to a late Hinantian age and corresponds to the *S. oulebsiri* Biozone. It is characterized by a relatively high abundance and diversity of marine palynomorphs (acritarchs and chitinozoans), A low abundance of cryptospores and the occurence of animal remains (e.g. scolecodonts). Based on this a inner shelf marine environment is suggested for this formation, deposited after the glacial maximum and during a period of overall transgression that resulting from the melting of the northern Gondwana ice cap. Such interpretation is consistent with Paris *et al*. (2000) who observed that the *S. oulebsiri* biozone in well Nl-2, northeast Algerian Sahara occurs after the glacial maximum and is interpreted as a transgressive event resulting from the melting of the northern Gondwana ice cap.

7. 4. 6. Formation: Tanzzuft Formation (Lower part)

7. 4. 6. 1. Well: E1-NC174 (core interval 7246 ft- 7287 ft).
B2-NC186 (cutting internat 3950 ft-4000 ft).
I3-NC186 (cutting interval 4600 ft- 4640 ft).

7. 4. 6. 2. Palynofacies

In this study the term (Hot Shale) is used following Lüning *et al.* (2003) who restricted this term to the interval containing the highest TOC and uranium values. The palynofacies type and palynomorph assemblages abruptly change at the base of the Tanezzuft Formation (early-mid Rhuddanian). It is characterized by a relatively high abundance of amorphous organic matter (AOM) that is yellowish brown and dark-brown in colour. Palynomorphs occur rarely and are much less diverse than in the preceding assemblage of the Bir

Tlacine Formation. In general the abundance of marine palynomprphs (acritarchs and chitinozoans) is rare to common, decreasing in abundance in the Hot Shale unit within the upper part of *B. postrobusta* biozone: the acritarchs (7-25%), chitinozoans (7-16%) and the sphaeromorph acritachs (5-11%). The cryptospore are rare to absent and cuticle is absent. Other animal remains (e.g. graptolites) are rare (less than 5%). The acritarchs show dark yellow to brown vesicles in colour and sphaeromorph acritarchs are common in abundance within this interval. In general they are much more abundant than the other acritarchs.

7. 4. 6. 2. Palaeoenvironment

The high proportion of amorphous organic matter (AOM) that is brownish in colour along with a low diversity and rare to common abundance marine palynomorphs (acritarchs and chitinozoans) and common of sphaeromorph acritach, associated with the presence of animal remains (graptolites), with very rare to absent of cryptospores, indicates that the depositional environment of the lower part of the Tanezzuft Formation is open marine. The high AOM content indicates anoxic (marine conditions). Such interpretation is consistent with the palynological study of Paris *et al*. (2012) who assigned the Tanezzuft to the Rhuddanian (*S. fragilis-L. nuayyimensis* Bizones) and suggested that the depositional environment is open marine, with minor land ward shift in the lower *L. nuayyimensis* Biozone. A similar scenario is also observed in the lower Silurian (Rhuddanian) sediments from borehole Well Tt1, Ghadamis Basin, southern Tunisia by Vecoli *et al*. (2009). Lüning *et al*. (1999, 2000) suggest that the deposition of the Silurian Hot Shale began after the melting of the late Ordovician ice sheets, which led to a major marine transgression.

7. 4. 7. . Formation: Tanezzuft Formation (middle and upper part)

7. 4. 7. 1. Wells: I3-NC186 (cutting interval 3600 ft- 4550 ft), H2-NC186 **(**cutting interval 4150 ft- 4500 ft), D1-200 (cutting interval 3850 ft 4750 ft) and E1-NC174 (cutting interval 6350 ft 7255ft).

7. 4. 7. 2. Palynofacies

The palynofacies in these sections of the Tanezzuft Formation are characterized generally by abundant to dominant, well preserved marine palynomorphs acritarchs (not more the 70%) and common to abundant chitinozoans (9-20%). Sphaeromorph acritarchs (*Leiosphaeridia* spp.) are present to common throughout the whole sections (not more than 15%) and other animal remains are present but rare (less than 2%). Cryptospores are present to common (5-15%). AOM is present to common, and is light in colour. Cuticle also occurs with varying abundances (less the 2%).

7. 4. 7. 2. Palaeoenvironment

The relatively high abundance and diversity of marine palynomorphs (acritarchs and chitinozoans) and low abundant of cryptospores in most of these sections indicates that the depositional environment is marginal marine. This is supported by the concurrent existence of animal remains (eg. scolecodonts and graptolites) through the whole section. Overall the middle and the upper part of the Tanezzuft Formation is regarded as being deposited in an inner shelf marine (shallow marine) setting, with open marine (anoxic conditions) for the lower part.

CHAPTER 8. THE EFFECT OF GLACIATION ON THE PALYNOMORPHS ASSEMBLAGES:

Palynomorph assemblages recovered from the Upper Ordovician (Melez Shugran, Memouniat and Bir Tlacsin Formations) and the Lower Silurian (Tanezzuft Formation) of the Murzuq Basin can be studied to determine the initial effects of the Late Ordovician glaciation on these assemblages and to document the impact of this major climatic stress on their comparison.

At the end of the Ordovician, a continental-scale ice sheet extended over present-day West and North Africa, as well as Arabia, possibly joining South Africa. Glacial depositional sequences essentially comprise tillites and fluvial, deltaic and shallow-marine sandstones and argillitic facies grading distally into turbidites succession (Le Heron *et al*., 2006; Ghienne *et al*., 2007).

At high latitude, the Hirnantian biostratigraphic zonation is defined by graptolite and chitinozoan assemblages, but chitinozoans are generally observed more than graptolites. The biostratigraphic analysis of both cored and exposed Hirnantian successions in Algeria and Morocco (Paris *et al*., 2000; Bourahrouh *et al*., 2004) split the glacial events in two chitinozoan biozones; a basal *T. elongata* Biozone overlain by a *S. oulebsiri* Biozone. In Algeria, Paris *et al*., (2000) recorded that the S. *oulebsiri* Biozone occurs strictly after the glacial maximum.

In this study, the depositional environment of the Melez Shugran and the shale intercalations in the lower part of the Memouniat Formation (pre-glacial sediments), considered to correspond to the *A. nigeria, A. merga* and lower *T. elongata* Biozones, is interpreted as inner shelf marine and generally deposited during a period of overall transgression related to relative sea level rise during glacial advance and loading of the continental shelf and subsequent glacial retreat. It yields well preserved and diverse chitinozoans and acritarchs, but the cryptospores display a low abundance throughout the studied sections. However, the sandy level of the Upper part of the Memouniat Formation was barren of palynomorphs and this may be regarded as evidence of major glacio-eustatic sea level fall (maximum glacial advance). This sandy body is assigned to the early Hirnantian based on the chitinozoan biozones established in this study from the intercalated shale unit of the Lower Memouniat Formation. Thus it is possible to assign the age of this Formation to be within the *T. elongata* Biozone, and the age of overlying shale bed of the Bir Tlachin Formation to late Hirnantian corresponding to the *S. oulebsiri* Biozone.

The marine sediments of the Bir Tlacsin Formation of latest Hirnantian age, which is considered to correspond to *S. oulebsiri* Biozone, contain a better preserved, more abundant and more diverse palynomorph assemblage. The composition of this assemblage indicates a fairly good faunal and phytoplankton recovery after the early Hirnantian climatic stress. The extinction of the Ordovician forms, the presence of reworked specimens of various ages from the Tremadocian up to the pre-Hirnantian, and the first occurrence of distinct morphotypes of Silurian ‘‘affinity’’ occur only in the uppermost Hirnantian. This indicates that the sediment was deposited in the inner marine shelf environment and deposited after the glacial maximum and during a period of overall transgression that resulting from the melting of the northern Gondwana ice cap.

The overlying Shale of early and mid Rhuddanian age (lower part of the Tanezzuft Formation) is indicative of marine anoxic environments.This part is characterized by a high abundance of amorphous organic matter (AOM) that is dark brown-black in colour. Marine palynomorphs occur rarely to common, with decreasing abundance in the Hot Shale unit within the upper part of the *B. postrobusta* Biozone. They are generally are much less diverse and abundant than in the preceding assemblage of the Bir Tlacsin Formation and the succeeding assemblages from the middle and upper part of Tanezzuft Formation (late Rhuddanian-Telychian).

An obvious increase in abundance and diversity of marine palynomorph in the middle and upper part of the Tanezzuft Formation, with a slight increase in the abundance of cryptospores, indicates that the depositional environment is inner shelf marine (shallow marine).

CHAPTER 9. CONCLUSIONS

The following conclusions can be drawn from the present palynological investigation of the Ordovician-Lower Silurian (Llandovery) sediments (As Shabiyat, Hawaz, Melez Shugran, Memouniat, Bir Tlacsin and Tanezzuft Formations) from the Muzuq Basin, southwest Libya.

1. Detailed palynological study of 167 core and cutting samples revealed the presence of assemblages of moderately and well preserved marine palynomophs (acritarch, chitinozoan, scolecodont and graptolite) and non-marine palynomorphs (spores). A total of 147 species belong to 57 genera of acritarch, 93 species belong to 23 genera of chitinozoan and 21 species belong to 16 genera of cryptospore/spore have been identified and taxonomically described. Scolecodonts as well as a graptolite remains were also recorded (counted but not taxonomically identified).

2. Acritarchs and chitinozoans recovered from all the six studied wells enabled precise age dating of these formations.

3. One Mid Ordovician chitinozoan assemblage zone, four Late Ordovician and six Early Silurian chitinozoan biozones belonging to the North Gondwana zonation are identified. The chitinozoan assemblage zone recorded in the Hawaz Formation do not provide a firm age assignment as no classical components of Darriwilian chitinozoan biozone have been recorded. However, the presence of acritarchs indicates this assemblage extends at least into the Mid Ordovician, and most likely into the mid-late Darriwilian age (Llanvirinian). The Late Ordovician chitinozoan biozones indicated that the Melez Shugran Formation ranges from early late Katian-early Hirnantian in age and it is considered to correspond to the *A. nigerica*, *A. merga* and lower *T. elongata* Biozones. The Memouniat Formation is early Hirnantian and is considered to be within the *T. elongata* Biozone, and the Bir Tlacsin Formation is late Hirnantian in age and is assigned to the *S. oulebsiri* Biozone. The lower Silurian chitinozoan biozones indicate that the lower part

of the Tanezzuft Formation is early- mid Rhuddanian and it is considered to correspond to the *S. fragilis* Biozone and the *B. postrobusta* Biozones. The Hot Shale is constrained to the upper part of the range of the *Belonechitina postrobusta* Biozone. The middle and upper part ranges from late Rhuddanian-Telychian in age and is considered to correspond to the A. *qusaibaensis, C.* cf. *alargada – P. paraguayensis, A. hemeri* and *A. macclurei* Biozones.

4. Eight acritarch assemblage zones, corresponding stratigraphically to the above chitinozoan biozones, are recognisable and informally designated as follows: AC-1 Assemblage Zone (mid-late Darriwilian), Ac-2 Assemblage Zone (early late Katian), Ac-3 Assemblage Zone (late Katian), Ac-4 Assemblage Zone (Hirnantian), Ac-5 Assemblage Zones (early Rhuddanian), Ac-6 Assemblage Zones (mid Rhuddanian), Ac-7 Assemblage Zone (late Rhuddanian-early Aeronian) and Ac-8 Assemblage Zone (mid-late Aeronian-Telychian).

5. Four cryptospore/spore assemblage zones, corresponding stratigraphically to the above chitinozoan biozones and acritarch assemblage zones, are recognisable and informally designated as follows: Cr-1 Assemblage Zone (mid-late Darriwilian), Cr-2 Assemblage Zone (early late Katian-Hirnantian), Cr-3 Assemblage Zone (early-mid Rhuddanian) and Cr-4 Assemblage Zone (late Rhuddanian-Telychian).

6. Palynostratigraphic correlation was established between the present chitinozoan biozones, acritach and cryptospore assemblage zones with those defined previously in the northern Gondwana (North Africa, Arabia Plate and Iran).

7- The acritarch assemblages from the Late Ordovician (late Hirnantian) of the Bir Tlacsin and Lower Silurian (early Rhuddanian) of the Tanezzuft Formation (Hot Shale) co-exist with some reworked acritarch specimens of various pre-Hirnantian ages.

8- Based on palynological and palynofacies analysis, the depositional environment is interpreted as inner shelf marine to marginal marine in the Hawaz Formation (mid-late Darriwilian). It is interpreted as inner shelf marine in the Melez Shugran Formation and the shale intercalations in the lower part of the Memouniat Formation (pre-glacial sediment), (early late Katian-early Hirnantian), and considered that these were generally deposited during a period of overall transgression related to relative sea level rise during glacial advance and loading of the continental shelf and subsequent glacial retreat. The upper part of the Memouniat Formation (early Hirnantian) was barren of palynomorphs and this can be regarded as evidence of major glacio-eustatic sea level fall (maximum glacial advance). An inner shelf marine environment is also interpreted for the Bir Tlacsin Formation (late Hirnantian) and suggested that it was deposited after the glacial maximum and during a period of overall transgression that resulted from the melting of the northern Gondwana ice cap. Open marine environment is also indicated for the lower part of the Tanezzuft Formation (early-mid Rhuddanian), before passing up into inner shelf marine (shallow marine) in the middle and upper part (late Rhuddanian-Telychian).

REFRENCES

Abugares, Y., Ramaekers, P., 1993. Short notes and guide book on the Palaeozoic geology of the Ghat area, southwest Libya: Field trip, October 14-17, Earth Science Society of Libya, Tripoli.

Abuhmida, F., 2000. Palynological investigation of the Upper Silurian (Acacus Formation) of Well A1-NC40B, Ghadames Basin, northwest Libya. MSc Desertation, unpublished, University of Sheffield, 133pp.

Achab, A., 1976. Les acritarches de la Formation d'Awantijsh (Llandovérien supérieur) du sondage Val Brillant, vallée de la Matapédia, Québec. Canadian Journal of Earth Science, 13, 1310-1318.

Achab, A., 1977a. Les chitinozoaires de la Zone à *Dicellograptus complanatus,* Formation de Vauréal, Ordovicien supérieur, Ile d'Anticosti, Québec. Canadian Journal of Earth Science, 14, 413-425.

Achab, A., 1977b. Les chitinozoaires de la Zone à *Clirnacograptus prominens elongatus* de la Formation de Vauréal (Ordovicien supérieur), lle d'Anticosti, Québec. Canadian Journal of Earth Science, 14, 2193-2212.

Achab, A., 1978a. Sur quelques chitinozoaires de la Formation de Vauréal et de la Formation de Macasty (Ordovicien supérieur); lie d'Anticosti, Québec, Canada. Review of Palaeobotany and Palynology, 25, 295-314.

Achab, A., 1978b. Les chitinozoaires de l'Ordovicien supérieur, Formations de Vauréal et d'Ellis Bay de l'Ile d'Anticosti, Québec. Palinologia, num. extraord, 1, 1-19.

Achab, A., 1980. Chitinozoaires de l'Arenig inférieur de la Formation de Lévis (Québec, Canada). Review of Palaeobotany and Palynology, 31, 219-239.

Achab, A. 1981. Biostratigraphie par les Chitinozoairesd e l'Ordovicien Supérieur - Silurien Inférieur de L'Anticosti. Résultats préliminaires. In: Lespérance, P.J. (Eds.), Subcommis-sion on Silurian Stratigraphy, Ordovician-Silurian Boundary Working Group. Field Meeting, Anticosti- Gaspe, Université de Montréal, 2, 143-15.

Achab, A., 1982. Chitinozoaires de l'Arenig supérieur (Zone D) de la Formation de Lévis, Québec, Canadian Journal of Earth Sciences, 19, 1295-1307.

Achab, A., 1983. Chitinozoaires du Llanvirn (Formation de Table Head) de la partie occidentale de Terre-Neuve, Canada. Canadian Journal of Earth Science, 20, 918-931.

Achab, A., 1986a. Assemblages de chitinozoaires dans l'Ordovicien inférieur de l'est du Canada. Canadian Journal of Earth Science, 23, 682-695.

Achab, A., 1986b. Succession des assemblages de chitinozoaires dans l'Ordovicien moyen du Québec et de l'est du Canada. Review of Palaeobotany and Palynology, 48, 269-294.

Achab, A., 1987. Chitinozoaires du Caradoc supérieur Ashgill inférieur du Québec, Canada. Canadian Journal of Earth Science, 24, 1212-1234.

Achab, A., 1989. Ordovician chitinozoan zonation of Québec and western Newfoundland. Journal of Paleontology, 63, 14-24.

Achab, A., Asselin, E., Soufiane, A., 1993. New morphological characters observed in the Order Operculatifera and their implications for the suprageneric Chitinozoan classification. Palynology, 17, 1-9.

Achab, A., Asselin, E., 1995. Ordovician chitinozoans from the Arctic Platform and the Franklinian miogeosyncline in northern Canada. Review of Palaeobotany and Palynology, 86, 69-90.

Achab, A., Rubinstein, C. V., Astini, R. A., 2006. Chitinozoans and acritarchs from the Ordovician peri-Gondwana volcanic arc of the Famatina System, northwestern Argentina. Review of Palaeobotany and Palynology, 139, 129-149.

Achab, A., Paris, F., 2007. The Ordovician chitinozoan biodiversification and its leading factors. Palaeogeography, Palaeoclimatology, Palaeoecology, 245, 5-19.

Al-Ameri, T. K., 1980. Palynology, biostratigraphy and paleoecology of subsurface Middle Palaeozoic strata from the Ghadames Basin Libya PhD Thesis, unpublished, King College, London University, 477 pp.

Al-Ameri, T. K., 1983a. Acid - resistant microfossils used in the determination of palaeozoic paleoenvironment in Libya. Palaeogeography Palaeoclimatolology Palaeoecology, 44, 103-116.

Al-Ameri, T. K., 1986. Observation on the wall structure and the excystment mechanism of acritarchs. Journal of Micropalaeontology, 5, 27-35.

Al-Ameri, T. K., 2010. Palynostratigraphy and the assessment of gas and oil generation and accumulations in the Lower Paleozoic, western Iraq. Arabian Journal of Geosciences, 3, 155-179.

Albani, R., Lelkes-Felvary, G., Tongiorgi, M., 1985a. First record of Ordovician (Upper Arenigian acritarchs) beds in Bakony Mts., Hungary, Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, 170, 45-65.

Albani, R., Di Milia, A. Minzoni, N., Tongiorgi, M. 1985b. Nuovi dati palinologici e e considerazioni geologiche sull'età delle Arenarie di Solanas (Cambro-Ordoviciano, Sardegna Centrale). Atti della Società Toscana di Scienze Naturali - Memorie, Pisa, (A), 91, 1-20.

Albani, R., 1989. Ordovician (Arenigian) acritarchs from the Solanas Sandstone Formation, central Sardinia, Italy. Bollettino della Societa` Paleontologica Italiana, 28, 3 – 37

.

Albani, R., Bagnoli, G., Maletz, J., Stouge, S., 2001. Integrated chitinozoan, conodont, and graptolite biostratigraphy from the upper part of the Cape Cormorant Formation (Middle Ordovician), western Newfoundland. Canadian Journal of Earth Sciences, 38, 387-409.

Aldridge, R. J., Dorning, K. J., Richardson, J. B., and Siveter, D. J., 1979. Microfossil distribution in the Silurian of Britain and Ireland. 433-438. In Harris, A. L., Holland, C. H. and Leake, B. E. (eds). The Caledonides of the British Isles - reviewed. Special Publication of the Geological Society of London, 8, 1-768.

Aldridge, R. J., Siveter, D. J. 1981. Distribution of microfossil groups across the Wenlock shelf of the Welsh Basin. 18-29. In Neale, J. and Brasier, M. D. (eds). Microfossils from Recent and fossil shelf seas. Ellis Horwood, Chichester, 380 pp.

Al-Fasatwi, Y. A., Van Dijk, P. M., and Erren, J. W. M. G., 2000. Surface and subsurface characteristics of Al Gargaf Arch and adjacent parts of the Ghadamis and Murzuq Basins, West Libya: An Integration of remote sensing, aeromagnetic and seismic interpretation. In: Salem, M. J., Khaled, M. O. and Hussein, M. S. The Geology of northwest Libya, III, 171-190.

Al-Ghammari, M., Booth, G. A., Paris, F., 2010. New chitinozoan species from the Saih Nihayda Formation, Middle Ordovician of the Sultanate of Oman. Review of Palaeobotany and Palynology, 158, 250-261.

Al-Ghazi, A., 2007. New evidence for the Early Devonian age of the Jauf Formation in northern Saudi Arabia. Revue de Micropaléontologie, 50, 59-72.

Al-Hajri, S., 1995. Biostratigraphy of the Ordovician chitinozoa of northwestern Saudi Arabia. Review of Palaeobotany and Palynology, 89, 27-48.

AI-Hajri, S., Owens, B. 2000. Sub-surface palynostratigraphy of the Palaeozoic of Saudi Arabia. In: AI-Hajri, S., Owens, B. (Eds), Stratigraphic Palynology of the Palaeozoic of Saudi Arabia. Special GeoArabia Publication 1, Gulf Petrolink, Bahrain, 10-17.

Anfray, R., Rubino, L. L., 2003. Self depositional systems of the Ordovician Hawaz Formation in the central Al Qarqaf High. In: The Geology of Northwest Libya (eds M.J. Salem and K.M. Oun). Academic Press, London, II, 123-134.

Al-Ruwaili, M., 2000. New Silurian acritarchs from the sub-surface of northwestern Saudi Arabia. In: AI-Hajri, S., Owens, B. (Eds), Stratigraphic Palynology of the Palaeozoic of Saudi Arabia. Special GeoArabia Publication 1, Gulf Petrolink, Bahrain, 82-91.

Aráoz, L., 2009. Microfloras Ordovícicas en Sierra de Zenta, Cordillera Oriental Argentina, Serie correlación geológica, 25, 1.

Armstrong, H. A., Dorning K. J., 1984. Silurian palynomorphs from the Chester Bjerg Formation, Hall Land, western North Greenland. Rapport Grønlands Geologiske Undersøgelse, 121, 97–103.

Asselin, E., Achab, A., Bourque, P. A., 1989. Chitinozoaires du Silurien inférieur dans la région de la baie des Chaleurs en Gaspésie, Québec, Canada. Canadian Journal of Earth Sciences, 26, 2435-2449.

Aziz, A., 2000. Stratigraphy and hydrocarbon potential of the Lower Palaeozoic succession of License NC-115, Murzuq Basin, southwest Libya. In: Sola, M. and Worsly, D. (Eds.). Geological Exploration in Murzuq Basin, Elsevier, Amsterdam, 349-368.

Bagnolio, G., Stouge, S., and Tongiorgi, M., 1988. Acritarchs and conodonts from the Cambro-Ordovician Furuhäll (Köpingsklint) section (Öland, Sweden) Rivista de Italiana Paleontologia e Stratigraphia, 94, 163-248.

Banerjee, S., 1980. Stratigraphic Lexicon of Libya. Bulletin No. 13. Industrial Research Centre, Tripoli, 300 pp.

Barnes, C. R., 2004a. Ordovician oceans and climates. In: Webby, B.D., Paris, F., Droser, M., Percival, I. (Eds.). The Great Ordovician Diversification Event. Columbia University Press, New York, 72–76.

Barnes, C. R. 2004b. Was There an Ordovician Superplume Event? In: Webby, B.D., Paris, F., Droser, M., Percival, I. (eds.), The Great Ordovician Diversification Event. Columbia University Press, New York, 77–80.

Barron, H. F., 1989. Mid-Wenlock acritarchs from a Silurian inlier in the Cheviot Hills, northeast England. Scottish Journal of Geology, 25, 81-98.

Basha, S. H., 1987. Acritarchs from Ordovician rocks in South Jordan. Revue de Micropaleontologie, 30, 145-149.

Basha, S. H., 1990. Palynomorphs from Ordovician-Silurian subsurface rocks of Wadi Sirhan, East Jordan. Revista Espanola de Micropaleontologia, 22, 137-141.

Bassett, D., Macleod, K. G., Miller, J. F., and Ethington, R. L., 2007. Oxygen isotopic composition of biogenic phosphate and the temperature of Early Ordovician seawater. Palaios, 22 (1), 98-103.

Batten, D.J., 1983. Identification of amorphous sedimentary organic matter by transmitted light microscopy. In: Brooks, I. (Ed), Petroleum Geochemistry and Exploration of Europe. Geological Society of London, Special Publication 12, 275-287.

Batten, D.J., 1996. Palynofacies and palaeoenvironmental interpretation. In: Jansonius, J., McGregor, D.C. (Eds), Palynology: Principles and Applications, Volume 3. American Association of Stratigraphic Palynologists Foundation, 1011-1064.

Batten, D.J., Stead, D.T., 2005. Palynofacies analysis and its stratigraphic application. In: Koutsoukos, E.A.M. (Ed), Applied Stratigraphy. Dordrecht, Netherlands, Springer, 203-226.

Baudelot, S., Gery, B., 1979. Decouverte d'Acritarches du Cambrien superieur et du Tremadoc dans Ie massif ancien de grande Kabylie, (Algerie). Comptes Rendus Academie Sciences, Paris, 288, 1513-1516.

Baudelot, S., Bessiére, G., 1977. Données palynostratigraphiques sur le Paléozoïque inférieur du Massif de Mouthoument (Hautes Cobiéres, Aude) Ann. Société Géologique du Nord, 97(1), 21-25.

Beck, J. H., Strother, P. K., 2001. Silurian Spores and Cryptospores from the Arisaig Group, Nova Scotia, Canada, Palynology, 25, 127-177.

Beju, D., Danet, N., 1962. Chitinozoare siluriene din Platforma Moldovenească şi Platforma Moesică. Petrol şi Gaze, 13, 12, Bucureşti.

Belaid, M., Krooss, B. M., Littke, R., 2010. Thermal history and source rock characterization of a Paleozoic section in the Awbari Trough, Murzuq Basin, southwest Libya. Marine and Petroleum Geology, 27, 612–632.

Belini, E., Massa, D., 1980. Stratgraphic contribution to the Paleozoic of southern basins of Libya. In: The Geology of Libya (Eds.) Salem, M. J., Busrewil, M. T. Academic Press, Londan, 1, 3-56.

Bengtson, P., 1988. Open nomenclature. Palaeontology, 31, 223-227.

Benoit, A., Taugourdeau, P., 1961. Sur quelques Chitinozoaires de l'Ordovicien du Sahara. Revue de l'Institut Francais du Petrole, 16, 1403-1421.

Bergström, S. M., 1986. Biostratigraphic integration of Ordovician graptolite and conodont zones - a regional review. In: Rickards R. B., Hughes, C. P. (Eds), Paleobiology and Biostratigraphy of Graptolites. Oxford, Blackwell Scientific, 61-78.

Bergström, S. M., Finney, S. C., Chen, X., Pålsson, C., Wang, Z., and Grahn, Y., 2000. A proposed global boundary stratotype for the base of the Upper Series of the Ordovician System: The Fågelsång section, Scania, southern Sweden. Episodes, 23, 102-109.

Bergström, S. M., Lofgren, A., Maltez, J., 2004. The GSSP of the Second (Upper) Stage of the Lower Ordovician Series: Diabas-brotter at Hunneberg, Province of Viistergdtland, southwestern Sweden. Episodes, 24, 265-272.

Bergström, S. M., Toprak, F. Ö., Huff, W. D., and Mundil, R., 2008. Implications of a new, biostratigraphically well-controlled, radio-isotopic age for the lower Telychian Stage of the Llandovery Series (Lower Silurian, Sweden). Episodes, 31, 309–314.

Berner, R. A., 1994, GEOCARB II: A revised model of atmospheric CO_2 over Phanerozoic time. American Journal of Science, 294, 56–91.

Berner, R. A., Kothavala, Z., 2001. GEOCARB III: A revised model of atmospheric CO_2 over Phanerozoic time. American Journal of Science, 301, 182-204.

Beswetherick, S., Himmali, A., Jho, J. S., 1996. Report on a Field Trip to Tihemboka High and Gargaph Arch, Murzuq Basin, southwest Libya. LGML Internal Report.

Beuf, S., Biju-Duval, B., De Charpal, O., Rognon, P., Gariel, O., and Bennacef, A., 1971. Les Gres du Paleozoique Inferier au Sahara: Paris, Editions Technip, Publ. Institute Francais du Petrole, Collège-sciences et technologies du Petrole, 18, 464 pp.

Bouché, P. M., 1965. Chitinozoaires du Silurien s.I. du Djado (Sahara Nigérien). Revue de Micropaléontologie, 8, 151-164.

Boulter, M.C., Riddick, A., 1986. Classification and analysis of palynodebris from the Palaeocene sediments of the Forties Field. Sedimentology, 33, 871-886.

Boumendjel, K., 1985. Nouvelles espéces de chitinozoaires dans le Silurien et le Dévonien du Bassin d'Illizi (S.E. du Sahara Algérien). Revue de Micropaléontologie, 28, 155-166.

Bourahrouh, A., Paris, F., Elaouad-Debbaj, Z., 2004. Biostratigraphy, biodiversity and palaeoenvironments of the chitinozoans and associated palynomorphs from the Upper Ordovician of the Anti-Atlas, Morocco, Review of Palaeobotany and Palynology, 130, 17-40.

Bozorgnia, F., 1973. Paleozoic foraminiferal biostratigraphy of central and east Alborz Mountains, Iran. National Iranian Oil Company, Geological Laboratories Publication, 4, 1-166.

Bracaccia, V., Carcano, C., Drera, K., 1991. Sedimentology of the Silurian-Devonian series in the southeastern parts of the Ghadames Basin. In: Salem, M. J., and Busrewill, M. T. (Eds). The Geology of Libya. Academic press, V, 1727-1744.

Brenchley, P. J., 1984. Late Ordovician extinction and their relation to Gondwana glaciations. In: Brenchley, P. (eds.) Fossils and Climate. Wiley, London. 291-315.

Brenchley, P. J., 2004. End Ordovician glaciation. In: Webby, B. D., Paris, F., Droser, M. (eds.), The Great Ordovician Diversification Event. Columbia University Press, New York, 81–83.

Brenchley, P. J. Marshall, J. D., Carden, C. A. F., Robertson, D. B. R., Long, D. G. F., Leidla, T., Hints, L., Anderson, T. F., 1994. Bathymetric and isotope evidence for a short-lived late Ordovician glaciation in a greenhouse period. Geology, 22, 295–298.

Breuer, P., Vanguestaine, M., 2004. The latest Tremadocian *messaoudensis–trifidum* acritarch assemblage from the upper part of the Lierneux Member (Salm Group, Stavelot Inlier, Belgium). Review of Palaeobotany and Palynology, 130, 41–58.

Brito, I. M., Santos, A. S., 1965. Contribuição ao conhecimento dos microfósseis Silurianos e Devonianos da Bacia do Maranhão, Departamento Nacional da Produção Mineral, Divisão de Geologiae Mineralogia, Notas Preliminaires e Estudos (Rio de Janeiro, Brasil), 129, 1–21.

Brito, M. B., 1967. Silurian and Devonian acritarchs from Maranhao Basin, Brazil, Micropaleontology, 13, 473-482.

Brocke, R., Fatka, O., Servais, T, 1997. A review of the Ordovician acritarchs *Aureotesta* and *Marrocanium*, Annales de la Société Géologique de Belgique, 120, 1-21.

Brocke, R., 1998. Evaluation of the Ordovician genus *Ampullula* Righi. Annales de la Société Géologique de Belgique, 120, 73-97.

Brocke, R., Li, J., Wang, Y. 2000. Upper Arenigian to lower Llanvirnian acritarch assemblages from South China: a preliminary evaluation. Review of Palaeobotany and Palynology, 113, 27-40.

Brück, P. M., Vanguestaine, M., 2004. Acritarchs from the lower Paleozoic succession on the south County Wexford coast, Ireland : new age constraints for the Cullenstown Formation and the Cahore and Ribband Groups. Geological Journal, 39, 199-224.

Burden, E. T., Quinn, L., Nowlan, G. S., Balley-Nill, L. A., 2002. Palynology and Micropaleontology of the Clam Bank Formation (Lower Devonian) of western Newfounland, Canada. Palynology, 26, 185-215.

Burgess, N. D., 1991. Silurian cryptospores and miospores from the type Llandovery area South-west Wales. Palaeontology, 34, 575-599.

Burgess, N. D., Richardson, J. B., 1991. Silurian cryptospores and miospores from the type Wenlock area, Shropshire, England. Palaeontology, 34, 601-628.

Burollet, P. F., Byramjee, R., 1969. Sedimentological remarks on Lower Palaeozoic sandstones of south Libya. In: Geology, archaeology and prehistory of the southwestern Fezzan, Libya (ed. Kanes, W. H.). Petroleum Exploration Society of Libya, Eleventh Annual Field Conference, 91-102.

Burmann, G., 1968. Diacrodien aus dem unteren Ordovizium. Paläontologische Abhandlungen II (4), 632-652.

Burmann, G., 1970. Weitere organische Mikrofossilien aus dem unteren Ordovizium. Palaöntologische Abhandlungen. Abteilung 3, 289–332.

Burmann, G., 1976. Åbersicht über das ordovizische Mikroplankton im Südteil der DDR (Vogtland, Wildenfelser Zwischengebirge). Geologisches Jahrbuch, 7-8, 47-62.

Butcher, A., 2009. Early Llandovery Chitinozoans from Jordan. Palaeontology, 52, 593-629.

Butcher, A., Mikulic, D. G., Joanne K., 2010. Late Ordovician–Early Silurian chitinozoans from north-eastern and western Illinois, USA. Review of Palaeobotany and Palynology, 159, 81–93.

Butcher, A, 2013. Chitinozoans from the middle Rhuddanian (Lower Llandovery, Silurian 'hot' shale in the E1-NC174 core, Murzuq Basin, southwest Libya. In Press**,** Review of Palaeobotany and Palynology

Cardoso, T. R. M., Rodrigues, M. A., 2005. “Complexo” *Veryhachium*: Acritarcos Indicativos do Siluriano?, Anuário do Instituto de Geociências-UFRJ, 28, 143-157.

Cardoso, T. R. M., Rodrigues, M. A., 2005. Acritarchs and prasinophytes from Amazonas Silurian basin: a good tool for the Trombetas Group biostratigraphic calibration, Anuário do Instituto de Geociências-UFRJ, 28, 131-142.

Cardoso, T. R. M., 2005. Acritarcos do Siluriano dabacia do Amazonas : bioesrrarigrafia e geocronologia Arquivos do Museu Nacional, Rio de Janeiro, 63, 727-759.

Carter, C., Laufeld, S., 1975. Ordovician and Silurian fossils in well cores from North Slope of Alaska, American Association of Petroleum Geologists Bulletin, 59, 457-464.

Castro, J. C., Della Favera, J. C., El-Jadi, 1985. Palaeozoic sedimentary facies, Murzuk Basin, SPLAJ, Internal report Braspetro-Petrobras, Rio De Janeiro, 117 pp.

Chen, X., Bergström, S. M., 1995. The base of the *Austrodentatus* Zone as a Level for global subdivision of the Ordovician system. Nanjing: Nanjing University Press, 117 pp.

Chen, X. H., Wang, X. F., Li, Z. H., 1996. Arenigian chitinozoan biostratigraphy and palaeobiogeography in South China. Geology Review, 43, 200–208.

Chen, X., Rong, J. Y., Mitchell, C. E., Harper, D. A. T., Fan, J. X., Zhan, R. B., Zhang, Y. D., Li, R. Y., and Wang, Y., 2000. Late Ordovician to earliest Silurian graptolite and brachiopod biozonation from the Yangtze region, South China, with a global correlation. Geological Magazine, 137, 623-650.

Chen, X. h., Zhang, M., 2005. Early Ordovician chitinozoans from the Honghuayuan Formation and Lower Part of Meitan Formation in Datangkou of Chenkou, Chongqing City. Acta Palaeontol. Sin. 44, 44–56 (in Chinese with English abstract).

Chen, X., Rong, J. Y., Fan, J. X., Zhan, R. B., Mitchell, C. E., Harper, D. A. T., Melchin, M. J., Peng, P., Finney, S. C., and Wang, X. F. 2006. The global boundary stratotype section and point (GSSP) for the base of the Hirnantian Stage (the uppermost of the Ordovician System). Episodes, 29, 183.196.

Chen, X., Paris, F., Wang, X., Zhang, M. 2009. Early and Middle Ordovician chitinozoans from the Dapingian type sections, Yichang area, China. Review of Palaeobotany and Palynology, 153, 310-330.

Chibrikova, E. V., 1959. Spores from the Devonian and older rocks of Bashkiria. Academy of Sciences of USSR, Bashkirian Branch, data on paleontology and stratigraphy of Devonian and older deposits of Bashkiria, 3-116.

Christensen, T., 1962. Alger. In: Böscher, T. W., Lange, M., Sorensen, T. (Eds.), Botanik 2, Systematisk Botanik 2. Munksgaard, Copenhagen, 1–178.

Cocchio, A., 1982. Données nouvelles sur le acritaches de Trémadoc et de l‘Arenig dans le Masif de Mouthoumet (Corbiéres, France). Revue de Micropaléontologie, 25, 26-39

Cocks, L. R. M., Torsvik, T. H., 2002. Earth geography from 500 to 400 million years ago. A faunal and palaeomagnetic review. Journal of the Geological Society, London, 159, 631-644.

Cocks, L. R. M., 2001 Ordovician and Silurian global geography. Journal of the Geological Society, London, 17, 1-26.

Cocks, L. R. M., 2005. Silurian. In: Selley, R. C., Cocks, L. R. M., Plimer, I. R. (Eds), Encyclopedia of Geology. Elsevier, 4, 184-193.

Cocks, L. R. M., Fortey, R. A., Rushton, A. W., 2009. Correlation for the Lower Palaeozoic. Geological Magazine, 147, 171-180.

Colbath, G. K., 1979. Organic-walled microphytoplankton from the Eden Shale (Upper Ordovician), Indiana, U.S.A. Palaeontographica Abteilung B, 171, 1-38.

Colbath, G. K., 1986. The Lower Palaeozoic organic-walled phytoplankton (“acritarch”) genus *Frankea* Burmann, 1970. Micropaleontology 32, 72-73.

Colbath, G. K., 1990. Palaeobiogeography of Middle Palaeozoic organic-walled phytoplankton. In: McKerrow, W. S., Scotese, C. R. (Eds.), Palaeozoic Palaeogeography and Biogeography. Geological Society Memoire, 12, 207–213.

Colbath, G. K., Grenfell, H. R., 1995. Review of biological affinities of Paleozoic acid-resistant, organic-walled eukaryotic algal microfossils (including ‘‘acritarchs’’). Review of Palaeobotany and Palynology, 86, 287– 314.

Cole, D. C., Harding, I. C., 1998. Use of palynofacies analysis to define Lower Jurassic (Sinemurian to Pliensbachian) genetic stratigraphic sequences in the Wessex Basin, England. Geological Society, London, Special Publication, 133, 165-185.

Combaz, A., 1964. Les palynofacies. Revue de Micropaléontologie, 7, 205-218.

Combaz, A., 1965. Un microbios à Chitinozoaires dans le Paléozoïque du Queensland (Australie). Comptes Rendus de l‟Académie des Sciences de Paris, 260, 3449-3451.

Combaz, A., Lange. F. W., Pansart. J., 1967. Les “*Leiofusidae*” Eisenack, 1938. Review of Palaeobotany and Palynology, 1, 291-307.

Combaz, A., Péniguel, G., 1972. Etude plalynostratigraphique de l'Ordovicien dans quelques sondages du bassin de Canning (Australie occidentale). Bulletin du Centre de Recherche de Pau-SNPA, 6, 121-167.

Conant, L. C., Gouadarzi, G. H., 1976. Stratigraphic and tectonic framework of Libya. American Association of Petroleum Geologists Bulletin, 51, 719-730.

Cooper, A. H., Molyneux, S. G., 1990. The age and correlation of Skiddaw Group (Early Ordovician) sediments in the Cross Fell inlier (northern England). Geological Magazine, 127, 147-157.

Cooper, R. A., 1999a. The Ordovician time scale-calibration of graptolite and conodont zones. Acta Universitatis Carolinae Geologica, 43, 1-4.

Cooper, R. A., 1999b. Ecostratigraphy, zonation and global correlation of earliest planktic graptolites. Lethaia, 32, 1-16.

Cooper, R. A. and Nowlan, G. S., 1999. Proposed global stratotype section and point for base of the Ordovician System. Acta Universitatis Carolinae Geologica, 43, 61–64.

Cooper, R. A., Nowlan, G. S., Williams, H. S., 2001. Global stratotype section and point for base of the Ordovician System. Episodes 24, 19-28

Cooper, R. A., Sadler, P. M., 2004. The Ordovician Period. In: Gradstein, F. M., Ogg, J. G. Smith, A. G. (Eds). A Geologic Time Scale 2004. Cambridge University Press, Cambridge, 165-187.

COREX (1998). Sedimentology, Biostratigraphy, Petrography and Reservoir quality of the Murzuq Basin- GSPLAJ, Volume I- IV. Repsol Oil Operations Company (internal report).

Costa, N. M., 1974. Distribuição estratigráfica e biocronologia de quitinozoários da Formação Trombetas, Estado do Pará. Anais do XXVIII Congresso Brasileiro de Geologia, 177-203.

Cramer, F. H., 1964a. Some Acritarchs from the San Pedro Formation (Gledinnien) of the Cantabric Mountains in Spain, Bll. Soc. Belge. Geol. 73, 33-38. Bruxelles.

Cramer, F. H., 1964b. Microplankton from three Paleozoic formations in the province of León (N.W. Spain). Leidse Geologische Mededelingen, 30, 253-360.

Cramer, F. H., 1966b. Palynology of Silurian and Devonian rocks in northwest Spain. Boletin del lnstituto Geológico y Minero de España, 77, 225-286.

Cramer, F. H., 1966a. Hoegispheres and other microfossils *incertae sedis* of the San Pedro Formation (Siluro-Devonian boundary) near Valproquero, Leon, NW Spain. Notas Comunicados Instituto Geológico y Minero de España, 86, 75-94.

Cramer, F.H., 1966b. Palynomorphs from the Siluro-Devonian border in NW Spain. Notas y Comunicaciones lnstituto Geologico y Minero de España, 85, 71-82.

Cramer, F. H., 1967a. Chitinozoans of a composite section of Upper Llandovery to basal Lower Gedinnian sediments in northern León, Spain. A preliminary report. Bulletin de la Société Belge de Géologié, Tom LXXV, Fascicule, 69–129.

Cramer, F. H, 1967. Palynology of Silurian and Devonian rocks in Northwest Spain. Boletin Inst. Geologico y Minero de España, 77, 225-286.

Cramer, F. H , 1968a. Palynological microfossils of the Middle Silurian Maplewood Shale in northwestern New York. Revue de Micropaléontologie, 11, 61-70.

Cramer, F. H., 1968. Silurian palynologic microfossils and paleolatitudes. Neues Jahrbuch fuör Geologie und Palaöntologie. Monatshefte, 10, 591-597.

Cramer, F. H., 1969. Possible implications for Silurian paleogeography from phytoplankton assemblages of the Rose Hill and Tuscarora Formations of Pennsylvania. Journal of Paleontology, 43, 485-491.

Cramer, F. H, 1969c. Geron, an acritarch genus from the Silurian. Bull. de la Société. Belge de Géologié de Paleontologie et d'Hydrologie, 77, 217-225.

Cramer, F. H., Díez, M., 1970. Acritarchs from the Lower Silurian Neahga Formation, Niagara Peninsula, North America. Canadian Journal of Earth Science., 7, 1077-1085.

Cramer, F. H., Díez, M., 1972. North American Silurian palynofacies and their spatial arrangement: Acritarchs. Palaeontographica, Abt. B, 138, 107-180.

Cramer, F. H., 1971. Distribution of selected Silurian acritarchs. An account of the palynostratigraphy and paleogeography of selected Silurian acritarch taxa. Revista Española de Micropaleontológia Número extraordinario, 1, 1-203.

Cramer, F. H., Díez, M., 1972a. Acritarch from Upper Middle Cambrian Oville Formation of Leon, northwest Spain. Revista Espanõla de Micropaleontológia, 10, 39-50.

Cramer, F. H., Díez, M., 1972b. North American Silurian palynofacies and their spatial arrangement: acritarchs. Pataeontographica, Abteilung B, 138, 107-180.
Cramer, F. H., 1973 Middle and Upper Silurian Chitinozoan sucession in Florida subsurface. Journal of Paleontology, 47, 279-288.

Cramer, F. H., Kanes, W.H., Diez, M., Christopher, R.A., 1974. Early Ordovician acritarchs from the Tadla Basin of Morocco. Palaeontographica B 146, 57-64.

Cramer, F. H., Diez, C. 1975. Earliest Devonian miospores from the province of León, Spain. Pollen et Spores, 17, 331–344.

Cramer, F. H., Diez, M., 1976. Seven new late Arenigian species of the acritarch genus *Coryphidium.* Palaontoloqische Zeitschrift, 50, 201-208.

Cramer, F. H., Diez, M., Del Rodriguez, R. M. and Fombella, M. A., 1976. Acritarcos de la Formacion San Pedro (Silúrico Superior) de Torrestio, Provincia de León, Espaiia. Revista Espanõla de Micropaleontológia, 8(3), 439-452.

Cramer, F. H., Diez, M., 1977. Late Arenigian (Ordovician) Acritarchs from Cis-Saharan Morocco, Micropaleontology, 23, 339-360.

Davidson, L., Simon, B., Jonthan, C., Martin, E., Andy, F., Ali, H., Jhoon, J., Bashir, M. and Jerry, S., 2000. The structure, stratigraphy and petroleum geology of the Murzuq Basin, southwest Libya. In: Sola, M. A. and Worsley, D. (Eds.) Geological Exploration in Murzuq Basin). Elsevier, Amstrdam, 295-320.

Dean, W. T., Martin, F., 1978. Lower Ordovician acritarchs and trilobites from Bell Island, eastern Newfoundland, Geological Survey of Canada Bulletin, 284, 1-35.

Dean, W. T., Martin, F., 1992. Ordovician biostratigraphic correlation in southern Turkey. In: Webby, B.D., Laurie, J.R. (Eds.), Global Perspectives on Ordovician Geology. Balkema, Rotterdam, 195-203.

Dean, W. T., Martin, F., Monod, O., Ali Gül, M., Bozdogan, N., Özgül, N., 1993. Early Palaeozoic evolution of the Gondwanaland margin in the western and central Taurids, Turkey. In: Turgut, S. (Eds), Tectonics and hydrocarbon potential of Anatolia and surrounding regions. Ozan Sungurlu Symposium Proceedings, 262-273.

Deflandre, G., 1936. Les flagellés fossiles. Aperçu biologique et paléontologique Rôle Géologique. Actualités Scientifique et Industrielles, 335, 1-97.

Deflandre, G., 1937. Microfossiles des silex crétacés. Deuxième partie. Flagellés incertae sedis Hystrichosphaeridés. Sarcodinés. Organismes divers. Annales de Paléontologie, 26, 51-103.

Deflandre, G., 1938. Microplankton des mers jurassiques conservé dans les marnes de Villerssur-Mer (Calvados). Étude liminaire et considerations générales. Travaux de la Station zoologique de Wimereux, 13, 147-200.

Deflandre, G., 1945. Microfossiles des calcaires siluriens de la Montagne Noire. Annales de paleontologie, 31, 41-75.

Deflandre, G., 1946. Radiolaires et Hystrichosphaeridts du Carbonifere de la Montagne Noire. Compte Rendu Hebdomadaire des Stances de l'Academie des Sciences, 223, 515-517.

Deflandre, G., 1954. Systématique des Hystrichosphaeridés: sur l’acception de genre *Cymatiosphaera* Wetzel. Comptes Rendu. Sommaire des Séances de la Société Géologique de France, 4, 9-10.

Deflandre, G., Cookson, I. C. 1955. Fossil microplankton from Australian late Mesozoic and Tertiary sediments. Austral. J. Marine and Freshwater Research 6, 242-313, Sidney.

Deflandre, G., Deflandre-Rigaud, M., 1961. Nomenclature et systematique des Hystrichos-phires (sens. lat.) Observations et rectifications. Lab. Micropaléontol. Ecole Pratique Hautes Etudes, Institut de Paléontologie Muséum, Paris, 1-14.

Deflandre, G., Cookson, I. C. 1955. Fossil microplankton from Australian late Mesozoic and Tertiary sediments. Austral. Journal of Marine and Fresh water Reasearch, 6, 242-313, Sidney.

Deflandre, G., Deflandre-Rigaud, M., 1962. Nomenclature et systématique des hystrichosphères (sensu lato); observations et rectifications, Revue de Micropaléontologie, 4, 190-196.

De Gibert, J. M., Ramos, E., Marzo, M., 2011. Trace fossils and depositional environments in the Hawaz Formation, Middle Ordovician, western Libya, Journal of African Earth Sciences, 60, 28–37.

Delabroye, A., Vecoli, M., 2010. The end-Ordovician glaciation and the Hirnantian Stage: a global review and questions about Late Ordovician event stratigraphy. Earth-Science Review. 98, 269–282.

Delabroye, A., Vecoli, M., Hints, O., and Servais, T., 2011. Acritarchs from the Ordovician-Silurian boundary beds of the Valga-10 drill core, southern Estonia (Balric) and their stratigraphical and paleogeographical implications. Palynology, 35, 4-45.

De la Puente, G. S., Rubinstein, C. V 2013. Ordovician chitinozoans and marine phytoplankton of the Central Andean Basin, northwestern Argentina: A biostratigraphic and paleobiogeographic approach. In Press, Review of Palaeobotany and Palynology.

Desio, A., 1936a. Prime notizie sulla presenza del Silurico fossilifero nel Fezzan. Bollettino. Societa Geologica Italiana, 55, 116-120.

Desio, A., 1936b. Riassunto sulla presenza del Silurico fossilifero nel Fezzan. Bollettino. Societa Geologica Italiana, 55, 319-356.

Deunff, J., 1951. Sur la prtsence de micro-organismes (Hystrichospheres) dans les schistes ordoviciens du Finistere. Compte Rendu Hebdomadaire des Stances de l'Academie des Sciences, 233, 321-323.

Deunff, J., 1954. *Veryhachium*, genre nouveau d''Hystrichosphères'' du Primaire. Compte Rendu Sommaire de la Société géologique de France, 13, 305-307.

Deunff, J., 1955a. *Aremoricanium*, genre nouveau d"Hystrichosphères du Silurien Breton, Compte Rendu Sommaire et Bulletin de la Société géologique de France, 5, 227-229.

Deunff, J., 1955b. Un microplancton fossile dévonien Hystrichosphéres du continent Nord-Americain. Bulletin de Microscopie appliquée, 2, 138-149.

Deunff, J., 1959. Microorganismes planctoniques du Primaire armoricain. I. Ordovicien du Veryhac'h (presqu'ile de Crozon). Bulletin de la Société géologique et minéralogique de Bretagne 2, 1-41.

Deunff, J., 1960. Etude palynoplanctologique du Cambro-Ordovicien d'El Gassi 2. Memoire d'Etudes, vol. XVII, a/60. Centre de Recherches-PAU, 18 pp.

Deunff, J., 1961. Un microplancton a Hystrichospheres dans le Tremadoc du Sahara. Revue de Micropaléontologie, 4, 37-52.

Deunff, J., 1964. Systematique du microplancton fossile a acritarches. Revision de deux genres de l'Ordovicien inferieur. Revue de Micropaléontologie, 7, 119-124.

Deunff, J., Evitt, W. R., 1968. *Tunisphaeridium*, a new acritarch genus from the Silurian and Devonian. Stanford University Publications, Geological Sciences, 12, 1-13.

Deunff, J., Górka, H., Rauscher, R., 1974. Observations nouvelles et precisions sur les Acritarches à large ouverture polaire du Paléozoïque inférieur. Geobios, 7, 5-18.

Deunff, J., Massa, D., 1975. Palynologie et stratigraphie du Cambro-Ordovicien (Libye nord-occidentale). Comptes Rendus de l'Academie des Seances de Paris (D), 281, 21-24.

Deunff, J., 1977. Un microplankton a`acritarches dans les schistes Llanvirnien de l’Anti-Atlas (Zagora-Maroc). Notes du Service geólogique du Maroc, 38, 141–151.

Deunff, J., 1980. Le paléoplancton des grés de Landévennec (Gedinnien) de la rade de Brest-Finiséhe). Ètude biostratigraphique. Géobios, 13, 483- 539.

Díaz-Martínez, E., Grahn, Y., 2007. Early Silurian glaciation along the western margin of Gondwana (Peru, Bolivia and northern Argentina): Palaeogeographic and geodynamic setting. Palaeogeography, Palaeoclimatology, Palaeoecology, 245, 62-81.

Di Milia, A., Ribecai, C., and Tongiorgi, M., 1989. Late Cambrian Acritarchs from the Peltura scarabaeoides Trilobite Zone at Degerhamn (Öland, Sweden). Palaeontographica Italica, 15, 1–56.

Di Milia, A., Tongiorgi, M., 1993. Tremadocian acritarch assemblages from the Solanas Sandstone Formation (Nappe Zone of Central Sardinia). Memoria della Societa Geologica Italiana, 49, 193–204.

Dorning, K. J., 1981. Silurian acritarch distribution in the Ludlovian shelf sea of South Wales and the Welsh borderland. In: Neale, J., Brasier, M. (Eds.), Microfossils From Recent and Fossil Shelf Seas. Ellis Horwood, Chichester, pp. 31– 36. Chapt. 3.

Dorning, K. J., 1981a. Silurian acritarchs from the type Wenlock and Ludlow of Shropshire, England. Review of Palaeobotany and Palynology, 34, 175-203.

Dorning, K. J., 1981. Silurian chitinozoa from the type Wenlock and Ludlow of Shropshire, England. Review of Palaeobotany and Palynology, 34, 205-208.

Dorning, K. J., 1986. Organic microfossil geothermal alteration and interpretation of regional tectonic provinces. Journal of Geological Society. London, 143, 219-220

Dorning, K. J., Bell, D. G., 1987. The Silurian carbonate shelf microflora: acritarch distribution in the Much Wenlock Limestone Formation. 266-287 In: Hart, M. B.(ed.) Micropaleontology of carbonate environments. Ellis Horwood, Chichester. 296pp.

Dorning, K. J., 1994. *Dactylofusa*, *Eupoikilofusa*, *Leiofusa* and *Poikilofusa*: four fusiform acritarch genera. Contribution to the CIMP Symposium on Palynology, Palaeoenvironments and Stratigraphy, University of Sheffield, 15.

Dorning, K. J., Harding, J. L., 1998. Environmental distribution of the Ordovician-Recent terrestrial to freshwater acritarchs and algae, including *Concentricystes*, *Moyeria* and *Pediastrum*. CIMP Symposium and Workshops, Pisa, September 11-15, Abstracts, 37.

Downie, C., 1959. Hystrichospheres from the Silurian Wenlock Shale of England. Palaeontology, 2, 56-71.

Downie, C., 1960. *Deunffia* and *Domasia*, new genera of hystrichospheres. Micropaleontology, 6, 197-202.

Downie, C., 1963. 'Hystrichospheres' (acritarchs) and spores of the Wenlock Shales (Silurian) of Wen- lock, England. Palaeontology, 6, 625-652.

Downie, C., Sarjeant, W. A. S., 1963. On the interpretation and status of some hystrichosphere genera. Palaeontology, 6, 88-96.

Downie, C., Evitt, W. R., Sarjeant, W. A. S., 1963. Dinoflagellates, hystrichospheres and the classification of the acritarchs. Stanford University Publications, Geological Sciences, 7, 3-16.

Downie, C., Sarjeant, W. A. S., 1965. Bibliography and index of fossil dinoflagellates and acritarchs. Geological Society of America, Memoir, 94, 180pp.

Downie, C., 1973. Observations on the nature of the acritarchs. Palaeontology, 16, 239-259.

Downie, C., 1982. Lower Cambrian acritarchs from Scotland, Norway, Greenland and Canada. Transactions of the Royal Society of Edinburgh: Earth Sciences, 72, 257-285.

Downie, C., 1984. Acritarchs in British stratigraphy. Special Report-Geological Society of London, 17, 1– 26.

Duffield, S. L., 1985. Land derived microfossils from the Jupiter Formation (Upper Llandoverian) Anticosti Island, Québec. Journal of Paleontology, 59, 1005-1010.

Duffield, S. L., Legault, J. A. L., 1981. Acritarch biostratigraphy of Upper Ordovician-Lower Silurian rocks, Anticosti Island, Quebec: Preliminary results. In: Lespérance, P.J. (ed.), Subcommission on Silurian Stratigraphy, Ordovician-Silurian Boundary Working Group, Field Meeting, Anticosti, Quebec, 2, 91-99.

Duffield, S. L., Legault, J. A. L., 1982. Gradational morphological series in Early Silurian acritarchs from Anticosti Island, Quebec. North American Palaeontological Convention III, 1, 137-141.

Dufka, P. 1992. Lower Silurian chitinozoans of the Prague Basin (Barrandian, Czechoslovakia) - preliminary results. Revue de Micropaleéntologie, 35, 117-126.

Droste, H. H. J., 1997. Stratigraphy of the Lower Paleozoic Haima supergroup of Oman. GeoArabia, 2, 419-492.

Dufka, P., Fatka, O., 1993. Chitinozoans and acritarchs of the Ordovician–Silurian boundary from the Prague Basin (Barrandian area: Czechoslovakia). In: Molyneux, S.G., Dorning, K.G. (Eds), Contribution to Acritarch and Chitinozoa Research. Special Papers in Palaeontology, 48, 7-16.

Echikh, K., 1998. Geology and hydrocarbon occurrences in the Ghadames Basin, Algeria, Tunisia, Libya. In: Petroleum Geology of North Africa: In Macgregor, D. S. R.T.J. Moody, D. D. Clark-Lowes (Eds), Geological Society. Special Publication, 132, 109-130.

Echikh, K., Sola, M. A., 2000. Geology and hydrocarbon occurrences in the Murzuq Basin, SW Libya. In: Sola, M.A., Worsley, D. (Eds.), Geological Exploration in the Murzuq Basin. Elsevier Science B.V., 175-222.

Eisenack, A., 1931. Neue Microfossilien des baltischen Silurs. I. Paläontologische Zeitschrift, 13, 74-118.

Eisenack, A., 1934. Neue Mikrofossilien des baltischen Silurs III und neue Mikrofossilien des böhmischen Silurs I. Paläontologische Zeitschrift, 16, 52-76.

Eisenack, A., 1937. Neue Mikrofossilien des baltischen Silurs 4. Paläontologische Zeitschrift, 19, 217-243

Eisenack, A., 1938. Hystrichosphaerideen und verwandte Formen im baltischen Silur. Zeitschrift f¨ur Geschiebeforschung und Flachlandsgeologie, 14, 1-30.

Eisenack, A., 1938a. Hystrichosphaerideen und verwandte Formen im baltischen Silur. Zeitschrift für Geschiebeforschung und Flachlandsgeologie, 14, 1-30.

Eisenack, A., 1938b. Neue Mikrofossilien des baltischen Silurs. IV. Paläeontologische Zeitschrift, 9, 217-243.

Eisenack, A., 1939. Chitinozoen und Hystrichosphäerideen im Ordovizium des Rheinischen Schiefergebirges. Senckenbergiana, 21,135-152.

Eisenack, A., 1955a. Chitinozoen, Hystrichosphäeren und andere Mikrofossilien aus dem Beyrichia Kalk. Senckenbergiana lethaea, 36, 157-188.

Eisenack, A., 1955b. Neue Chitinozoen aus dem Silur des Baltikums und dem Devon der Eifel. Senckenbergiana lethaea, 36, 311-319.

Eisenack, A., 1958a. *Tasmanites* Newton, 1875 and *Leiosphaeridia* n. gen. Als Gattungen der Hystrichosphäeridea. Paläeontographica A, 110, 1-19.

Eisenack, A., 1958b. Mikroplankton aus dem norddeutschen Apt nebst einigen Bemerkungen über fossile Dinoflagellaten. Neues Jahrbuch für Geologie und Paläontologie Abhandlungen, 106, 383–422.

Eisenack, A., 1959a. Neotypen baltischer Silur-Hystrichosphären und neue Arten. Paläeontographica Abhandlungen, A 112, 193–211.

Eisenack, A., 1959b. Neotypen baltischer Silur-Chitinozoen und neue Arten. Neues Jahrbuch fiir Geologie und Paläontologie, Abhandlungen, 108, 1-20.

Eisenack, A., 1962a. Mikrofossilien aus dem Ordovizium des Baltikums. Vaginatenkalk bis Lyckholmer Stufe. Senckenbergiana, 43, 349-366.

Eisenack, A., 1962b. Neotypen baltischer Silur-Chitinozoen und neue Arten. Neues Jahrbuch fur Geologie und Paläeontologie, Abhandlungen, 114, 291-316.

Eisenack, A., 1963. Mitteilungen zur Biologie der Hystrichosphären und neue Arten. Paläeontographica Abhandlungen.,118, 207–216.

Eisenack A., 1964. Mikrofossilien aus dem Silur Gotlands. Chitinozoen. Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, 120, 308–342.

Eisenack, A., 1965. Die Mikrofauna der Ostseekalke 1. Chitinozoen, Hystrichosphären. Neues Jahrbuch für Geologie und Paläeontologie, Abhandlungen, 123, 115-148.

Eisenack, A., 1968. Über die fortpflanzung paläozoischer Hystrichosphären. Neues Jahrbuch für Geologie und Paläeontologie, Abhandlungen, 131, 1-22, Stuugart.

Eisenack, A., 1968a. Mikrofossilien eines Geschiebes der Borkholmer Stufe, baltisches Ordovizium F2. Mitteilungen aus dem Geologischen Staatsinstitut in Hamburg 37, 81–94.

Eisenack, A., 1968b. Über Chitinozoen des Baltischen Gebietes. Paläeontographica A, 131, 137-198.

Eisenack, A., 1969. Zur Systematik einiger paläozoischer Hystrichosph¨aren (Acritarcha) des baltischen Gebietes. Neues Jahrbuch für Geologie und Paläeontologie, Abhandlungen, 133, 245–266.

Eisenack, A., 1970. Mikrofossilien aus dem Silur Estlands und der Insel oé sel. Geologiska Föreningens i Stockholm Förhandlingar, 92, 302-322.

Eisenack, A., 1972. Kritische Bemerkung zur Gattung *Pterospermopsis* (Chlorophyta, Prasinophyceae). Neues Jahrbuch für Geologie und Paläeontologie, Abhandlungen, 10, 596-601.

Eisenack, A., 1972a. Chitinozoen und andere mikrofossilien aus der Bohrung Leba, Pommern. Paläeontographica, Abteilung A, 139, 64-87.

Eisenack, A., 1972b. Beiträge zur Chitinozoen - Forschung. Paläeontographica, Abteilung A, 140, 117-130.

Eisenack, A., Cramer, F.H., Díez, M., 1973. Katalog der fossilen Dinoflagellaten, Hystrichosphären und verwandten Mikrofossilien. Acritarcha, Band 3, Teil 1. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart, 1104pp.

Eisenack, A., 1976. Mikrofossilien aus dem Vaginatenkalk von Hälludden, Öland. Paläeontographica Abteilung. A 154, 181-203.

Eisenack, A., Cramer, F.H., Díez, M., 1979. Katalog der fossilen Dinoflagellaten, Hystrichosphären und verwandten Mikrofossilien. Acritarcha, Band 6, Teil 3. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart, 533pp.

Eiserhardt, K. H., 1985. *Orthosphaeridium rectangulare* (Eisenack 1963) (Acritarcha) aus einem Öjlemyrflint-Geschiebe (Schweden). Mitteilungen des Geologisch-Paläontologischen Instituts der Universität Hamburg, 59, 137-154.

Eiserhardt, K. H., 1989. Baltisphären aus Gotländer Öjlemyrflint (Acritarcha, Oberordoviz Geschiebe Schweden). Mitteilungen des Geologisch-Paläontologischen Instituts der Universität Hamburg, 68, 79-129.

Eiserhardt, K.-H., 1992. Die Acritarcha des Öjlemyrflintes. Palaeontographica Abteilung B, 226, 1–132.

Elaouad-Debbaj, Z., 1978. Acritarches de l’Ordovicien Superieur du Synclinal de Bucao (Portugal). Bulletin de la Societé Géologique et Mineralogique de Bretagne 10, 1-101.

Elaouad-Debbaj, Z., 1984. Acritarches et chitinozoaires de I'Arenig-Lianvirn de I'Anti-Atlas (Maroc). Review of Palaeobotany and Palynology, 43, 67-88.

Elaouad-Debbaj, Z., 1988. Acritarches de l'Ordovicien superieur (Caradocian-Ashgillian) de l'Anti-Atlas, Maroc. Revue de Micropaleontologie, 30, 232-248.

Elaouad-Debbaj, Z., 1988. Acritarches et chitinozoaires du Trémadoc de l’Anti-Atlas Central (Maroc). Revue de Micropaléontologie, 31, 85– 128.

Eley, B, E., Legault, J. A., 1988. Playnomorphs from the Manitoulin Formation (Early Llandovery) of southern Ontario, Canada, Palynology, 12, 49-63.

Eley, B, E., 1992. Acritarchs from the Fossil Hill Formation (Silurian) of southern Ontario, Canada, Palynology, 16, 73-92.

El-ghali, M. A. K., 2005. Depositional environments and sequence stratigraphy of paralic glacial, paraglacial and postglacial Upper Ordovician siliciclastic deposits in the Murzuq Basin, southwest Libya. Sedimentary Geology, 177, 145–173.

Elles, G. L., 1925. The characteristic assemblages of the graptolite zones of the British Isles. Geological Magazine, 62, 337-47.

Erkmen, U., 1979. Stratigraphical distribution of the Lower Paleozoic acritarchs from southeast Turkey: comparison with other Mediterranean countries. GEOCOME I, First Geological Congress of the Middle East, September 4-7, 1979, Ankara: 472-495.

Erkmen, u., Bozdoğan, N., 1979. Acritarchs from the Dadas Formationin Southeast Turkey, Geobios, 12, 445-449.

Evitt, W. R., 1963. A discussion and proposals concerning fossil dinoflagellates, hystrichospheres and acritarchs, I, II. Proceedings of the National Academy of Sciences 49, 298-302.

Fatka, 0., Brocke, R., 1999. Morphologic variability in two populations of *Arbusculidium filamenfosum* (Vavrdova. 1965) Vavrdova, 1972. Palynology, 23,153-180.

Fatka, O., Molyneux, S. G., Servais T., 1997. The Ordovician acritarch *Frankea*: Some critical remarks. Geobios, 30, 321-326.

Fatka, O., 2003. Organic-walled microfossils (Chitinozoa and Acritarcha) from Praha-Červený vrch Hill (Šárka Formation, Middle Ordovician, Prague Basin), Bulletin of Geosciences, 78, 119–127.

Fello, N., M. Litha A., 2003. Depositional environments of the Upper Ordovician Mamuniyat Formation, northwest Murzuq Basin, Libya. Abstract in AAPG Hedberg conference “Paleozoic and Triassic Petroleum Systems in North Africa*”.*

Fello, N., Lüning, S., Storch, P., Redfern, J., 2006. Identification of early Llandovery (Silurian) anoxic palaeo-depressions at the western margin of Murzuq Basin (southwest Libya), based on gamma-ray spectrometry in surface exposures. GeoArabia, 11, 101–118.

Fensome, R. A., Williams, G. L., Barss, M. S., Freeman, J. M., and Hill, J. M., 1990. Acritarchs and fossil prasinophytes: an index to genera, species and infraspecific taxa. Contributions Series-American Association of Stratigraphic Palynologists 25 (Dallas), 771pp.

Finney, S. C., Berry, W. B. N., Cooper, J. D., Ripperdan, R. L., Sweet, W. C., Jacobson, S. R., Soufiane, A., Achab, A., and Noble, P. J., 1999. Late Ordovician mass extinction: a new perspective from stratigraphic sections in central Nevada. Geology, 27, 215– 218.

Fortey, R. A., Bassett, M. G., Harper, D. A. T., Hughes, R. A., Ingham, J. K., Molyneux, S. G., Owen, A. W., Owens, R. M., Rushton, A. W. A., and Sheldon, P. R., 1991. Progress and problems in the selection of stratotypes for the bases of series int he Ordovician System of the historical type area in the U.K. In: Barnes, C.R., Williams, S.H. (Eds), Advances in Ordovician Geology. Geological Survey of Canada, Bull. 345.

Fortey, R. A., Harper, D. T., Ingham, J. K., Owen, A. W., Rushton, A. W. A., 1995. A revision of Ordovician series and stages from the historical type area. Geological Magazine, 132, 15-30.

Fortey, R. A., Harper, D. A. T., Ingham, J. K., Owen, A. W., Parkes, M. A., Rushton, A. W., and Woodcoock, N. H., 2000. A revised correlation of

Ordovician rocks in the British Isles, Journal of Geological Society, London, Special Report, 24, 8.

Fortey, R. A., Cocks, L. R. M., 2003. Paleontological evidence bearing on global Ordovician Silurian continental reconstruction. Earth Science Reviews, 61, 245-307.

Fortey, R. A., 2005. Ordovician, In: Selley, R. C., Cocks, L. R. M., Plimmer, I. R. (Eds), Encyclopedia of Geology. Elsevier, 4, 175-184.

Fournier-Vinas, C., 1985. Acritarches Ordoviciens des Zekkara (Maroc oriental), Geobios, 18, 807-813.

Frakes, L. A., Francis, J. E., Syktus, J. I., 1992. Climate Modes of the Phanerozoic. Cambridge University Press, 274pp.

Gabbott, S. E., Aldridge, R. J., and Theron, J. N. 1998. Chitinozoan chains and cocoons from the Upper Ordovician Soom Shale Lagerstätte, South Africa: implications for affinity. Journal of the Geological Society, London, 155, 447-452.

Gagnier, P. Y., Blieck, A., Emig, C. C., Sempere, T., Vachard, D., and Vanguestaine, M., 1996. New palaeontological and geological data on the Ordovician and Silurian of Bolivia. Journal of South American Earth Sciences, 9, 329-347.

Gelsthorpe, D. N, 2004. Microplankton changes through the early Silurian Ireviken extinction event on Gotland, Sweden. Review of Palaeobotany and Palynology, 130, 89-103.

Geng, L. yu., Qian Z. S., Ding, L. S., Wang, Y., Wang, G. X., and Caixi, Y., 1997. Silurian chitinozoans from the Yangtze Region. Palaeoworld, 8, 1-152.

Ghavidel-syooki, M., 1993. Palynological study of Palaeozoic sediments of the Chal-I-Sheh area, southwestern Iran. Journal of Sciences, Islamic Republic of Iran, 4, 32-46.

Ghavidel-syooki, M., 1995. Palynostratigraphy and palaeogeography of a Palaeozoic sequence in the Hassanakdar area, Central Alborz Range, northern Iran. Review of Palaeobotany and Palynology, 86, 91-109.

Ghavidel-syooki, M., 1996. Acritarch biostratigraphy of the Palaeozoic rock units in the Zagros Basin, Southern Iran. In: Fatka, 0., Servais, T. (Eds.), Acritarcha in Praha 1996. Proceedings of International Meeting and Workshop. Acta Universitatis Carolinae, Geologica, 40, 385-411.

Ghavidel-syooki, M., 2000. Biostratigraphy and Palaeobiogeography of Late Ordovician and Early Silurian chitinozoans from the Zagros Basin, southern Iran. Historical Biology, 15, 29-39.

Ghavidel-syooki, M., 2001. Palynostratigraphy and paleobiogeography of the Lower Palaeozoic sequence in the northeastern Alborz Range (Kopeh-Dagh Region) of Iran. Journal of Sciences, Islamic Republic of Iran, 11, 305-318

Ghavidel-syooki, M., Winchester-Seeto, T., 2002. Biostratigraphy and palaeogeography of Late Ordovician chitinozoans from the northeastern Alborz Range, Iran. Review of Palaeobotany and Palynology, 118, 77-99.

Ghavidel-syooki, 2003. Palynostratigraphy and Palaeogeography of Lower Palaeozoic strata at Kuh-e-Boghou, Southwest of Kashmar city, at Eastern Central Iran. Iranian International Journal of Science, 4, 181-207.

Ghavidel-syooki, M., Winchester-Seeto, T., 2004. Chitinozoan biostratigraphy and palaeogeography of lower Silurian strata (Sarchahan Formation) in the Zagros Basin of southern Iran. Memoirs of the Association of the Australian Palaeontologists, 29, 161-182.

Ghavidel-syooki, M., 2006. Palynostratigraphy and palaeogeography of the Cambro-Ordovician strata in southwest of Shahrud city (Kuh-e-Kharbash, near Deh molla) Central Alborz Range, northern Iran. Review of Palaeobotany and Palynology, 139, 81-95.

Ghavidel-syooki, M., Vecoli, M., 2007. Latest Ordovician–early Silurian chitinozoans from the eastern Alborz Mountain Range, Kopet–Dagh region, northeastern Iran: biostratigraphy and palaeobiogeography. Review of Palaeobotany and Palynology, 145, 173-192.

Ghavidel-syooki, M., 2008. Palynostratigraphy and Palaeogeography of the Upper Ordovician Gorgan Schists (Southeastern Caspian Sea), Eastern Alborz Mountain Ranges, Northern Iran. Comunicações Geológicas, 95, 123-155.

Ghavidel-syooki, M., Vecoli, M., 2008. Palynostratigraphy of Middle Cambrian to lowermost Ordovician strata sequences in the High Zagros Mountains, southern Iran: Regional stratigraphic implications, and palaeobiogeographic significance. Review of Palaeobotany and Palynology, 150, 97–114.

Ghavidel-syooki, M., Hassanzadeh, j., Vecoli, M., 2011. Palynology and isotope geochronology of the Upper Ordovician–Silurian successions (Ghelli and Soltan Maidan Formations) in the Khoshyeilagh area, eastern Alborz Range, northern Iran; stratigraphic and palaeogeographic implications. Review of Palaeobotany and Palynology, 164, 251–271.

Ghavidel-syooki, M., Javier Álvaro, J., Popov, L., Ghobadi Pour, M., Ehsani, M., Suyarkova, A., 2011. Stratigraphic evidence for the Hirnantian (latest Ordovician) glaciation in the Zagros Mountains, Iran. Palaeogeography, Palaeoclimatology, Palaeoecology, 307, 1-16.

Ghienne, J. F., 2003. Late Ordovician sedimentary environments, glacial cycles, and post-glacial transgression in the Taoudeni Basin, West Africa. Palaeogeography Palaeoclimatology Palaeoecology., 189, 117-145.

Ghienne, J. F., Boumendjel, K., Paris, F., Videt, B., Racheboeuf, P. and Salem, H. A., 2007b. The Cambrian-Ordovician succession in the Ougarta Range (western Algeria, North Africa) and interference of the Late Ordovician glaciation on the development of the Lower Palaerozoic transgression on northern Gondwana. Bulletin. Geoscience, 82, 183-214.

Górka, H., 1967. Quelques nouveaux acritarches des silexites du Trémadocien supérieur de la région de Kielce (Montagne de Ste Croix, Pologne). Cahiers de Micropaléontologie Série I, 6, 1-8.

Górka,H., 1969. Microorganismes de l'Ordovicien de Pologne. Palaeontologia Polonica, 22, 1-102.

Górka,H., 1979. Les acritarches de l'Ordovicien Moyen D'Olsztyn IG 2 (Pologne), Acta Palaeontologica Polonica, 24, 351-382.

Górka, H., 1980. Le microplancton de l'Ordovicien moyen de Suabla (Pologne). Acta Palaeontologica Polonica, 25 (2), 261-277.

Górka, H., 1987. Acritarches et Prasinophyceae de l'ordovicien Moyen (Viruen) de sondage de Smedsby Gard no. 1 (Gotland, Sue`de). Review of Palaeobotany and Palynology, 52, 257-297.

Goudarzi, G. H. 1980. Structure-Libya. In: Salem, M. J., Busrewil, M. T. (Eds), Second Symposium on the Geology of Libya, Academic Press, London, III, 879-892.

Gradstein, F. M., Ogg, J. G., Smith, A. G., 2004. A Geologic Time Scale 2004. Cambridge University Press, Cambridge, 589pp.

Grahn, Y., 1980 Early Ordovician Chitinozoa from Oland. Sveriges Geologiska Undersokning Serie C, 775, 1-41.

Grahn, Y., 1981 Ordovician Chitinozoa from the Stora Asbotorp boring in Vistergtland, south-central Sweden. Sveriges Geologiska Undersokning Serie C, 787, 1-40.

Grahn, Y., 1982 Caradocian and Ashgillian Chitinozoa from the sub-surface of Gotland. Sveriges Geologiska Undersokning Serie C, 788, 1-66.

Grahn, Y., Bergström, S. M., 1984. Lower Middle Ordovician chitinozoa from the southern Appalachians, United States. Review of Palaeobotany and Palynology, 43, 89-122.

Grahn, Y. 1984. Ordovician Chitinozoa from Tallinn, northern Estonia. Review of Palaeobotany and Palynology, 43, 5-31.

Grahn, Y., 1985. Llandoverian and early Wenlockian chitinozoa from southern Ohio and northern Kentucky, USA. Palynology, 9, 1-17.

Grahn Y., Bergström, S. M.,. 1985. Chitinozoans from the Ordovician-Silurian boundary beds in the eastern Cincinnati Region in Ohio and Kentucky. Ohio Journal of Science, 85, 175-83.

Grahn Y., 1988. Chitinozoan stratigraphy in the Ashgillian and Llandovery. In Cocks, L. R. M. and Rickards, R. B. (Eds). A Global Analysis of the Ordovician–Silurian Boundary, Bulletin of the British Museum (Natural History), 43, 317-323.

Grahn, Y., 1992a. Ordovician chitinozoa and stratigraphy of Brazil. Geobios, 25, 703-723.

Grahn, Y. 1992b. Revision of Silurian and Devonian strata of Brazil. Palynology, 16, 35-61.

Grahn, Y., Paris, F., 1992. Age and correlation of the Trombetas Group, Amazonas Basin, Brazil. Revue de Micropaléontologie, 35, 20-32.

Grahn, Y., 1997. Chitinozoan biostratigraphy of the early Caradocian Lockne impact structure, Jamtland, Sweden, Mrteoritics & Planetary Science 32, 745-751.

Grahn, Y., Pereira, E. and Bergmaschi, S. 2000. Silurian and Lower Devonian chitinozoan biostratigraphy of the Paran´a Basin in Brazil and Paraguay. Palynology, 24, 143-72.

Grahn, Y., Gutiérrez, P. R., 2001. Silurian and Middle Devonian chitinozoa from the Zapla and Santa Bárbara Ranges, Tarija Basin, northwestern Argentina. Ameghiniana, 38, 35-50.

Grahn, Y., Loboziak, S., and Melo, J. H. G. 2001. Integrated miospore-chitinozoan biozonation of the Parnaíba Basin and its correlation with Petrobras (Müller 1962). Silurian-Lower Carboniferous palynozones. In: Correlação de Seqüências Paleozóicas Sul- Americanas (Melo, J. H. G., and Terra, G. J. S., eds.). Ciência – Técnica – Petróleo. Seção: Exploração de Petróleo, 20, 81-89.

Grahn, Y., 2002. Upper Silurian and Devonian Chitinozoa from central and southern Bolivia, central Andes. Journal of South American Earth Sciences, 15, 315-26.

Grahn, Y., 2003. Silurian and Devonian chitinozoan assemblages from the Chaco-Paran´a Basin, northeastern Argentina and central Uruguay. Revista Española de Micropaleontologia, 35, 1-8.

Grahn, Y. 2005a. Silurian and Lower Devonian chitinozoan taxonomy and biostratigraphy from the Trombetas Group in the Amazonas Basin, northern Brazil. Bulletin of Geosciences, 80, 245-76.

Grahn, Y. 2005b. Early Silurian chitinozoans in the Apucarana sub-basin (Paranaìba Basin), south Brazil, and their biostratigraphic provenance. Revista Brasileira de Paleontologia, 8, 209-14.

Grahn, Y., De Melo, J. H. G., Steemans, P., 2005. Integrated chitinozoan and miospore zonation of the Serra Grande Group (Silurian-Lower Devonian), Parnaiba Basin, northeast Brazil. Revista Española de Micropaleontología, 37, 183-204.

Grahn, Y., 2006. Ordovician and Silurian chitinozoan biozones of western Gondwana. Geological Magazine, 143, 509-529.

Grahn, Y., Nõlvak, J., 2007. Ordovician Chitinozoa and biostratigraphy from Skåne and Bornholm, southernmost Scandanavia- an overview and update. Bulletin of Geosciences, 82, 11-26.

Gray, J., Boucot, A. J. Early Silurian spore tetrads from New York: earliest new world evidence for vascular plants? Science,173, 918-921.

Gray, J., 1985. The microfossil record of early land plants: advances in understanding of early terrestrialization, 1970-1984. Philosophical Transactions of the Royal Society of London, B, 309, 167-195.

Gray, J., 1991. Tetrahedraletes, Nodospora, and the "cross' tetrad, an accretion of myth. In: Blackmore, S., Barnes, S.H. (Eds), Pollen and spores, patterns of diversification. Systematics Association Special Volume. 44, 49-87.

Gray, J., Boucot, A. J., 1989. Is *Moyeria* a euglenoid?. Lethaia, 22, 447-456.

Gray, J., Massa, D., Boucot, A. J., 1982. Caradocian land plant microfossils from Libya. Geology, 10, 197-201.

Gray, J., Boucot, A. J., Grahn, Y., Himes, G., 1992. A new record of early Silurian land plant spores from the Parana Basin, Paraguay (Malvinokaffric Realm). Geological Magazine, 129, 741-752.

Grebe, H., 1971. A recommended terminology and descriptive method for spores. In: Alpern, B., Neves, R. (Eds), Microfossiles Organique du Paléozoique, CIMP, 4, 1-87.

Greuter, W., McNeill, J., Barrie, F. R., Burdet, H. M., Demoulin, V., Filguerias, T. S., Nicolson, D. H., Silva, P. C., Skog, J. E., Trehane, P., Turland, N. J., Hawksworth, D. L., (editors and compilers), 2000. International Code of Botanical Nomenclature (St. Louis Code), adopted by the Sixteenth International Botanical Congress, St. Louis, Missouri, July–August 1999. Regnum Vegetabile 138. Koeltz Scientific Books, Königstein, 1–474.

Grignani, D., Lanzoni, E., and Elatrash, H., 1991. Palaeozoic and Mesozoic subsurface palynostratigraphy in the Al Kufrah Basin, Libya. In M. J. Salem, O. S. Hammuda, B. A. Eliagoubi, The geology of Libya, 4. 1159-1227.

Hammann, W., Heunisch, C., and Schüssler, U., 1989. Organische Mikrofossilien (Chlorophyta, Acritarcha, Sporae dispersae, Scolecodonten) aus den Schichten des Streichengrundes, Unterdevon, im Raum Guttenberg-Kupferberg des Frankenwaldes, Beringeria, 1, 57-113.

Gundobin, V. M., Yevdokimov, S. V., 1985. Sheet Qasr ash Shwayrif (NH 33-10), Geological Map of Libya, scale 1:250,000, Explanatory Booklet, Industrial Research Centre, Tripoli.

Hallet, D., 2002. Petroleum Geology of Libya. Elsevier, Amsterdam, the Netherlands, 508pp.

Hemer, D. O., 1968. Diagnostic palynological fossils from Arabian formations. Second Regional Technical Symposium. Society of Petroleum Engineers of AIME, Saudi Arabia Section, Dhahran, 311-325.

Havliceck, V., Massa, D., 1973. Brachiopodes de Ordovicien superieur de Libye occidentale, implications stratigraphiques regionales. Geobios, 6, 267-290

He, S., Yin, L., 1993. Late Ordovician acritarchs from Changwu Formation of Jiangshan, Zhejiang, China. Acta Palaeontol. Sin. 32, 610-633 (in Chinese with English abstract).

Hennelly, J. P. F., 1958. Spores and pollens from a Permian-Triassic transition, New South Wales. Proceedings of the Linnean Society of New South Wales. 83, 363-369.

Henry, J. L., 1966. Quelques Acritarches (micro-organismes incertae sedis) de l Ordovicien de Bertagne. C. R. Somm. Séances Société Géolgie de France. 8, 265-267

Henry, J. L., 1969. Micro-organismes incertae sedis (acritarches et chitinozoaires) de l'Ordovicien de la presqui'île de Crozon (Finistère): gisements de Mort-Anglaise et de Kerglintin. Bulletin de la Societé Géologique et Mineralogiquede Bretagne, 1, 59-100.

Henry, J. L., Nion, J. P. F., Thadeu, D., 1974. Chitinozoaires, Ostracodes et Trilobites de l’Ordovicien du Portugal (serra de Bucaco) et du massif Armoricain: essai de comparaison et signification paléogéographique. Comunicacões dos Servicos Geológicos de Portugal 57, 303-45.

Herrmann, A. D., Patzkowsky, M. E., Pollard, D., 2004a. The impact of paleogeography, pCO_2: poleward ocean heat transport and sea level change on global cooling during the Late Ordovician. Palaeogeography, Palaeoclimatology, Palaeoecology, 206, 59-74.

Herrmann A. D., Haupt B. J., Patzkowsky M. E., Seidov, D., Slingerland, R. L., 2004b. Response of Late Ordovician paleoceanography to changes in sea level, continental drift, and atmospheric pCO_2: potential causes for long-term cooling and glaciation. Palaeogeography, Palaeoclimatology, Palaeoecology, 210, 385-401.

Higgs, K. T., 2004. An Early Devonian (Lochkovian) microflora from the Freshwater West Formation, Lower Old Red Sandstone, southwest Wales. Geological Journal, 39, 359–374

Hill, P. J., 1974. Stratigraphic palynology of acritarchs from the type area of the Llandovery and the Welsh Borderland. Review of Palaeobotany and Palynology, 18, 11-23.

Hill, P. J., 1978. A review of *Cymbosphaeridium pilar* and comparison with *Multiplicisphaeridium pachymurum* sp. nov. From the Llandovery and Wenlock of Shropshire, Great Britain, Palynology, 2, 181-185.

Hill, P. J., Dorning, K. J., 1984. The Llandovery series in the type area. Appendix 1. Acritarchs. In: L. R. M. Cocks et al. (Eds), The Llandovery Series of the Type Area. Bulletin British Museum National History. 4, 27-48.

Hill, P. J., Paris, F., and Richardson, J. B., 1985. Silurian palynomorphs. In: Palynostratigraphy of North east Libya. Journal of Micropalaeontol. 4, 27-48.

Hill, P. J., Molyneux, S. G., 1988. Palynostratigraphy, palynofacies and provincialism of Late Ordovician-Early Silurian acritarchs from Northeast Libya. In: El-Arnauti, A, Owens, B., Thusu, B. (Eds), Subsurface Palynostratigraphy of northeast Libya. Publication of the University of Garyounis, Libya, 27-43.

Hints, O., Killinga, M., Männika, P., and Nestor, V., 2006. Frequency patterns of chitinozoans, scolecodonts, and conodonts in the upper Llandovery and lower Wenlock of the Paatsalu core, western Estonia. Procceding of the Estonian Academic of Sciences Geology, 55, 128-155

Hints, O., Eriksson, M. E., 2007. Diversification and biogeography of scolecodont-bearing polychaetes in the Ordovician. Palaeogeography, Palaeoclimatology, Palaeoecology, 245, 95-114.

Hints, L. Hints, O., Nemliher, R., and Nõlvak, J., 2007. Hulterstad brachiopods and associated faunas in the Vormsi Stage (Upper Ordovician, Katian) of the Lelle core, Central Estonia, Estonian Journal of Earth Sciences, 56, 131-142.

Hints, L., Hints, O., Kaljo, D., Kiipli, T., Männik, P., Nõlvak, J., and Pärnaste, H., 2010. Hirnantian (latest Ordovician) bio-and chemostratigraphy of the Stirnas-18 core, western Latvia, Estonian Journal of Earth Sciences, 59, 1-24

Hoffmeister, W. S., 1959. Lower Silurian plant spores from Libya. Micropaleontology, 5, 331-334.

House, M. R., Gradstein, F. M., 2004. The Devonian Period. In: Gradstein, F. M., Ogg, J. G. Smith, A. G. (Eds). A Geologic Time Scale 2004. Cambridge University Press, Cambridge, 202-221.

Jachowicz, M., 1995. Ordovician acritarch assemblages from central and northwestern Saudi Arabia. Review of Palaeobotany and Palynology, 89, 19-25.

Jacobson, S. R., 1979. Acritarchs as paleoenvironmental indicators in Middle and Upper Ordovician rocks from Kentucky, Ohio and New York. Journal of Paleontology, 53, 1197-1212.

Jacobson, S. R., Achab, A., 1985. Acritarch biostratigraphy of the Dicellograpfus cornplanatus graptolite zone from the Vaureal Formation (Ashgillian), Anticosti Island, Quebec, Canada. Palynology, 9, 165-198.

Jaglin, J. C., Paris, F., 2002. Biostratigraphy, biodiversity and palaeogeography of late Silurian chitinozoans from A1-61 borehole (north-western Libya). Review of Palaeobotany and Palynology, 118, 335-358.

Jankauskas, T., Gritytë, 2004. Upper Llandoverian and Lower Wenlockian acritarch assemblages from the Ledai-179 boring in Lithuania, Geologija, 48, 38-43.

Jansonius, J., 1964. Morphology and classification of some Chitinozoa. Bulletin of Canadian Petroleum Geologists, 12, 901-918.

Jardiné, S., Yapaudjan, L., 1968. Lithostratigraphie et palynologie du Dévonien-Gothlandien gréseux du Bassin de Polignac (Sahara). Revue de 1'Institut Francais du Pétrôle et Annales des Combustibles Liquides. 23, 439-456.

Jardiné, S., Combaz, A., Magloire, L., Peniguel, G. and Vachey, G., 1972. Acritarches du Silurien terminal et du Dévonien du Sahara Algérien. Comptes Rendus du 7e Congres International de Stratigraphie et de Géologie du Carbonifere, Krefeld, August 1971, 1, 295-311.

Jardine, S., Combaz, A., Magloire, L., Vachey, G., 1974. Distribution stratigraphique des acritarches dans Ie paleozoique du Sahara Algerien. Review of Palaeobotany and Palynolynology 18, 99-129.

Jenkins, W. A. M., 1967. Ordovician chitinozoa from Shropshire. Palaeontology, 10, 436-488.

Jenkins, W. A. M., 1969. Chitinozoa from the Ordovician Viola and Fernvale Limestones of the Arbuckle Mountains, Oklahoma. Palaeontology, Special Paper, 5, 1-44.

Jenkins, W. A. M., 1970. Chitinozoa from the Ordovician Sylvan Shale of the Arbuckle Mountains, Oklahoma. Palaeontology, 13, 261-288.

Jeppsson, L., 1998. Silurian oceanic events: summary of general characteristics. In: Landing, E., Johnson, M. E. (Eds), Silurian Cycles: Linkages of Dynamic Stratigraphy with Atmospheric, Oceanic and Tectonic Changes. New York State Museum Bulletin, 491, 239-257.

Johnson, N. G., 1985. Early Silurian palynomorphs from the and Tuscarora Formation in central Pennsylvania and their paleobotanical and geological significance. Review of Palaeobotany and Palynology, 45, 307-359.

Johnson, M. E., 1996. Stable cratonic sequences and a standard for Silurian eustasy. In: Witzke, B.J., Ludvigson, G. A., Day, J. (Eds), Paleozoic sequence stratigraphy: views from the North American craton. Geological Society of America Special Paper, 306, 203-211.

Johnson, M. E., Kaljo, D. L., Rong, J. Y., 1991. Silurian eustasy. Special Papers in Palaeontology, 44, 145-63.

Kaljo, D., Hints, L., Männik, P., Nõlvak, J. 2008. The succession of Hirnantian events based on data from Baltica: brachiopods, chitinozoans, conodonts, and carbon isotopes. Estonian Journal of Earth Sciences, 57, 197-218.

Kalvacheva, R., 1978. Acritarch stratigraphy of Lower Paleozoic formations in the west Balkan Mountains, Bulgaria. Palinologia, Numero Extraordinario, 1, 303-311.

Keegan, J. B., Rasul, S. M., Shaheen, Y., 1990. Palynostratigraphy of the Lower Paleozoic, Cambrian to Silurian, sediments of the Hashemite Kingdom of Jordan, Review of Palaeobotany and Palynology, 66,167-180.

Khanna, A. K., Sinha, A. K., Sah, S. C. D., 1985. Yong Limestone of Tethys HimalayaIts stratigraphic status and palynological fossils. Geological Society of India, 26, 191-198.

Kiryanov, V. V. 1978. Akritarkhi siluria Volyno–Podolii. Akademiya Nauk Ukrainskoi SSR, Institut Geologicheskikh Nauk, Kiev, Naukova Dumka, 116pp, (In Russian).

Kjellström, G., 1971a. Ordovician microplankton (baltisphaerids) from the Grötlingbo Borehole no 1 in Gotland, Sweden. Sveriges Geologiska Undersökning, Series C 65, 1-75.

Kjellström, G., 1971b. Middle Ordovician microplankton from the Grötlingbo Borehole no 1 in Gotland, Sweden. Sveriges Geologiska Undersökning, Series C 65, 1-35.

Kjellström, G., 1976. Lower Viruan (middle Ordovician) microplankton (baltisphaerids) from the Ekön borehole no 1 in Östergotland, Sweden. Sveriges Geologiska Undersökning, Series C 70, 1-44.

Klitzsch, E. 1965. Bin profit aus dem typusgebiet gotlandischer und devonische schichten der zentralsahara (westrand Murzukbecken, Libyen). Erdol und Kohle. Deutsche, 18, 605-607.

Klitzsch, E., 1969. Stratigraphic section from the type areas of Silurian and Devonian strata at western Murzuk Basin (Libya). In: Geology, archaeology and prehistory of the southwestern Fezzan, Libya (ed. Kanes, W. H.). Petroleum Exploration Society of Libya, Eleventh Annual Field Conference, 83-90.

Klitzsch, E. H., 2000, The structural development of the Murzuq and Kufra basins-Significance for oil and mineral exploration, in M. A. Sola and D. Worsley, eds., Geological exploration in Murzuq Basin: Amsterdam, Elsevier Science, 143-150

Kir'yanov, V. V., 1978. Akritarki silura Volyno-Podalii. Izd Nauk Dymka, 1-114, Kiev.

Kui, Y., Jun L., Servais T. In Press, 2013. An Early–Middle Ordovician acritarch and prasinophyte assemblage from Houping, Chongqing city, South China: Biostratigraphical and palaeoenvironmental implications**,** Review of Palaeobotany and Palynology

Lange, F., 1952. Chitinozoarios do Folhelho Barreirinha, Devoniano do Parà. Dusenia 3, 373-386.

Laufeld, S., 1967. Caradocian Chitinozoan from Dalarna, Sweden. Geologiska Foreningens Stockholm Forhandlingar, 89, 275-349

Laufeld, S., 1971. Chitinozoa and correlation of the Moldova and Restevo Beds of Podolia: USSR. Mémoires du Bureau de Recherches Géologiques et Minéres, 73, 291-300.

Laufeld, S., 1974. Silurian Chitinozoa from Gotland. Fossils and Strata, 5, 1-130.

Laufeld, S., 1979. Chitinozoa. 70-76. In Jaanusson, V., Laufeld, S. and Skoglund, R. (eds). Lower Wenlock faunal and flora dynamics - Vattenfallet section, Gotland. Sveriges Geologiska Undersökning, 762, 294pp.

Lavender, K., Wellman, C. H., 2002. Lower Devonian spore assemblages from the Arbuthnott Group at Canterland Den in the Midland Valley of Scotland. Review of Palaeobotany and Palynology, 118, 157-180.

Le Hérissé, A., 1989. Acritarches et kystes d'algues Prasinophycées du Silurien de Gotland, Suède. Palaeontographia Italica, 76, 57-302.

Le Hérissé, A, Al-Tayyar, H., van der Eem, H., 1995. Stratigraphic and paleogeographical significance of Silurian acritarchs from Saudi Arabia. Review of Palaeobotany and Palynology, 89, 49-74.

Le Hérissé, A., Gourvennec, R., 1995. Biogeography of upper Llandovery and Wenlock acritarchs. Review of Palaeobotany and Palynology 86, 111-133.

Le Hérissé, A., Gourvennec, R., Wicander, R., 1997. Biogeography of Late Silurian and Devonian acritarchs and prasinophytes. Review of Palaeobotany and Palynology 98, 105-124.

Le Hérissé, A, 2000. Characteristics of the acritarch recovery in the Early Silurian of Saudi Arabia. In: Al-Hajri, S., Owens, B. (Eds), Stratigraphic

Palynology of the Palaeozoic of Saudi Arabia. Special GeoArabia Publication 1, Gulf Petrolink, Bahrain, 57-81.

Le Hérissé, A., Melo, J.H.G., Quadros, L.P., Grahn, Y., and Steemans, P., 2001. Palynological characterization and dating of the Tianguá Formation, Serra Grande Group, northern Brazil. In: Melo, J.H.G., Terra, G.J.S. (Eds), Correlaçao de Seqüencias Paleozóicas Sul-Americanas. Ciencia-Técnica-Petróleo. Seçao: Exploraçao de Petróleo. 20, 25-40.

Le Hérissé, A., 2002. Paleoecology, biostratigraphy, and biogeography of late Silurian to early Devonian acritarchs and prasinophycean phycomata in well A1-61, Western Libya, North Africa. Review of Palaeobotany and Palynology, 242, 1-37.

Le Hérissé, A., AI-Ruwaili, M., Miller, M., Vecoli, M., 2007. Environmental changes reflected by palynomorphs in the early Middle Ordovician Hanadir Member of the Oasim Formation, Saudi Arabia. Revue de Micropaléontologie, 50, 3-16.

Le Hérissé, A., Paris, F., Steemans, P., 2013. Late Ordovician-earliest Silurian palynomorphs from northern Chad and correlation with contemporaneous deposites southern eastern Libya, Bulletin Geosciences, 88, 1-22.

Le Heron, D., Sutcliffe, O., Bourgig, K., Craig, J., Visentin, C. and Whittington, R., 2004. Sedimentary architecture of Upper Ordovician tunnel valleys Gargaf Arch, Libya: implication for the genesis of a hydrocarbon reservoir. Geoarabia, 9, 137-159.

Le Heron, D. P., Sutcliffe, O. E., Whittington, R. J., and Craig, J., 2005. The origins of glacially related soft-sediment deformation structures in Upper Ordovician glaciogenic rocks: implication for ice-sheet dynamics. Palaeogeography. Palaeoclimatolology, Palaeoecology, 218, 75-103.

Le Heron, P., Craig, J., Sutcliffe, O. E. and Whittington, R., 2006. Late Ordovician glaciogenic reservoir heterogeneity: an example from the Murzuq Basin, Libya. Marine and Petroleum Geology, 23, 655-677.

Le Heron, D. P., Craig, J., 2008. First-order reconstructions of a Late Ordovician Saharan ice sheet. Journal of the Geological Society, London, 165, 19-29.

Le Heron, D. P., Khoukhi, Y., Paris, F., Ghienne, J.F., and Le Hérissé, A., 2008. Black shale, grey shale, fossils and glaciers: Anatomy of the Upper Ordovician-Silurian succession in the Tazzeka Massif of eastern Morocco. Gondwana Research, 14, 483-496.

Le Heron, D. P., Armstrong, H. A., Wilson, C., Howard, J. P. and Gindre, L., 2010. Glaciation and deglaciation of the Libyan Desert: the Late Ordovician record. Sedimentary Geology, 223, 100-125.

Leiming, Y., 1995. Early Ordovician acritarchs from Hunjiang region, Jilin, and Yichang region, Hubei, China. Palaeontologia Sinica, 185, 1-170.

Leiming, Y., Wicander, R., Yan, K., and Zhu, H., 2006. An Upper Ordovician acritarch and prasinophyte assemblage from Dawangou, Xinjiang, northwestern China: Biostratigraphic and paleogeographic implications, Review of Palaeobotany and Palynology, 139, 97-128.

Li, J., 1987. Ordovician acritarchs from the Meitan Formation of Guizhou province, South-West China. Palaeontology, 30, 613-634.

Li, J., 1989. Early Ordovician Mediterranean province acritarchs from Upper Yangtze Region, China. In: Developments in Geoscience: Contribution to the 28th Geological Congress 1989, Washington, DC. Chinese Academy of Science, Beijing, 231-234.

Li, J., 1995. Ordovician (Caradoc) acritarchs from Qilang Formaton of Kalpin, Xinjiang, China Acta Geologica Sinica, 34, 454–467 (in Chinese with English abstract).

Li, J., Wang, Y., 1997. Ordovician acritarchs from boreholes in the Tarim Basin. Acta Micropalaeontologica Sinica, 14, 175–190 (in Chinese with English abstract).

Li, J., Wang, Y., Oi, Y., Zhu, Y., 2000. Late Ludlow-Early Pridoli palynomorphs from Northern Jiangsu, South China. In: Song, Z. (Ed.), Palynofloras and palynomorphs of China. Press of University of Science and Technology of China, Hefei, 138-143.

Li, J., Servais, T., Brocke, R., 2002. Chinese Palaeozoic acritarch research: review and perspectives. Review of Palaeobotany and Palynology, 118, 181-193.

Li, J., Servais, T., Yan, K., Zhu, H., 2004. A nearshore-offshore trend in the acritarch distribution of the Early-Middle Ordovician of the Yangtze Platform, South China. Review of Palaeobotany and Palynology, 130, 141-161.

Li, J., Wicander, R., Yan, K., and Zhu, H., 2006. An Upper Ordovician acritarch and prasinophyte assemblage from Dawangou, Xinjiang, northwestern China: biostratigraphics and paleogeographics implication. Review of Palaeobotany and Palynology, 139, 97-128.

Li, J., Servais, T., Van, K., Su, W., 2007. Microphytop/ankton diversity curves of the Chinese Ordovician. Bulletin de la Societe geologique de France, 178, 399-409.

Lianda, G. , 1991. Acritarch from the Lower Ordovician Hongshiyan Formation of Wuding, Yunnan Geology Review, 37, 445-455.

Lister, T. R., 1970. A monograph of the acritarchs and Chitinozoa from the Wenlock and Ludlow Series of the Ludlow and Millichope areas, Shropshire. Part I. Palaeontographical Society (Monographs), 124, 1-100.

Lister, T. R., Downie, C., 1974. The stratigraphic distribution of the acritarch in the Ludlow succession at Ludlow. Review of Palaeobotany and Palynology, 18, 25-27.

Loeblich, A. R. Jr., Drugg, W.S., 1968. New acritarchs from the Early Devonian (Late Gedinnian) Haragan Formation of Oklahoma, USA. Tulane Studies in Geology, 6, 129-137.

Loeblich, A. R. Jr., Tappan, H., 1969. Acritarch excystment and surface ultrastructure with descriptions of some Ordovician taxa. Revista Espanõla de Micropaleontológia, 1, 45-57.

Loeblich. A. R., 1970. Morphology, Ultrastructure and distribution of Palaeozoic acritarch. Proceeding of the North American Paleontological Convention. Pt G, 705-788.

Loeblich Jr., A. R., MacAdam, R. B., 1971. North American species of the Ordovician acritarch genus *Aremoricanium*. Palaeontographica Abteilung B, 135, 41-47.

Loeblich, A. R. Jr., Tappan, H., 1971. Two new *Orthosphaeridium* (Acritarcha) from the Middle and Upper Ordovician. Transactions of the American Microscopical Society, 90, 182-188.

Loeblich. A. R., H., 1976. Some new and revised organic walled phytoplankton microfossil genera. Journal of Paleontology. 50, 301-308

Loeblich. A. R., Wicander, E. R., 1976. Organic walled microplankton from the lower Devonian late Gedinian Haragan and Bois'd Arc formation of Oklahoma, USA Abteilung B, 159, 1-39.

Loeblich Jr., A. R., Tappan, H., 1976. Some new and revised organic-walled phytoplankton microfossil genera. Journal of Paleontology, 50, 301-308.

Loeblich Jr., A. R., Tappan, H. 1978. Some Middle and Late Ordovician microphytoplankton from central North America. Journal of Paleontology 52, 1233-1287.

Loydell, D. K., 1998. Early Silurian sea-level changes. Geological Magazine, 135, 447-471.

Loydell, D. K., Kaljo, D., Männik, P. 1998. Integrated biostratigraphy of the lower Silurian of the Ohesaare core, Saaremaa, Estonia. Geological Magazine, 135, 769-783.

Loydell, D. K., Männik, P., Nestor, V. 2003. Integrated biostratigraphy of the lower Silurian of the Aizpute-41 core, Latvia. Geological Magazine, 140, 205-229.

Loydell, D. K., Nestor, V. 2005. Integrated graptolite and chitinozoan biostratigraphy of the upper Telychian (Llandovery, Silurian) of the Ventspils D-3 core, Latvia. Geological Magazine, 142, 369–376.

Loydell, D. K. 2007. Graptolites from the Upper Ordovician and Lower Silurian of Jordan. Special Papers in Palaeontology 78, 1–66.

Loydell, D. K., Butcher, A., Frýda, J., Lüning, S., Fowler, M., 2009. Lower Silurian “Hot Shales” in Jordan: a new depositional model. Journal of Petroleum Geology, 32, 261-270.

Loydell, D. K., Nestor, V., Männik, P. 2010. Integrated biostratigraphy of the lower Silurian of the Kolka-54 core, Latvia. Geological Magazine, 147, 253-280.

Loydell. D. K. 2012. Graptolite biostratigraphy of the E1-NC174 core, Rhuddanian (lower Llandovery, Silurian), Murzuq Basin (Libya). Bulletin of Geosciences, 87, 651-660.

Lüning, S., Craig, J., Fitches, W. R., Mayouf, J., Busrewil, A., El Dieb, M., Gammudi, A., Loydell, D. K., McIlroy, D., 1999. Re-evaluation of the petroleum potential of the Kufra Basin (SE Libya, NE Chad): does the source rock barrier fail?. Marine and Petroleum Geology 16, 693-718.

Lüning, S., Craig, J., Loydell, D. K., Storch, P., Fitches, W. R., 2000. Lower most Silurian 'hot shales' in North Africa and Arabia: regional distribution and depositional Model. Earth Science Reviews 49, 121-200.

Lüning, S., Kolonic, S., Loydell, D., Craig, J., 2003. Reconstruction of the original organic richness in weathered shale outcrops (Murzuq and Kufra Basins, southern Libya). GeoArabia, 8, 299-308.

Mabillard, J. E., Aldridge, R. J., 1985. Microfossil distribution across the base of the Wenlock Series in the type area. Palaeontology, 28, 89-100

Mădler, K. A., 1963. Die figurierten organischen Bestandteile der Posidonienschiefer. Geologisches Jahrbuch Beihefte, 58, 287-406.

Mamgain, V. D. 1980. The pre-Mesozoic (Precambrian to Palaeozoic) statigraphy of Libya - a reappraisal. Bulletin No. 14. Industrial Research Centre, Tripoli, 104pp.

Maletz, J., Servais, T., 1993. Acritarchs and graptolites from the Early Llanvirn (Ordovician) of the Herscheider Schichten (Reinische Schiefergerbirge, Germany). Neues Jahrbuch für Geologie und Paläontologie. Abhandlungen, 190, 125-142.

Martin, F., 1965. Les Acritarches de Sart-Bernard (Ordovicien belge). Bulletin de la Société Belge du Géologie. Paléontologie et Hydrologie 74, 423–444.

Martin, F., 1966. Les Acritarches du sondage de la brasserie Lust, à Kortrijk (Courtrai) (Silurien belge). Bulletin de la Société belge de Géologie, Bruxelles, 74, 354-400.

Martin, F., 1969. Les acritarches de l'Ordovicien et du Silurien belges. Détermination et valeur stratigraphique. Mémoires de l'Institut Royale du Sciences Naturelles du Belgique, 160, 1-175.

Martin, F., 1973. Les acritarches de l'Ordovicien inférieur de la Montagne Noire (Hérault, France). Bulletin de l'Institut Royale des Sciences Naturelles de Belgique, 48, 1-61.

Martin, F., 1974. Ordovicien supérieur et Silurien inférieur à Deerlijk (Belgium). Palynofacies et microfacies. Memoire Institut royal des Sciences naturelles de Belgium, Brussels, 174, 1-71.

Martin, F., 1977. Acritarches du Cambro-Ordovicien du Massif du Brabant, Belgique. Bulletin de l'Institut Royale des Sciences Naturelles de Belgique, 51, 1-33.

Martin, F., Rickards, B., 1979. Acritarchs, chitinozoaires et graptolithes Ordoviciens et Siluriens de la vallee de la Sennette (Massif du Brabant, Belgique). Annales de la Société géologique de Belgique, 102, 181-197.

Martin, F., 1980. Quelques chitinozoaires et acritarches ordoviciens supérieurs de la formation de White Head en Gaspésie Québec, Canadian Journal of Earth Sciences, 17, 106-117.

Martin, F., 1982. Some aspects of late Cambrian and early Ordovician acritarchs. In: Bassett, M.G., Dean, W.T. (Eds), The Cambrian-Ordovician Boundary: Sections, Fossil Distributions, and Correlations. Geological Series-National Museum of Wales, 3, 29-40.

Martin, F., 1983. Chitinozoaires et acritarches ordoviciens de la plate-forme du Saint-Laurent (Québec et sud-est de l'Ontario). Geological Survey of Canada Bulletin, 310, 1–59.

Martin, F., 1988. Late Ordovician and Early Silurian acritarchs. In: Cocks, L. R. M., Rickards, R. B. (Eds), A global analysis of the Ordovician-Silurian boundary. Bulletin of the British Museum (Natural History), Geology Series, 43, London, 299–309.

Martin, F., Dean, W. T., 1988. Middle and Upper Cambrian acritarch and trilobite Zonation at Manuels River and Random Island, eastern Newfoundland, Geological Survey of Canada Bulletin, 381, 1-91.

Martin, F., 1992. Uppermost Cambrian and lower Ordovician acritarchs and lower Ordovician chitinozoans from Wilcox Pass, Alberta. Bulletin Geological Survey of Canada, 420, 1-40.

Martin, F., 1993. Acritarchs: a review. Biological Review 68, 475-538.

Martin, F., 1996. Systematic revision of the acritarch *Ferromia pellita* and its bearing on lower Ordovician stratigraphy. Review of Palaeobotany and Palynology, 93, 23- 34.

Martin, F., Yin, L. M., 1988. Early Ordovician acritarchs from southern Jilin Province, North-East China. Palaeontology 31, 109-127.

Masiak, M., Podhalanska, T., Stempien-Salek, M., 2003. Ordovician-Silurian boundary in the Bardo Syncline, Holy Cross Mountains, Poland-new data on fossil assemblages and sedimentary succession. Geological Quarterly, 47, 311-330.

Massa, D., Collomb, G. R., 1960. Observations nouvelles sur la region d'Aouinet Ouenine et du Djebel Fezzan (Libye). 21st International Geological Congress Proceeding, 12, Copenhagen, 65-73.

Massa, D., Havlicek, V. and Bonnefous, J. 1977. Stratigraphie and faunal data on the Ordovician of the Rhadames (Ghadames) Basin (Libya and Tunisia). Bulletin Centre de Recherche d' Exploration et Production, Elf-Aquit, 2, 3-27.

Masran, T. C., Pocock, S. A. J., 1981. The classification of plant-derived particulate organic matter in sedimentary rocks. In: Brooks, J. (Eds), Organic Maturation Studies and Fossil Fuel Exploration, London, Academic Press. 145-176.

Mauller, P. M., Pereira, E., Grahn, Y., Steemans, P., 2004. Anàlise Biostratigràfica do interval Llandoveriano da Bacia do Paranàno Paraguai Oriental. Revista Brasileira de Paleontologia 7, 199-212.

Maziane-Serraj, N., Brück, P. M., Higgs, K. T., and Vanguestaine, M., 2000. Ordovician and Silurian acritarch assemblages from the west Leinster and Slievenamon areas of southeast Ireland. Review of Palaeobotany and Palynology, 113, 57-71.

McClure, H.A 1988. Chitinozoan and acritarch assemblages, stratigraphy and biogeography of the Early Palaeozoic of northwest Arabia. Review of Palaeobotany and Palynology, 56, 41-60.

McDougall, N. and Martin, M. 2000. Facies models and sequence stratigraphy of upper Ordovician outcrops in the Murzuk Basin, SW Libya. In: Sola, M. A., Worsley, D. (Eds), Geological Exploration in the Murzuq Basin. Elsevier Science B.V., 223-236.

McDougall, N. And Gruenwald, R., 2011. Ice in the Sahara: The Upper Ordovician Glaciation in southwest Libya- a subsurface perspective. 11th International Symposium on the Ordovician System, Spain, 347-352.

Mehrjerdi, H., 2001. Palynostratigraphy and Palaeobiogeography of a Lower Palaeozoic Sequence in the Type-Section of Shirgesht Formation, Northern

Tabas City, East-Central Iran, Iranian International Jornal of Science. 2(2). No pages no.

Melchin, M. J., Williams, S. H., 2000. A restudy of the akidograptine graptolites from Dobb‘s Linn and a proposed redefined zonation of the Silurian Stratotype. Palaeontology Down Under 2000, Geological Society of Australia, 61, 63pp.

Melchin, M. J., Cooper, R. A., Sadler, P. M., 2004. The Silurian Period. In: Gradstein, F.M., Ogg, J.G. Smith, A.G. (Eds), A Geologic Time Scale 2004. Cambridge University Press, Cambridge, 188-201.

Mette, W., 1989. Acritarchs from Lower Palaeozoic rocks of the western Sierra Morena, SW-Spain and biostratigraphic results. Geologica et Palaeontologica, 23, 1-19.

Miller, M.A., Eames, L.E., 1982. Palynomorphs from the Silurian Medina Group (Lower Llandovery) of the Niagara Gorge, Lewiston, New York, U.S.A. Palynology, 6, 221-254.

Miller, M.A., 1987. A diagnosis excystment sucture in the Silurian acritarchs *Circinatisphaera aenigma* Gen Et. sp.nov, Palynology, 11, 97-105.

Miller, M. A., 1991. *Paniculaferum missouriensis* gen. et sp. nov., a new Upper Ordovician acritarch from Missouri, U.S.A. Review of Palaeobotany and Palynology, 70, 17-223.

Miller, M. A., 1996. Chitinozoa. In: Jansonius, J., McGregor, D.C. (Eds), Palynology: Principles and Applications, Volume 1. American Association of Stratigraphic Palynologists Foundation, 307-336.

Miller, M. A., Playford, G., Le Hérissé, A., 1997. *Clypeolus*, A new acritarch genus from the Ordovician and Silurian. Review of Palaeobotany and Palynology, 98, 95-103.

Miller, M. A, Al-Ruwaili, M. H., 2007. Preliminary palynological investigation of Saudi Arabian Upper Ordovician glacial sediments. Revue de Micropaleontologie, 50, 17-26.

Millward, D., Molyneux, S. G., 1992. Field and biostratigraphic evidence for an unconformity at the base of the Eycott Volcanic Group in the English Lake District. Geological Magazine, 129, 77-92.

Mitchell, C. E., Chen Xu, Bergstrom, S. M., Yuan-dong, Z., Zhi-hao, W., Webby, B. D., Finney, S. C., 1997, Definition of a global boundary stratotype for the Darriwilian Stage of the Ordovician System. Episodes 20, 158-66.

Mizusaki, A. M. P., de Melo, J. H. G., Vignol-Lelarge, M. L., and Steemans, P., 2002. Vila Maria Formation (Silurian, Parana Basin, Brazil): Integrated radiometric and palynological age determinations. Geological Magazine, 139, 453-463.

Moczydlowska, M., Crimes, T. P, 1995, Late Cambrian acritarchs and their age constraints on an Ediacaran-type fauna from the Booley Bay Formation, Co. Wexford (Eire). Geology Journal , 30, 111-128.

Moczydłowska, M., 1998. Cambrian acritarchs from Upper Silesia, Poland-biochronology and tectonic implications. Fossils and Strata, 46, 121pp.

Moczydłowska, M., 2005. Taxonomic review of some Ediacaran acritarchs fromthe Siberian Platform. Precambrian Research, 136, 283-307.

Molyneux, S. G., 1979. New evidence for the age of the Manx Group, Isle of Man: In A. L. Harris, C. H. Holland and B. E. Leake (Eds). The Caledonides of the British Isles-Reviewed. Special Publication of the Geological Society of London, 415-423.

Molyneux, S. G., Paris, F., 1985. Late Ordovician palynomorphs. In: Thusu, B., Owens, B. (Eds), Palynostratigraphy of North-East Libya. Journal of Micropalaeontology, 4, 11-26.

Molyneux, S. G., 1987. Acritarchs and Chitinozoa from the Arenigian Series of south-west Wales. Bulletin of the British Museum, Natural History. Geology 41, 309-364.

Molyneux, S. G., 1988. Late Ordovician acritarchs from northeast Libya. In: El-Arnauti, A, Owens, B., Thusu, B, (Eds.), Subsurface Palynostratigraphy of Northeast Libya. Garyounis University Publishing, Benghazi, 45-59.

Molyneux, S. G., Paris, F., 1988. Late Ordovician palynomorphs. Journal of Micropalaeontology, 4, 11-26.

Molyneux, S. G., Rushton, A. W. A., 1988. The age of the Watch Hill Grits (Ordovician), English Lake District: structural and palaeogeographical implications. Transactions of the Royal Society of Edinburgh, Earth Sciences, 79, 43-69.

Molyneux, S. G., Dorning, K. J., 1989. Acritarch dating of latest Tremadocian–earliest Arenigian (early Ordovician) sediments in the Carmarthen district, South Wales. Geological Magazine, 126, 707-714.

Molyneux, S. G., 1990. Advances and problems in Ordovician palynology of England and Wales. Journal of the Geological Society (London), 147, 615-618.

Molyneux, S. G., Le Hérissé, A., Wicander, R., 1996. Palaeozoic phytoplankton. In: Jansonius, J., McGregor, D.C. (Eds), Palynology: Principles and Applications, vol. 2. American Association of Stratigraphic Palynologists Foundation, Salt Lake City, UT, 493–530.

Molyneux, S. G., Al-Hajri, S., 2000. Palynology of a problematic Lower Palaeozoic lithofacies in Central Saudi Arabia. In: Al-Hajri, S., Owens, B. (Eds), Stratigraphic Palynology of the Palaeozoic of Saudi Arabia. Special GeoArabia Publication 1, Gulf Petrolink, Bahrain, 18-41.

Molyneux, S. G. Osterloff, P., Penney, R. Spaak, P. 2006. Biostratigraphy of the Lower Palaeozoic Haima Supergroup, Oman; its application in sequence stratigraphy and hydrocarbon exploration. GeoArabia, 11, 17-48.

Molyneux, S. G., Barron, H. F., Smith, R. A. 2008. Upper Llandovery-Wenlock (Silurian) palynology of the Pentland Hills inliers, Midland Valley of Scotland, British Geological Survey, 1-22.

Molyneux, S. G., 2009. Acritarch (marine microphytoplankton) diversity in an Early Ordovician deep-water setting (the Skiddaw Group, northern England): Implications for the relationship between sea-level change and phytoplankton diversity. Palaeogeography, Palaeoclimatology, Palaeoecology, 275, 59-76.

Morávek, R., 2008. Late Ludlovian Chitinozoa from the locality “Na Požárech” (Silurian, Prague Basin, Barrandian area, Czech Republic). Review of Palaeobotany and Palynology, 148, 124-135.

Moreau-Beniot, A., 1969. Etude palynologique des formations schisto-gréseuses associées au Calcaire de Chalonnes aux carriéres Saint-Charles et Tarare en Chaudefonds (Maine-et-Loire). Bulletin de la Société d′Etudes Scientifiques de l'Anjou, new set, 7, 93-99.

Moreau-Benoit, A., 1974. Recherches de palynologie et de planctologie sur le Dévonien et quelques formations silurien-nes dans le Sud-est du Massif Armoricain. Mémoire de la Société géologique et minéralogique de Bretagne, 18, 1-248.

Mullins, G. L. 2000. A chitinozoan morphological lineage and its importance in lower Silurian stratigraphy. Palaeontology, 43, 359-373.

Mullins, G. L., Loydell, D. K., 2001. Integrated Silurian chitinozoan and graptolite biostratigraphy of the Banwy River section, Wales. Palaeontology, 44, 731-781.

Mullins, G. L. 2001. Acritarchs and prasinophyte algae of the Elton Group, Ludlow Series, of the type Ludlow area. Monograph of the Palaeontographical Society, 615, 1-151.

Mullins, G. L., Loydell, D. K., 2002. Integrated lower Silurian chitinozoan and graptolite biostratigraphy of Buttington Brick Pit, Wales. Geological Magazine, 139, 89-96.

Mullins, G. L. 2004. Microplanktonic biostratigraphy of the Bringewood group, Ludlow series, Silurian, of the Type area, Journal of Systematic Palaeontology 2, 163-205.

Mullins, G. L., Aldridge, R. J., 2004. Chitinozoan biostratigraphy of the basal Wenlock Series (Silurian) global stratotype section and point. Palaeontology, 47, 745-773.

Mullins, G., L., Aldridge, R. J., Siveter, D. J., 2004. Microplankton associations, biofacies and palaeoenvironment of the type lower Ludlow Series, Silurian. Review of Palaeobotany and Palynology. 130, 163-194.

Nestor, V., 1980. New chitinozoan species from the lower Llandoverian of Estonia. Proceedings of the Estonian Academy of Sciences (Eesti NSV Teaduste Akadeemia Toimetised) Geoloog´ıa, 29, 98–107 (in Russian with English summary).

Nestor, V., 1982a. New Wenlockian species of *Conochitina* from Estonia. Eesti NSV Teaduste Akadeemia Toimetised, 31, 105-111.

Nestor, V., 1982b. Chitinozoan zonal assemblages (Wenlock, Estonia). 84-97. In Kaljo, D. and Klaamann, E. (eds). Communities and biozones in the Baltic

Silurian. Academy of Sciences of the Estonian SSR Institute of Geology, Tallinn, 140pp.

Nestor, V., 1982c. Correlation of the East-Baltic and Gotland Silurian by Chitinozoans. 89-95. In Kaljo, D. and Klaamann, E. (Eds). Ecostratigraphy of the East Baltic Silurian. Academy of Sciences of the Estonian SSR Institute of Geology, Tallinn, 109pp.

Nestor, V., 1984. Distribution of chitinozoans in the Late Llandoverian Rumba Formation (*Pentamerus oblongus* beds) of Estonia. Review of Palaeobotany and Palynology, 43, 145-53.

Nestor, V., 1990. Silurian chitinozoans. 80-83. In Kaljo, D., Nestor, H. (eds). Field meeting, Estonia. An excursion guidebook. Estonian Academy of Sciences, Tallinn, 209pp.

Nestor, V., 1993. Chitinozoans at the Llandovery-Wenlock transition in the Jaagarahu core, Estonia. Proceedings of the Estonian Academy of Sciences, 42, 167-175.

Nestor, V., 1994. Early Silurian chitinozoans of Estonia and North Latvia. Academia, 4, 1–163.

Nestor, V., Einasto, R., 1997. Ordovician and Silurian carbonate sedimentation basin. In: Raukas, A., Teedumäe, A. (Eds.), Geology and Mineral Ressources of Estonia. Estonian Academy Publishers, Tallinn, 192–204.

Nestor, V., 1998. Chitinozoan biofacies of late early Llandovery (Coronograptus cyphus) age in the East Baltic. Proceedings of the Estonian Academy of Sciences, Geology, 4, 219–228.

Nestor, V., 1999. Distribution of chitinozoans in the Llandovery of the Oslo region. Bolletino della Società Paleontologica Italiana, 38, 227-238.

Nestor, V. 2003. Distribution of Silurian chitinozoans. In Ruhnu (500) Drill Core (Põldvere, A., ed.), Estonian Geological Sections, 5, 13-14.

Nestor, V. 2007. Chitinozoans in the Wenlock-Ludlow boundary beds of the East Baltic. Estonian Journal of Earth Sciences, 56, 109-128.

Nestor, V., 2009. Biostratigraphy of the Ludlow chitinozoans from East Baltic drill cores. Estonia Journal of Earth Sciences, 58, 170-184

Neville, R. W., 1974. Ordovician Chitinozoa from western Newfoundland. Review of Palaeobotany and Palynology, 18, 187-221.

Nicoll, R. S., Nielsen, A. T., Laurie, J. R., Shergold, J. H., 1992. Preliminary correlation of latest Cambrian to Early Ordovician sea level events in Australia and Scandinavia. In: Webby, B. D., Laurie, J. R. (Eds), Global Perspectives on Ordovician Geology. Proceedings of the International Symposium on the Ordovician System 6, Elsevier, Rotterdam, 381-394.

Nielsen, A. T., 1992. Ecostratigraphy and the recognition of Arenigian (Early Ordovician) sea-level changes. In: Webby, B. D., Laurie, J. R. (Eds), Global Perspectives on Ordovician Geology. Proceedings of the International Symposium on the Ordovician System 6, Elsevier, Rotterdam, 355-366

Nielsen, A. T., 2004. Ordovician sea-level changes: a Baltoscandian perspective. In: Webby, B. D., Paris, F., Droser, M., Percival, I. (Eds), The Great Ordovician Biodiversification Event. Columbia University Press, New York, 84-93.

Nõlvak, J., 1980. Chitinozoan in biostratigraphy of the northern East Baltic Ashgillian. A preliminary report. Acta Palaeontologica Polonica, 25, 253-260.

Nõlvak, J., Grahn, Y., 1993. Ordovician chitinozoan zones from Baltoscandia. Review of Palaeobotany and Palynology, 79, 245-69.

Oliveira, S. F., Lima, M. R. 1990. Acritarcas silurianos da Formação Trombetas, bacia do Amazonas.Revista do Instituto de Geociências USP, 11, 43-50.

Ottone, E. G., Toro, B.A., Waisfeld, B.G., 1992. Lower Ordovician palynomorphs from the Acoite Formation, northwestern Argentina. Palynology, 16, 93-116.

Otton, E. G., 1996. Devonian palynomorphs from the Los Monos Formation, Tarija Basin, Argentina. Palynology, 20, 105-155.

Ottone, E. G., Albanesi, G. L., Ortega, G., Holfeltz, G. D., 1999. Palynomorphs, *Conodonts* and Associated *Graptolites* from the Ordovician Los Azules Formation, Central Precordillera, Argentina. Micropaleontology, 45, 225-250

Ottone, E. G., Holfeltz, G. D., Albanesi, G. L., Ortega, G., 2001. Chitinozoans from the Ordovician Los Azules Formation, Central Precordillera, Argentina micropaleontology, 47, 97-110.

Oulebsir, L., Paris, F., 1993. Nouvelles espèces de chitinozoaires dans l'Ordovicien inférieur et moyen du sud-est du Sahara Algérien. Revue de Micropaléontologie, 36, 257-280.

Oulebsir, L., Paris, F., 1995. Chitinozoaires ordoviciens du Sahara algérien: biostratigraphie et affinités paléogéographiques. Review of Palaeobotany and Palynology, 86, 49-68.

Padilha de Quadros, L., 1986. Occorencia de Microfosseis (Acritarchae) Ordovicianos na sub-Bacia do Alto Amazonas, Brasil. Boletim tecnico da, Petrobras, 29, 181-191.

Padilha de Quadros, L., 1988. Zoneamento Bioestratigrafico do Paleozoico inferior e medic (Seiao Marinha) da Bacia do Solimoes. Boletim de geociencias da Petrobras, 2, 95-110.

Palacios, T., Jensen, S., Barr, S. M., White, C. E., 2009. Acritarchs from the MacLean Brook Formation, southeastern Cape Breton Island, Nova Scotia, Canada: New data on Middle Cambrian-Lower Furongian acritarch zonation. Palaeogeography, Palaeoclimatology, Palaeoecology, 273, 123-141.

Paris, F., Deunff, J., 1970. Le paleoplancton llanvirnien de la Rocheau-Merle (Commune de Vieux-Vy-sur-Coueson, Ile-et-Vilaine). Bulletin de la Société Géologique et Mineralogique de Bretagne. 2, 25-43.

Paris, F., 1978. Apports du microscope électronique à balayage dans l'étude des Chitinozoaires opaques. Annales des Mines de Belgique, 2, 193-202.

Paris, F., 1981. Les chitinozoaires dans le Paléozoïque du sud-ouest de l‟Europe (cadre géologique-étude systématique-biostratigraphie). Mémoire de la Société Géologique et Minéralogique de Bretagne, 26, 1-496.

Paris, F., 1988. Late Ordovician and Early Silurian chitinozoans from central and southern Cyrenaica. In: El-Arnauti, A., Owens, B., Thusu, B. (Eds), Subsurface palynostratigraphy of northeast Libya. Garyounis University Publishing, Benghazi, 61-71.

Paris, F., 1988. New Chitinozoans from the Late Ordovician - Late Devonian of northeast Libya. In: El-Arnauti, A., Owens, B., Thusu, B. (Eds.), Subsurface palynostratigraphy of northeast Libya. Garyounis University Publishing, Benghazi, 77-87.

Paris, F., 1990. The Ordovician chitinozoan biozones of the northern Gondwana Domain. Review of Palaeobotany and Palynology, 66, 181-209.

Paris, F., Verniers, J., Al-Hajri, S., Al-Tayyar, H., 1995. Biostratigraphy and palaeogeographic affinities of Early Silurian chitinozoans from central Saudi Arabia. Review of Palaeobotany and Palynology, 89, 75-90.

Paris, F., Al-Hajri, S., 1995. New chitinozoan species from the Llandovery of Saudi Arabia. Micropaleontology, 38, 311-328.

Paris, F., Verniers, J., 1995. Chitinozoa. In: Selley, R. C., Cocks, L. R. M., Plimer, I. R. (Eds), Encyclopedia of Geology. Elsevier, 3, 428-440.

Paris, F., 1996. Chitinozoan biostratigraphy and palaeogeography. In: Jansonius, J., McGregor, D.C. (Eds), Palynology: Principles and Applications, Volume 2, American Association of Stratigraphic Palynologists Foundation, 531-552.

Paris, F., Deynoux, M., Ghienne, J. F., 1998. Découverte de chitinozoaires à la limite Ordovicien-Silurien en Mauritanie implications paléogéographiques. Comptes Rendus de l‟Académie des Sciences, 326, 499-504.

Paris, F., Grahn, Y., Nestor, V., Lakova, I., 1999. A revised chitinozoan classification. Journal of Paleontology, 73, 549-570.

Paris, F., Verniers, J., Al-Hajri, S., 2000a. Ordovician Chitinozoans from Central Saudi Arabia. In: Al-Hajri, S., Owens, B. (Eds), Stratigraphic Palynology of the Palaeozoic of Saudi Arabia. GeoArabia Special Publication, 1, 42-56.

Paris, F., Bourahrouh, A., Le Herisse, A, 2000b. The effects of the final stages of the Late Ordovician glaciations on marine palynomorphs (chitinozoans, acritarchs, leiospheres) in well NI-2 (NE Algerian Sahara). Review of Palaeobotany and Palynology, 113,87-104.

Paris, F., Achab, A., Asselin, E., Chen, X., Grahn, Y., Nolvak, J., Obut, O., Samuelsson, J., Sennikov, N., Vecoli, M., Verniers, J., Wang X., Winchester-Seeto, T., 2004. Chitinozoa. In: Webby, B.D, Paris, F., Droser, M., Percival, I. (Eds), The Great Ordovician Biodiversification Event. Columbia University Press, New York, 294-311.

Paris, F., Le Herisse, A, Monod, O. Kozlu, H., Ghienne, J.F., Dean, W.T., Vecoli, M., and Gonay, Y., 2007. Ordovician chitinozoans and acritarchs from southern and southeastern Turkey. Revue de Micropaléontologie, 50, 81-107.

Paris, F., Thusu B., Rasul S., Meinhold G., Strogen D., Howard J. P., Abutarruma Y., Elgadry M., and Whitham A. G., 2012 Palynological and palynofacies analysis of early Silurian shales from borehole CDEG-2a in Dor el Gussa, eastern Murzuq Basin, Libya. Review of Palaeobotany and Palynology, 174, 1-26

Parizek, A., Klen, L., Rohlich, P., 1984. Geological map of Libya, 1:250,000, Sheet: Idris NG 33-1, Explanatory Booklet, 1-108, Industrial Research Center, Libya.

Pasquo, M. M., Noetinger, S., 2008. First record of Early Devonian (Lochkovian) flora from the Santa Rosa Formation - Alarache, Southern Bolivia Geologica Acta, 6, 191-210.

Pascher, A., 1914. Über Flagellaten und Algen. Berichte der deutschen botanischen Gesellschaft, 32, 136–160.

Pierobon, E. S. T. 1991 Contribution to the stratigraphy of the Murzuk Basin, Southwest Libya. In: Salem, M. J. and Bbelaid, M. N. (Eds). The Geology of Libya, 5, 1769-1784.

Playford, G., 1977. Lower to Middle Devonian acritarchs of the Moose River Basin, Ontario, Geological Survey of Canada, Bulletin, 279, 1-87.

Playford, G., Martin, F., 1984. Ordovician acritarchs from the Canning Basin, Western Australia. Alcheringa, 8,187-223.

Playford, G., Ribecai, C., Tongiorgi, M., 1995. Ordovician genera *Peteinosphaeridium, Liliosphaeridium,* and *Cycloposphaeridium:* morphology, taxonomy, biostratigraphy, and palaeogeographic significance. Bollettino delia Societa Paleontologica Italiana, 34, 3-54.

Playford, G., Wicander, R., 2006. Organic-walled microphytoplankton of the Sylvan Shale (Richmondian: Upper Ordovician), Arbuckle Mountains, southern Oklahoma U.S.A. Oklahoma Geological Survey Bulletin, 148, 1-116.

Porębska, E., Kozyowska-Dawidziu, A., Masiak, M., 2004. The *lundgreni* event in the Silurian of the East European Platform, Poland. Palaeogeography, Palaeoclimatology, Palaeoecology, 213, 271-294.

Pöthé de Baldis, E. D., 1971. Microplancton del Siliirico superior de la provincia de Santiago del Estero, Republica Argentina. Ameghiniana, 8, 282-290.

Pöthé de Baldis, E. D., 1974. El microplanction del Devonico medio de Paraguay. Revista Española de Micropaleontologia, 6, 367-379.

Pöthé de Baldis, E.D., 1975. Microplancton del Wenlockiano de la Precordillera Argentina. Revista Española de Micropaleontologia, 7, 489-505.

Pöthé de Baldis, E. D., 1978. Paleomicroplancton adicional del Devonico inferior de Uruguay- Revista Española de Micropaleontologia, 9, 235-250.

Pöthe de Baldis, E. D. 1997. Acritarcas del Llandoveriano temprano- medio de la Formación Don Braulio, Precordillera Oriental, provincia de San Juan, Argentina. Revista Española de Micropaleontología 29, 31-68.

Potonié, R., Lele, K. R., 1961. Studies in the Talchir flora of India. Sporae dispersae from the Talchir beds of South Rewa, Gondwana Basin. The Palaeobotanist, 8, 22-37.

Poumot, C. 1968. *Arnphorachitina, Ollachitina, Velatachitina,* trios nouveaux genres de Chitinozoaires de l'Erg oriental (Algérie-Tunisie). Bulletin du Centre de Recherche de Pau, 2, 45-55.

Priewalder H., 1997. SEM-Revision of a chitinozoan assemblage from the uppermost San Pedro Formation (Pridoli) Cantabrian Mountain (Spain). Jahrbuch der Geologischen Bundesanstalt, 140, 73-93.

Punt, W., Hoen, P. P., Blackmore, S., Nilsson, S., and Le Thomas, A., 2007. Glossary of pollen and spore terminology. Review of Palaeobotany and Palynology, 143, 1–81

Quadros, 1999. Novos acritarcos do Devoniano superior da Bacia do Amazonas Acta Geologica Leopoldensia, 23, 15-27.

Quintavalle, M., Tongiorgi, M., Gaetani, M., 2000. Lower to Middle Ordovician acritarchs and chitinozoans from northern Karakorum mountains, Pakistan. Rivista Italiana di Paleontologia e Stratigrafia, 106, 3-18.

Quintavalle, M., Playford, G., 2006a. Palynostratigraphy of Ordovician strata, Canning Basin, Western Australia. Part One: acritarchs and prasinophytes. Palaeontographica B, 275, 1-88

Quintavalle, M., Playford, G., 2006b. Palynostratigraphy of Ordovician strata, Canning Basin, Western Australia. Part Two: chitinozoans and biostratigraphy. Palaeontographica B, 275, 89-131.

Quintavalle, M., Playford, G., 2008. Stratigraphic distribution of selected acritarchs in the Ordovician subsurface, Canning Basin, Western Australia. Revue de Micropaléontologie, 51, 23-37.

Raevskaya, E. G., Volkova, N. A., and Sivertseva, I. A., 2006. The Darriwilian Acritarch Assemblage from Ordovician Deposits of the Arkhangelsk Oblast, the Northern Russian Plate, Stratigraphy and Geological Correlation, 14, 386-398.

Raevskaya, E., Vecoli, M., Bednarczyk, W., and Tongiorgi, M., 2004. “Billingen (Lower Arenig/Lower Ordovician) acritarchs from the East-European Platform

(St. Petersburg Region, Northwestern Russia, and Leba Area, Northwestern Poland) and Their Palaeobiogeographic Significance," Lethaia 37, 97-111.

Ramos, E., Marzo, M., Gibert, j., Tawengi, K., Khoja, A., and Bolatti, N. 2006. Stratigraphy and sedimentology of the Middle Ordovician Hawaz Formation Murzuq Basin, Libya. American Association of Petroleum Geologists, 90, 1309-1336

Rasul, S. M., Downie, C. 1974. The stratigraphie distribution of Tremadoc acritarchs in the Shineton Shales succession, Shropshire, England. Review Palaeobotany Palynology, 18, 1-9.

Rasul, S. M., 1979. Acritarch zonation of the Tremadoc Series of the Sineton Shales, Wrekin, Shropshire, England. Palynology. 3, 53-72.

Rauscher, R., 1970. Les Chitinozoaires de l‟Ordovicien du Synclinal de May-sur- Orne (Clavados). Bulletin de la Société Linnéenne de Normandie, 101-117.

Rauscher, R., 1971. Acritarches du Paléozoique Inférieur de la Montagne Noire. Bulletin du Service de la Carte Géologique d'Alsace-Lorraine, 24, 291-296.

Rauscher, R., 1974. Recherches micropaléontologiques et stratigraphiques dans lʼOrdovicien et le Silurien en France. Étude des acritarches, des chitinozoaires et des spores. Science Géologiques, Université Louis Pasteur de Strasbourg, Institut de géologie Mémoire, 38, 1-224.

Ribecai, C., Tongiorgi, M., 1995. Arenigian acritarchs from Horns Udde (Öland, Sweden): a preliminary report. Review of Palaeobotany and Palynology, 86, 1-11.

Ribecai, C., Tongiorgi, M., 1999. The Ordovician acritarch genus *Pachysphaeridium* Burmann 1970: new, revised, and reassigned species. Palaeontographia Italica, 86, 117-153.

Ribecai, C., Raevskaya, E., Tongiorgi, M., 2002. *Sacculidium* gen. nov. (Acritarcha), a new representative of the Ordovician *Stelomorpha-Tranvikium plexus*. Review of Palaeobotany and Palynology, 121, 163-203.

Richard, R. E., Mullins, G., 2003. Upper Silurian microplanktonic of the Leintwardine group, Ludlow series, in the type Ludlow area and adjacent regions. Palaeontology, 46, 557-611.

Richardson, J. B., Lister, T. R. 1969. Upper Silurian and Lower Devonian spore assemblages from the Welsh Borderland and South Wales. Palaeontology 12, 201-252.

Richardson, J. B., Ioannides, N. S., 1973. Silurian palyynomorphs from the Tanezzut and Acacus formations, Tripoltania North Africa. Micropaleontology, 19, 257-307.

Richardson, J. B., McGregor, D. C., 1986. Silurian and Devonian spore zones of the Old Red Sandsone continent and adjacent area. Geological Survey of Cannadian Bulletin, 364, 1-79.

Richardson, J. B., Rasul, S. M., 1978. Palynomorphs in Lower Devonian sediments from the Apley Barn Borehole, southern England. Pollen et Spores, 20, 423-462.

Richardson, J. B., 1988. Late Ordovician and Early Silurian cryptospores and miospores from northeast Libya. In: El-Arnauti, A., Owens, B., Thusu, B. (Eds), Subsurface palynostratigraphy of northeast Libya. Garyounis University Publishing, Benghazi, 89-109.

Richardson, J. B., Ford, J. H., Parker, F., 1984. Miospores, correlation and age of some Scottish Lower Old Red Sandstone sediments from the Strathmore region (Fife and Angus). Journal of Micropalaeontology, 3, 109-124.

Richardson, J. B., Edwards, D., 1989. Sporomorphs and plant megafossils. In: Holland, C.H., Basset, M.G. (Eds.), A Global Standard for the Silurian System. National Museum of Wales, Geological Series, 9, 216-226.

Richardson, J. B., Rasul, S. M., 1990. Palynofacies in a Late Silurian regressive sequence in the Welsh Borderland and Wales. Journal of the Geological Society, 147, 675-686.

Richardson, J. B., 1996a. Taxonomy and classification of some new Early Devonian cryptospores from England. Special Papers in Palaeontology, 55, 7-40.

Richardson, J. B. 1996b. Chapter 18A . Lower and Middle Palaeozoic records of terrestrial palynomorphs. In: Jansonius, J., McGregor, D.C. (Eds) Palynology: principles and applications. American Association of Stratigraphical Palynologists Foundation, Dallas. 2, 555–574.

Richardson, J. B., 2006. Lower Devonian cryptospores and miospores, their distribution patterns in the Lower Old Red Sandstone of the Anglo-Welsh Basin and the habitat of their parent plants, 44–45. In: Bek, J., Brocke, R., Daškova, J., Fatka, O. (eds) Abstracts, Palaeozoic Palynology in Space and Time, CIMP Meeting Prague.

Richardson, J. B., 2007. Cryptospores and miospores, their distribution patterns in the Lower Old Red Sandstone of the Anglo-Welsh Basin, and the habitat of their parent plants. Bulletin of Geosciences 82, 355–364.

Righi, E., 1991. *Ampullula*, a new acritarch genus from the Ordovician (Arenig-Llanvirn) of Öland, Sweden. Review of Palaeobotany and Palynology, 68, 119-126.

Robertson, E. B, 1997. Fossil microplankton from the upper Ordovician Maquoketa Formation exposed in Pike County, Missouri. Georgia Journal of Science, 55-76.

Ross, C. A., Ross, R. P., 1996. Silurian sea-level fluctuations: In: Witzke, B. J., Ludvigson, G. A., Day, J. (Eds), Paleozoic sequence stratigraphy: views from the North American craton. Geological Society of America Special Paper 306, 187-192.

Ruban, D. A., Al-Husseini, M. I., Iwasaki, Y., 2007. Review of Middle East Paleozoic plate tectonics. GeoArabia, 12, 35-56.

Rubel, M., Hints, O., Männik, P., Meidla, T., Nestor, V., Sarv, L., and Sibul, I. 2007. Lower Silurian biostratigraphy of the Viirelaid core, western Estonia. Estonian journal of Earth Sciences, 56, 193-204

Rubinstein, C. V., 1993. Acritarchs from the upper Silurian of San Juan, Argentina: Biostratigraphy and Paleobiogeography. In: Contributions to acritarch and chitinozoan research (edited by S. Molyneux and K. Doming). Special Papers in Paleontology. 48, 67-78.

Rubinstein, C. V., 1995. Acritarchs from the upper Silurian of Argentina: their relationship with Gondwana. Journal of South American Earth Sciences, 8, 103-115.

Rubinstein, C. V., Toro, B. A., 2001. Review of acritarch biostratigraphy in the Arenig of the Eastern Cordillera, northwestern Argentina: new data and calibration with the graptolite zonation. Contributions to Geology and Palaeontology of Gondwana in Honour of Helmut Wopfner, Köln, 421-439.

Rubinstein, C. V., Steemans, P., 2002. Miospore assemblages from the Silurian-Devonian boundary, in borehole A1-61, Ghadamis Basin, Libya. In: Steemans, P., Servais, T. and Streel, M. (Eds), Palaeozoic Palynology. Review of Palaeobotany and Palynology, 118, 397-421.

Rubinstein, C. V., Toro, B. A., 2003. Palinomorfos del Llandoveriano medio (Aeroniano superior) de la Formación Lipeón. Cordillera Oriental, Argentina. Ameghiniana, Resúmenes, 40, 91-92.

Rubinstein, C. V., Vaccari, N. E., 2004. Cryptospore assemblages from the Ordovician-Silurian boundary in the Puna region, north-west Argentina. Palaeontology 47, 1037–1061

Rubinstein, C. V., 2005. Ordovician to Lower Silurian Playnomorphs from the Sierras Subbandias (Subandean ranges), northwestern Argentina: preliminary report. Camets de Géologie, 51-56.

Rubinstein, C. V., Toro, A. B., 2006. Aeronian (Llandovery, Lower Silurian) palynomorphs and graptolites from the Lipeón Formation, Eastern Cordillera, north-west Argentina. Geobios, 39, 103-111.

Rubinstein, C. V., Gerrienne, P., de la Puente1, G. S., Astini, R. A., and Steemans, P., 2010. Early Middle Ordovician evidence for land plants in Argentina (eastern Gondwana). New Phytologist, 188, 365-369.

Rushton, A. W., Molyneux, S. G. 1989. The biostratigraphic age of the Ordovician Skiddaw Group in the Black Combe Inlier, English Lake District. Proceedings of the Yorkshire Geological Society, 41, 267-276.

Rusk, 2002. Introduction to the Regional Geology of Libya, SEPM sequence stratigraphy Web.

Sansom, I. J., Miller, C. G., Heward, A. P., Davies, N. S., Booth, G. A., Fortey, R. A., and Paris, F., 2009. Ordovician fish from the Arabian Peninsula. Palaeontology, 52, 337-342.

Sarjeant, W. A. S., 1967. Observations on the acritarch genus *Micrhystridium* (Deflandre). Revue de Micropaléontologie, 9, 201-208.

Sarjeant, W. A. S., Stancliffe, R.P.W., 1994. The *Micrhystridium* and *Veryhachium* complexes (Acritarcha: Acanthomorphitae and Polygonomorphitae): a taxonomic reconsideration. Micropaleontology, 40, 1–77.

Sarjeant, W. A. S., Stancliffe, R. P. W., 1996. The acritarch genus *Polygonium*, Vavrdov´a emend Sarjeant and Stancliffe 1994: a reassessment of its constituent species. Annales de la Société géologique de Belgique, 117, 355-369.

Sarjeant, W. A. S., Vavrdov´a, M., 1997. Taxonomic reconsideration of *Multiplicisphaeridium* Staplin, 1961 and other acritarch genera with branching processes. Geolines. 5, 1-52.

Samuelsson, J., Verniers, J., 2000. Ordovician chitinozoan biozonation of the Brabant Massif, Belgium. Review of Palaeobotany and Palynology, 113, 105-123.

Samuelsson, J., Verniers, J., Vecoli, M., 2000. Chitinozoan faunas from the Rügen Ordovician (Rügen 5/66 and Binz 1/73 wells), NE Germany. Review of Palaeobotany and Palynology, 113, 131-143.

Samuelsson, J., Van Roy, P., Vecoli, M., 2001. Micropalaeontology of a Moroccan Ordovician deposit yielding soft-bodied organisms showing Ediacara-like preservation. Geobios, 34, 365-373.

Schallreuter, R., 1963. Neue Chitinozoen aus ordovizischen Geschieben und Bemerkungen zur Gattung Illichitina. Palaeontologische Abhandlungen, 1, 392-405.

Schaarschmidt, F., 1963. Sporen und Hystrichospaerideen aus dem Zechstein von Budingen in der Wetterau. Palaeontographica, Abteilung B, 113, 38-91.

Scotese, C. R., McKerrow, W. S., 1990. Revised world maps and introduction. In: McKerrow, W. S., Scotese, C. R. (Eds), Palaeozoic Palaeogeography and Biogeography. Geological Society, London, Memoir 12, 1-21.

Scotese, C. R., Boucot, A. J., and McKerrow, W. S., 1999, Gondwanan paleogeography and paleoclimatology. Journal of African Earth Sciences 28, 99-144.

Seilacher, A., Luning, S., Martin, M. A., Klitzsch, E., Khoja, A., and Craig, J., 2002. Ichnostratigraphic correlation of Lower Palaeozoic clastics in the Kufra Basin (southeast Libya). Lethaia 35, 257–262.

Sepkoski, J. J., 1995. The Ordovician Radiations: Diversification and extinction shown by global genuslevel taxonomic data. In: Cooper, J. D., Droser, M. L., Finney, S. C. (Eds), Ordovician Odyssey: Short Papers, 7th International Symposium on the Ordovician System. California, 393-396.

Sepkoski, J. J., 1996. Global Biological Events in Earth History. In : O. H. Walliser (Eds). In Global Events and Event Stratigraphy in the Phanerozoic: Results of International Interdisciplinary Cooperation in the IGCP Project 216. (Springer- Verlag, Berlin, 1996), 35–51

Sepkoski, J. J., 1995. In Ordovician Odyssey. In: J. D. Cooper, M. L. Droser, S. C. Finney (Eds): Short papers for the Seventh International Symposium on the Ordovician System (The Pacific Section Society for Sedimentary Geology, Fullerton,), 393-396

Segroves, K. L., 1967 Cutinized microfossils of probable nonvascular origin from the Permian of Western Australia, Micropaleontology. 13, 289-305.

Servais, T., 1991. Contribution to the Ordovician stratigraphy of the Rigenée Formation (Brabant Massif, Belgium) with a preliminary study on acritarchs. Annales de la Societe Geologique de Belgique, 114, 233-245.

Servais, T., Maletz, J., 1992. Lower Llanvirn (Ordovician) graptolites and acritarchs from the “Assise de Huy”, Bande de Sambre-et-Meuse, Belgium. Annales de la Société Géologique de Belgique, 115, 265-284.

Servais, T., 1993. The Ordovician acritarch Frankea. In: Molyneux, S. G., Dorning, K. J. (Eds), Contributions to Acritarch and Chitinozoan Research. Special Papers in Palaeontology, 48, 79-95

Servais, T., Eiserhardt, K. H., 1995. A discussion and proposals concerning the Lower Palaeozoic ‘‘galeate’’ acritarch plexus. Palynology, 19, 121-210.

Servais, T., 1996. Some considerations on acritarch classification. Review of Palaeobotany and Palynology, 3, 9-22.

Servais, T., Brocke, R., Fatka, O., 1996. Variability in the Ordovician acritarch *Dicrodiacrodium.* Palaeontology, 39, 389-405.

Servais, T., 1997. The Ordovician *Arkonia-Striatotheca* acritarch plexus. Review of Palaeobotany and Palynology, 98, 47-79.

Servais, T., Molyneux, S. G., 1997. The *messaoudensis–trifidum* acritarch assemblage (Ordovician: late Tremadoc.–early Arenig.) from subsurface of Rügen (Baltic Sea, northeast Germany). Palaeontographia Italica, 84, 113-161.

Servais, T., Mette, W., 2000. The *messaoudensis-trifidum* acritarch assemblage (Ordovician: late Tremadoc.–early Arenig.) of the Barriga Shale Formation, Sierra Morena (southwest Spain). Review of Palaeobotany and Palynology, 113, 145-163.

Servais, T., Li, J., Molyneux, S. G., and Raevskaya, E., 2003. Ordovician organic walled microphytoplankton (acritarch) distribution: the global scenario. Palaeogeography, Palaeoclimatology, Palaeoecology, 195,149-172.

Servais, T., Li, J., Stricanne, L., Vecoli, M., Wicander, R., 2004. Chapter 32. Acritarchs. In: Webby, B.D., Droser, M.L., Paris, F. (Eds.), The Great Ordovician Biodiversification Event. Columbia University Press, New York, 348–360.

Servais, T., Vecoli, M., Li, J., Molyneux, S. G., Raevskaya, E., and Rubinstein, C. V., 2007. The acritarch genus *Veryhachium* Deunff 1954: taxonomic evaluation and first appearance. Palynology, 31, 191-203.

Sharland, P. R., Archer, R., Casey, D. M., Davies, R. B., Hall, S. H., Heward, A. P., Horbury, A. D., and Simmons, M. D., 2001. Arabian Plate Sequence Stratigraphy. GeoArabia Special Publication 2, 371pp.

Sheehan, P. M., 2001. The Late Ordovician mass extinction. Annual Review of Earth and Planetary Sciences, 29, 331-364.

Sheshegova, L. I., 1984. The Acritarchs of Silurian of the northern Siberian platform. (Nauka) Siberian division, 1, 179, Novosibirsk.

Siesser, W. G., Hendley II, J. W., Kessler, T. E., Marler, J. C., Wehner, E. T., 1998. Caradocian chitinozoans from the Central Basin, Tennessee. Review of Palaeobotany and Palynology, 102, 213-222.

Sikander, A. H., Basu, S., Rasul., 2000. Geochemical source-maturation and volumetric evaluation of Lower Paleozoic source rock in the West Libya Basin, In: Salem, M. J., Khaled, M. Oun. and Hussein, M. S. The Geology of northwest Libya, III, 3-53.

Sinha, H. N., Srivastava, S. S., Prasad, B., 1996a. Record of prolific and indubitable acritarchs from the Lower Paleozoic strata of the Tethyan Garhwal Himalaya and age implication. Current Science, 71, 24-31.

Sinha, H. N., Prasad, B., Srivastava, S. S., 1998. Ordovician-Silurian acritarch biostratigraphy of the Tethyan Garhwal Himalaya, India. Review of Palaeobotany and Palynology, 103, 167-199.

Smart, J., 2000. Seismic expressions of depositional processes in the Upper Ordovician succession of the Murzuq basin, southwest Libya. In: Sola, M.A., Worsley, D. (Eds), Geological Exploration in Murzuq. Elsevier Science, 397–415

Smelror, M., 1987. Early Silurian acritarchs and prasinophycean algae from the Ringerike District, Oslo Region (Norway). Review of Palaeobotany and Palynology 52, 137-159.

S..P.T., 1994). Sedimentology of the Ordovician Sandstones in Block NC174, Murzuq Basin, Libya. Simon Petroleum Technology (Robertson Research International) Report prepared for LGML.

Soufiane, A., Achab, A., 1993. Some chitinozoan assemblages from the Ordovician of the Tedla Basin, Morocco. Geobios, 26, 535-553.

Soufiane, A., Achab, A., 2000a. Upper Ordovician and Lower Silurian chitinozoans from central Nevada and Arctic Canada. Review of Palaeobotany and Palynology, 113, 165-187.

Spina, A., Vecoli, M., 2009. Palynostratigraphy and vegetational changes in the Siluro-Devonian of the Ghadamis Basin, North Africa, Palaeogeography, Palaeoclimatology, Palaeoecology, 282, 1-18

Staplin, F. L., 1961. Reef-controlled distribution of Devonian microplankton in Alberta. Palaeontology, 4, 392-424.

Staplin, F. L., Jansonius, J., Pocock, S. A. J., 1965. Evaluation of some acritarchous hystrichosphere genera, Neues Jahrbuch für Geologie und Paläeontologie Abhandlungen, 123, 167-201.

Stauffer, C. R., 1933. Middle Ordovician Polychaeta from Minnesota. 1933. Geological Society of American Bulletin, 44, 1173-1218.

Steemans, P., 1995. Silurian and Lower Emsian spores in Saudi Arabia. Review of Palaeobotany and Palynology, 89, 91-104.

Steemans, P., Le Hérissé, A., Bozdogan, N., 1996. Ordovician and Silurian cryptospores and miospores from Southeastern Turkey. Review of Palaeobotany and Palynology, 93, 35-76.

Steemans, P., 2000. Miospore evolution from the Ordovician to the Silurian. Review of Palaeobotany and Palynology, 113, 189-196.

Steemans, P., Higgs, K. T., Wellman, C. H., 2000. Cryptospores and Trilete Spores from the Llandovery, Nuayyim-2 Borehole, Saudi Arabia. In: Al-Hajri, S. and Owens, B. (Eds), Stratigraphic Palynology of the Palaeozoic of Saudi Arabia. GeoArabia Special Publication, 1, 92-115.

Steemans, P., 2001. Ordovician cryptospores from the Oostduinkerke borehole, Brabant Massif, Belgium. Geobios, 34, 3-12.

Steemans, P., Pereira, E., 2002. Llandovery miospore biostratigraphy and stratigraphic evolution of the Paraná Basin, Paraguay-Palaeogeographic implications. Bulletin de la Société géologique de France, 173, 407-414.

Steemans, P., Wellman, C. H., 2004. Miospores and the emergence of land plants. In: Webby, B.D., Paris, F., Droser, M., Percival, I. (Eds), The Great Ordovician Biodiversification Event. Columbia University Press, New York, 361-366.

Steemans, P., Wellman, C. H., Filatoff, J., 2007. Palaeophytogeographical and palaeoecological implications of a miospore assemblage of earliest Devonian (Lochkovian) age from Saudi Arabia. Palaeogeography, Palaeoclimatology, Palaeoecology, 250, 237-254.

Steemans, P., Rubinstein, C., de Melo, J. H. G., 2008. Siluro-Devonian miospore biostratigraphy of the Urubu River area, western Amazon Basin, northern Brazil. Geobios, 41, 263-282.

Steemans, P., Hérissé, A., Melvin, J., Miller, M. A., Paris, F., Verniers, J., Wellman, C. H., 2009. Origin and radiation of the earliest vascular land plants. Science, 324, 353.

Stockmans, F., Willière, Y., 1963. Les Hystricosphères ou mieux les Acritarches du Silurien belge. Sondage de la Brasserie Lust à Courtrai (Kortrijk). Bulletin de la Société belge de Géologie, 71, 450-481.

Štorch, P., Massa, D., 2006. Middle Llandovery (Aeronian) graptolites of the western Murzuq Basin and Al Qarqaf Arch Region, South-West Libya. Palaeontology, 49, 83-112.

Stricanne, L., Munnecke, A., Pross, J., Servais, T. 2004. Acritarch distribution along an inshore-offshore transect in the Gorstian (lower Ludlow) of Gotland, Sweden. Review of Palaeobotany and Palynology, 130, 195-216.

Strother, P. K., Traverse, A., 1979. Plant microfossils from Llandoverian and Wenlockian rocks in Pennsylvania. Palynology, 3, 1-21.

Strother, P. K., 1991. A Classification Schema for the Cryptospores. Palynology, 15, 219-236.

Strother, P. K., Al-Hajri, S., Traverse, A., 1996. New evidence of land plants from the lower Middle Ordovician of Saudi Arabia. Geology, 24, 55-58.

Strother, P. K., 1996. Acritarchs. In: Jansonius, J., McGregor, D.C. (Eds.), Palynology: Principles and Applications, vol. 1. American Association of Stratigraphic Palynologists Foundation, Salt Lake City, UT, 81– 106.

Sutcliffe, O. E., Adamson, K. and Ben Rahuma, M. M. 2000. The geological evolution of the Palaeozoic rocks of western Libya: a review and fieldguide. Second Symposium on the Sedimentary Basins of Libya, Geology of northwestern Libya. Field Guide. Earth Sciences Society of Libya. 93pp.

Sutcliffe, O. E., Dowdeswell, J. A., Whittington, R. J., Theron, J. N. and Craig, J., 2000. Calibrating the Late Ordovician glaciation and mass extinction by the eccentricity cycles of Earth’s orbit. Geology, 28, 967-970.

Swire, P. H., 1990. New chitinozoan taxa from the lower Wenlock (Silurian) of the Welsh Borderlands, England. Journal of Micropalaeontology. 9, 107–13.

Tammekänd, M., Hints, O., and Nõlvak, J. 2010. Chitinozoan dynamics and biostratigraphy in the Väo Formation (Darriwilian) of the Uuga Cliff, Pakri Peninsula, NW Estonia, Estonian Journal of Earth Sciences, 59, 25-36.

Tang, P., Paris, F., Yu Geng, L., Cheng Zhu, H., 2007. Chitinozoan biostratigraphy across the base of Darriwilian stage from the type area in Eastern China. Review of Palaeobotany and Palynology, 146, 74-101.

Tappan, H., Loeblich, A. R. Jr., 1971. Surface sculpture of the wall in Lower Paleozoic acritarchs. Micropaleontology, 17, 799-826.

Tappan, H., 1980. The paleobiology of plant protists. W. H. Fremean and Co, 1028pp, San Francisco.

Taugourdeau, P., de Jekhowsky, B., 1960. Répartition et description des Chitinozoaires siluro-dévoniens de quelques sondages de la C.R.E.P.S., de la C.F.P.A. et de la S.N. Repal au Sahara. Revue de l‘Institut Français du Pétrole, 15, 1199-1260.

Taugourdeau, P., 1961. Chitinozoaires du Silurien d'Aquitaine. Revue de Micropaléontologie, 4, 135-154.

Taugourdeau, P., 1962. Associations de Chitinozoaires dans quelques sondages de la region d′Esjelé (Sahara). Revue de Micropaléontologie, 4, 229-236.

Taugourdeau, P., 1963. Etude de quelques espèces critiques de chitinozoaires d'Edjelé et compléments à la faune locale. Rev-Micropaléontol. 6, 130–144

Taugourdeau, P., 1965. Chitinozoaires de l'Ordovicien des U.S.A.; comparaison avec les faunes de l'Ancien Monde. Rev. Inst. Fr. Pét. Ann. Combust. Liq. 20, 463-485.

Taugourdeau, P., 1966. Les Chitinozoaires, techniques d'études, morphologie et classification. Mémoire de la Société Géologique de France, Nouvelle Série, 45, 1-64.

Taugourdeau, P., Bouché, P., Combaz, A., Magloire, L., and Millepied, P., 1967. Microfossiles organiques du Paléozoïque. 1, Les Chitinozoaires: analyse bibliographique illustrée. Commission Internationale de Microflore du Paléozoïque, Editions du Centre National de la Recherche Scientifique. 96pp.

Tekbali, A. O., Wood, G. D., (1991): Silurian spores, acritarch and chitinozoa from the Bani walid Bore hole of the Ghadmes Basin, North west Libya. In: Salem, M. J., and Busrewill, M. T. (Eds). The Geology of Libya. Academic press . IV, 1243-1277.

Théry, J. M., 1985. Nouvelles données de l‟Ordovicien Colombien, implications regionales. Geodynamique des Caraibes. Symposium, Paris, 5-8, 495-503.

Théry, J.M., Peniguel, T., Haye, G. 1986. Descubrimiento de Acritarco del Arenigiano cerca a Araracuara (Caqueta-Colombia). Ensayo de Reinterpretacion de esta Region de la Salienta del Vaupes. Geologia norandina, 9, 1-20.

Thusu, B., 1973a. Acritarchs of the Middle Silurian Rochester Formation of southern Ontario. Palaeontology, 16, 799-826.

Thusu, B., 1973b. Acritarches provenant de l'Illion Shale *(*Wenlockian*),* Utica*,* New York*.* Revue de Micropaléontologie, 16, 137-146.

Thusu, B., 1974. Middle Silurian acritarchs in the upper type Clinton group, east-central New York, Journal of Paleontology, 48, 840-843.

Timofeev, B. V., 1956a. Hystrichosphaeridae Kembriya (Cambrian Hystrichosphaeridae). Dokl. Akad. Nauk SSSR 106, 130-132.

Timofeev, B. V., 1958. Über das Alter sächsischer Grauwacken. Mikropalaeophytologische Untersuchungen von Proben aus der Weisensteiner unf Lausitzer Grauwacke. Geologie, 7, 826-845.

Timofeev, B. V., 1959. Drevneishaya flora Pribaltiki i ee stratigraficheskoe znachenie. Leningrad: Vsesoyuznyi Neftyanoi Nauchno-Issledovatelskii Geologorazvedochnyi Institut (VNIGRI), Trudy, 129, l-136.

Tongiorgi, M., Di Milia, A., Le Fort, P., Gaetani, M., 1994. Palynological dating *(*Arenig) of the sedimentary sequence overlying the Ishkarwaz Granite *(*Upper Yarkhun valley*,* Chitral*,* Pakistan*.* Terra Nova, 6, 595-607.

Tongiorgi, M., Leiming, Y., Di Milia, A, 1995. Arenigian acritarchs from the Oaping section (Yangtze Gorges area, Hubei Province, Southern China) and their palaeogeographic significance. Review of Palaeobotany and Palynology 86, 13-48.

Tongiorgi, M., Yin, L., Milia, A, Ribecai, C., 1998. Changing paleogeographical affinities ofthe acritarch assemblages throughout the Oawan Formation (Arenig., Yichang Area, South China). Palynology, 22, 181-196.

Traverse, A., Strother, P.K., 1994. On the Current Nomenclatural Status of *Tetrahedraletes* (Fossiles). Taxon, 43, 71-74.

Traverse, A., 1996. Nomenclature and Taxonomy: Systematics. In Jansonius, J., McGregor, D.C. (Eds), Palynology: Principles and Applications. American Association of Stratigraphic Palynologists Foundation, volume 1, 11-28.

Traverse, A., 2007. Paleopalynology, (Second Edition), Topics in Geobiology, 28. Springer, Dordrecht, Netherlands, 813pp.

Trotter, J. A., Williams, I. A., Barnes, C. R., Lécuyer, C., Nicoll, R. S., 2008. Did cooling oceans trigger Ordovician Biodiversification? Evidence from conodont thermometry. Science, 321, 550-554.

Turner, N., Spinner, E., Dorning, K.J. 1995. A palynological study of the Lower Carboniferous Lydebrook Sandstone and adjacent late Wenlock and Langsettian strata, Shropshire, England. Review of Palaeobotany and Palynology, 84, 305-329.

Turner, R. E., 1982. Reworked acritarchs from the type section of the Ordovician Caradoc. Series, Shropshire. Palaeontology 25, 119– 143.

Turner, R. E., Wadge, A. J., 1979. Acritarch dating of Arenig. volcanism in the Lake District. Proceedings of the Yorkshire Geological Society. Leeds, 42, 23, 405-414.

Turner, R. E., 1984. Acritarchs from the type area of the Ordovician Caradoc Series, Shropshire, England. Palaeontographica. Abteilung B 190, 87-157.

Turner, R. E., 1985. Acritarchs from the type area of the Ordovician Llandeilo series, south Wales. Palynology, 9, 211-234.

Tynni, R. 1975. Ordovician hystrichospheres and chitinozoans in limestone from the Bothnian Sea. Bulletin Geology. Survey of Finland, 279, 1-59.

Tynni, R., 1982. On Paleozoic microfossils in clastic dykes in the Åland Islands and in the core samples of Lumparn. In: Bergman, L., Tynni, R., Winterhalter, B.

(Eds), Palaeozoic sediments in the Rapakivi area of the Åland Islands, Geology- Survey. Finland, Bulletin. 317, 36–132.

Tyson, R.V., 1995. Sedimentary organic matter: Organic facies and Palynofacies. Chapman and Hall, London, 615 pp.

Umnova, N. I., 1969, Distribution of chitinozoa in the Ordovician of the Russian Platform. Paleontology Journal, 3, 45-62.

Umnova, N. I. 1981, Ordovician and Silurian chitinozoa from the northern part of the Russian Platform. Paleontology Journal, 3, 18-28.

Uutela, A., Tynni, R., 1991. Ordovician acritarchs from the Rapla borehole, Estonia. Geological Survey of Finland Bulletin, 353, 135pp.

Uutela, A., Sarjeant, W. A. S., 2000. The Ordovician acritarch genera *Tranvikium* and *Ampullula*: their relationship and taxonomy. Review of Palaeobotany and Palynology, 112, 23-38.

Van Bergen, P., Janssen, N., Alferink, J., Kerp, J., 1990. Recognition of organic matter types in standard palynological slides. In: Fermont, W.J.J., Weegink, J.W. (Eds), Proceedings of the International Symposium on Organic Petrology. Mededelingen Rijks Geologische Dienst, 45, 9-21.

Van der Zwan, C.J., 1990. Palynostratigraphy and palynofacies reconstruction of the upper Jurassic to lowermost Cretaceous of the Draugen Field, offshore mid Norway. Review of Palaeobotany and Palynology, 62, 157-186.

VandenBerg, A. H. M., Cooper, R. A., 1992. The Ordovician graptolite sequence of Australasia. Alcheringa, 16, 33-65.

Van, K., Li, J., Liu, J. B., 2005. Biodiversity of Early-Middle Ordovician acritarchs and sea level changes in South China. Chinese Science Bulletin, 50, 2362-2368.

Van Nieuwenhove, N., Vandenbroucke, T. R. A., Verniers, J., 2006. Chitinozoan biostratigraphy of the Upper Ordovician Greenscoe section, Southern Lake District, U.K. Review of Palaeobotany and Palynology, 139, 151-169.

Vandenbroucke, T., Verniers, J., and Clarkson e. N. K., 2003 A chitinozoan biostratigraphy of the Upper Ordovician and lower Silurian strata of the Girvan area, Midland Valley, Scotland, Transactions of the Royal Society of Edinburgh: Earth Sciences, 93, 111-134.

Vandenbroucke, T. R. A., 2004. Chitinozoan biostratigraphy of the Upper Ordovician Fågelsång GSSP, Scania, southern Sweden. Review of Palaeobotany and Palynology, 130, 217-239.

Vandenbroucke, T. R. A., Rickards, B. Verniers, J. 2005. Upper Ordovician Chitinozoan biostratigraphy from the type Ashgill Area (Cautley district) and the Pus Gill section (Dufton district, Cross Fell Inlier), Cumbria, Northern England. Geological Magazine, 142, 6, 783–807

Vandenbroucke, T. R. A., Hennissen, J., Zalasiewicz, J. A., Verniers, J. 2008. New chitinozoans from the historical type area of the Hirnantian and additional key sections in the Wye Valley, Wales, UK. Geological Journal, 43, 397–414.

Vandenbroucke, T., Gabbott, S., Paris, F., Aldridge, R. J., Theron, J. N., 2009. Chitinozoans and the age of the Soom Shale, an Ordovician black shale Lagerstätte, South Africa, Journal of Micropalaeontology, 28, 53–66.

Van Grootel, G., Zalasiewicz, J., Verniers, J., and Servais, T., 1998. Chitinozoan and graptolite biozonation of the Aeronian and lower Telychian in the Brabant Massif (Belgium). In: Gutierrez-Marco, J.C.& Rabano, I. (Eds) 6th International Graptolite Conference (GWG-IPA) and 1998 Field Meeting, IUGS Subcommission on Silurian Stratigraphy, Madrid, 135-136.

Vanmeirhaeghe, J., 2006. Chitinozoan biostratigraphy of the Upper Ordovician of Faulx-les-Tombes (central Condroz Inlier, Belgium). Review of Palaeobotany and Palynology, 139, 171-188.

Vanguestaine, M., 2008 Early and Middle Ordovician acritarchs of the Senne-Sennette river (Brabant Massif, Belgium) and their stratigraphic implication, Geologica Belgica, 11, 3-24.

Vanguestaine, M., Wauthoz, B., 2011. Acritarchs from the Abbaye Villers and Tribotte Formations in their type section of the Thyle river valley (Middle Ordovician, Brabant Massive, Belgium) and their stratigraphic pimplication, Geologica Belgica, 14, 3-22.

Van Nieuwenhove, N., Vanderbrouck, T. R. A., and Verniers, J., 2006. The Chitinozoan biostratigraphy of the Upper Ordovician Greenscoe section, southern Lake District, UK. Review of Palaeobotany and Palynology, 139, 151-169.

Vavrdová, M., 1965. Ordovician acritarchs from central Bohemia. Véstnik Ostrednıho ustavu Geologického, 40, 351-357.

Vavrdová, M., 1966. Palaeozoic microplankton from central Bohemia. Easopis pro Mineralogii a Geologického, 11, 409-414.

Vavrdová, M., 1972. Acritarchs from the Klabava Shales (Arenig). Véstnik Ostrednıho ustavu Geologického, 47, 79-86.

Vavrdová, M., 1973. New acritarchs from Bohemian Arenig (Ordovician). Véstnik Ostrednıho ustavu Geologického, 48, 285-289.

Vavrdová, M., 1974. Geographical differentiation of Ordovician acritarch assemblages in Europe. Review of Palaeobotany and Palynology, 18, 171-176.

Vavrdová, M., 1977. Acritarchs from the Šárka Formation (Llanvirnian). Véstnik Ostrednıho ustavu Geologického, 52, 109-118.

Vavrdová, M., 1982. Recycled acritarchs in the uppermost Ordovician of Bohemia. Easopis pro Mineralogii a Geologii, 27, 337-345.

Vavrdová, M., 1986. New genera of acritarchs from the Bohemian Ordovician. Cásopis pro Mineralogii a Geologii, 31, 349-359.

Vavrdová, M., 1988. Further acritarchs and terrestrial plant remains from the Late Ordovician at Hlásná Treban (Czechoslovakia). Cásopis pro Mineralogii a Geologii, 33, 1-10.

Vavrdová, M., 1989. New acritarchs and miospores from the Late Ordovician of Hlasna Treban, Czechoslovakia. Cásopis pro Mineralogii a geologii, 34, 403-419.

Vavrdová, M., 1990. Early Ordovician acritarchs from the locality Mŷto near Rokycany (late Arenig, Czechoslovakia). Cásopis pro Mineralogii a Geologii 35, 239- 250.

Vavrdová, M., 1990. Coenobial acritarchs and other palynomorphs from the Arenig-Llanvirn. boundary, Prague basin. Véstnik Ostrednıho ustavu Geologického 65, 237-242.

Vavrdová, M., 1993. Acritarch assemblages in the Arenig. Series of the Prague Basin, Czech Republic. In: Molyneux, S. G., Dorning, K. G. (Eds.), Contribution to Acritarch and Chitinozoa Research. Special Papers in Palaeontology, 48, 125-139.

Vavrdová, M., 1997. Early Ordovician provincialism in acritarch distribution. Review of Palaeobotany and Palynology, 98, 33-40.

Vecoli, M., 1996. Stratigraphic significance of acritarchs in Cambro-Ordovician boundary strata, Hassi-Rrnel area, Algerian Sahara. Bollettino delia Societa Paleontologica Italiana, 35, 3-58.

Vecoli, M., 1999. Cambro-Ordovician palynostratigraphy (acritarchs and prasinophytes) of the Hassi-R'Mel area and northern Rhadames Basin, North Africa, Palaeontographia Italica, 86, 1-112.

Vecoli, M., Tongiorgi, M., Abdesselam-Roughi, F., Benzarti, R., and Massa, D., 1999. Palynostratigraphy of Upper Cambrian–Upper Ordovician intracratonic clastic sequences, North Africa. Bollettino della Societa` Paleontologica Italiana 38, 331–341.

Vecoli, M., Tongiorgi, M., Playford, G., 1999. The Ordovician acritarchs *Frankea breviuscula, F. longiuscula,* and *F. sartbernardensis*: a new study. Bollettino della Societa Paleontologica Italiana 38, 343-358.

Vecoli, M., 2000a. Palaeoenvironmental interpretation of microphytoplankton diversity trends in the Cambrian-Ordovician of the northen Sahara Platform. Palaeogeography, Palaeoclimatology, Palaeoecology, 160, 329-346.

Vecoli, M., Samuelsson, J., 2001. Quantitative evaluation of microplanktonic paleobiogeography in the Ordovician-Early Silurian of the northern Trans European Structure Zone: implication for the timing of the Avalonia-Baltica. Review of Palaeobotany and Palynology, 115, 43-68.

Vecoli, M., Tongirogi, M., Quintavalle, M., Massa, D., 2003. Palynological Contribution to the Cambro-Ordovician Stratigraphy of NW Ghadamis Basin (Libya and Tunisia) in: The Geology of Northwest Libya (eds M. J. Salem and K. M. Oun). Academic press, Londan, 1, 253-266.

Vecoli, M., Le Herisse, A., 2004. Biostratigraphy, taxonomic diversity, and patterns of morphological evolution of Ordovician acritarchs (organic-walled microphytoplankton) from the northern Gondwana margin in relation to palaeoclimatic and palaeogeographic changes, Earth-Science Reviews, 67, 267-311.

Vecoli, M., 2008. Fossil microphytoplankton dynamics across the Ordovician-Silurian boundary. Review of Palaeobotany and Palynology, 148, 91-107.

Vecoli, M., Riboulleau, M., Versteegh, G. J. M., 2009. Palynology, organic geochemistry and carbon isotope analysis of a latest Ordovician through Silurian clastic succession from borehole Tt1, Ghadamis Basin, southern Tunisia, North Africa: Palaeoenvironmental interpretation. Palaeogeography, Palaeoclimatology, Palaeoecology, 273, 378-394.

Vecoli, M., Delabroye, A., Spina, A. and Hints, O., 2011. Cryptospore assemblages from Upper Ordovician (Katian–Hirnantian) strata of Anticosti Island, Québec, Canada, and Estonia: Palaeophytogeographic and palaeoclimatic implications. Review of Palaeobotany and Palynology, 166, 76-93

Vergel, M. d. M., Aráoz, L., Rubinstein, C. V., 2002. Ordovician palynomorphs of Argentina: an integrated approach. In: Aceñolaza, F.G. (Eds), Aspects of the Ordovician System in Argentina. Serie Correlación Geológica, 16, 209-224.

Verniers, J., Rickards, B. 1978. Graptolites and chitinozoaires siluriens de la vallée de la Burdinale, Massif du Brabant, Belgique. Annales de la Société Géologique de Belgique, 101, 149-161.

Verniers, J., 1981. The Silurian of the Mehaigne Valley (Brabant Massif, Belgium): biostratigraphy (Chitinozoa). Review of Palaeobotany and Palynology, 34, 165-174.

Verniers, J., Nestor, V., Paris, F., Dufka, P., Sutherland S., Grootel G. Van., 1995. A Global Chitinozoa Biozonation for the Silurian. Gelogical Magazine, 132, 651-666.

Verniers, J., 1999. Calibration of Chitinozoa versus graptolite biozonation in the Wenlock of Builth Wells district (Wales, U.K.), compared with other areas in Avalonia and Baltica. Bollettino della Società Paleontologica Italiana, 38, 359-80.

Verniers, J., Grootel, G., Van Louwye, S., Dipendele, B. 2002. The chitinozoan biostratigraphy of the Silurian of the Ronqui´eres-Monstreux area (Brabant Massif, Belgium). Review of Palaeobotany and Palynology, 118, 287-322.

Vos, R. G. 1981. Sedimentology of an Ordocician fan complex, western Libya. sediment, Geology, 29, 153-170.

Wang, X. F., Chen, X. H., 1992. Earliest Ordovician chitinozoans from the eastern Yangtze Gorges. Acta Micropalaeontol. Sin. 9, 283-290 (in Chinese with English abstract).

Wang, X. F., Chen, X. H., 1994. Lower Ordovician chitinozoan biostratigraphy and paleogeography of Upper Yangtze Region. Acta Palaeontologica Sinica, 33, 720-738.

Wang, Y., Li, J., Wang R., 1997. Latest Ordovician cryptospores from southern Xinjiang, China. Review of Palaeobotany and Palynology, 99, 61-74.

Wang, Y., Zhu, H., Li, J., 2005. Late Silurian plant microfossil assemblage from Guangyuan, Sichuan, China. Review of Palaeobotany and Palynology, 133, 153-168.

Wang, Y., Zhang, Y., 2010. Llandovery sporomorphs and graptolites from the Manbo Formation, the Mojiang County, Yunnan, China. Proceedings of the Royal Society B, 277, 267-275.

Wauthoz, B., 2005. Correlation and biostratigraphy of the Kortrijk (sint-Antonius) and Kortrijk (Lust) boreholes (early Silurian, Belgium), Camets de Géologie/Notebook of geology, 71-77.

Webby, B. D., Paris, F., Droser, M. L., Percival, I. G. 2004 The Great Ordovician Biodiversification Event. Columbia University Press. New York. 1-37.

Wellman, C. H., Richardson, J.B., 1993. Terrestrial plant microfossils from Silurian inliers of the Midland Valley of Scotland. Palaeontology, 36, 155-193.

Wellman, C. H., 1996. Cryptospores from the type area for the Caradoc Series (Ordovician) in southern Britain. Palaeontology, 55, 103-136.

Wellman, C. H., Richardson, J.B., 1996. Sporomorph assemblages from the "Lower Old Red Sandstone" at Lorne, Scotland. Special Papers in Palaeontology, 55, 41-101.

Wellman, C. H., Higgs, K. T., Steemans, P., 2000. Spore Assemblages from a Silurian Sequence in Borehole Hawiyah-151 from Saudi Arabia. In: Al-Hajri, S. and Owens, B. (Eds), Stratigraphic Palynology of the Palaeozoic of Saudi Arabia. GeoArabia Special Publication 1, 116-133.

Wellman, C. H., Osterloff, P. L., Mohiuddin, U., 2003. Fragments of the earliest land plants. Nature, 425, 282-284.

Wellman, C. H., 2010. The invasion of the land by plants: when and where? New Phytologist, 188, 306-309.

Wetzel, O., 1933. Die in organischer Substanz erhaltenen Mikrofossilien des baltischen Kreide-Feuersteins mit einem sediment-petrographischen und stratigraphischen Anhang. Palaeontographica Abteilung. A 78, 1-110.

Wetzel, W., 1952. Beitrag zur Kenntnis des Dan-zeitlichen Meeresplanktons. Geologie Jahrbuch, 66, 391-419.
Wicander, E. R., 1974. Upper Devonian-Lower Mississippian acritarchs and prasinophycean algae from Ohio, USA. Palaeontographica Abteilung.. B 148, 9-43.

Wicander, R., Loeblich, A. R. J., 1977. Organic-walled microphytoplankton and its stratigraphic significance from the Upper Devonian Antrim Shale, Indiana, USA., Palaeontographica B, 160, 129-165.

Wicander, R., Wood, G. D., 1981. Systematics and biostratigraphy of the organic walled microphytoplankton from the Middle Devonian (Givetian) Silica Formation, Ohio, USA. American Association of Stratigraphic Palynologists, Contribution Series, 8, 137pp.

Wicander, R., Playford, G., 1985. Acritarchs and spores from the Upper Devonian Lime Creek Formation, Iowa, U.S.A. Micropaleontology, 31, 97-138.

Wicander, R., Foster, C. B., Reed, J. D., 1996. Chapter 7 E. *Gloeocapsomorpha*.In: Jansonius, J., McGregor, D.C. (Eds.), Palynology: Principles and Applications, vol. 1. American Association of Stratigraphic Palynologists Foundation, Dallas, Texas, 215–225.

Wicander, R., Wood, G. D., 1997. The use of microphytoplankton and chitinozoans for Interpreting transgressive/regressive cycles in the Rapid Member of the Cedar Valley Formation (Middle Devonian), Iowa. Review of Palaeobotany and Palynology, 98, 125-152.

Wicander, R., Playford, G., 1999. Biostratigraphic and paleogeographic implications of an Upper Ordovician acritarch assemblage from the Bill’s Creek and Stonington Formations, Michigan, U.S.A. Acta Universitatis Carolinae. Geologica 43, 267–268.

Wicander, R., Playford, G., Robertson, E. B., 1999. Stratigraphic and paleogeographic significance of an Upper Ordovician acritarch flora from the Maquoketa Shale, northeastern Missouri, USA. The Paleontological Society Memoir 51, 1–38 (supplement to Journal of Paleontology 73).

Wicander, R., 2004. A review of Ordovician Laurentian acritarch assemblages and their relevance to palaeogeographic and biodiversification trends. Memoirs of the Association of Australasian Palaeontologists 29, 245–251.

Wicander, R., Playford, G., 2008. Upper Ordovician microphytoplankton of the Bills Creek Shale and Stonington Formation, Upper Peninsula of Michigan, USA: Biostratigraphy and paleogeographic significance. Revue de Micropaléontologie, 51, 39-66.

Wilson, L. R., Hedlund, R. W., 1964. *Calpichitina scabiosa,* a new Chitinozoan from the Sylvan Shale (Ordovician) of Oklahoma. Oklahoma Geological Notes, 24, 161-164.

Winchester-Seeto, T., Foster, C., O'Leary, T., 2000a. Chitinozoan from the Middle Ordovician (Darriwilian) Goldwyer and Nita Formations, Canning basin (Western Australia). Acta Palaeontologica Polonica, 45, 271-300.

Winchester-Seeto, T., Foster, C. B., O'Leary, T., 2000b. The environmental response of Middle Ordovician large organic walled microfossils from the Goldwyer and Nita Formations, Canning Basin, Western Australia, Canning Basin (Western Australia). Review of Palaeobotany and Palynology, 113, 197-212.

Wolf, R., 1980. Acritarchen aus dem Tremadoc Keltiberiens. Courier Forschung-Institut Senckenberg, 42, 64-72.

Wood, G. D., Miller, M. A., 1991. Distinctive Silurian Chitinozoans from the Itacurubi Group (Vargas Peña Shale), Chaco Basin, Paraguay. Palynology, 15, 181-192.

Wright, R. P., Meyers, W. C., 1981. Organic walled microplankton in the subsurface Ordovician of northeastern Kansas, Kansas Geologicla Survey, Subsurface Geology Series. 4. 1-49.

Xu, W., 1996. Depth zonation of Arenigian acritarchs in South China. Chinese Science Bulletin, 42, 248-251.

Xiaofeng, W., Xiaohong, C., 2004. Ordovician chitinozoan diversification events. China Science in China Series D: Earth Sciences, 47. 874-879.

Yan, Kui, Li, Jun, 2005. Ordovician biostratigraphy of acritarchs from the Meitan Formation of Honghuayuan Section, Tongzi, Guizhou, Southwest China. Journal of Stratigraphy, 29, 236-256 (in Chinese with English abstract).

Yan, Kui, Li, Jun, 2010. The palaeoenvironmental implication of Early–Middle Ordovician acritarch communities from South China. Chinese Science Bulletin, 55, 957–964.

Yan, Kui, Li, Jun, Liu, Jianbo, 2005. Biodiversity of Early–Middle Ordovician acritarchs and sea level changes in South China. Chinese Science Bulletin, 50, 2362–2368.

Yan Kui, Servais, T., Li Jun, 2010. Revision of the Ordovician acritarch genus Ampullula Righi 1991. Review of Palaeobotany and Palynology. 163, 11-25.

Yin, L., 1994. New forms of acritarchs from Early Ordovician sediments in Yichang, Hubei, China. Acta. Micropalaeontologica Sinica 11, 41–53 (in Chinese).

Yin, L., 1995. Early Ordovician acritarchs from Hunjiang region, Jilin, and Yichang region, Hubei, China (in Chinese with English translation). Palaeontologica Sinica, A, 185, 1-170.

Yin, L., He, S., 2000. Palynomorphs from the transitional sequences between Ordovician and Silurian of northwestern Zhejiang, South China. In: Song, Z., Zhan, R., Jin, J., Zhang, Y., Yuan, W., 2008. The great Ordovician radiation of marine life: Examples from South China. Progress in Natural Science, 18, 1-12.

Zhu, H., Wicander, R., Marshall, J., 2008. Biostratigraphic and paleogeographic significance of a palynological assemblage from the Middle Devonian Ulusubasite Formation, eastern Junggar Basin, Xinjiang, China. Review of Palaeobotany and Palynology, 152, 141-157.

Web References:

ICS (International Commission on Stratigraphy), 2008. www.stratigraphy.org
Lugowski, A., Ogg, J., Gradstein, F.M., 2012. TSCreator, www.tscreator.com.
Scotese, C. R. 2003, Paleomap Project, Earth History, Ordovician.

VOLUME 2

PLATES

ARITACH AND PRASINOPHYCEAE PLATES

PLATE 1-27

PLATE 1

1- *Acanthodiacrodium crassus*, Well-A28i-NC186, 4505 ft., T28/1, scale bar = 10µm.

2- *Acanthodiacrodium* sp. A, Well-A28i-NC186, 4508 ft., O43/1, scale bar = 10µm.

3- *Ammonidium microladum,* Well-I3-NC186, 3950 ft., U44/4, scale bar = 10µm.

4- *Ampullala suetica,* Well-A28i-NC186, 4611 ft., D38/4, scale bar = 20µm.

5- *Ampullala suetica,* Well-A28i-NC186, 4611 ft., D38/4, scale bar = 10µm.

6- *Anomaloplaisum johnsium,* Well-E1-NC174, 7287ft., L32/4, scale bar = 20µm.

7- *Anomaloplaisum johnsium,* Well-E1-NC174, 7287 ft., L32/4, scale bar = 10µm.

8- ***Aremoricanium squarrosum,*** Well-H2-NC186, 4590 ft., S26, scale bar = 10 µm.

PLATE 1

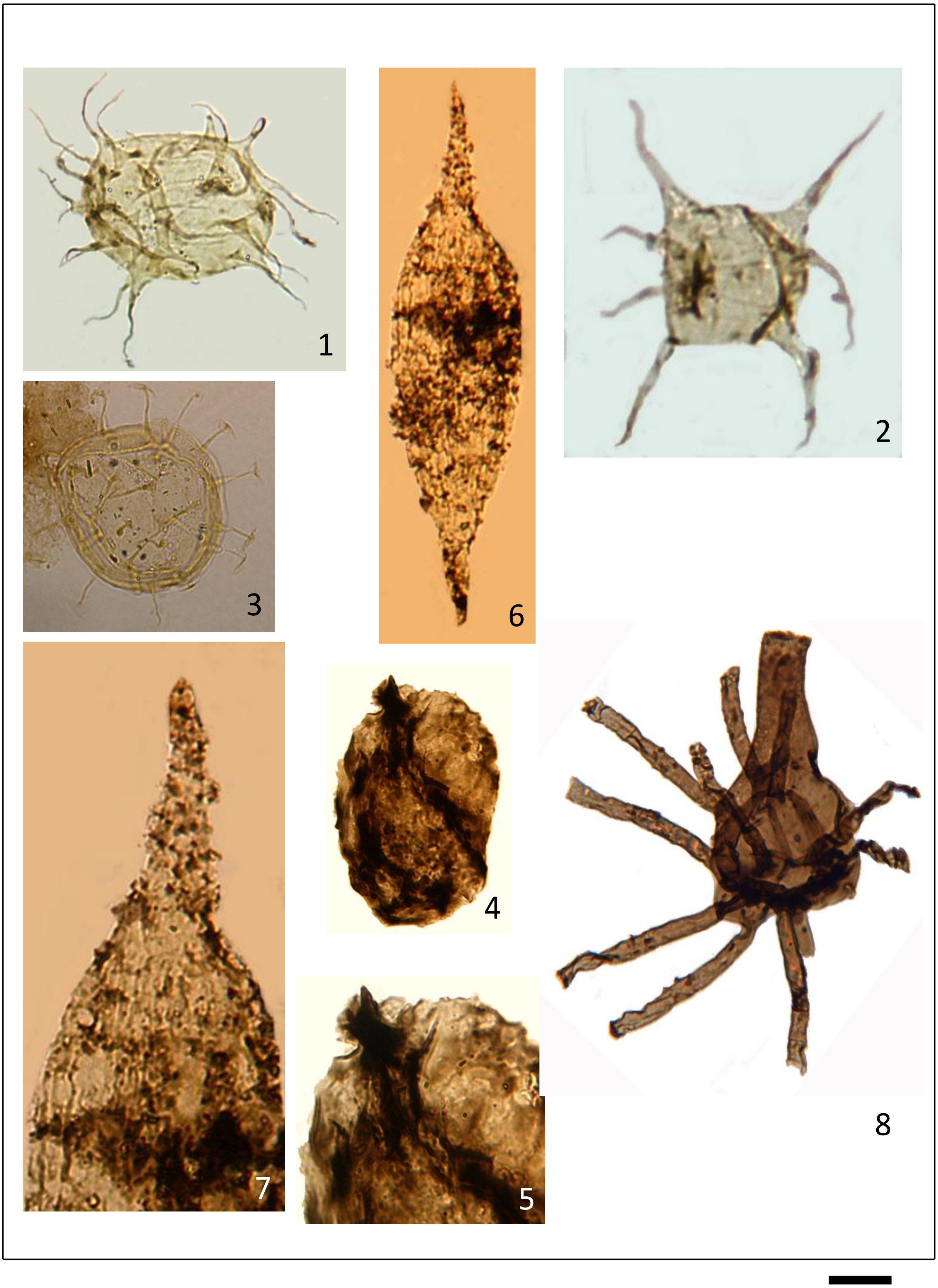


PLATE 2

1- *Baiomeniscus camurus,* Well-H2-NC186, 4200 ft., U35, scale bar = 10 µm.

2- ***Baltisphaeridium adiastalatum,*** Well-H2-NC186, 4550 ft., K43/3, scale bar =15µm.

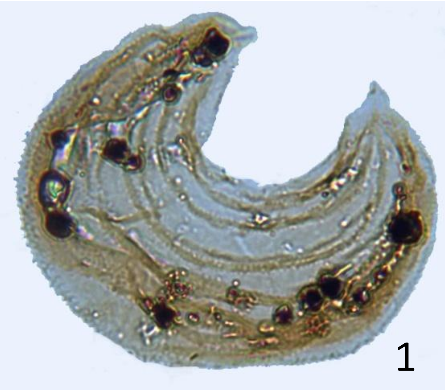
3- ***Baltisphaeridium aliquigranulum,*** Well-H2-NC186, 4590 ft., K24/2, scale bar = 30µm.

4- ***Baltisphaeridium christoferi,*** Well-D1-200, 5854 ft., J50/3, scale bar = 20 µm.

5- *Baltisphaeridium bramkaense,* Well-A28i-NC186, 4513 ft., O44, scale bar = 20µm.

6- *Baltisphaeridium* cf. *druggi,* Well-A28i-NC186, 4508 ft., G27, scale bar = 5 µm.

PLATE 2


1


2


3


5


4


6

PLATE 3

1- ***Baltisphaeridium klabavense,*** Well-A28i-NC186, 4708 ft., V41/2, scale bar = 10µm.

2- ***Baltisphaeridium klabavense,*** Well-A28i-NC186, 4708 ft., V41/2, scale bar = 20µm.

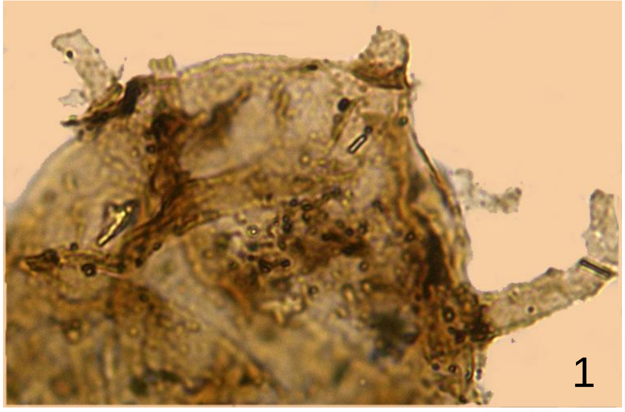
3- ***Baltisphaeridium* cf. *lancettispinae,*** Well-A28i-NC186, 4508 ft., O28, scale bar = 15µm.

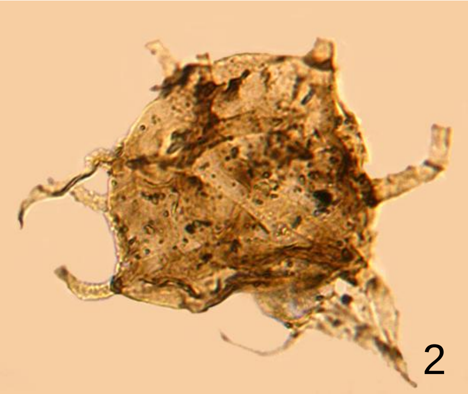
4- ***Baltisphaeridium latiradiatum ,*** Well-A28i-NC186, 4508 ft., M44/3, scale bar = 20µm.

5- ***Baltisphaeridium longispinosum delicatum*,** Well-D1-200, 4854 ft., G34/1, scale bar = 20µm

6- ***Baltisphaeridium longispinosum,*** Well-D1-200, 4854 ft., P42/2, scale bar = 20µm

PLATE 3


1


2


3


4


5


6

PLATE 4

1- ***Baltisphaeridium longispinosum,*** Well-I3-NC186, 4700 ft., K47, scale bar = 20µm. Rewarked.

2- ***Baltisphaeridium perclarum,*** Well- A28i-NC186, 4513 ft., S24/1, scale bar = 20µm.

3- ***Baltisphaeridium* sp. A**, Well-D1-200, 4810 ft., U51/2, scale bar = 20µm.

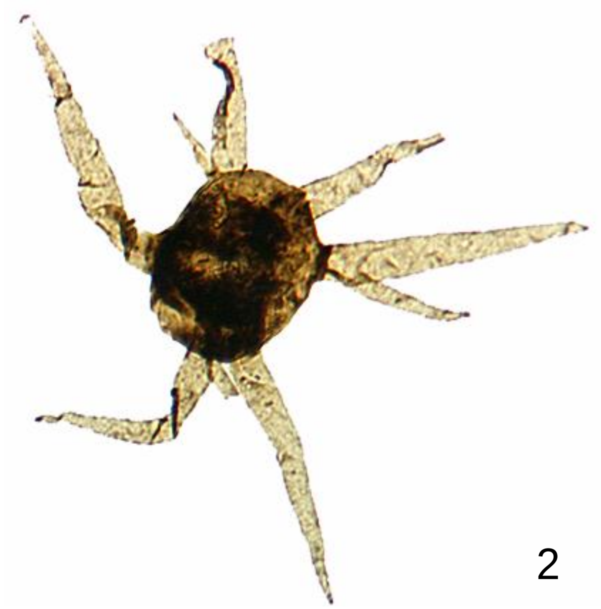
4- ***Buedingiisphaeridium* cf. *pyramidale***, Well-I3-NC186, 4300 ft., K45/3, scale bar = 5µm.

5- ***Carminella maplewoodensis,*** Well-I3-NC186, 3950 ft., M32/1, scale bar = 15µm.

6- ***Carminella maplewoodensis,*** Well-I3-NC186, 3950 ft., M32/1, scale bar = 7.5µm.

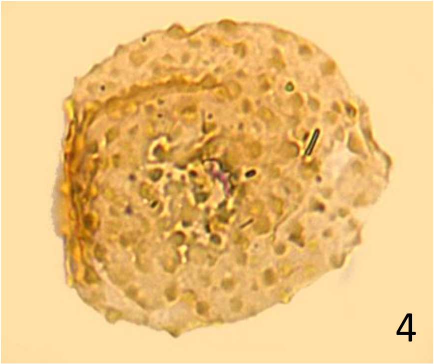
PLATE 4


1


2


3


5


4


6

PLATE 5

1- ***Cheleutochroa* cf. *diaphorosa,*** Well- A28i-NC186, 4513 ft., J25, scale bar = 10µm.

2- ***Cheleutochroa* cf. *gymnobrachiata,*** Well- A28i-NC186, 4513 ft., P49/, scale bar = 10µm.

3- ***Circinatisphaera enigma,*** Well-I3-NC186, 4350 ft., K32/1, scale bar = 10µm.

4- ***Cymatiosphaera* cf. *densisepta,*** Well-E1-NC174, 7287 ft., E38/4, scale bar = 10µm.

5- ***Cymatiosphaera* sp. A,** Well- A28i-NC186, 4708 ft., U27/4, scale bar = 10 µm.

6- ***Cymatiosphaera* sp. A,** Well- A28i-NC186, 4633 ft., Y39/1, scale bar = 10 µm.

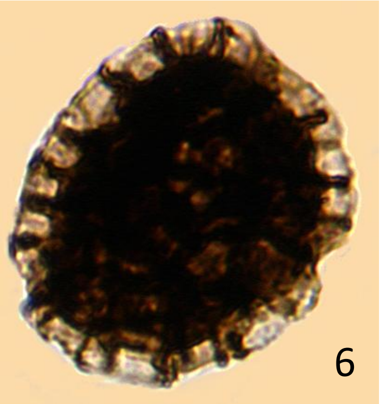
***7- Cymatiosphaera* sp. B,** Well- A28i-NC186, 4604 ft., U40/3, scale bar = 10 µm.

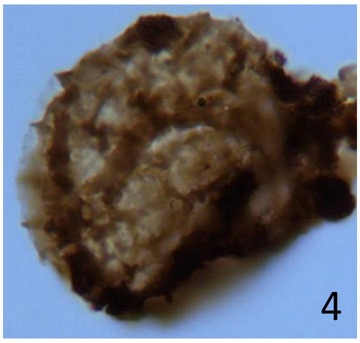
PLATE 5

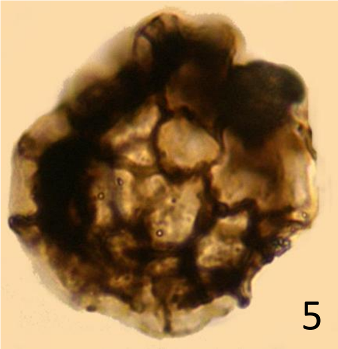

1


2


3


6


4


5


7

PLATE 6

1- ***Cymbosphaeridium pilaris typicum,*** Well-I3-NC186, 3890 ft., O47/1, scale bar = 10µm.

2- ***Cymbosphaeridium*** **sp. 1,** Well-I3-NC186, 3950 ft., Q26/2, scale bar = 10 µm.

3- ***Cymbosphaeridium*** **sp. 1,** Well-I3-NC186, 3950 ft., L50/2, scale bar = 10 µm.

4- ***Cymbosphaeridium*** **sp. 1,** Well-I3-NC186, 3950 ft., O29, scale bar = 10 µm.

5- ***Cymbosphaeridium*** **sp. A,** Well-I3-NC186, 4300 ft., N28/2, scale bar = 10 µm.

6- ***Dactylofusa cucurbita,*** Well D1-200, 4878 ft., F24/3**,** scale bar = 10µm.

PLATE 6


1


5


2


4


3


6

PLATE 7

1- ***Dilatisphaera* cf. *wimanii,*** Well D1-200, 4878 ft., K51, scale bar = 17µm.

2- ***Deunffia brevispinosa,*** Well-E1-NC174, 7287 ft., ...scale bar = 10µm.

3- ***Dictyotidium dictyotum,*** Well-E1-NC174, 7287 ft., H37/3, scale bar = 7.5 µm

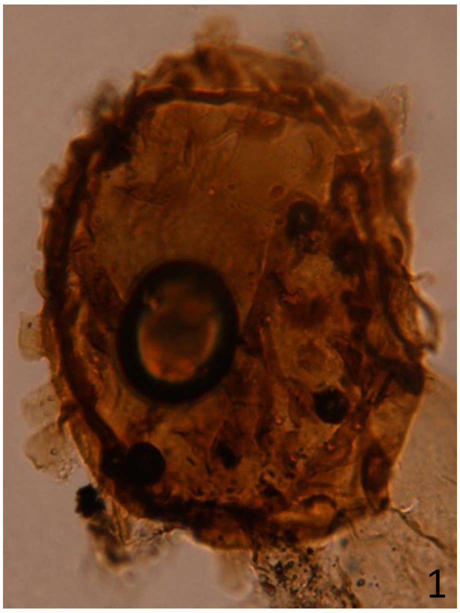
4- ***Dictyotidium* sp. A,** Well A28i-NC186, 4611 ft., P39/3, scale bar = 10µm.

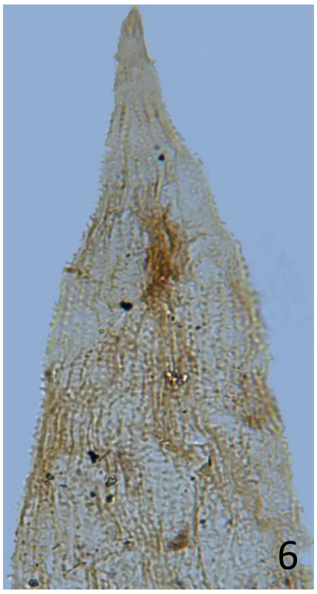
5- ***Dactylofusa striatogranulata,*** Well A28i-NC186, 4550 ft., U34/3, scale bar = 10µm.

6- **Details of 5, showing spines ornamentation**, scale bar = 7.5µm.

7- ***Disparifusa hystricosa,*** Well A28i-NC186, 4513 ft., E37/4, scale bar = 10 µm.

PLATE 7

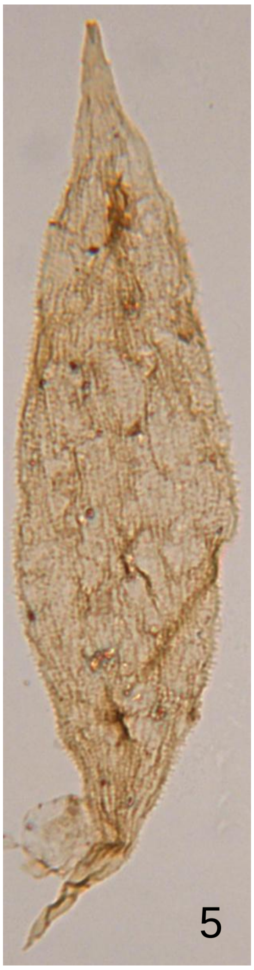

1


6


2


3


4


5


7

PLATE 8

1- ***Domasia limaciforme,*** Well-E1-NC174, 7287 ft., K51/1, scale bar = 10 µm.
2- ***Electoriskos* sp. A,** Well A28i-NC186, 4715 ft., R33/4, scale bar = 10µm.
3- ***Eupoililofusa* cf. *ampulliformis,*** Well-I3-NC186, 4360 ft., O29/4 scale bar =10 µm.
4- ***Eupoililofusa cantabrica,*** Well-I3-NC186, 3890 ft., L36 scale bar = 10 µm.
5- ***Eupoikilofusa ctenista,*** Well I3-NC186, 44517 ft., K37/4, scale bar = 15 µm.
6- ***Eupoikilofusa* cf. *ctenista,*** Well A28i-NC186, 4508 ft., N24/4, scale bar = 15µm.
7- ***Eupokilofusa rhikne,*** Well-I3-NC186, 4350 ft., O41, scale bar = 20µm.
8- ***Eupoikilofusa saetosa,*** Well-I3-NC186, 4300 ft., H40/3, scale bar = 10 µm.

PLATE 8

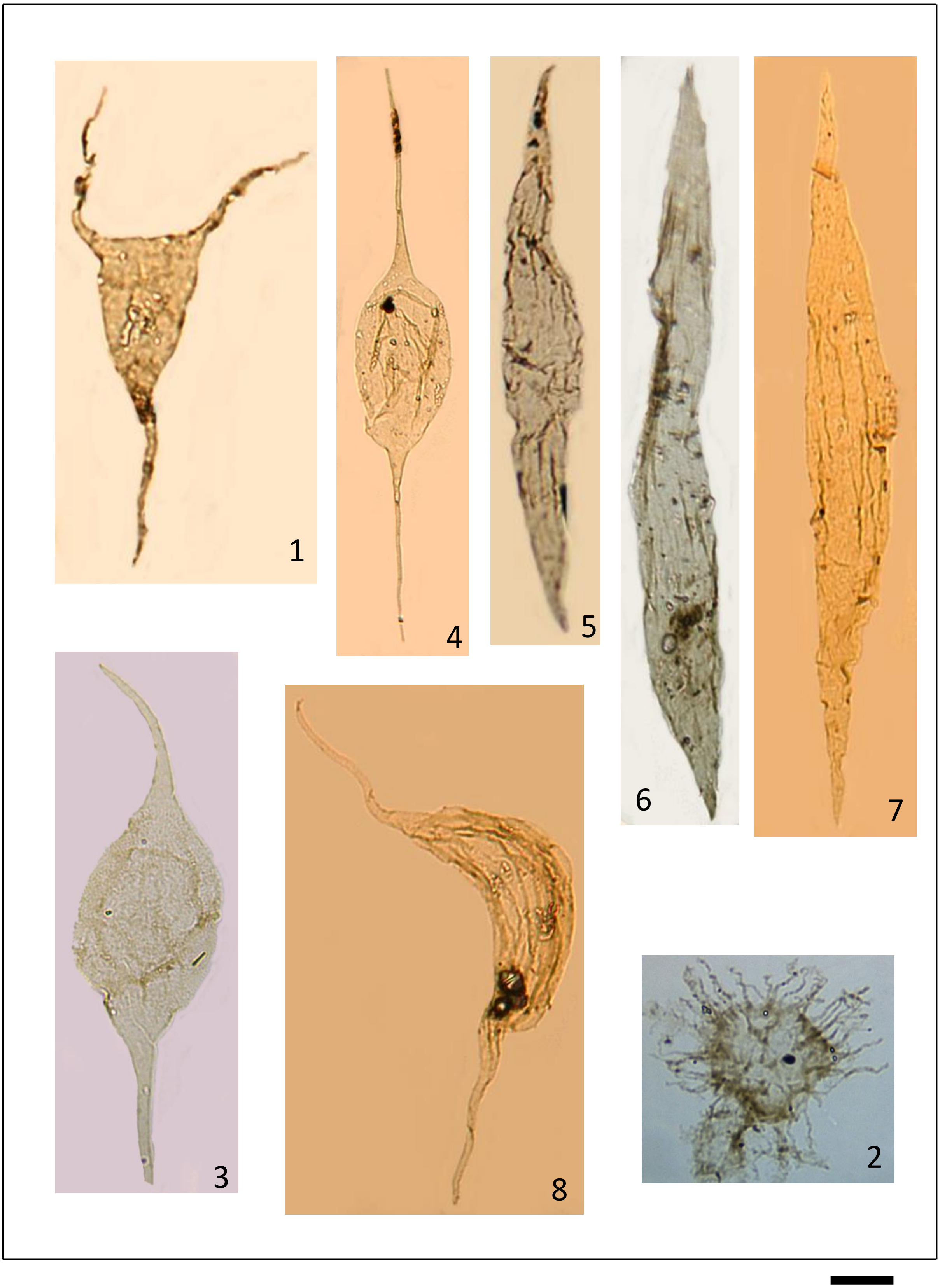


PLATE 9

1- ***Eupoikilofusa saetosa,*** Well-I3-NC186, 4300 ft., J40, scale bar = 10µm.
2- ***Eupoikilofusa playnetrella,*** Well D1-200, 4854 ft. J50/3, scale bar = 10µm.
3- ***Eupoikilofusa striata,*** Well D1-200, 4778.64-5 ft., K54, scale bar = 10µm.
4- ***Eupoikilofusa striatifera,*** Well-I3-NC186, 4300 ft., N42/3, scale bar = 10µm.
5- ***Eupoikilofusa* sp. A,** Well-I3-NC186, 4650 ft., T44/4. , scale bar = 20µm.
6- ***Evittia denticulate,*** Well-I3-NC186, 7287 ft., F32/4, scale bar = 10 µm.
7- ***Evittia ?*sp.,** Well-E1-NC174, 7287 ft., C44, scale bar = 10µm

PLATE 9

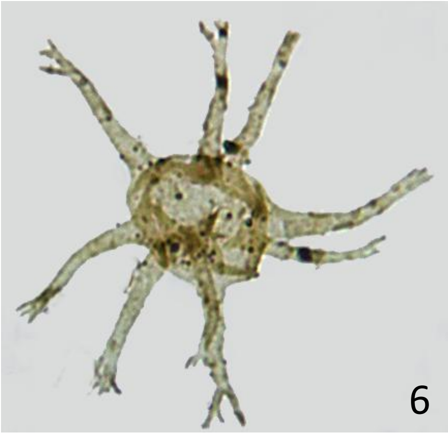

1


2


3


4


5


6


7

PLATE 10

1- *Evittia sanpetrensis,* Well-I3-NC186, 4700 ft., S46/2, scale bar = 10µm.

2- *Evittia sanpetrensis,* Well-I3-NC186, 4700 ft., S46/2, scale bar = 7µm.

3- *Evittia* sp. 1, Well-I3-NC186, 4700 ft., Q31/1, scale bar = 10µm.

4- *Evittia* sp. 1, Well-I3-NC186, 4700 ft., Q31/1, scale bar = 7µm.

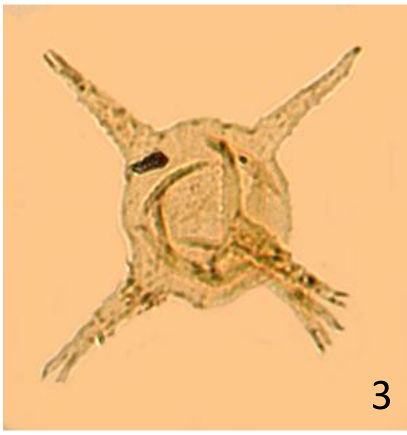
5- *Evittia remota podolica,* Well-I3-NC186, 4350 ft., P35, scale bar = 10µm.

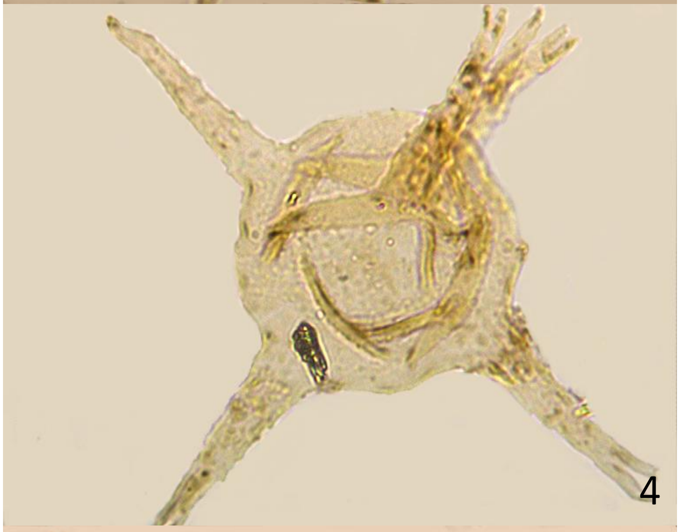
6- *Evittia remota podolica,* Well-I3-NC186, 4350 ft., P35, scale bar = 5µm.

PLATE 10


1


2


3


4


5

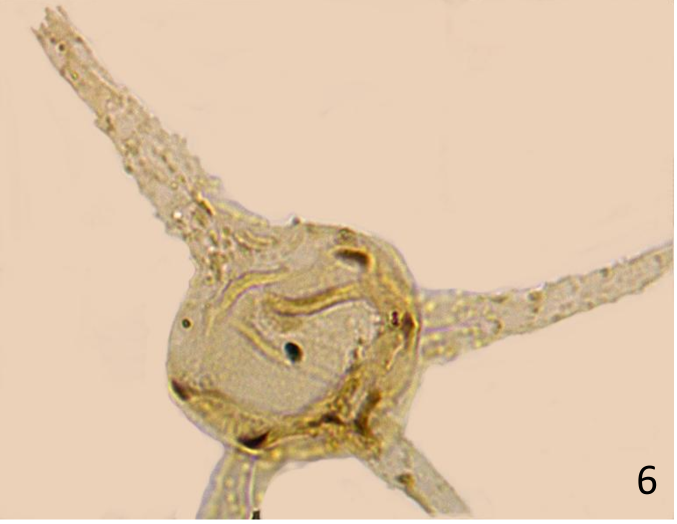

6

PLATE 11

1- ***Evittia remota,*** Well-E1-NC174, 7287 ft., H44, scale bar = 10µm.

2- ***Frankea breviuscula,*** Well A28i-NC186, 4706 ft., S25, scale bar = 5µm.

3- ***Frankea longiuscula*****,** Well A28i-NC186, 4708 ft., T36/2, scale bar =10µm.

4- ***Frankea longiuscula,*** Well A28i-NC186, 4708 ft., G23/1, scale bar =10µm.

PLATE 11

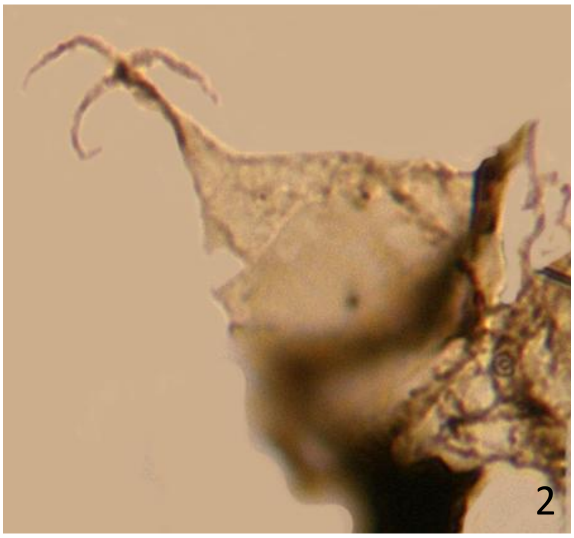


PLATE 12

1- ***Frankea hamata,*** Well-H2-NC186, 4870 ft.T42, scale bar = 10µm.
2- ***Frankea* sp. A,** Well-H2-NC186, 4870 ft., U35, scale bar = 10µm.
3- ***Geron* sp. 1,** Well-I3-NC186, 4300 ft., H33/3, scale bar = 10µm.
4- ***Helosphaeridium* cf*. latispinosum,*** Well I3-NCI86, 4799 ft., D59/2, scale bar = 20µm.
5- ***Helosphaeridium* sp. A,** Well A28i-NC186, 4715 ft., W50, scale bar = 10 µm.
6- ***Leiofusa estrecha,*** Well-I3-NC186, 3890 ft., O30, scale bar = 20µm.
7- ***Leiofusa fusiforms,*** Well A28i-NC186, 4513 ft., E36, scale bar = 20µm.
8- ***Leiofusa litotes,*** Well A28i-NC186, 4513 ft., O49/4, scale bar = 20µm.
9- ***Leiofusa* cf. *litotes,*** Well A28i-NC186, 4513 ft., U40, scale bar = 20µm.
10- ***Leiofusa* cf*. fusiformis,*** Well A28i-NC186, 4715 ft., T25, scale bar = 10 µm.
11- ***Leiofusa* cf. t*umida,*** Well I3-NC186, 4590 ft., V50/2, scale bar = 15µm.

PLATE 12

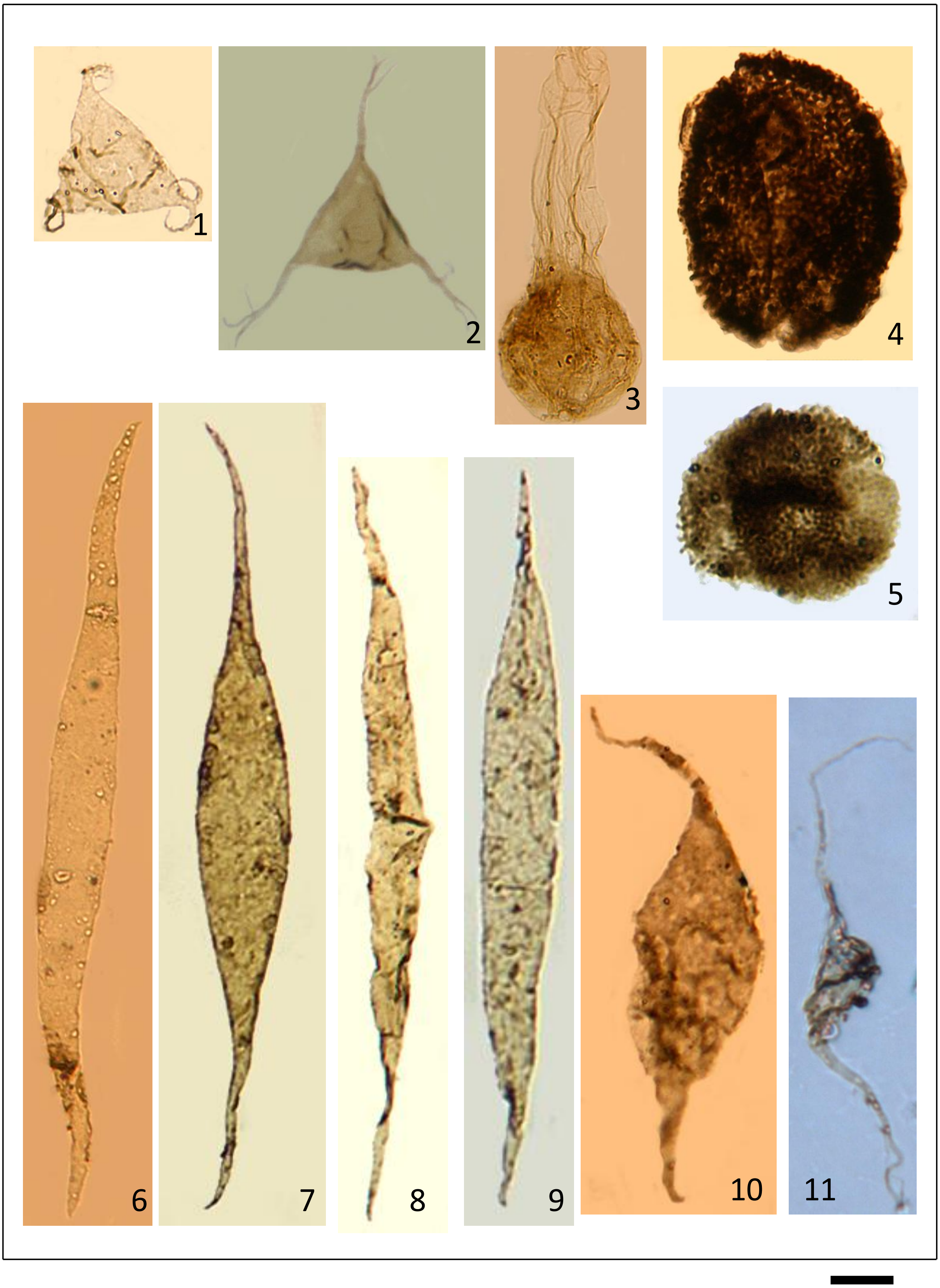


PLATE 13

1- *Hoegklintia visbyense* Well-E1-NC174, 7287 ft., E38/4, scale bar = 30µm.

2- *Leiosphaeridia* spp. Well-I3-NC186, 3950 ft., P52/2, scale bar = 20µm.

3- *Leiosphaeridia* spp.*,* Well A28i-NC186, 4723 ft., E40, scale bar = 10µm.

4- *Leiosphaeridia* spp.*,* Well-E1-NC174, 7287 ft., E31/4, scale bar = 10µm.

5- *Leprotolypa evexa,* Well-I3-NC186, 4799 ft., N37/4, scale bar = 10µm

6- *Lophosphaeridium acinatum,* Well-S1-NC115, 4801 ft., O43/2, scale bar = 10µm.

7- *Lophosphaeridium fuscipetiolatum,* Well A28i-NC186, 4708 ft., O38/3/1, scale bar = 20µm.

8- *Lophosphaeridium* sp. A, Well A28i-NC186, 4508 ft., O43/1, scale bar = 10µm.

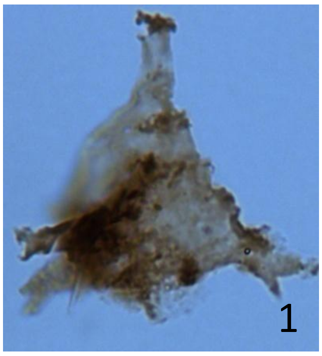
9- *Lophosphaeridium* sp. B, Well A28i-NC186, 4513 ft., N33/3, scale bar = 10 µm.

10-*Micrhystridium stellatum,* Well-I3-NC186, 3950 ft., E41/3, scale bar = 10µm.

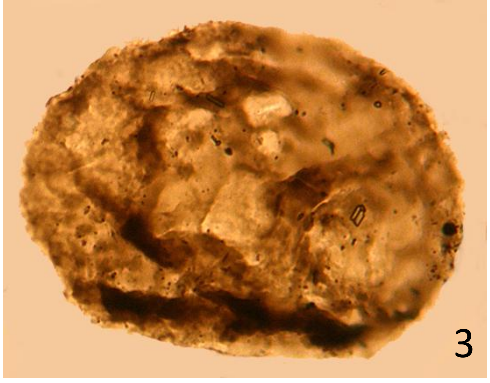
11-*Micryhistridium* cf. *equispinosum,* Well-H2-NC186, 4870 ft.,D24/2, scale bar = 10µm.

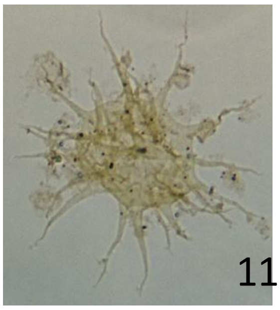
12*- Moyeria cabotti,* WellI3-NC186, 4799 ft., Q44, scale bar = 10µm.

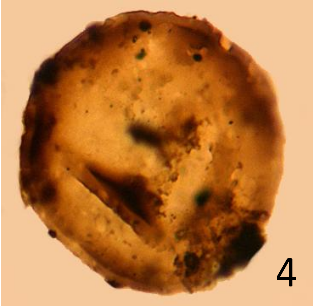
PLATE 13


1

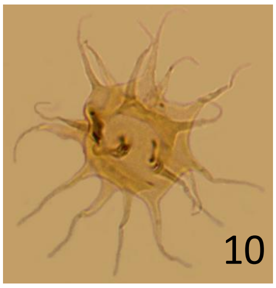

2


3

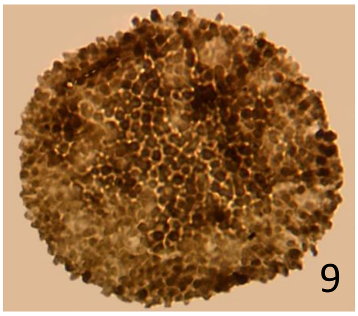

11


4

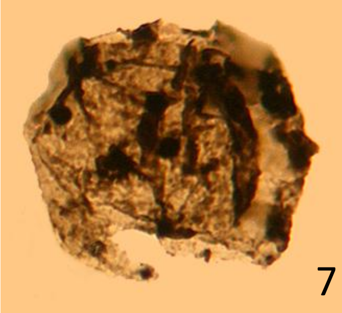

6


10


5


9


12


7


8

PLATE 14

1- ***Micrhystridium* sp. A,** Well-I3-NC186, 3700 ft., V46/1scale bar = 5µm.

2- ***Multiplicisphaeridium bifurcatum,*** Well A28i-NC186, 4513 ft., U38, scale bar = 10µm.

3- ***Multiplicisphaeridium irregulare,*** Well A28i-NC186, 4513 ft., Y29/1, scale bar = 10µm.

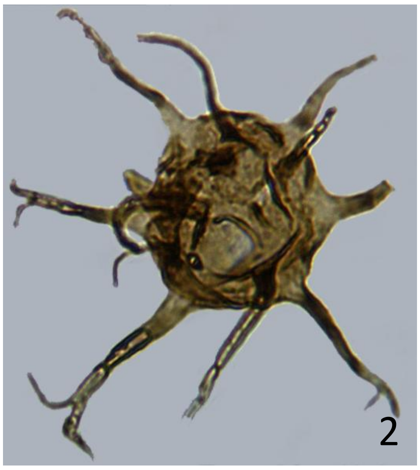
4- ***Multiplicisphaeridium circumscriptum,*** Well-E1-NC174, 7287 ft., E42/3, scale bar = 10µm.

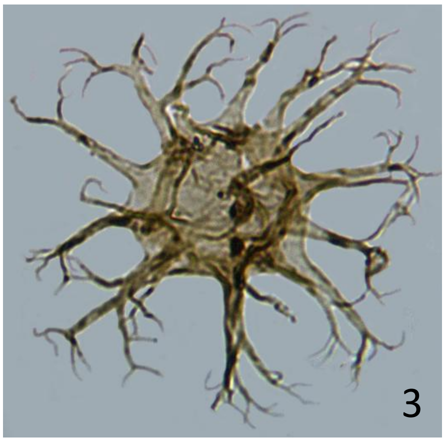
5- ***Multiplicisphaeridium fermosum,*** Well-E1-NC174, 7287 ft., E31/2, scale bar = 10µm.

6- ***Multiplicisphaeridium* cf. *raspa,*** A28i-NC186, 4513 ft., O44/1, scale bar = 5µm.

PLATE 14


1


2


3


4


5

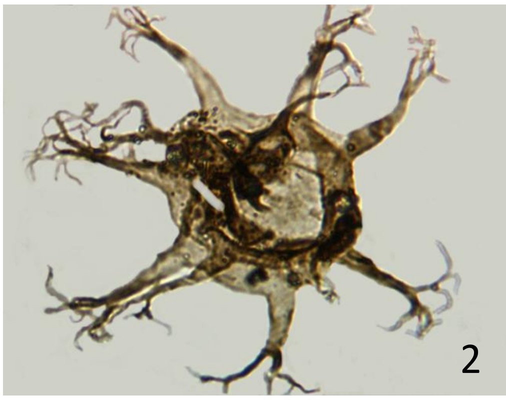

6

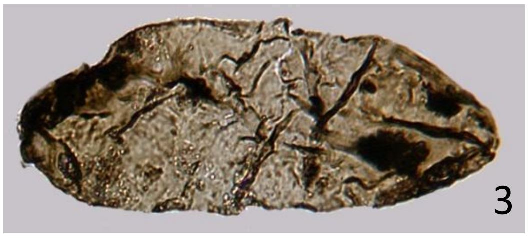
PLATE 15

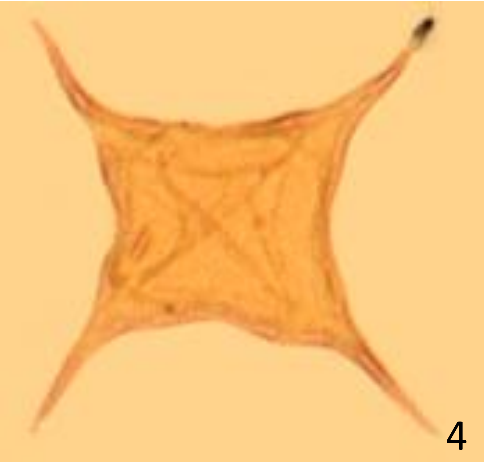
1- ***Multiplicisphaeridium* cf. *brazusdesnodem,*** Well-E1-NC174, 7287 ft.K50/2, scale bar = 10µm.
2- ***Multiplicisphaeridium sp*. A,** Well A28i-NC186, 4505 ft., T25/1, scale bar = 10µm.
3- ***Navifusa* sp. A,** Well A28i-NC186, 4513 ft., V28/1, scale bar = 20µm.
4- ***Neoverhachium carminae,*** Well-E1-NC174, 7287 ft., E28/2, scale bar = 10 µm.
5- ***Neoveryhacium* cf. *carminae,*** Well-I3-NC186, 3890 ft., K30, scale bar = 10 µm.
6- ***Neoveryhachium carminae constricta,*** Well-I3-NC186, 4350 ft., V52/3, scale bar = 5 µm.
7- ***Neoveryhachium* cf. *carminae constricta,*** Well-I3-NC186, 4350 ft., J49/3, scale bar = 5µm.

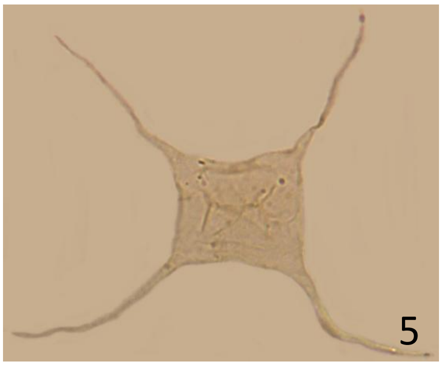
PLATE 15

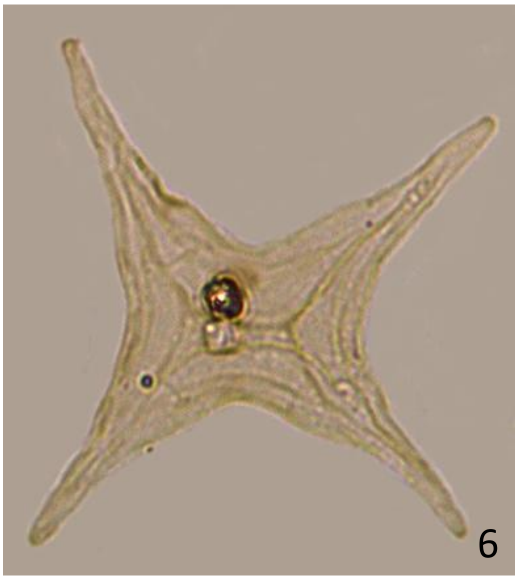

1


2


3


4


5


6

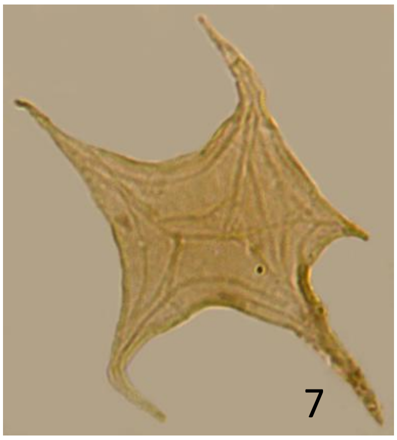
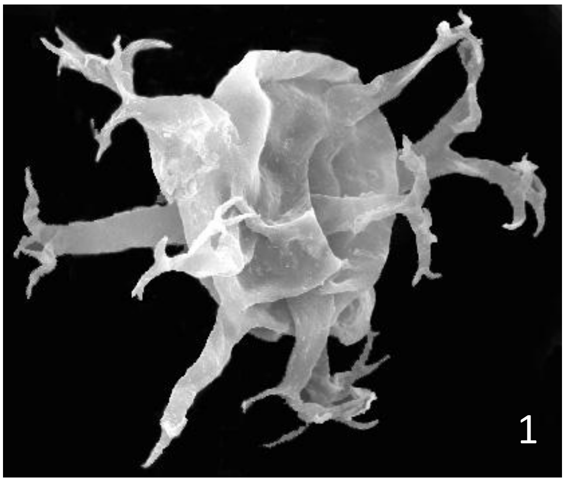

7

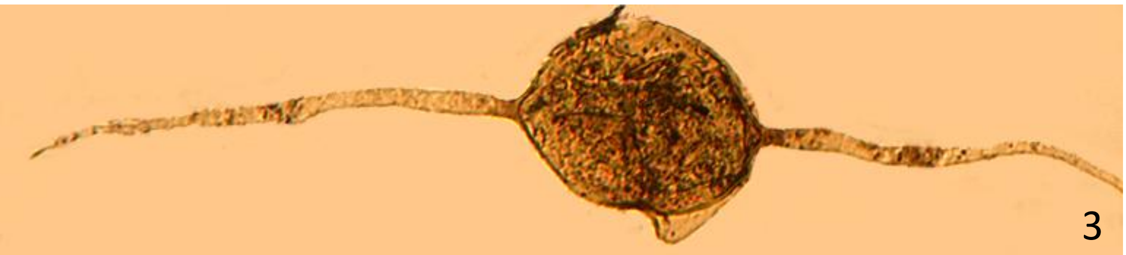
PLATE 16

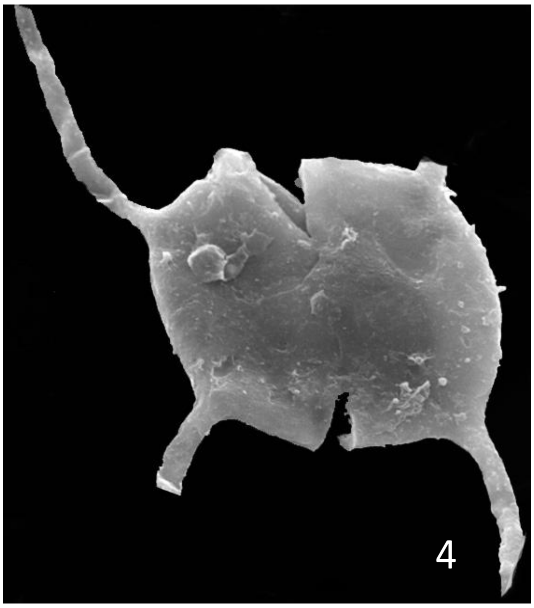
1. **1-** ***Ordovicidium elegantulum****,* Well A28i-NC186, 4508 ft., P42/1, scale bar = 10µm.
2. **2-** ***Ordovicidium*** **sp. A*,*** Well A28i-NC186, 4501 ft., R55/3 scale bar = 10µm.
3. **3-** ***Orthosphaeridium bispinosum,*** Well D1-200, 4840 ft., U39/4 scale bar = 10 µm.
4. **4-** ***Orthosphaeridium rectangulare*****,** Well A28i-NC186, 4482 ft., scale bar = 15µm.
5. **5-** ***Orthosphaeridium rectangulare,*** Well-E1-NC174, 7287 ft., Y31/4, scale bar = 15µm. Reworked.

PLATE 16


1


2


3


4


5

PLATE 17

1- ***Orthosphaeridium insculptum,*** Well A28i-NC186, 4513 ft., E41/2, scale bar = 20µm.
2- ***Orthosphaeridium insculptum,*** Well A28i-NC186, 4513 ft., E41/2, scale bar = 10µm.
3- ***Orthosphaeridium octospinosum,*** Well A28i-NC186, 4513 ft., M38/2, scale bar = 20µm.
4- ***Orthosphaeridium octospinosum,*** Well A28i-NC186, 4513 ft., M38/2, scale bar = 10µm.
5- ***Orthosphaeridium* spp.,** Well A28i-NC186, 4508 ft., S41/4, scale bar = 20µm.
6- ***Orthosphaeridium* spp.,** Well A28i-NC186, 4513 ft., V45/1, scale bar = 20µm.

PLATE 17


1


2


3


4


5


6

PLATE 18

1- *Pirea cf. sinensis*, Well A28i-NC186, 4513 ft., E41/2, scale bar = 5 µm.

2- *Pirea cf. sinensis,* Well A28i-NC186, 4505 ft., L46/4, scale bar = 5 µm.

3- *Pirea dubia,* Well A28i-NC186, 4513 ft., L41, scale bar = 10 µm.

4- *Pirea* cf. *dubia,* Well A28i-NC186, 4708 ft., Q43/3, scale bar = 20 µm.

5- *Poikilofusa ciliaris,* Well A28i-NC186, 4708 ft., L31/3, scale bar = 20 µm.

6- *Poikilofusa spinata,* Well A28i-NC186, 4513 ft., V33/3, scale bar = 20 µm.

7- *Polygonium gracile* Well A28i-NC186, 4706 ft, L33/2 scale bar = 8µm.

8- *Polygonium* sp. 1*,* Well E1-NC174, 7287 ft., E24/3, scale bar = 10µm.

PLATE 18

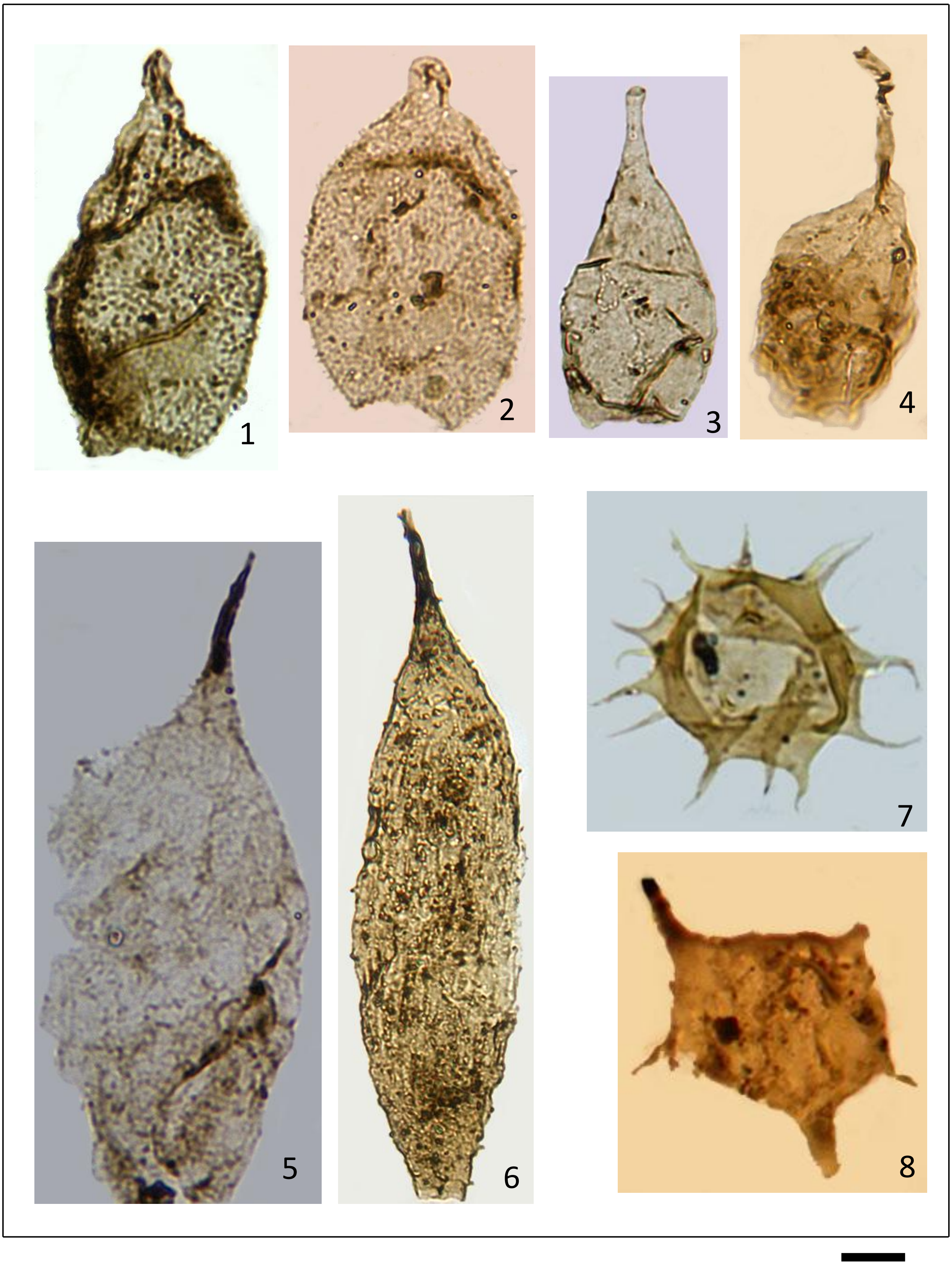


PLATE 19

1- ***Polygonium conjunctum,*** A28i-NC186, 4513 ft., G52, scale bar = 10µm.

2- ***Polygonium* sp.A,** Well A28i-NC186, 4513 ft., H28/1 scale bar = 10µm.

3- ***Pterospermella colbathii,*** Well A28i-NC186, 4633 ft., R42, scale bar = 5µm.

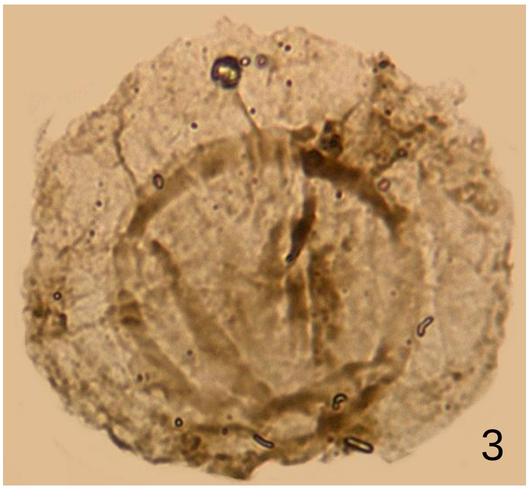
4- ***Pterospermella colbathii,*** Well A28i-NC186, 4715 ft., O53/4, scale bar = 5 µm.

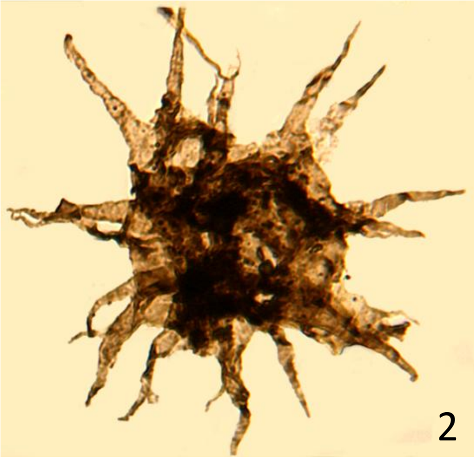
5- ***Pterospermella* sp. A,** Well-I3-NC186, 3890 ft., K38/3, scale bar = 10µm.

6- ***Pterospermella* sp. B,** Well A28i-NC186, 4725 ft., J36/1, scale bar =10 µm.

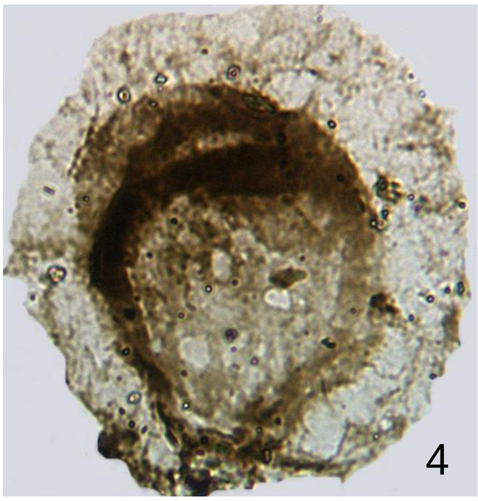
PLATE 19


1


3


2


5


4

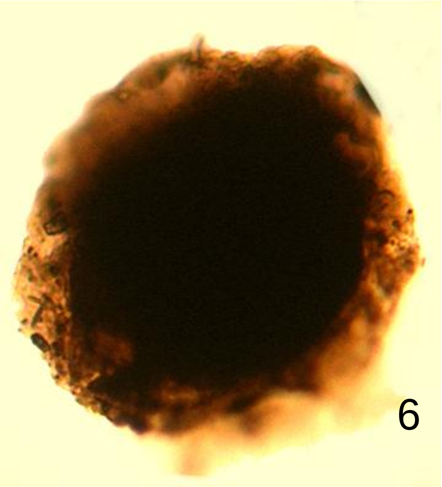

6

PLATE 20

1- ***Pteroverricatus occuliformis,*** Well-I3-NC186, 3890 ft., O30, scale bar = 5µm.

2- ***Pteroverricatus zonocylindrus*****,** Well-I3-NC186, 3890 ft., K26, scale bar = 10 µm.

3- ***Rhopaliophora?*** **sp. A,** Well A28i-NC186, 4708 ft., N32/2, scale bar = 10 µm.

4- ***Solisphaeridium*** **cf.** ***solare,*** Well H2-NC186, 5000 ft., N47/1, scale bar = 5 µm.

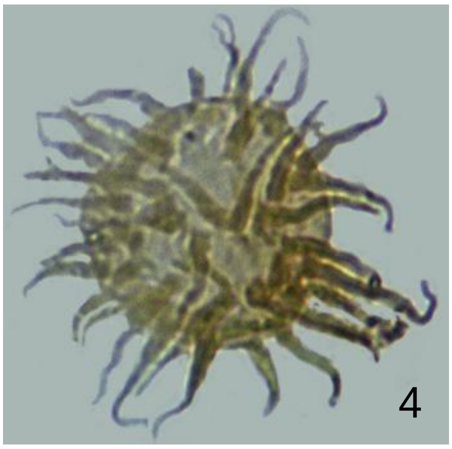
5- ***Stellechinatum celestum,*** Well-I3-NC186, 4782 ft., T48/2, scale bar = 10 µm.

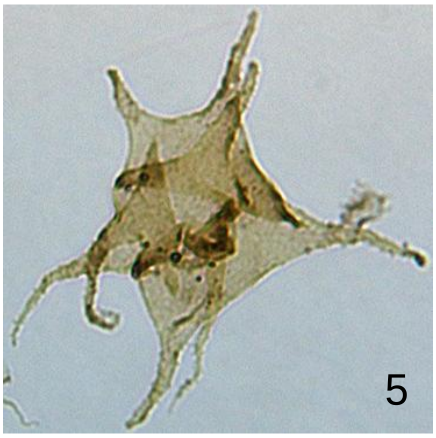
6- ***Stelliferidium philippotii,*** Well H2-NC186, 5000 ft., S30/2, scale bar = 5 µm.

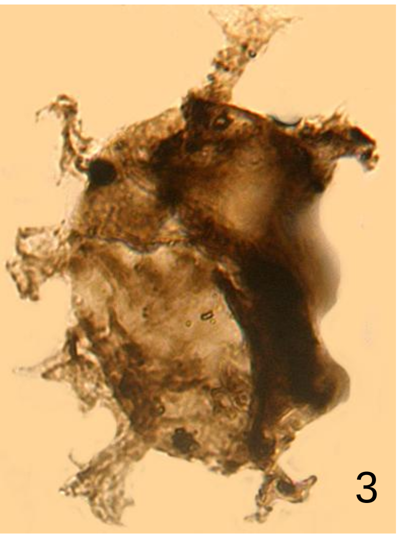
PLATE 20


1


2


4


5


3

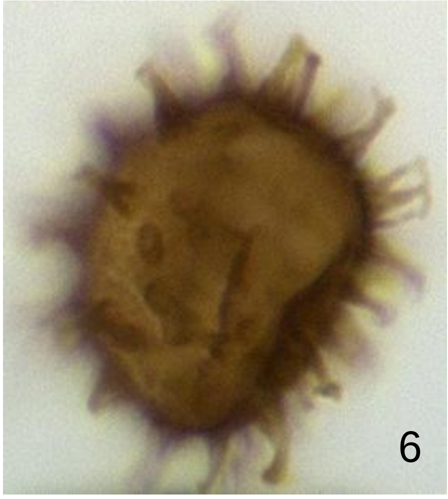

6

PLATE 21

1- ***Stelliferidium striatulum,*** Well D1-200, 5600-5650 ft., S42, scale bar = 10 µm.

2- ***Stelliferidium stelligerum,*** Well A28i-NC186, 4708 ft., C35, scale bar = 10µm

3- ***Stelliferidium stelligerum,*** Well A28i-NC186, 4708 ft., scale bar = 5 µm

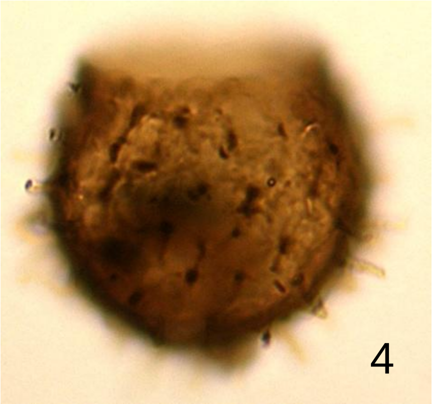
4- ***Stelliferidium simplex,*** Well A28i-NC186, 4708 ft., O32, scale bar = 5µm.

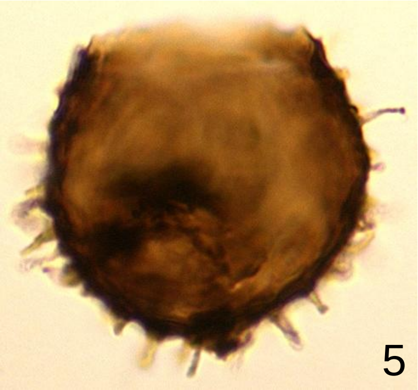
5- ***Stelliferidium simplex,*** Well A28i-NC186, 4706 ft., O32, scale bar = 5µm.

6- ***Striatotheca* sp. A,** Well A28i-NC186, 4706, 4513 ft., O47/2, scale bar = 10µm.

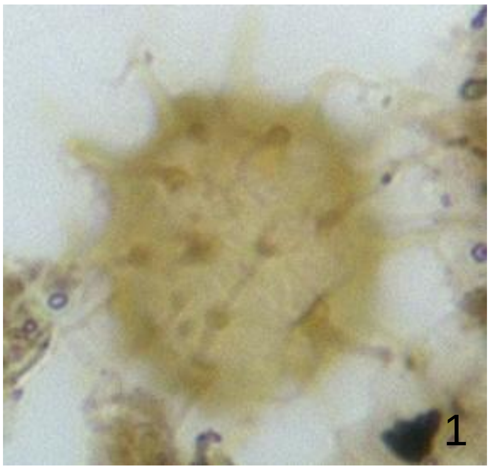
7- ***Striatotheca* sp. B,** Well A28i-NC186, 4706 ft., 4513, O51, scale bar = 5µm.

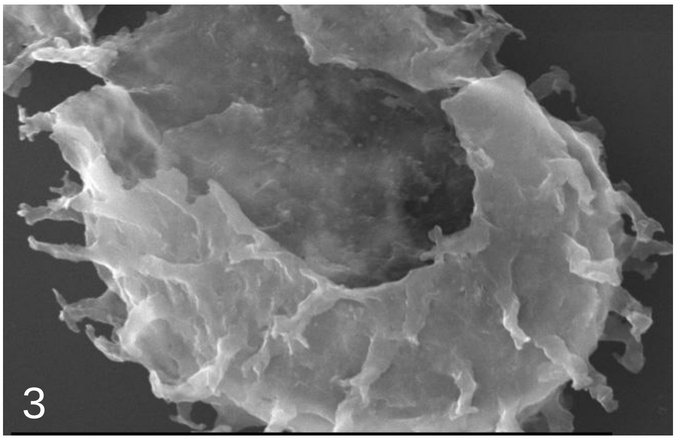
PLATE 21

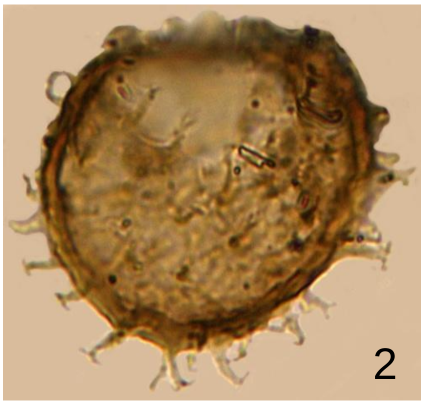

4


5


6


1


3


2


7

PLATE 22

1- ***Tectitheca spinifera,*** Well A28i-NC186, 4708 ft., K43, scale bar = 10µm.

2- ***Tectitheca* sp. A,** Well A28i-NC186, 4715 ft., L43/4, scale bar = 10µm.

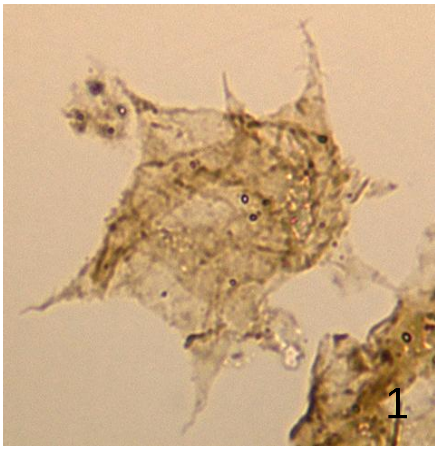
3- ***Tunisphaeridium tentaculiferum,*** Well-I3-NC186, 3890 ft., O47/2, scale bar = 10µm.

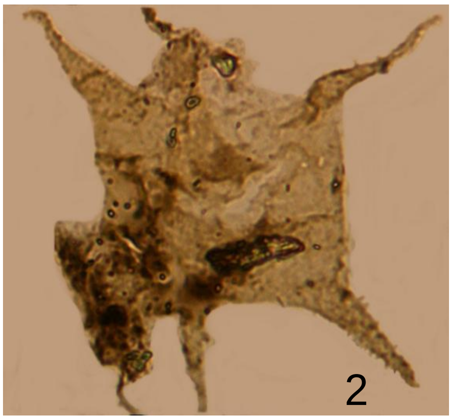
4- ***Tunisphaeridium caudatum,*** Well-I3-NC186, 3890 ft., O33/2, scale bar = 5µm.

5- ***Tylotopalla aniae,*** Well-I3-NC186, 3890 ft., M31/4, scale bar = 5µm.

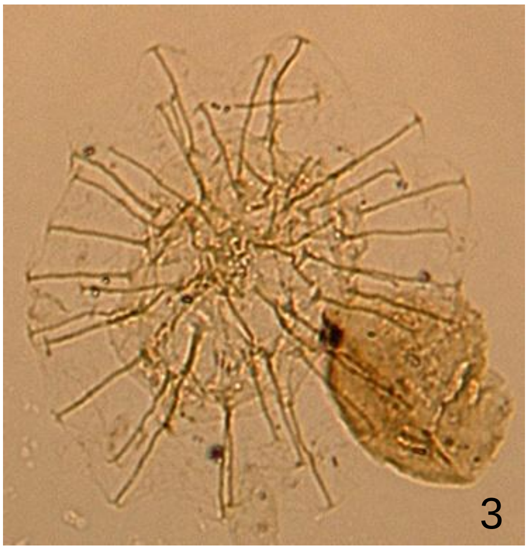
6- ***Tylotopalla caelamenicutis,*** Well-E1-NC174, 7287 ft., D50/2, scale bar = 5µm.

PLATE 22


1


2


5


3

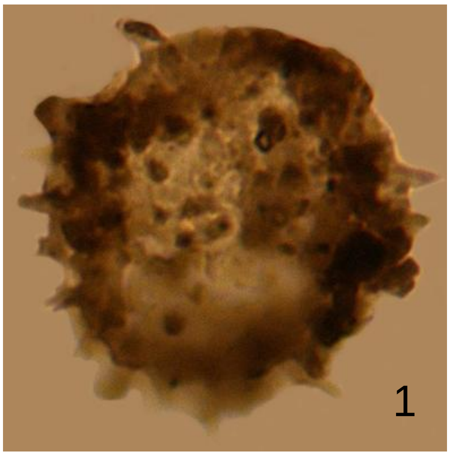

4

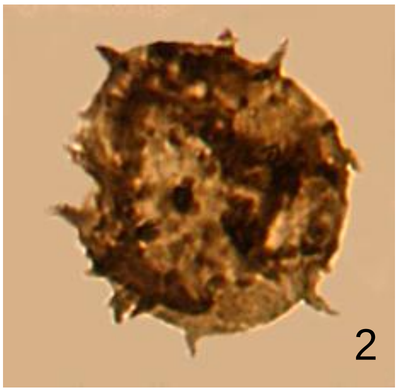

6

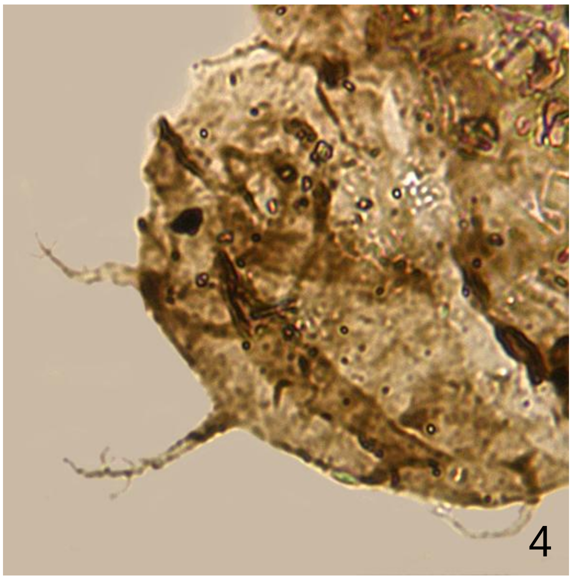
PLATE 23

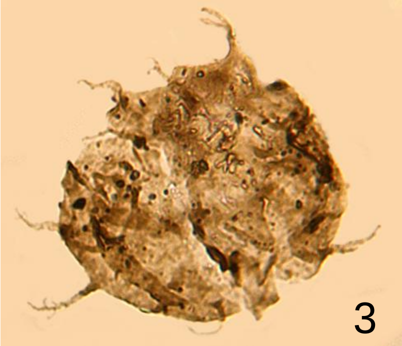
1. ***Tylotopalla caelamenicutis,*** Well-E1-NC174, 7287 ft., J34, scale bar = 5 µm.
2. ***Tylotopalla* cf. *deerlijkianum,*** Well-E1-NC174, 7287 ft., V32, scale bar = 10µm.
3. ***Uncinisphaera fusticula,*** Well A28i-NC186, 4708 ft., T30/4, scale bar = 10µm.
4. ***Uncinisphaera fusticula,*** Well A28i-NC186, 4708 ft., T30/4, scale bar = 5µm.
5. ***Veryhachium lairdi,*** Well A28i-NC186, 4513 ft., H44/3, scale bar = 10µm.
6. ***Veryhachium* cf. *lairdii,*** Well A28i-NC186, 4513 ft., G51/3, scale bar = 5µm.
7. ***Veryhachium oklahomenses,*** Well A28i-NC186, 4513 ft., H30, scale bar = 10µm.

PLATE 23


1


2


4


3


5


7

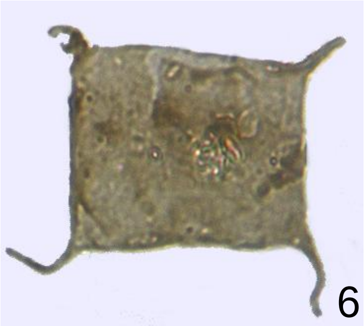

6

PLATE 24

1- ***Veryhacium reductum,*** Well A28i-NC186, 4508 ft., Q47/2, scale bar = 5 µm.

2- ***Veryhachium subglobosium,*** Well A28i-NC186, 4508 ft., S47/3, scale bar = 10µm.

3- ***Veryhachium trispinosum,*** Well A28i-NC186, 4513 ft., K31/1, scale bar = 10µm.

4- ***Veryhachium trispinosum,*** Well-I3-NC186, 4350 ft., W51, scale bar = 10µm.

5- ***Veryhachium trispinosum,*** Well-I3-NC186, 3950 ft., O46, scale bar = 5µm.

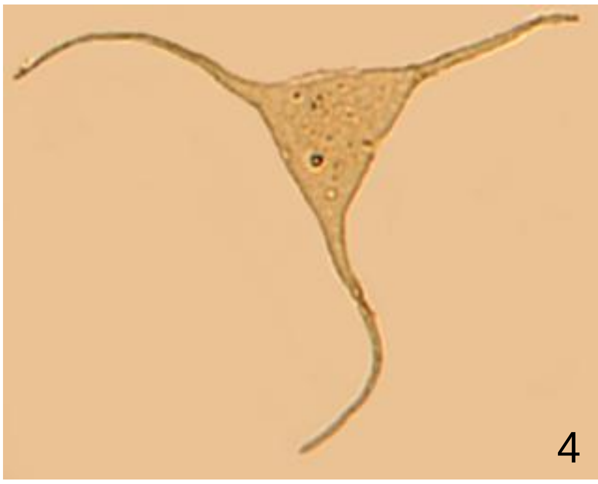
6- ***Veryhachium* cf. *trapezionarion,*** Well-I3-NC186, 4350 ft., W36, scale bar = 10µm.

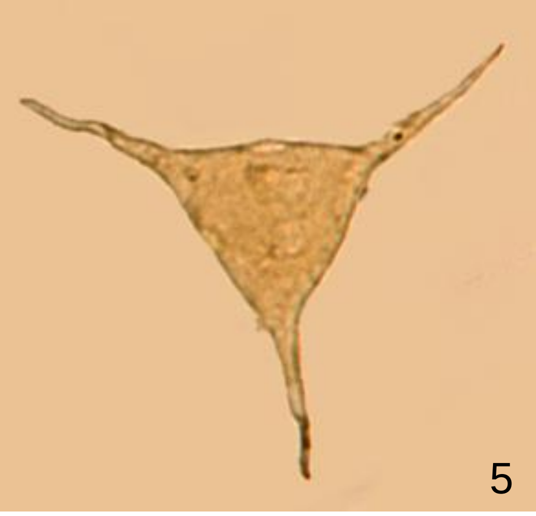
PLATE 24


1


2


3


4


5

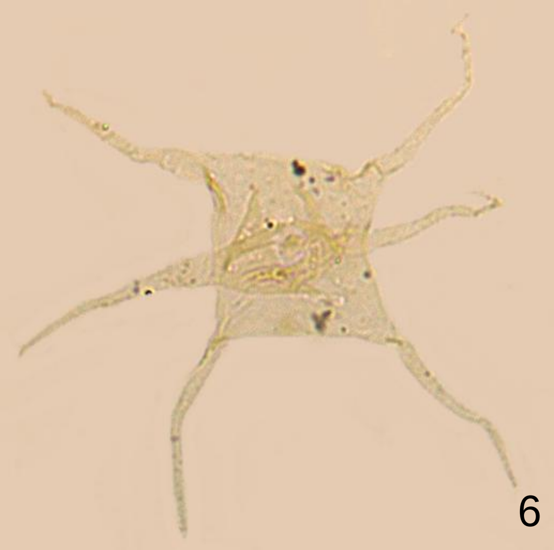

6

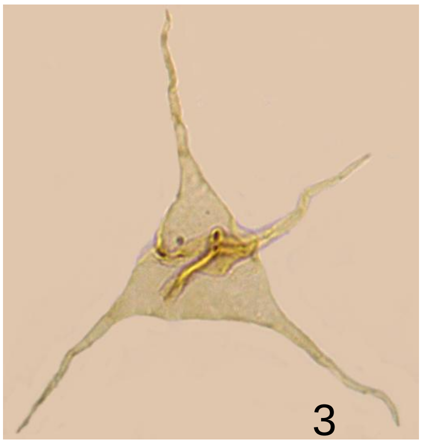
PLATE 25

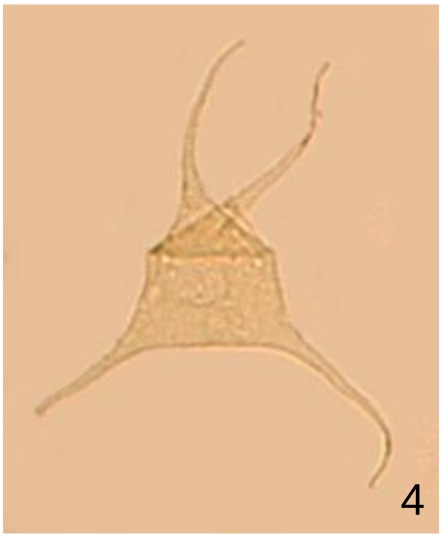
1- ***Veryhachium* cf. *strangulatum,*** Well A28i-NC186, 4513 ft., H48/4, scale bar = 10µm.
2- ***Veryhachium valiente,*** Well-E1-NC174, 7287 ft., E42/3, scale bar = 10 µm.
3- ***Veryhachium wenlockianum,*** Well-I3-NC186, 4350 ft., V30/1, scale bar = 10µm.
4- ***Veryhachium wenlockianum,*** Well-I3-NC186, 3950 ft., L46/4, scale bar = 10µm.
5- ***Villosacapsula irrorata,*** Well A28i-NC186, 4505 ft., P33/3, scale bar = 10µm.
6- ***Villosacapsula setosapellicula,*** Well A28i-NC186, 4508 ft., H42/3, scale bar = 5µm.

PLATE 25


1


2


3


4


5

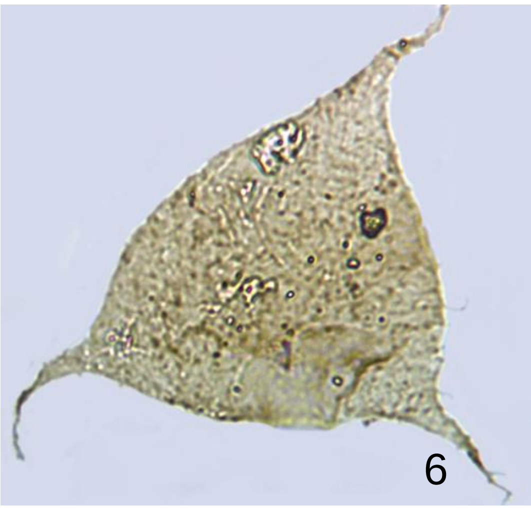

6

PLATE 26

1- ***Visbysphaera gotlandica,*** Well-I3-NC186, 3950 ft., S48, scale bar = 10µm.

2- ***Visbysphaera microspinosa,*** Well-I3-NC186, 3950 ft., N36/2 scale bar = 10µm.

3- ***Visbysphaera pirifera*** Well-I3-NC186, 4799 ft., Q47, scale bar = 10 µm.

4- ***Virgatasporites* cf. *rudi*,** A28i-NC186, 4715 ft., R43, scale bar = 5µm.

5- ***Tasmanites* spp.,** Well H2-NC186, 4500 ft., T35/3, scale bar = 8µm.

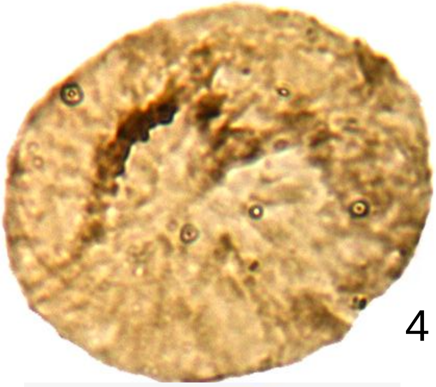
6- ***Tasmanites* spp.,** Well I3-NC186, 3950 ft., R33, scale bar = 8µm.

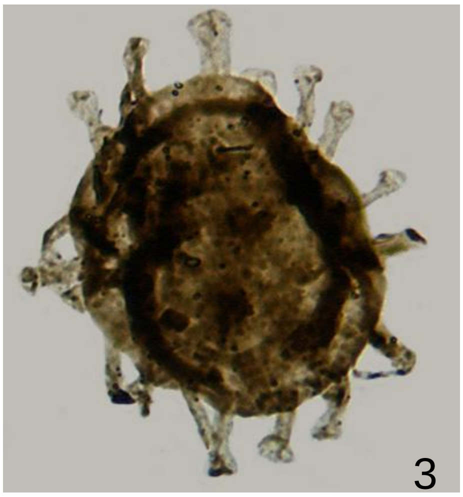
7- **Gen. et sp. Indent,** Well A28i-NC186, 4513 ft., Q29/3, scale bar = 20µm.

PLATE 26

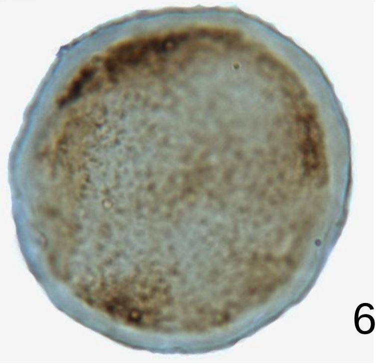

1


2


4


3


5


6


7

CHITINOZOAN PLATES

PLATE 1-16

PLATE 1

1- ***Acanthochitina* cf. *barbata,*** Well-A28i-NC186, 4492 ft., scale bar = 54µm.

2- ***Acanthochitina* cf. *barbata,*** Well-A28i-N186, 4492 ft., scale bar =50 µm.

3- ***Ancyrochitina ancyrea,*** Well-I3-NC186, 4349 ft., scale bar = 25µm.

4- ***Ancyrochitina* cf. *porrectaspina,*** Well-I3-NC186, 4550 ft., scale bar = 20µm.

5- ***Angochitina gurupiense,*** Well-I3-NC186, 4550 ft., scale bar = 35µm.

6- **Details of 5, showing spiny ornamentation**, scale bar = 20µm.

7- ***Angochitina hemeri,*** Well D1-200, 4050 ft., scale bar= 22µm.

8- **Details of 7 showing spines,** scale bar = 15µm.

9- ***Angochitina macclurei,*** Well-I3-NC186, 3700 ft., scale bar = 25µm.

10-***Angochitina murzukensis,*** Well-E1-NC174, 4287 ft., scale bar = 20µm.

11-**Details of 10, showing spiny ornamentation**, scale bar = 15µm

PLATE 1

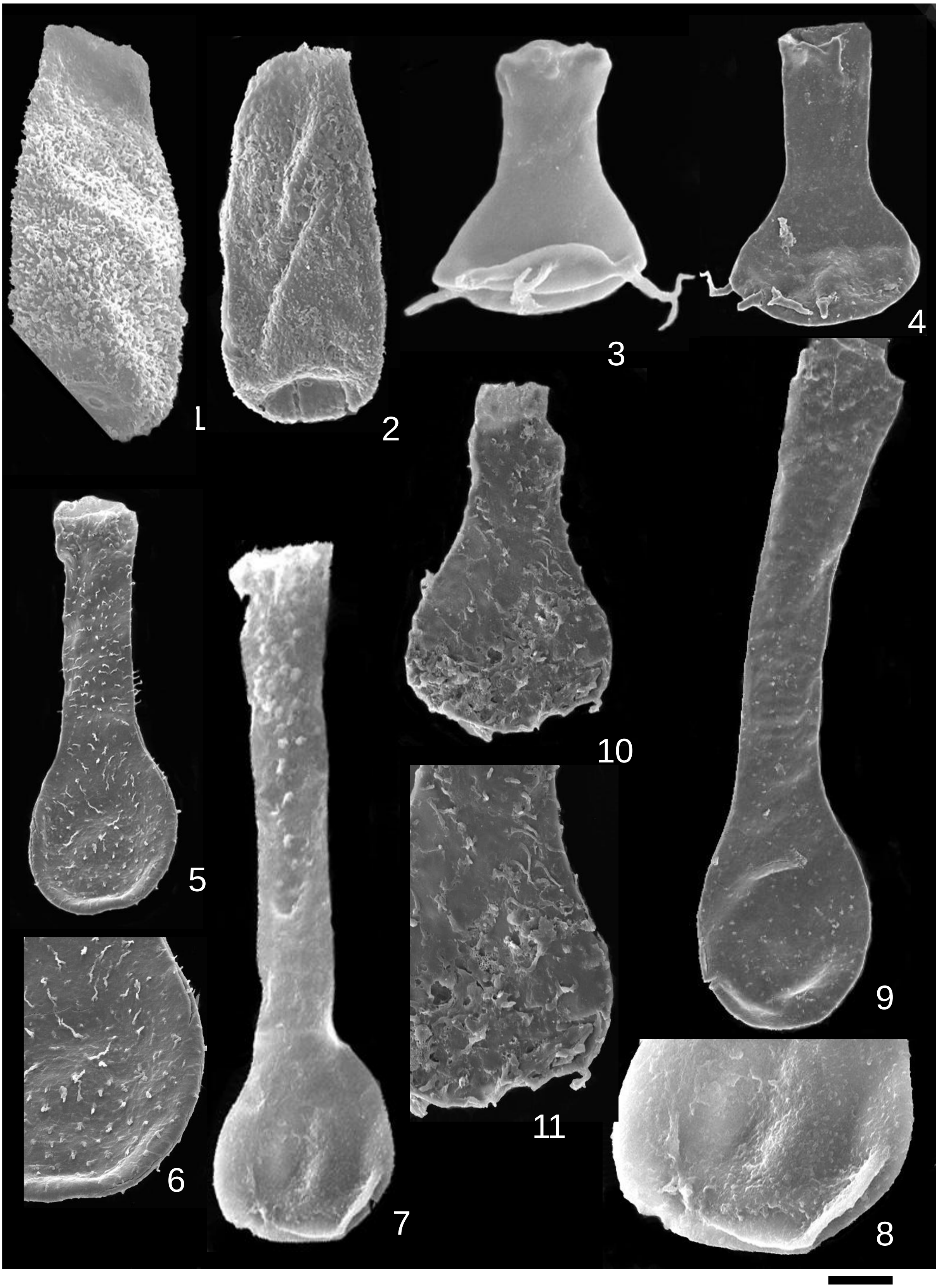


PLATE 2

1- ***Armoricochitina nigerica,*** Well-D1-200, 4778 ft., scale bar = 25µm.
2- ***Armoricochitina nigerica,*** Well-D1-200, 4778 ft., scale bar = 30µm.
3- ***Armoricochitina* cf. *iranica,*** Well-A28i-NC186, 4513 ft., scale bar = 30µm.
4- ***Armoricochitina* sp. A,** Well-D1-200, 4778 ft., scale bar = 35µm.
5- ***Belonechitina americana,*** Well-A28i-NC186, 4513 ft., scale bar = 30µm
6- **Details of 5, showing spiny ornamentation**, scale bar = 15µm
7- ***Belonechitina aspera*** Well E1-NC174, 7246 ft., scale bar = 35µm
8- ***Belonechitina aspera*** Well E1-NC174, 7270 ft., scale bar = 40µm
9- ***Belonechitina capitata,*** Well-D1-200, 4778 ft., scale bar = 30µm.
10- **Details of 9, showing spiny ornamentation**, scale bar = 7.5µm.
11- ***Belonechitina capitata,*** Well-I3-NC186, 4799 ft., scale bar = 20µm.
12- **Details of 11, showing spiny ornamentation**, scale bar = 15µm.
13- ***Belonechitina* cf. *capitata*** Well- A28i-NC186, 4500 ft., scale bar = 25µm.

PLATE 2

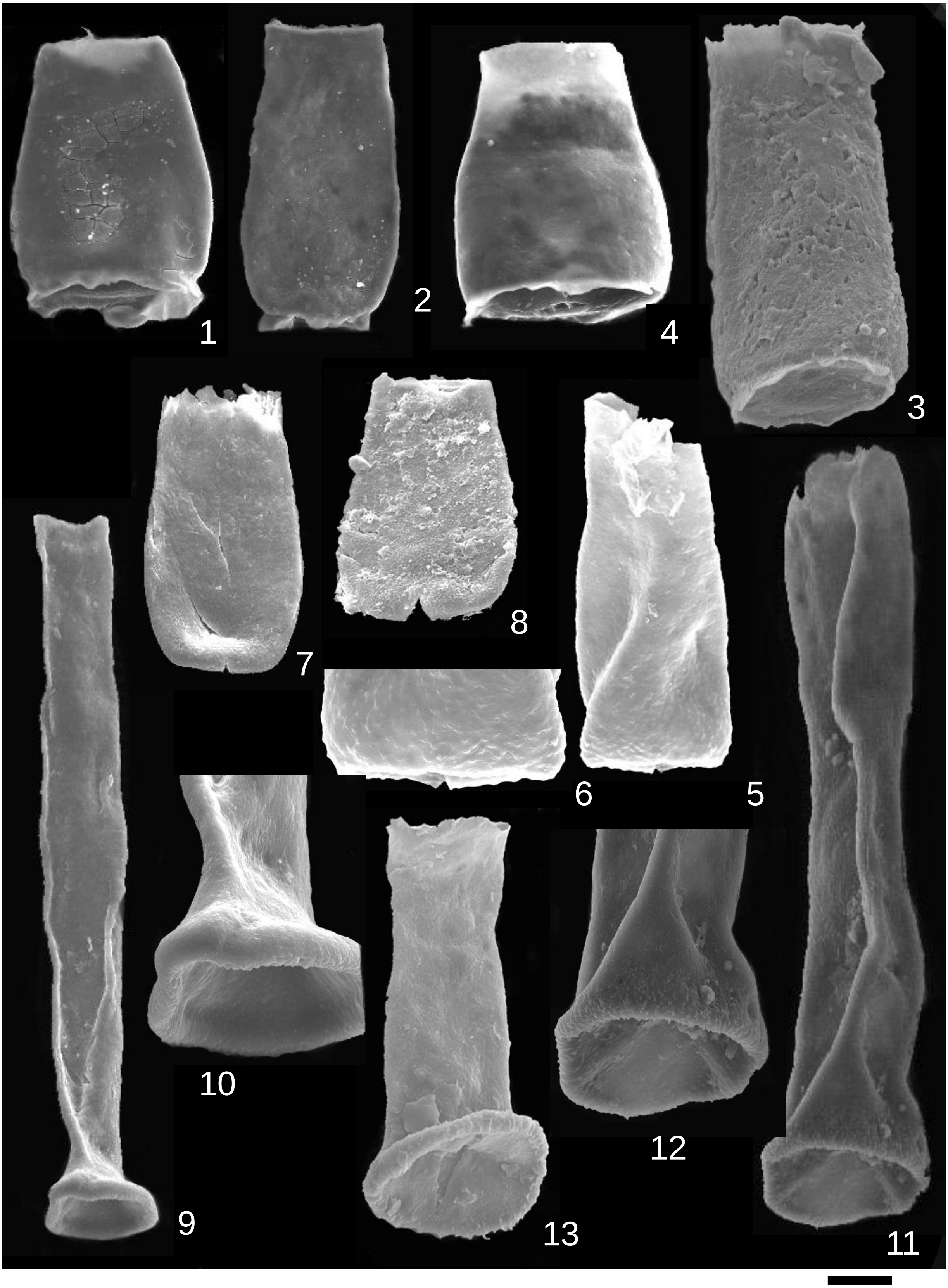


PLATE 3

1- ***Belonechitina micracantha*** Well-D1-200, 4778 ft., scale bar = 45µm

2- **Details of 2, showing spiny ornamentation**, scale bar = 15µm.

3- ***Belonechitina micracantha*** Well-H2-NC186, 4833 ft., scale bar = 25µm.

4- ***Belonechitina paraviterea*** Well-D1-200, 4050 ft., scale bar = 17µm

5- **Details of 4, showing spiny ornamentation**, scale bar = 11µm

6- ***Belonechitina postrobusta*** Well-E1-NC174, 7246 ft., scale bar = 22µm.

7- ***Belonechitina postrobusta*** Well- E1-NC174, 7287 ft., scale bar = 25µm.

8- ***Belonechitina postrobusta*** Well- E1-NC174, 7287 ft., scale bar = 22µm

9- ***Belonechitina* sp. A** Well-D1-200, 4794 ft., scale bar = 20µm.

10-***Belonechitina* sp. B** Well-A28i-NC186, 4508 ft., scale bar = 25µm.

11-***Belonechitina* sp. D** Well-A28i-NC186, 4508 ft., scale bar = 40µm.

12-Details of 11, showing spiny ornamentation, scale bar = 10µm.

PLATE 3

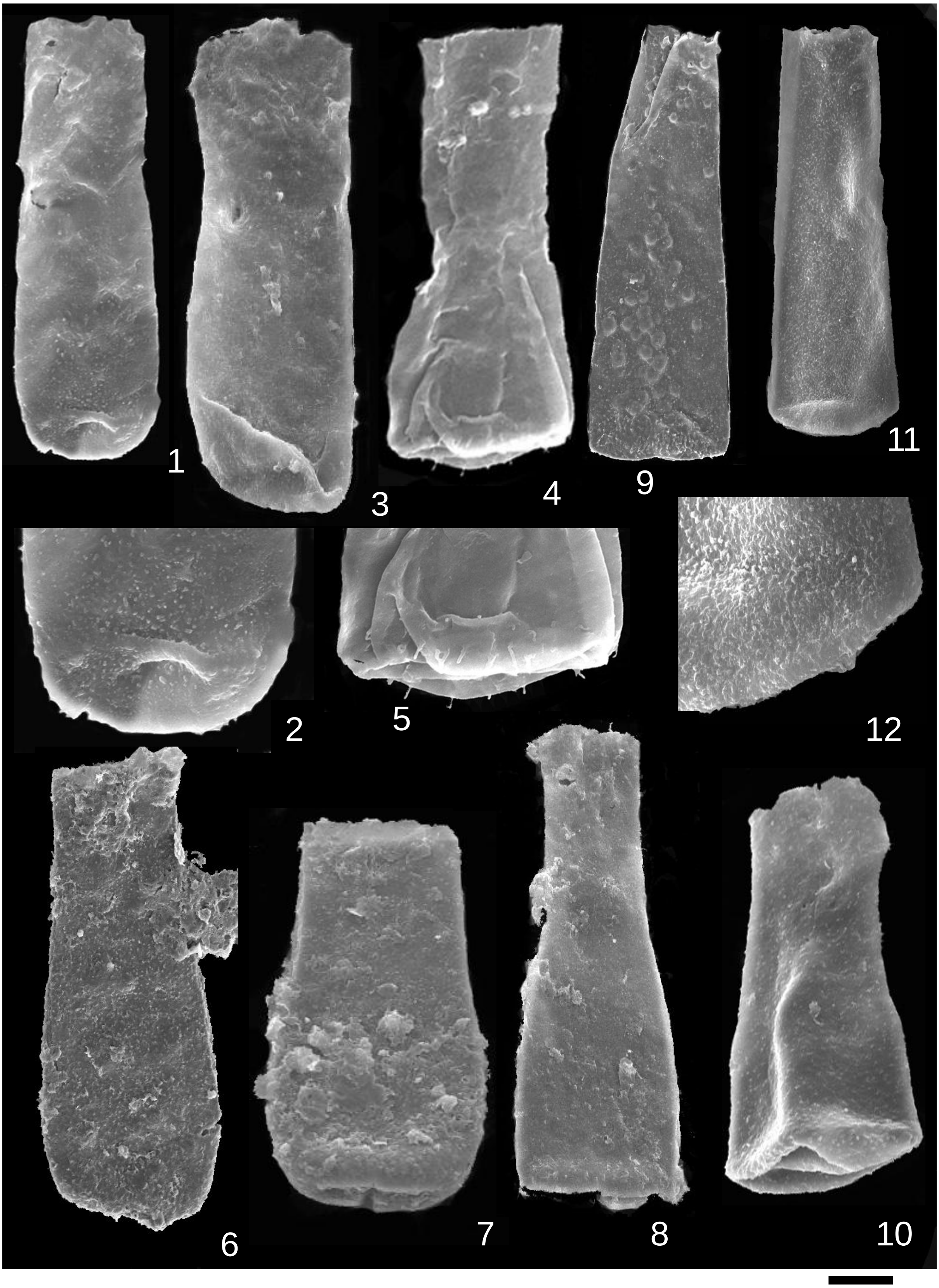


PLATE 4

1- ***Calpichitina lenticularis,*** Well-D1-200, 4854 ft., scale bar = 25µm.
2- ***Calpichitina lenticularis,*** Well-D1-200, 4874 ft., scale bar = 25µm.
3- ***Calpichitina lenticularis,*** boral view, Well-D1-200, 4878 ft., scale bar = 25µm.
4- ***Clavachitina* cf. *grandis,*** Well-A28i-NC186, 4513, scale bar = 20µm.
5- ***Conochitina* cf. *alargada,*** Well I3-NC186, 4450 ft., scale bar = 30µm.
6- ***Conochitina* cf. *armillata,*** Well-E1-NC174, 6950 ft., scale bar = 35µm.
7- ***Conochitina* cf. *electa,*** Well B2-NC186, 3850 ft., scale bar = 30µm.
8- ***Conochitina elegans,*** Well-D1-200, 4874 ft., scale bar = 35µm.
9- ***Conochitina* cf. *elegans,*** Well-A28i-NC186, 4492 ft., scale bar = 35µm.
10- ***Conochitina* cf. *minnesotensis,*** Well-H2-NC186, 4950 ft., scale bar = 48µm.
11- **Details of 10, showing spiny ornamentation**, scale bar = 15µm.
12- ***Conochitina proboscifera,*** Well D1-200, 4050 ft., scale bar = 37µm.
13- ***Conochitina* sp. A,** Well-I3-NC186, 3950 ft., scale bar = 27µm.
14- ***Conochitina* sp. B,** Well-I3i-NC186,3890 ft., scale bar = 30µm.

PLATE 4

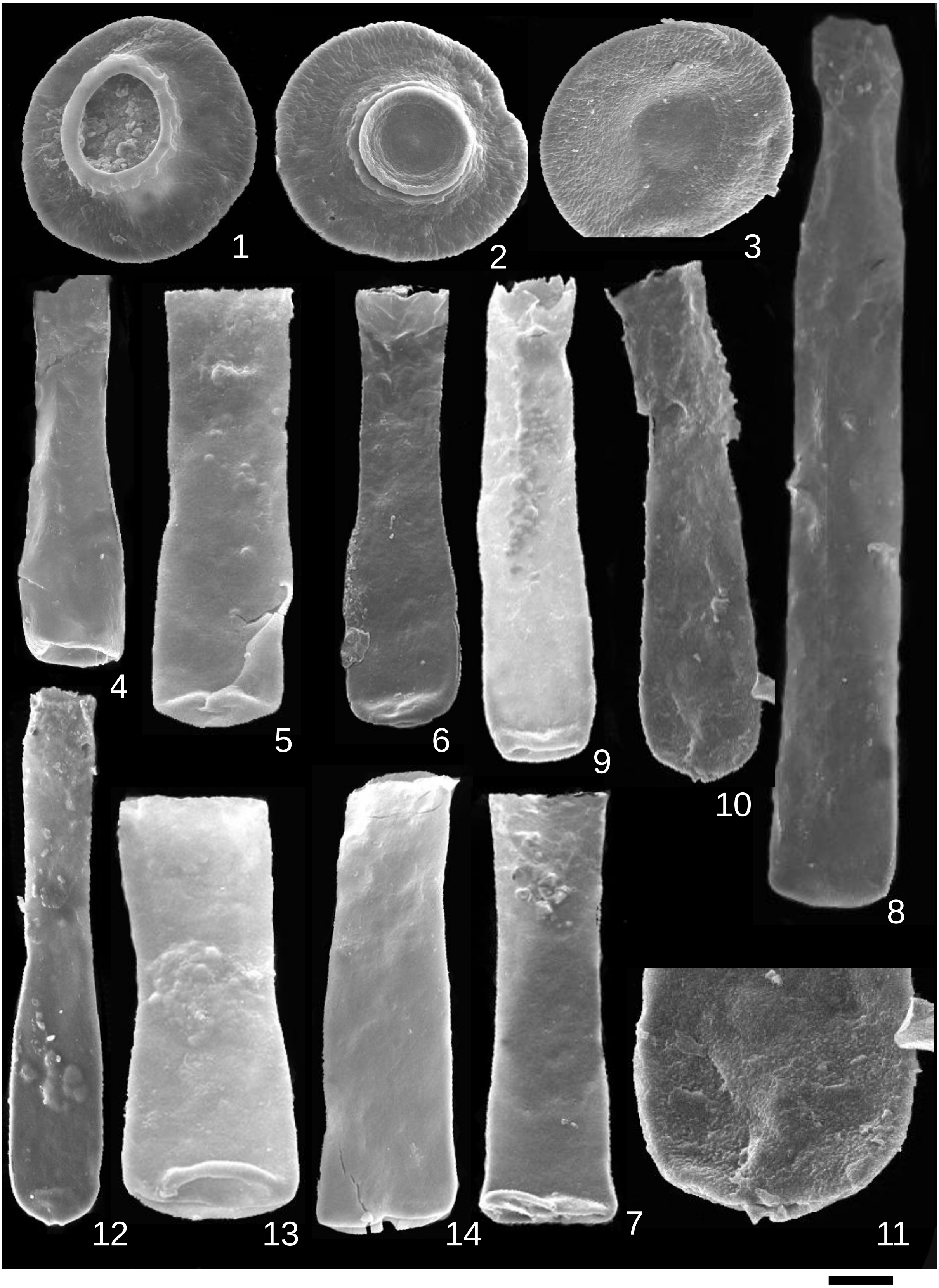


PLATE 5

1. ***Cyathochitina campanulaeformis,*** Well-D1-200, 4854 ft., scale bar = 30µm.
2. ***Cyathochitina campanulaeformis,*** Well-D1-200, 4874 ft., scale bar = 30µm.
3. ***Cyathochitina costata,*** Well A28i-NC186,4508 ft. scale bar = 30µm.
4. ***Cyathochitina costata,*** Well A28i-NC186, 4518fi. scale bar = 37µm.
5. ***Cyathochitina kuckersiana,*** Well-E1-NC174, 4287 ft., scale bar = 40µm.
6. ***Cyathochitina kuckersiana,*** Well-E1-NC174, 4287 ft., scale bar = 40µm.
7. ***Cyathochitina kuckersiana,*** Well-E1-NC174, 4287 ft., scale bar = 40µm.
8. ***Cyathochitina* cf. *regnelli,*** Well-D1-200, 4810 ft., scale bar = 30µm.
9. ***Cyathochitina* cf. *regnelli,*** Well-D1-200, 4810 ft., scale bar = 25µm.

PLATE 5

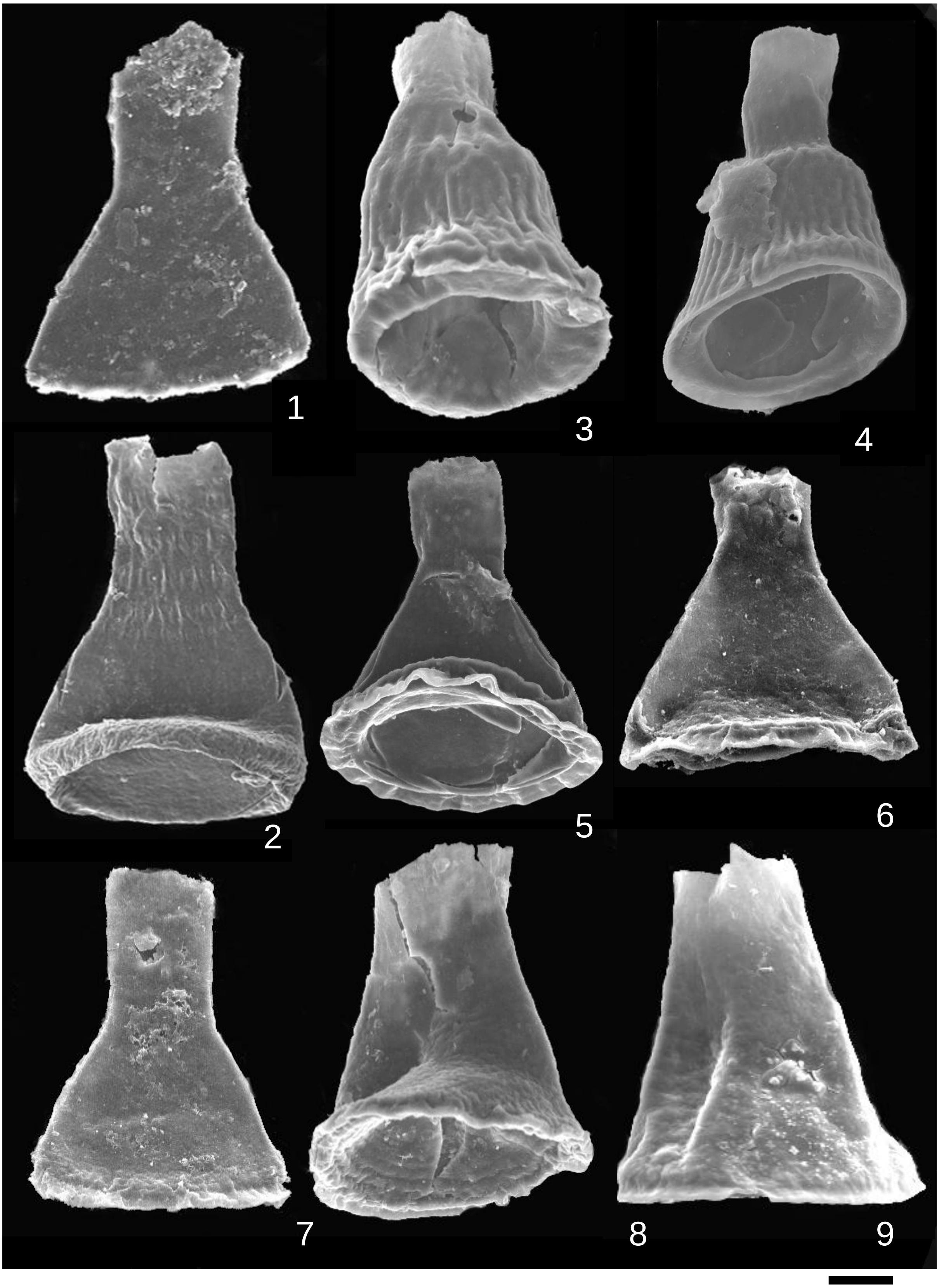


PLATE 6

1- ***Desmochitina minor,*** Well-A28i-NC186, 4501 ft., scale bar = 22µm.
2- ***Euconochitina lepta,*** Well-D1-200, 4831.5 ft., scale bar = 20µm.
3- ***Fungochitina actonica,*** Well-A28i-NC186, 4500 ft., scale bar = 30µm.
4- **Details of 3, showing spiny ornamentation**, scale bar = 12µm.
5- ***Fungochitina spinifera,*** Well-A28i-NC186, 4500 ft., scale bar = 30µm.
6- **Details of 5, showing spiny ornamentation**, scale bar = 14µm.
7- ***Lagenochitina baltica,*** Well-D1-200, 4878 ft., scale bar = 25 µm.
8- ***Lagenochitina prussica,*** Well-A28i-NC186, 4992 ft., scale bar = 25µm.
9- **Details of 8, showing spiny ornamentation**, scale bar = 2.6µm.
10- **Details of 8, showing spiny ornamentation**, scale bar = 7µm.

PLATE 6

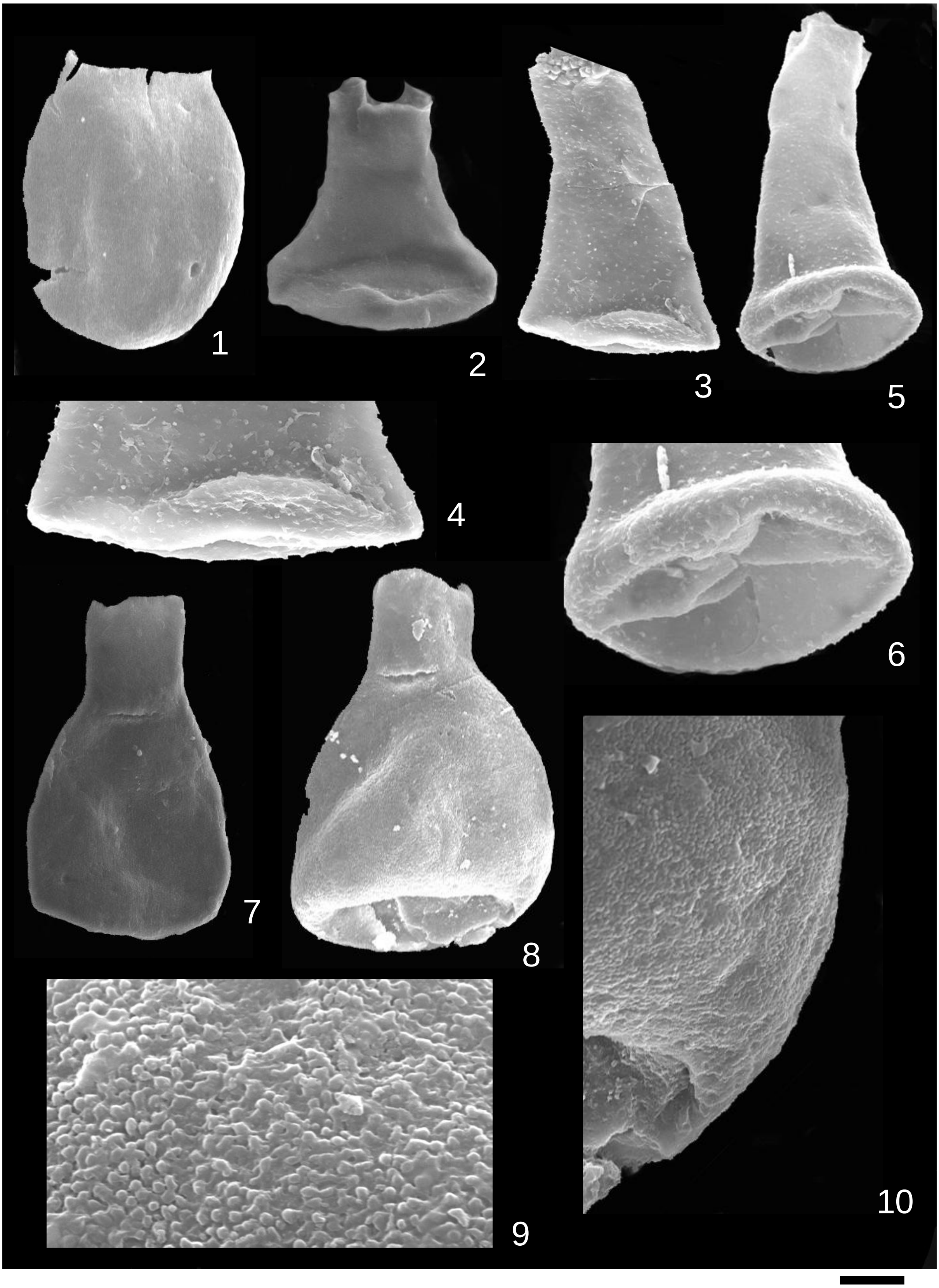


PLATE 7

1- ***Lagenochitina* cf. *avelinoi*** Well-E1-NC174, 4287 ft., scale bar = 39µm.
2- ***Lagenochitina* cf. *dalbyensis*** Well-D1-200, 4874 ft., scale bar = 30µm.
3- ***Lagenochitina* sp. A** Well-D1-200, 4864 ft., scale bar = 30µm.
4- ***Lagenochitina* sp. B** Well-A28i-NC186, 4513 ft., scale bar = 45µm.
5- **Details of 4, showing foveolate ornamentation**, scale bar = 9µm.
6- **Details of 4, showing foveolate ornamentation scale** bar = 5µm.
7- ***Laufeldochitina* sp. A** Well A28i-NC186, 4492 ft, scale bar = 21µm.
8- ***Plectochitina paraguayensis*** Well-E1-NC174, 7255 ft., scale bar = 30µm.
9- ***Plectochitina pseudoagglutinans*** Well-I3-NC186, 4450 ft., scale bar = 20µm.
10- ***Plectochitina* cf. *kazhdumiensis*** Well-I3-NC186, 4350 ft., scale bar = 20µm.

PLATE 7

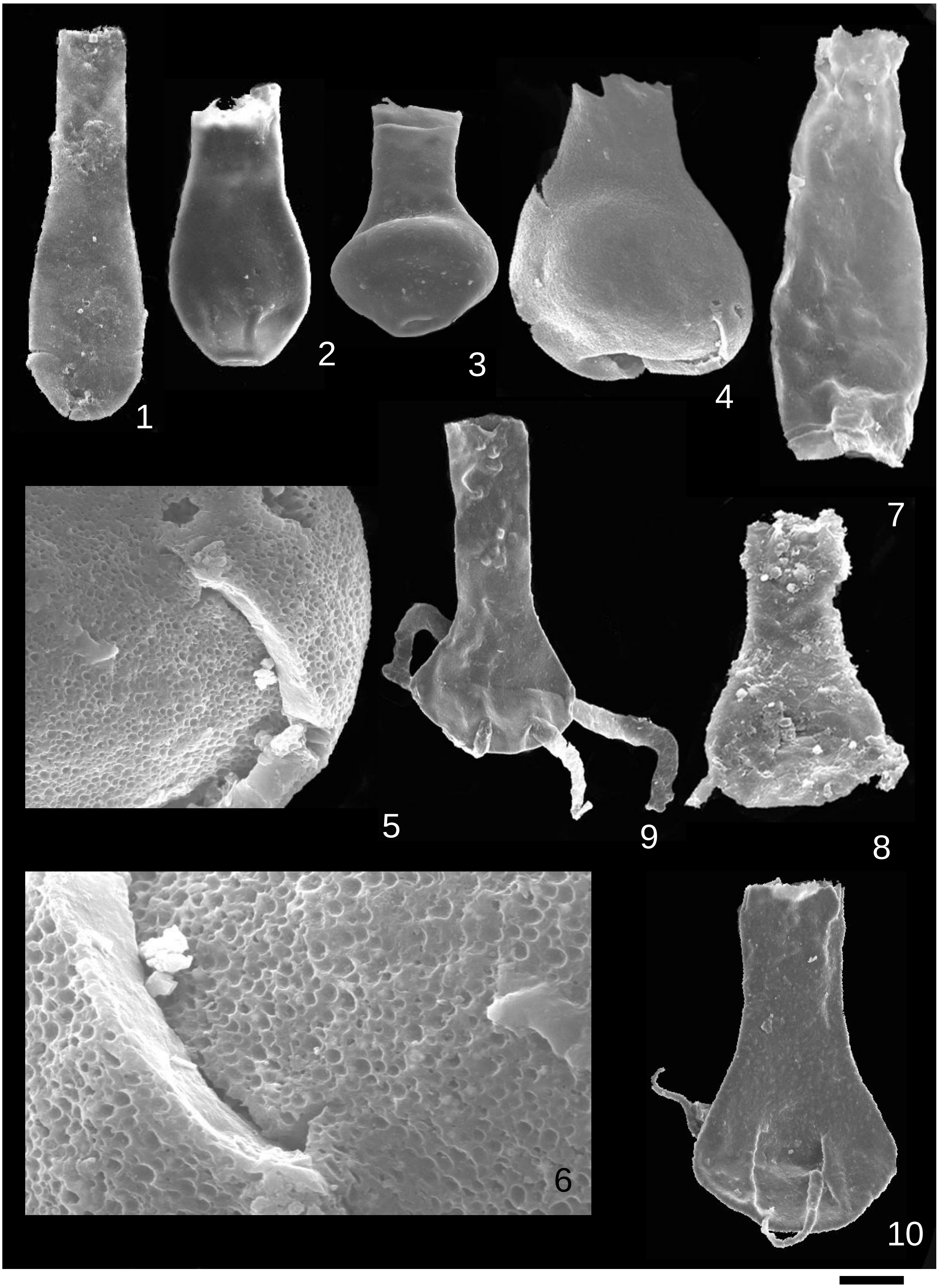
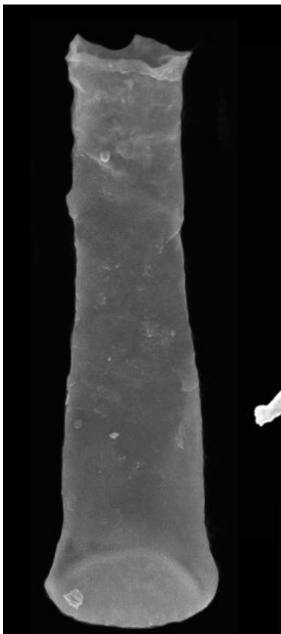


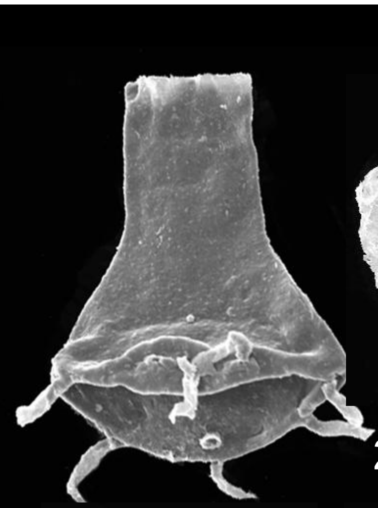
PLATE 8

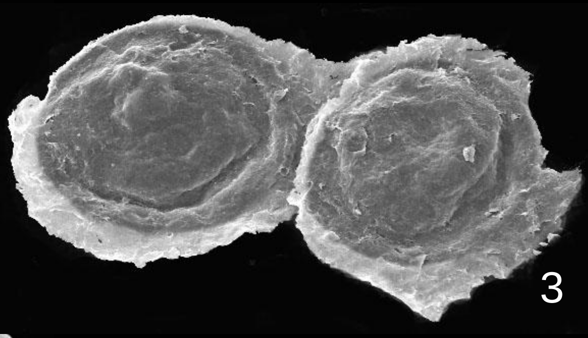
1- ***Plectochitina* spp.,** Well-I3-NC186, 4450 ft., scale bar = 25µm.
2- ***Pistillachitina* cf*. pistilifrons,*** Well-D1-200, 4810 ft., scale bar = 25µm.
3- ***Pterochitina deichaii,*** Well-I3-NC186, 4450 ft., scale bar = 25µm.
4- ***Rhabdochitina gracilis,*** Well-D1-200, 4854 ft., scale bar = 30µm.
5- **Details of 4, showing a basal part,** scale bar = 10µm.
6- ***Rhabdochitina magna,*** Well-D1-200, 4874 ft., scale bar = 30µm.
7- ***Rhabdochitina turgida,*** Well-D1-200, 4874 ft., scale bar = 30µm.
8- ***Sphaerochitina* cf. *silurica,*** Well-I3-NC186, 4180 ft., scale bar = 25µm

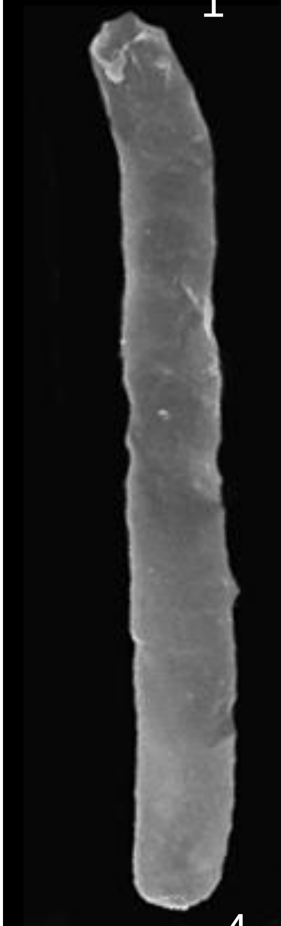
.

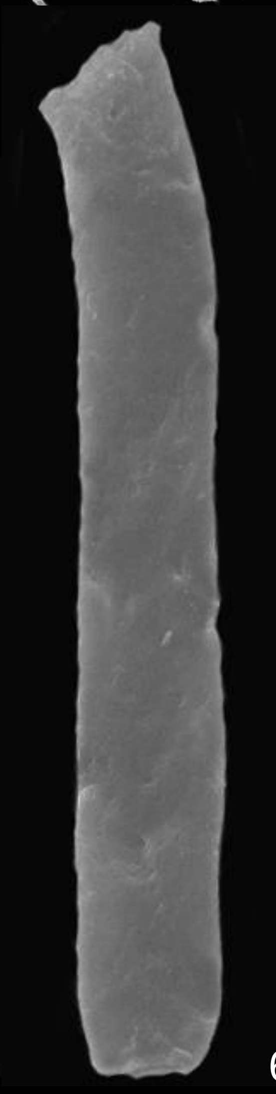
PLATE 8

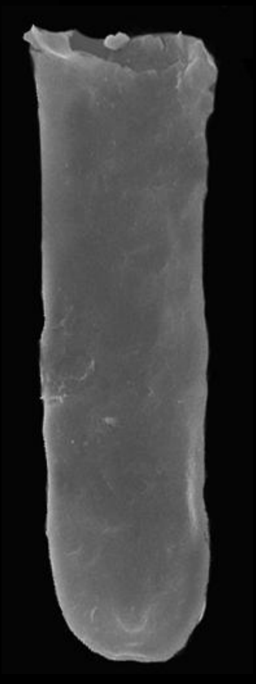

1


2


3


4


6


7


8

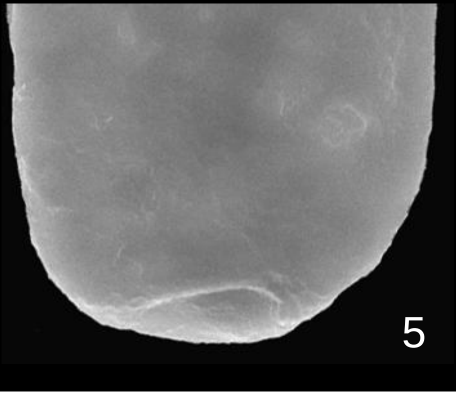

5

PLATE 9

1- ***Spinachitina fragilis,*** Well-B2-NC186-NC174, 3950 ft., scale bar = 33µm.
2- **Details of 1, showing spines,** scale bar = 18.5µm.
3- ***Spinachitina oulebsiri,*** Well-A28i-NC186,4508 ft., scale bar = 20µm
4- **Details of 3, showing spines,** scale bar = 12µm
5- ***Spinachitina oulebsiri,*** Well-A28i-NC186, 4523 ft., scale bar = 20µm
6- **Details of 5, showing spines,** scale bar = 15µm
7- ***Spinachitina oulebsiri,*** Well-A28i-NC186, 4505 ft., scale bar =25 µm
8- **Details of 7, showing spines,** scale bar = 15µm.
9- ***Spinachitina* cf. *oulebsiri,*** Well-A28i-NC186, 4513 ft., scale bar = 21 µm
10-**Details of 9, showing spines,** scale bar = 13µm.
11-***Spinachitina fossensis,*** Well-D1-200, 4778 ft., scale bar = 17µm.
12-**Details of 11, showing spines,** scale bar = 12µm.

PLATE 9

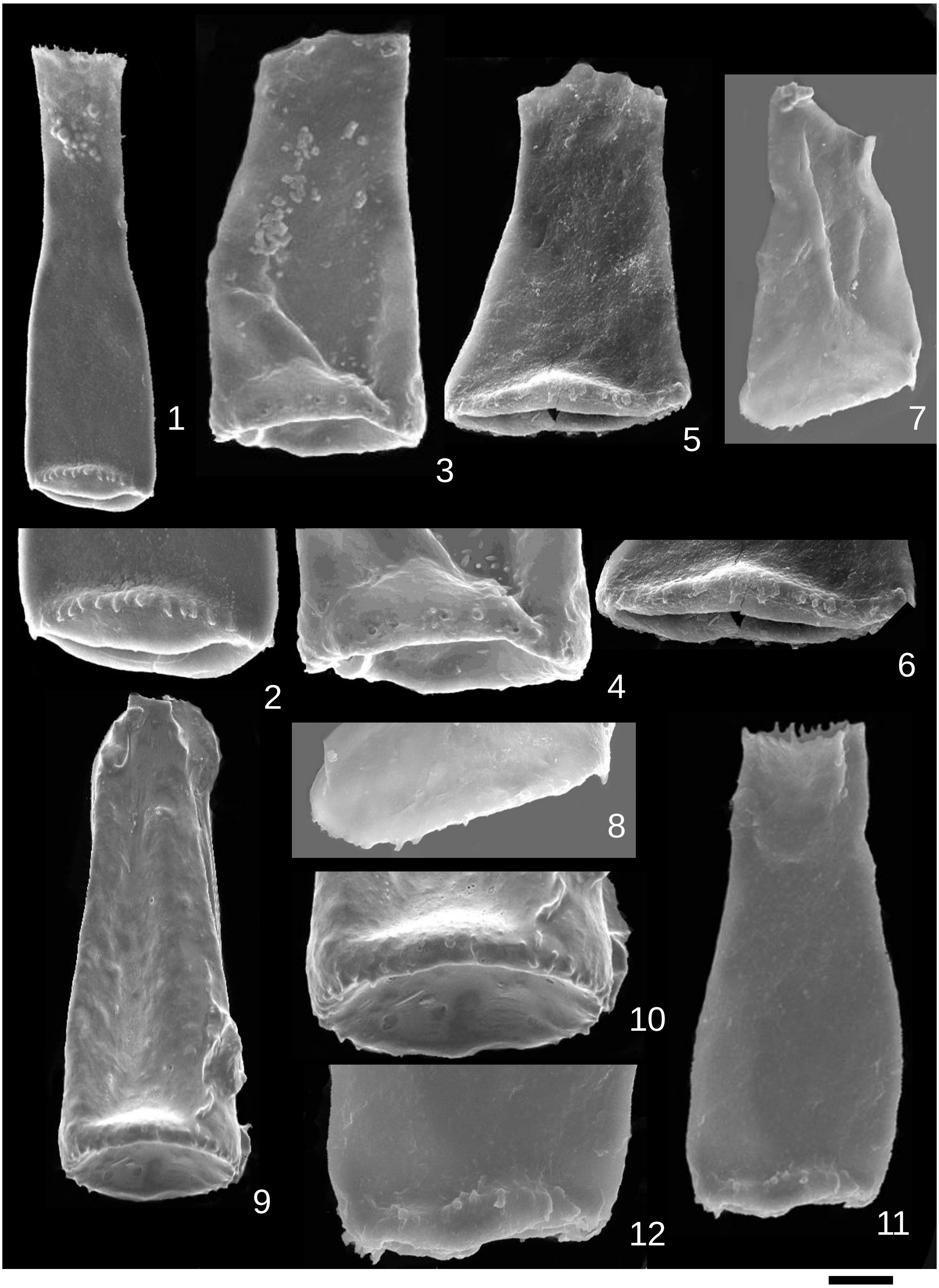


PLATE 10

1- ***Spinachitina* cf. *fragilis*** Well-B2-NC186, 3850 ft., scale bar = 45µm.
2- **Details of 2, showing spines,** scale bar = 24µm.
3- ***Tanuchitina anticostiensis*** Well I3-NC-186, 4782 ft., scale bar = 30µm.
4- ***Tanuchitina anticostiensis*** Well-D1-200, 4854 ft., scale bar = 40µm.
5- **Details of 4, showing carina,** scale bar = 20µm.
6- ***Tanuchitina elongata*** Well-D1-200, 4825 ft., scale bar = 40µm.
7- ***Tanuchitina* sp.A** Well-D1-200, 4778 ft., scale bar = 40µm.
8- **Details of 7, showing carina,** scale bar = 15µm.
9- ***Tanuchitiuna* sp. B** Well-D1-200, 4778 ft., scale bar = 37µm.
10-***Tanuchitina* sp.C** Well-A28i-NC186, 4492 ft., scale bar = 29µm.
11-**Details of 10, carina,** scale bar = 10µm.
12-***Velatachitina* cf. *veligera*** Well-H2-NC186, 4950 ft., scale bar = 40 µm.

PLATE 10

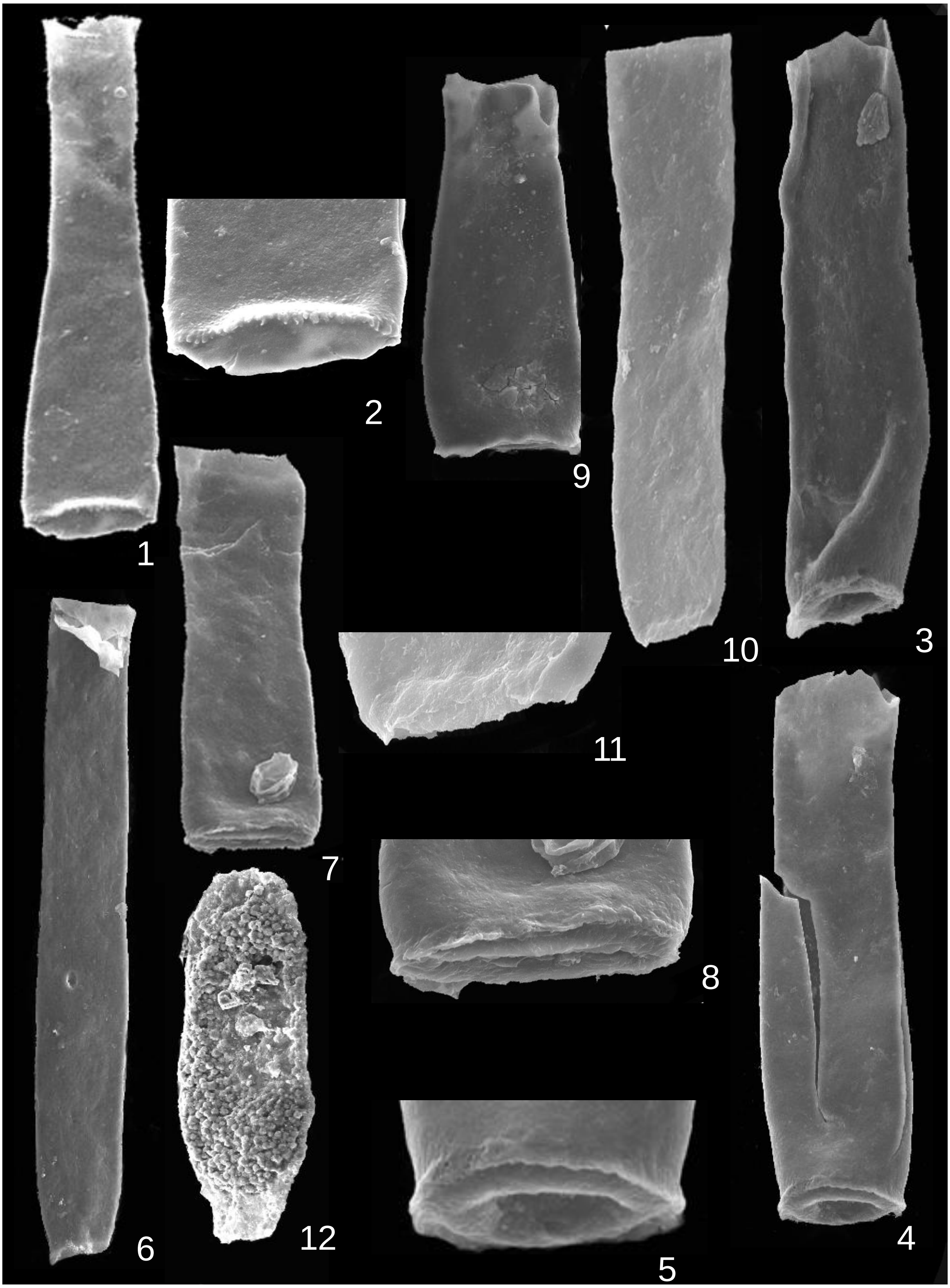


PLATE 11

1- ***Ancyrochitina ancyrea,*** Well-I3-NC186, 3950 ft., G45/2, scale bar = 25µm.
2- ***Ancyrochitina* cf. *laevaensis,*** Well-E1-NC174, 7287 ft., O30, scale bar = 20µm.
3- ***Ancyrochitina merga,*** Well-D1-200, 4831.5 ft., H52/1, scale bar = 20µm.
4- ***Ancyrochitina merga,*** Well-D1-200, 4878 ft., S34/2, scale bar = 20µm.
5- ***Ancyrochitina ramosaspina,*** Well-D1-200, 4550 ft., S42/3, scale bar = 20µm.
6- ***Ancyrochitina* cf. *udaynanensis,*** Well-I3-NC186, 4800 ft., scale bar = 20µm.
7- ***Ancyrochitina* sp. A,** Well-D1-200, 4450 ft., P44/2 scale bar = 20µm.
8- ***Ancyrochitina* sp. A,** Well-D1-200, 4650 ft., P44/2 scale bar = 20µm.

PLATE 11

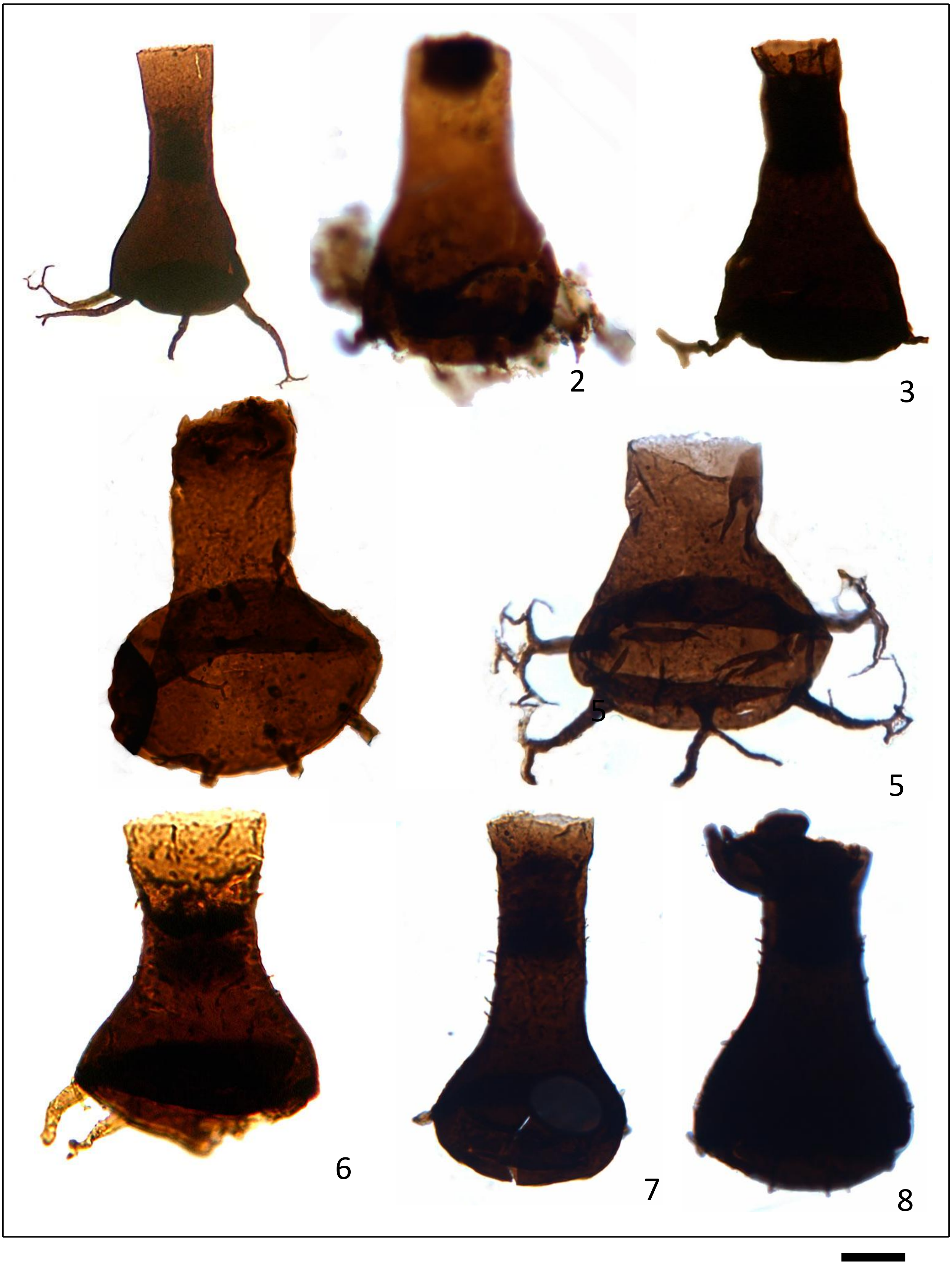


PLATE 12

1- ***Angochitina hemeri,*** Well I3-NC186, 3950 ft., E51/3, scale bar= 20µm.
2- **Details of 1 showing spines,** scale bar = 10µm.
3- ***Angochitina macclurei,*** Well-I3-NC186, 3700 ft., P29, scale bar = 20µm.
4- **Details of 3 showing spines,** scale bar = 10µm.
5- ***Angochitina qusaibaensis,*** Well-I3-NC186, 4400ft., K47, scale bar = 20µm.
6- ***Angochitina qusaibaensis,*** Well-I3-NC186, 4400ft., J33/4, scale bar = 20µm.
7- ***Angochitina* sp. A,** Well-E1-NC174, 6750 ft., S44/1, scale bar = 20µm.
8- **Details of 7 showing spines,** scale bar = 12µm.

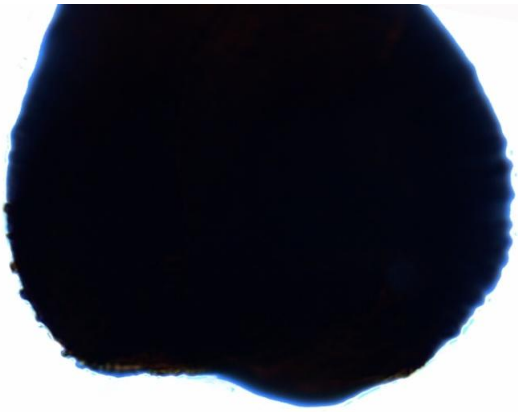
PLATE 12


1


5


6


3


2


4


7


8

PLATE 13

1- ***Armoricochitina nigerica,*** Well-D1-200, 4854 ft., U54, scale bar = 25µm.

2- ***Belonechitina arabiensis*,** Well I3-NC186, 3700 ft., P29, scale bar = 13µm.

3- ***Belonechitina micracantha,*** Well-D1-200, 4854 ft., J52, scale bar = 35µm.

4- ***Belonechitina micracantha,*** Well-D1-200, 4854 ft., F53/3, scale bar = 35µm.

5- ***Belonechitina paraviterea,*** Well I3-NC186, 4400 ft., T46/3 scale bar = 15µm.

6- ***Belonechitina paraviterea,*** Well D1-200, 4550 ft., T45, scale bar = 20µm.

7- ***Belonechitina psudarabiensis,*** Well E1-NC174, 4287ft., X50/4, scale bar = 20µm.

8- ***Belonechitina psudarabiensis,*** Well E1-NC174, 7287 ft., V48/2, scale bar = 20µm.

9- ***Belonechitina* sp.C,** Well I3-NC186, 4782 ft., scale bar = 25µm.

10-***Calpichitina densa,*** Well D1-200, 4050 ft., T42, scale bar = 16µm.

11-***Conochitina cf. armillata,*** WellD1-200, 4550, P36, scale bar = 32µm.

PLATE 13


1


2


7

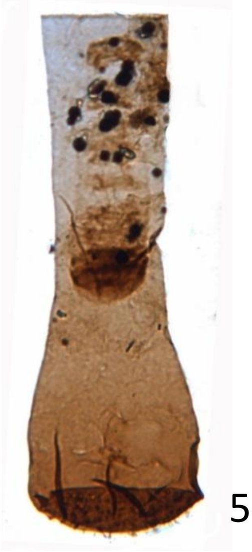

8


3


4


9


11


5


6

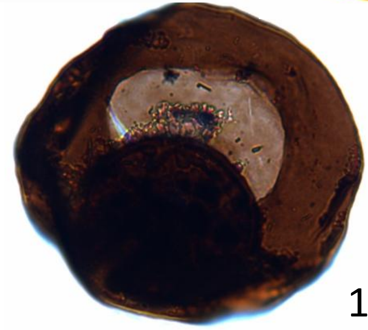

10

PLATE 14

1- ***Conochitina edjelensis,*** Well-I3-NC186, 3950ft., scale bar = 25µm.

2- ***Conochitina* cf. *electa,*** Well-D1-200, 4650 ft., O48/3, scale bar = 27µm.

3- ***Conochitina proboscifera,*** Well-I3-NC186, 3950ft., scale bar = 35µm.

4- ***Conochitina* cf. *subcyatha,*** Well-I3-NC186, 4400ft., scale bar = 35µm.

5- ***Desmochitina minor,*** Well-D1-200, 4831.5 ft., scale bar = 20µm.

6- ***Desmochitina minor,*** Well-D1-200, 4831.5 ft., scale bar = 20µm.

7- ***Desmochitina minor,*** Well-D1-200, 4831.5 ft., scale bar = 20µm.

8- ***Desmochitina cf. piriformis,*** Well-D1-200, 4831.5 ft., scale bar = 20µm.

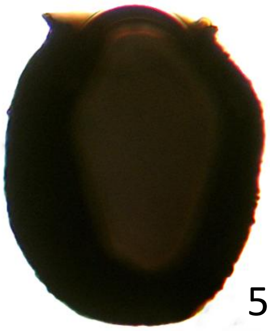
9- ***Euconochitina lepta,*** Well-D1-200, 4831.5ft., scale bar = 20µm.

10-***Euconochitina brevis,*** Well-H2-NC186, 4950 ft., S50/3, scale bar = 34µm.

PLATE 14


1


4


5


6


8


7


2


3


9


10

PLATE 15

1- ***Euconochitina vitrea,*** Well B2-NC186, 4950 ft., C28/4, scale bar = 17µm.
2- ***Lagenochitina* cf. *navicula,*** E1-NC174, 7267 ft., B32, scale bar=25µm.
3- ***Lagenochitina* cf. *nuayyimensis,*** I3-NC186, 3890 ft., E41/2, scale bar= 20µm.
4- **Details of 3 showing irregular verrucae ornamentation,** scale bar = 12µm.
5- ***Plectochitina* cf. *nodifera,*** Well-E1-NC174, 7287 ft., U54/1, scale bar = 25µm.
6- ***Plectochitina paraguayensis,*** Well-I3-NC186, 3950ft., J55, scale bar = 25µm.
7- ***Plectochitina pseudoagglutinans,*** Well D1200, 4550 ft., X33, scale bar = 25µm.
8- ***Plectochitina* cf. *sylvanica,*** Well-D1200, 4810 ft., U34/4, scale bar = 27µm.
9- ***Plectochitina* cf. *carminae,*** Well-I3-NC186, 4200ft., D46/3, scale bar = 20µm.

PLATE 15

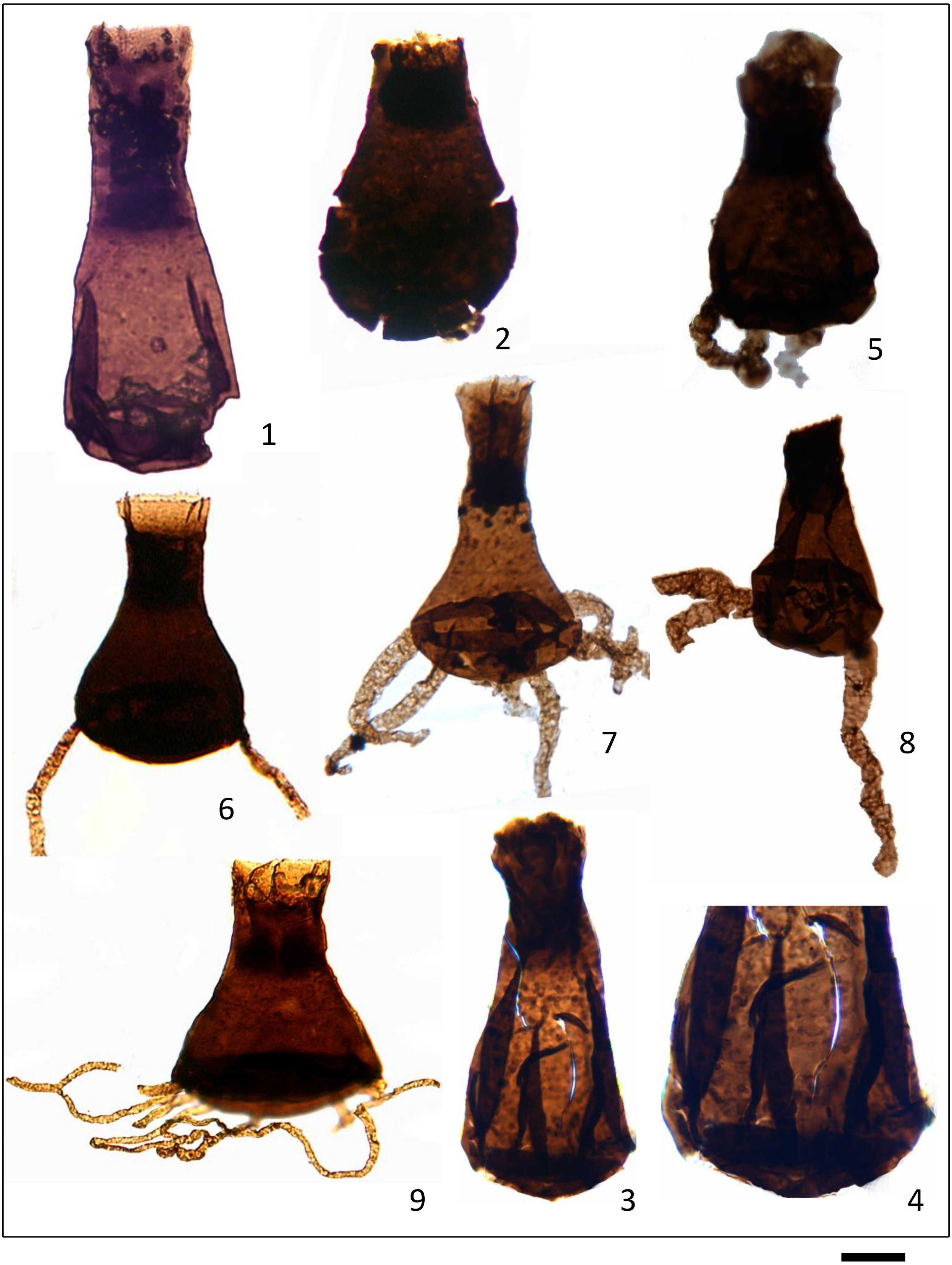


PLATE 16

1- ***Pterochitina deichaii,*** Well, I3-NC186, 4400 ft., T46/ 3, scale bar = 22µm.

2- ***Pterochitina deichaii,*** Well I3-NC186, 4400 ft., p42/3, scale bar = 28µm.

3- ***Rhabdochitina usitata,*** Well-D1-200, 4831.5 ft., Y35/1, scale bar = 30µm.

4- ***Siphonochitina* cf. *formosa,*** Well H2-NC186, 4950 ft., scale bar = 35µm.

5- ***Sphaerochitina* cf. *palestinaense,*** Well-D1-200, 4854 ft., T31, scale bar = 25µm.

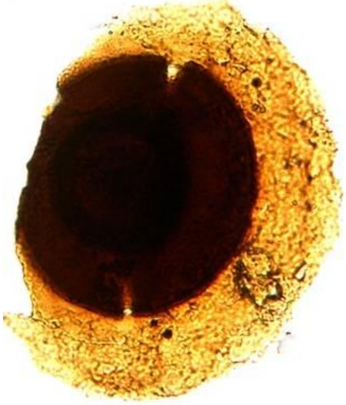
6- ***Sphaerochitina* sp. A,** Well-I3-NC186, 3950ft., R27, scale bar = 22µm.

7- ***Sphaerochitina* sp. B,** Well-D1-200, 4854ft., H34, scale bar = 22µm.

8- ***Spinachitina bulmani,*** Well I2-NC186, 4787 ft., Q41/2, scale bar = 15µm.

9- ***Tanuchitina elongata,*** Well-D1-200, 4788ft., W43, scale bar = 35µm.

PLATE 16


1


2


3


4


5


6


7


8


9

ANIMAL REMAINS PLATE

PLATE 1

PLATE 1

1- **Scolecodont 1**. Well, D1-200, 4400 ft., scale bar = 22µm.

2- **Scolecodont 2**. Well, D1-200, 4400 ft., scale bar = 22µm

3- **Scolecodont 3**. Well, D1-200, 4400 ft., scale bar = 22µm

4- **Scolecodont 4**. Well, D1-200, 4400 ft., scale bar = 22µm

5- **Scolecodont 5**. Well, D1-200, 4400 ft., scale bar = 22µm

6- **Scolecodont 6**. Well, D1-200, 4400 ft., scale bar = 22µm

7- **Cuticle,** Well, D1-200, 4400 ft.,

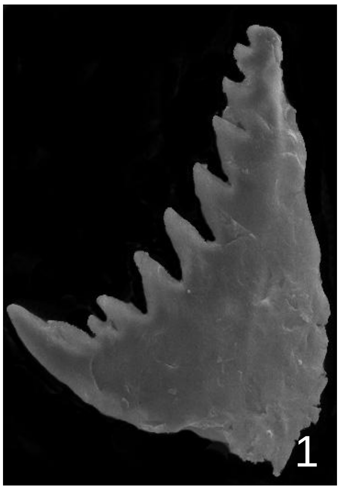
8- **Cuticle,** Well, D1-200, 4400 ft.,

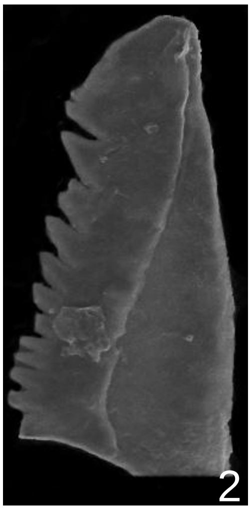
9- ***Graptolite* ,** Well E1-NC174, 4690 ft., T32, scale bar = 120µm

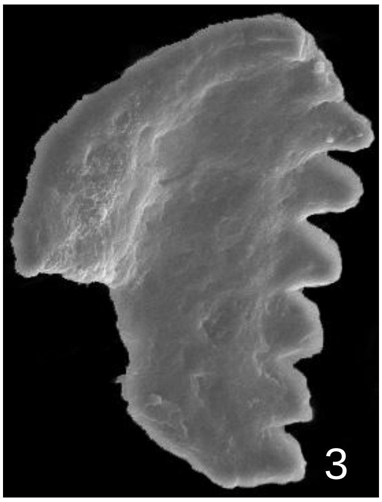
10- ***Graptolite,*** Well H2-NC186, 4560 ft., K44, scale bar = 77µm

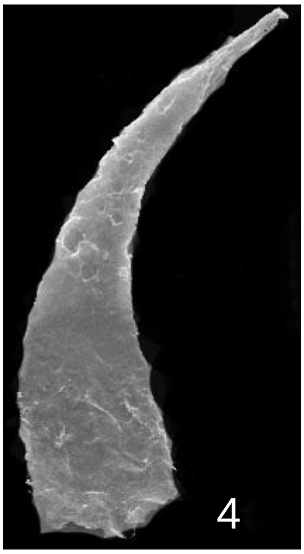
11- ***Graptolite,*** Well H2-NC186, 4560 ft., scale bar = 115µm

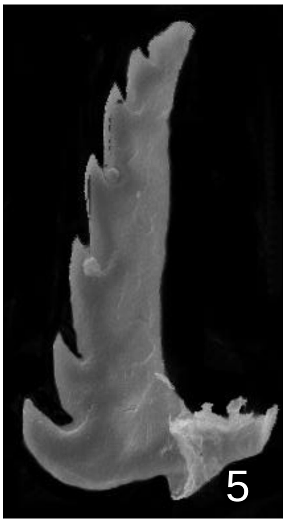
PLATE 1

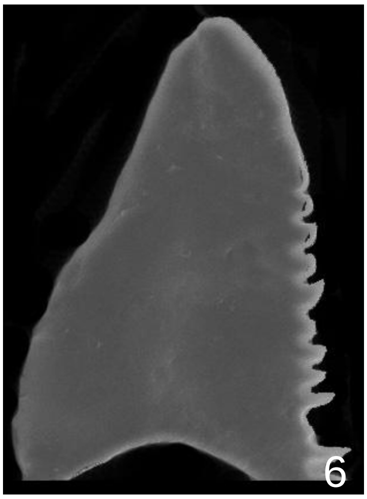

1

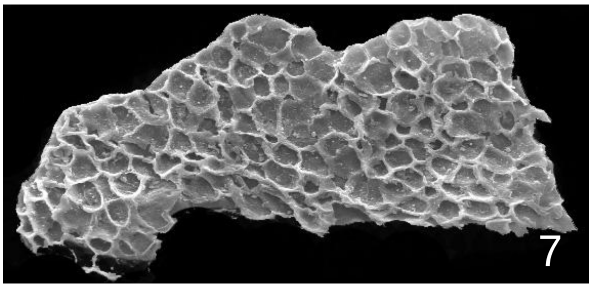

2

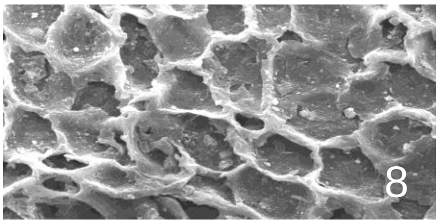

3


4


5


6


7


8


9


10


11

CRYPTOSPORE/SPORE PLATES

PLATE 1-4

PLATE 1

1- ***Acontotetras inconspicuis,*** Well A28i-NC186, 4508 ft., S30/3, scale bar = 5µm.

2- ***Chelinohilates maculatus,*** Well A28i-NC186, 4604 ft., C37, scale bar = 10 µm.

3- ***Dyadospora murusattenuata,*** Well A28i-NC186, 4604 ft., R26/4, scale bar = 5µm.

4- ***Dyadospora murusattenuata,*** Well A28i-NC186, 4604 ft., S19, scale bar = 5µm.

5- ***Dyadospora murusattenuata,*** Well A28i-NC186, 4604 ft., R26/4, scale bar = 5µm.

6- ***Hispanaediscus verrucatus,*** Well A28i-NC186,4633ft., R22/3, scale bar = 5µm.

7- ***Hispanaediscus* cf. *wenlockensis,*** Well A28i-NC186, 4604 ft., P37/1, scale bar = 10 µm.

8- ***Imperfectotriletes vavrdovae,*** Well I3-NC186, 4360 ft., O35/3, scale bar = 10µm.

9- ***Laevolancis chibrikovae,*** Well A28i-NC186, 4604 ft., M34/1, scale bar = 7.5µm.

PLATE 1

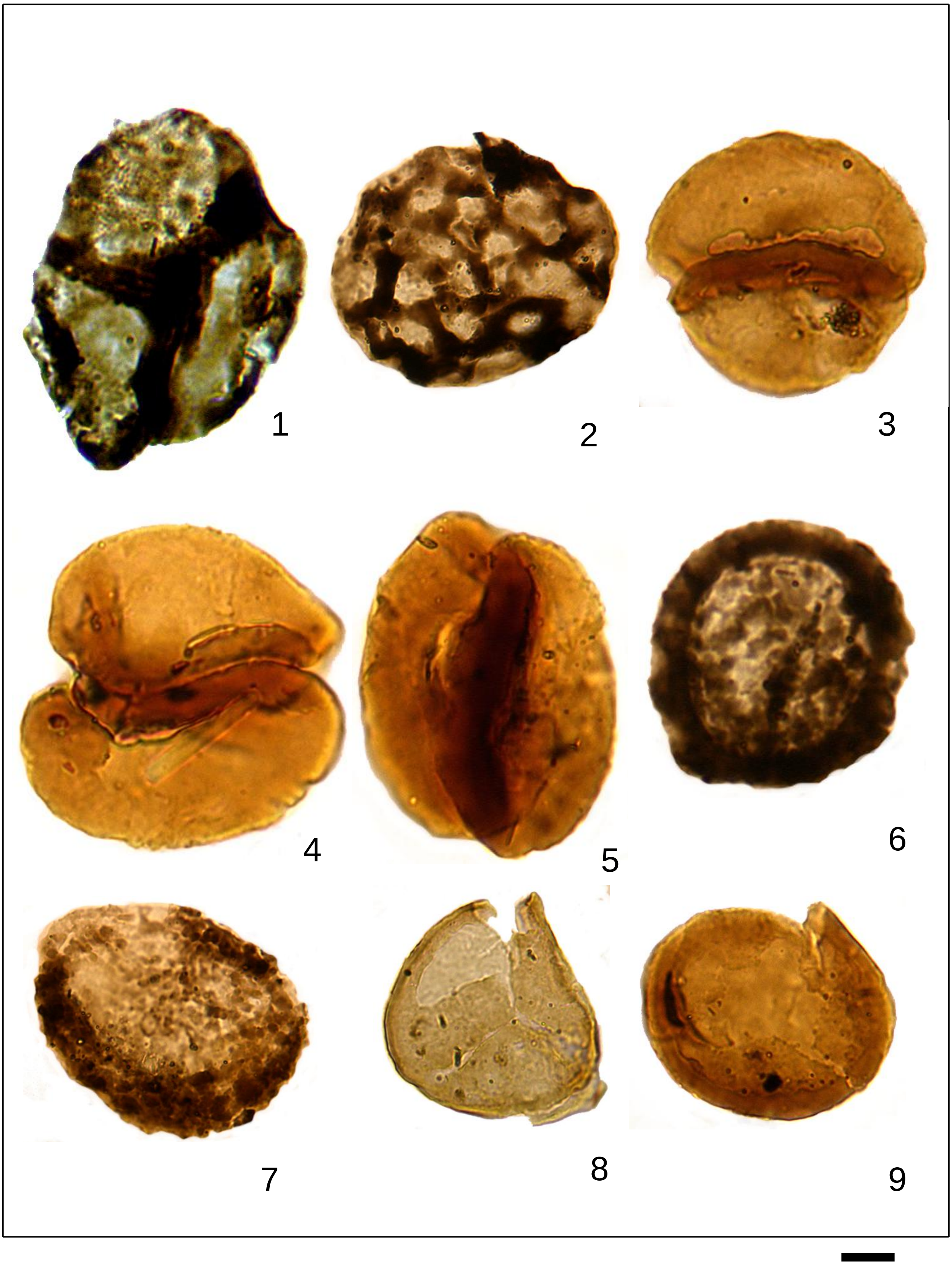
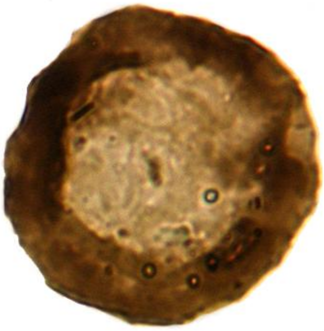


PLATE 2

1- ***Laevolancis divellomedia-plicata,*** Well A28i-NC186, 4715 ft., J33, scale bar = 5µm.
2- ***Laevolancis divellomedia-plicata,*** Well A28i-NC186, 4604 ft., O44/4, scale bar = 5µm.
3- ***Pseudodyadospora laevigata,*** Well A28i-NC186, 4604 ft., W29, scale bar = 10µm.
4- ***Pseudodyadospora laevigata,*** Well A28i-NC186, 4604 ft., W28/2, scale bar = 10µm.
5- ***Pseudodyadospora laevigata,*** Well A28i-NC186, 4604 ft., J39, scale bar = 10µm.
6- ***Pseudodyadospora petasus,*** Well A28i-NC186, 4604 ft., M23/4, scale bar = 7.5µm.
7- ***Pseudodyadospora petasus,*** Well A28i-NC186, 4604 ft., M44/3, scale bar = 10µm.
8- ***Rimosotetras problematica,*** Well A28i-NC186, 4708 ft., S40/1, scale bar = 7.5µm.
9- ***Rimosotetras problematica,*** Well A28i-NC186, 4604 ft., D26/4, scale bar = 10µm.

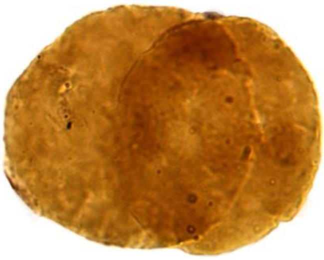
PLATE 2



1

2

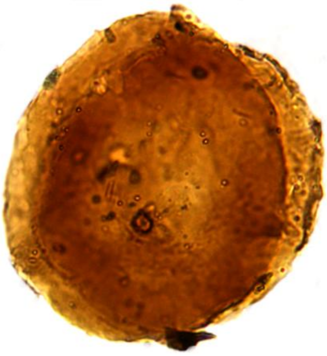
3



4

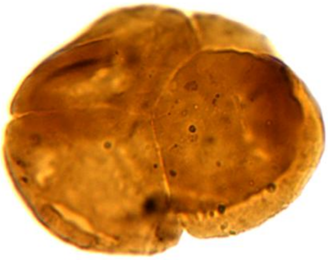
5

6



7

8

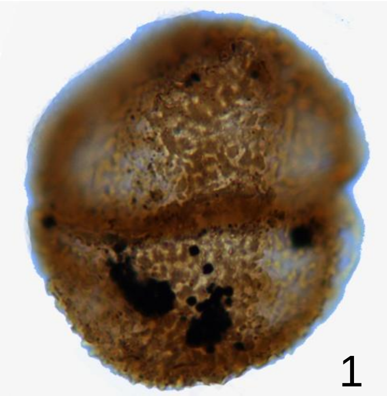


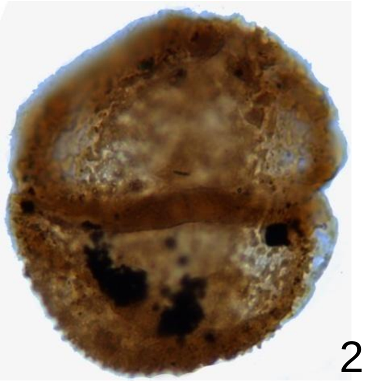
9

PLATE 3

1- ***Segesterospora* sp. A,** Well E1-NC174, 6850ft., F48/2, scale bar = 12µm
2- ***Segesterospora* sp. A,** Well E1-NC174, 6850ft., F48/2, scale bar = 12µm
3- ***Sphaerasaccus glabellus,*** Well A28i-NC186, 4604 ft., T37/1, scale bar = 5µm.
4- ***Tetrahedraletes medinensis,*** Well A28i-NC186, 4604 ft., U38/4, scale bar = 5 µm.
5- ***Tetrahedraletes medinensis,*** Well A28i-NC186, 4604 ft., W31, scale bar = 5µm.
6- ***Tetrahedraletes medinensis,*** Well A28i-NC186, 4604 ft., W43/2, scale bar = 10 µm.
7- **Tetrad sp. A*,*** Well H2-NC186, 4833 ft., Q34/3, scale bar = 10µm.
8- **Tetrad spp.*,*** Well A28i-NC186, 4715 ft., S48, scale bar = 5 µm,
9- **Tetrad spp.*,*** Well A28i-NC186, 4611 ft., N36/2, scale bar = 5µm,

PLATE 3

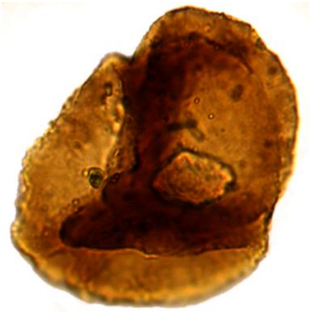

1

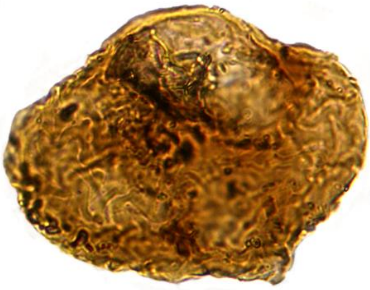

2


3


4


5


6


7

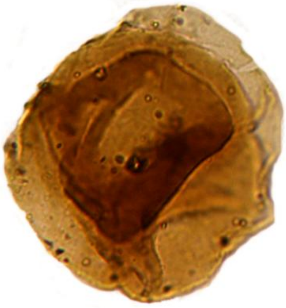

8


9

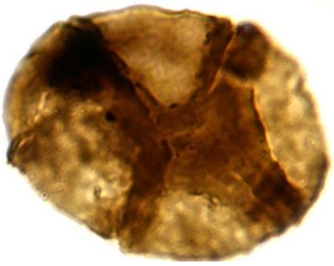
PLATE 4

1- ***Velatiteras laevigata,*** Well A28i-NC186, 4604 ft., C40, scale bar = 10 µm.
2- ***Quadrisporites granulatus,*** Well A28i-NC186, 4604 ft., M20/3, scale bar = 7.5µm.
3- ***Quadrisporites granulatus***, Well A28i-NC186, 4611 ft., N36/2, scale bar = 10µm.
4- ***Quadrisporites granulatus,*** Well A28i-NC186, 4604 ft., F17/2, scale bar = 5µm.
5- **Genus A. Sp. A.** Well A28i-NC186, 4604 ft., D26, scale bar = 10µm.
6- **Micro-ornamented monads,** Well A28i-NC186, 4604 ft., C40, scale bar = 5µm.
7- ***Ambitisporites dilutus,*** Well I3-NC186, 4200 ft., O20/2, scale bar = 10µm.
8- **Monad cluster**
9- **Monad cluster**

PLATE 4


1


2

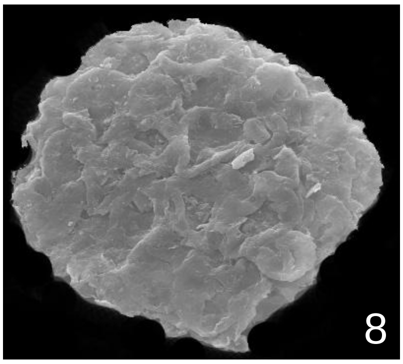

3

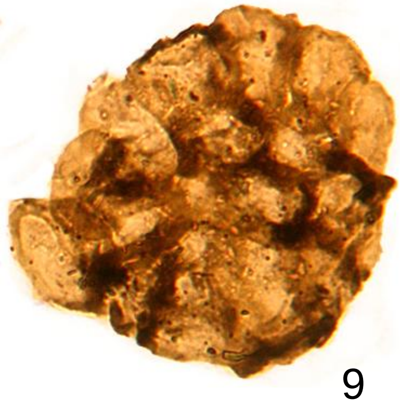

4


5


6


7


8


9

CUTICLE, AOM AND PALYNOFACIES PLATES

PALTE 1-3

PLATE 1

1- **Cuticle,** D1-200, 4854 ft., K35/1.
2- **Cuticle,** A28i-NC186, 4706 ft., N32/2.
3- **Cuticle,** H2-NC186, 4604 ft., C45.
4- **Cuticle,** D1-200, 4854 ft., E33/1.
5- **Cuticle,** H2-NC186, 4590 ft., T47/2.
6- **AOM (dark brown),** E1-NC174, 4270, R20/3.
7- **AOM (dark brown),** A28i-NC186, 4796ft, T26/2.
8- **AOM (yellowish brown),** A28i-NC186, 4796ft, S23/1.
9- **Palynofacies, Tanezzuft Formation**, Well E1-NC174, 6800ft.

PLATE 1

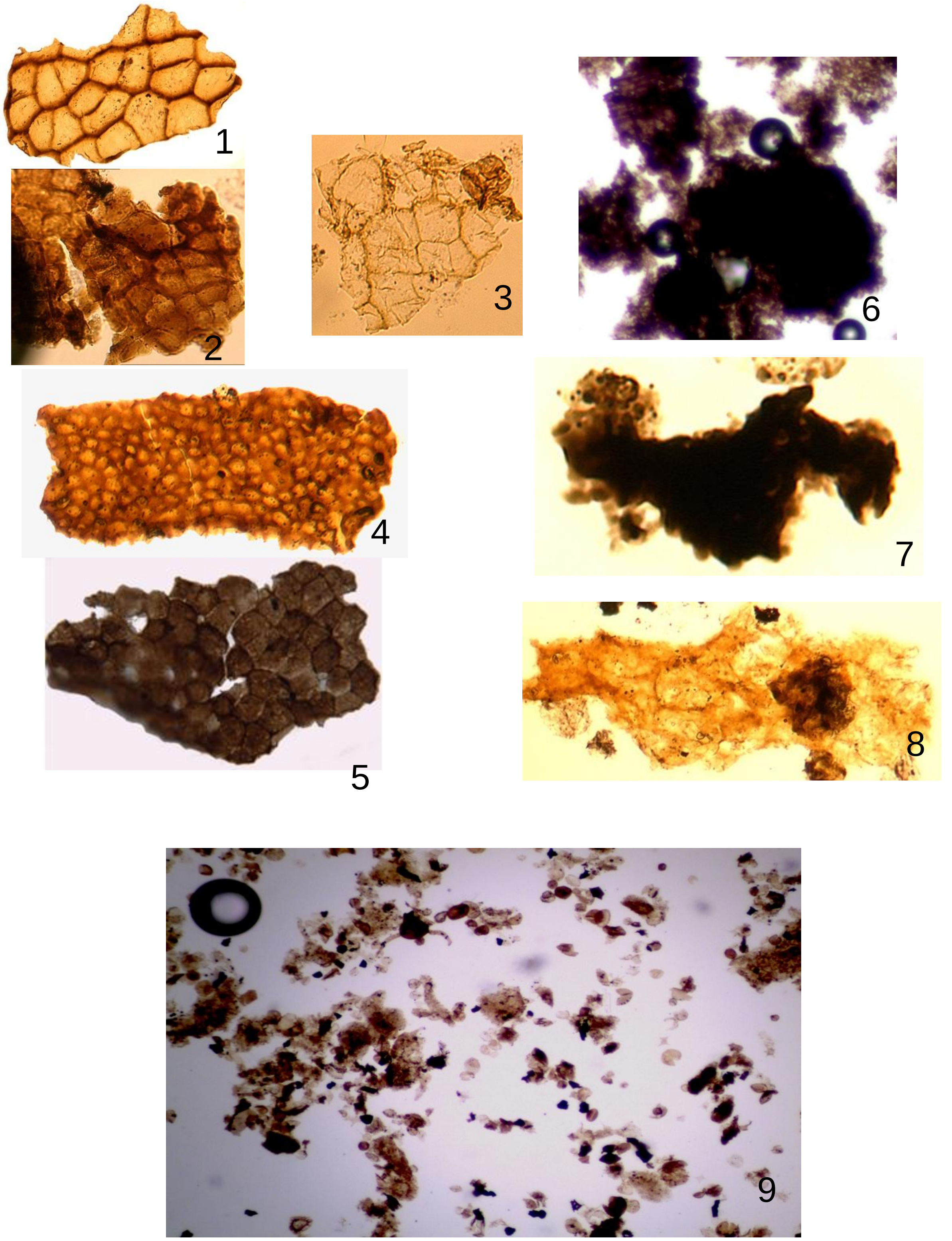
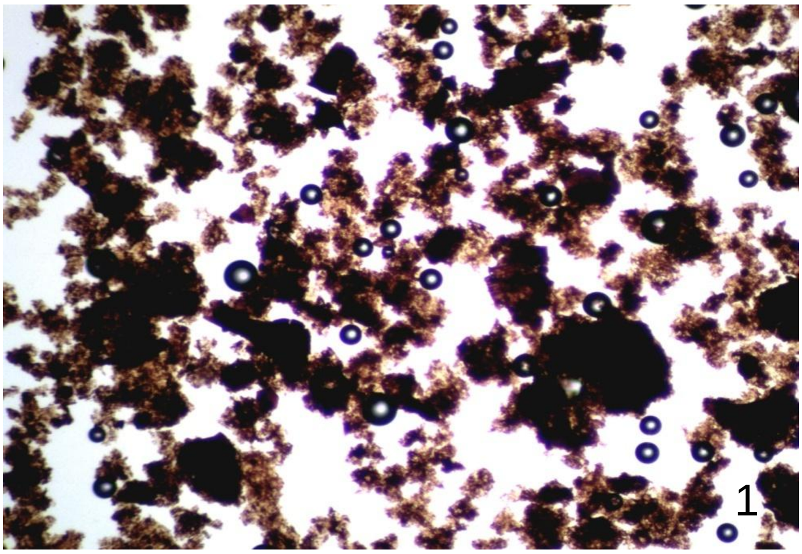
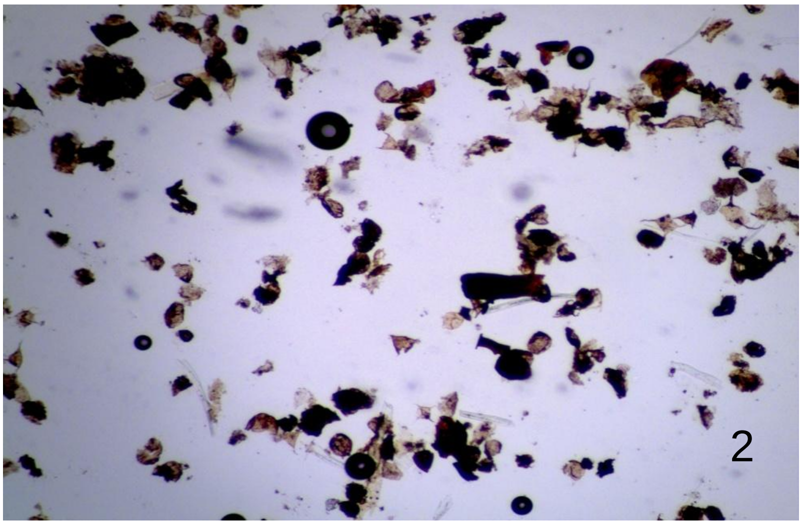


PLATE 2

1- **Palynofacies, Tanezzuft Formation (Lower part)**, Well E1-NC174, 7287ft.
2- **Palynofacies, Bir Tlacsin Formation**, Well A28i-NC186, 4492ft.
3- **Palynofacies, Memouniat Formation**, Well I3-NC186, 4796ft.

PLATE 2


1


2

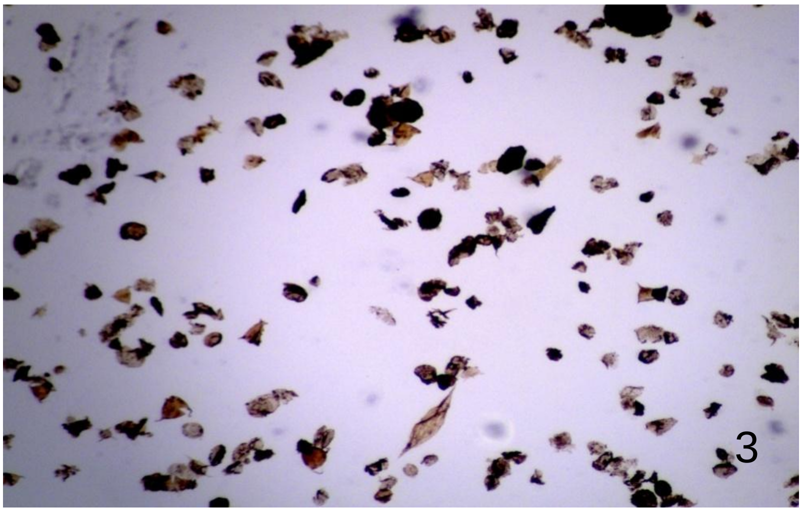
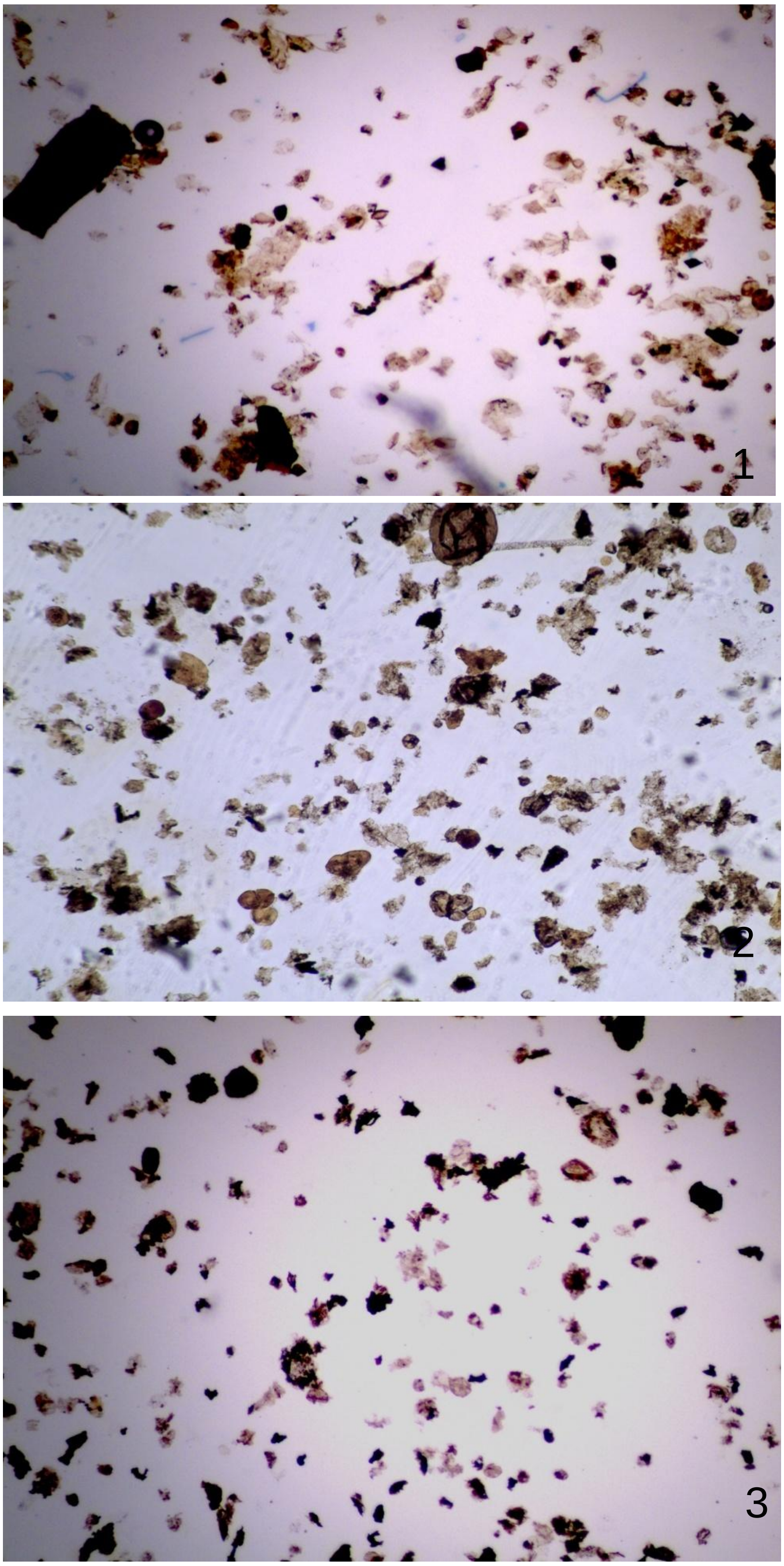

3

PLATE 3

1- **Palynofacies, Melez Shugran**, D1-200, 4854ft.
2- **Palynofacies, Hawaz Formation**, Well A28i-NC186, 4544ft.
3- **Palynofacies, Hawaz**, Well A28i-NC186, 4706ft.

PLATE 3



APPENDICES

Well: A28i-NC186

Formation	C#	Depth	Type
Tanezzuft			
=			
=			
=			
=			
=			
=			
=			
Hot shale			
=			
🟥	🟥	🟥	🟥
M. Shugran	1	4482	Core
=	1	4492	=
=	1	4499.5	=
=	1	4501	=
=	1	4505	=
=	1	4508	=
=	2	4513	=
=	2	4517	=
🟥	🟥	🟥	🟥
Hawaz	2	4518	Core
=	2	4519	=
=	2	4544	=
=	2	4557.5	=
=	2	4562	=
=	3	4570	=
=	3	4571	=
=	5	4604	=
=	5	4611	=
=	5	4633	=
=	5	4639	=
=	5	4641	=
=	6	4681	=
=	6	4706	=
=	7	4715	=
=	7	4723	=

Well: H2-NC186

Formation	C#	Depth	Type
Tanezzuft		4160	Cutting
=		4200	=
=		4250	=
=		4300	=
=		4350	=
=		4400	=
=		4450	=
=		4500	=
🟥	🟥	🟥	🟥
Bir Tlacsin		4550	Cutting
=		4590	=
🟥	🟥	🟥	🟥
Hawaz	1	4606	Core
=	2	4637	=
=	2	4644	=
=	3	4665	=
=	3	4672	=
=	3	4682	=
=	3	4687	=
=	4	4742	=
=		4815	Cutting
=	6	4833	Core
=	6	4842	=
=		4930	Cutting
=		4950	
=		4990	=
=		5040	Cutting
=		5100	=
=		5200	=
Ash Shbiyat		5250	=
=		5300	=

Well: D1-200

Formation	C#	Depth	Type
Taezzuft		3850	Cutting
=		3900	=
=		3970	=
		4050	
=		4150	=
		4200	
=		4250	=
=		4300	=
=		4340	=
=		4400	=
=		4450	=
=		4500	=
=		4550	=
=		4600	=
=		4650	=
=		4700	=
🟥	🟥	🟥	🟥
M. Shugran	1	4778	Core
=	1	4788	=
=	2	4794	=
=	2	4810	=
=	3	4825	=
=	3	4831.5	=
=	3	4846	=
=	3	4854	=
=	3	4864	=
=	3	4878	=
=		4900	Cutting
=		4950	=
=		4960	=
=		4970	=
=		5000	=
=		5130	=
🟥	🟥	🟥	🟥
Hawaz		5150	=
=		5250	=
=		5350	=
=		5450	
=		5550	=
=		5600	=
=		5700	=

Well: I3-NC186

Formation	C#	Depth	Type
Tanezzuft		3700	Cutting
=		3750	=
=		3800	=
=		3890	=
=		3900	=
=		3950	=
=		4000	=
=		4050	=
=		4100	=
=		4180	=
=		4200	=
=		4250	=
=		4300	=
=		4350	=
=		4400	=
=		4450	=
=		4500	=
=		4550	=
Hot shale		4600	=
=		4640	=
🟥	🟥	🟥	🟥
Bir Tlacsin		4680	Cutting
=		4700	=
=		4740	=
Memouniat	1	4782	Core
=	1	4787	=
=	1	4796	=
=	1	4799	=
🟥	🟥	🟥	🟥
M.Shugran		4810	Cutting
=		4850	=
=		4900	=
=		4975	=
=		5040	=
=		5075	=
=		5200	=
=		5230	=
🟥	🟥	🟥	🟥
Ash Shabiyat		5250	Cutting
=		5320	=
=		5340	=
=		5400	=

Well: E1-NC174

Formation	C#	Depth	Type
Taezzuft		6350	Cutting
=		6500	=
=		6690	=
=		6800	=
=		6850	=
=		6950	=
=		7000	=
=		7050	=
=		7110	=
=		7150	=
=		7200	=
=	1	7246	Core
=	1	7255	=
=	1	7267	=
=	1	7270	=
=	1	7287	=
Memouniat			
=			
=			
=			
=			
=			

Well: B2-NC186

Formation	C#	Depth	Type
Tanezuft		3700	Cutting
=		3750	=
=		3800	=
=		3850	=
Hot shale		3900	=
=		3950	=
🟥	🟥	🟥	🟥
Memouniat		4100	Cutting
=		4200	=
=		4300	=
=		4410	=
=		4520	=
=		4535	=
=		4565	=
=		4640	=
=		4690	=
🟥	🟥	🟥	🟥
Ash Shabiyat		4800	Cutting
=		4900	=

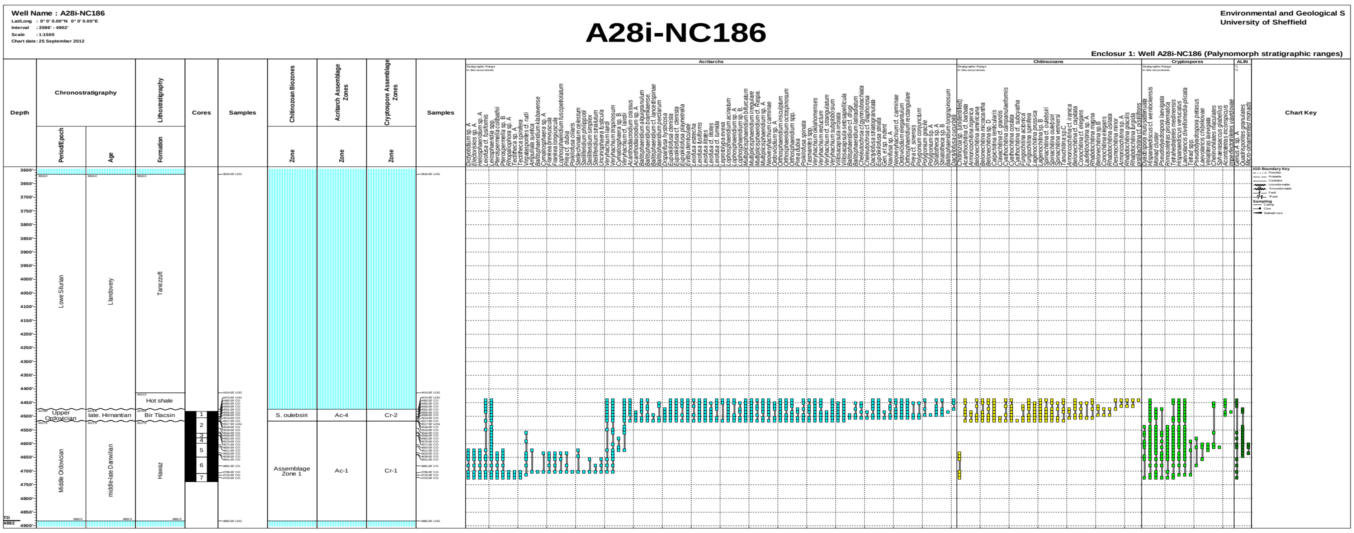
▨	No samples available
🟥	Unconformaties

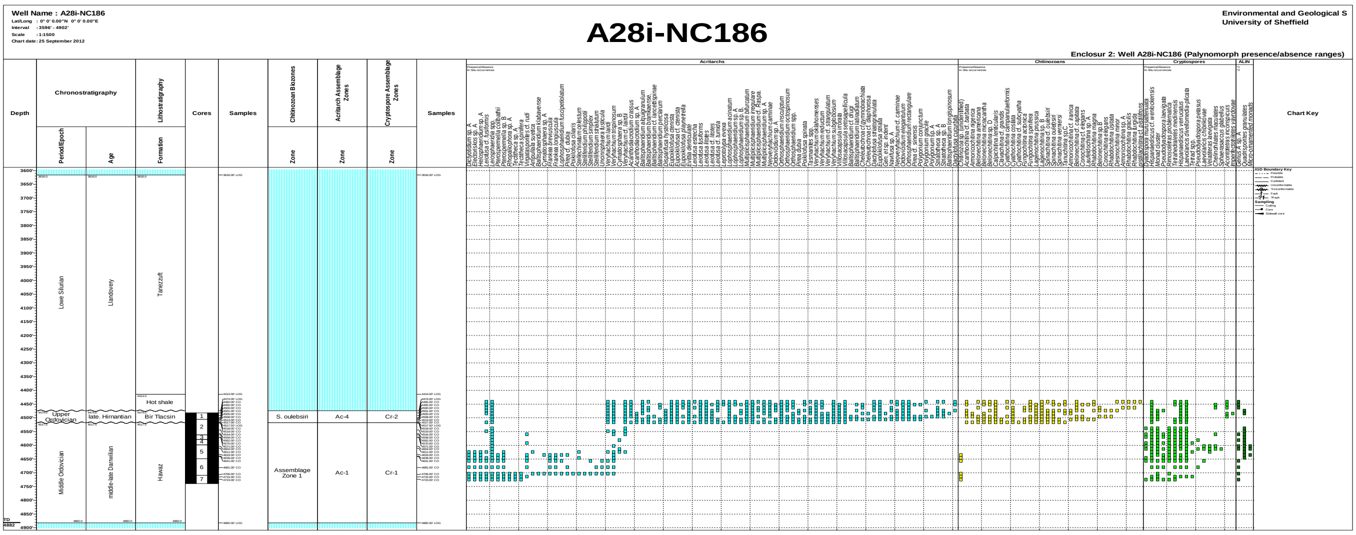
Appendix 1. Spreadsheet detailing all samples collected, prepared and analysed

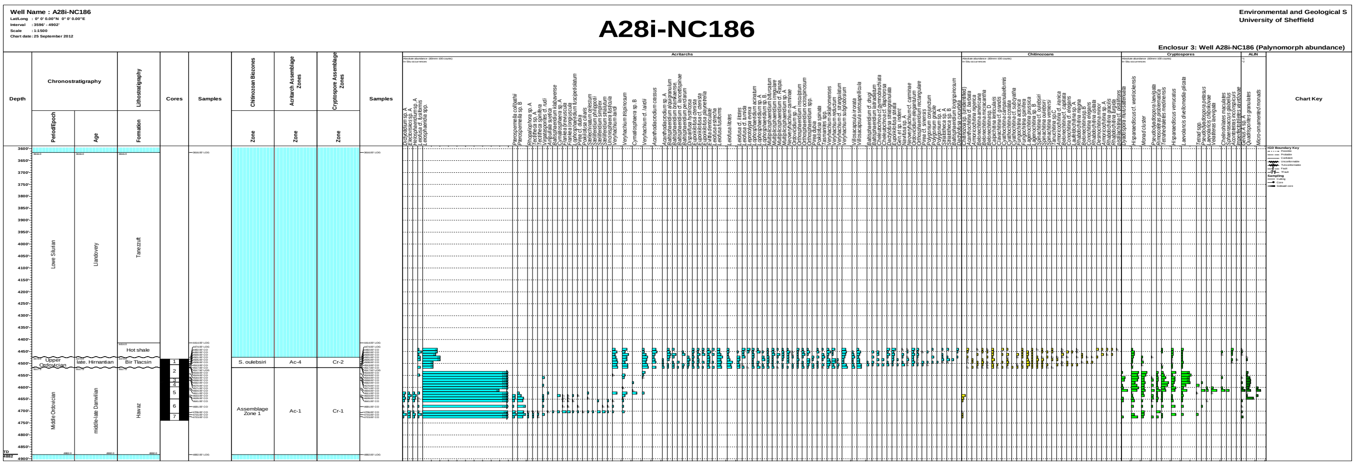
Well	B2-NC186	H2-NC186	I3-NC186	A28i-NC186	D1-200	E1-NC174
Coordinates	26° 46′ 47.54″ N	26° 43′ 02.47″ N	26° 44′ 00.92″ N	NA	25° 44′ 09.21″ N	25° 02′ 06.9″ N
	12° 40′ 12.51″ N	12° 33′ 21.65″ E	12° 25′ 19.71″ E	NA	11° 14′ 58.20″ E	12° 34′ 42.8″ E
KB (ft.)	1635	1757	1764	1633	2250	2029
GL (ft)	1630	1734	1741	1615	2229	2014
Formation	Tops (ft.)					
Quaternary	22	22	22	18	NA	NA
Mesak	NA	NA	NA	NA	21	15
Zarzatine/Tiguentourine		NA	NA	NA	NA	1910
Tiguentourine	352	800	429	212	547	3980
Dembaba	1498	1964	1385	1159	1217	4904
Assedjefar	1568	2023	1504	1298	1301	5005
Marar CB	1677	2183	1600	1555	1536	NA
Marar	1803	2310	1799	NA	1756	5278
Marar.Lw	2467	2997	2499	2406	2234	NA
Awaynat_Wanin	3117	2636	3154	3093	2563	6070
Tadrart	NA	NA	NA	NA	2649	NA
Akakus	NA	NA	NA	NA	3077	NA
BDS_II	3411	3912	3425	3379	NA	NA
BDS_Sh	3450	3979	3506	3451	NA	NA
BDS_I	3527	4040	3562	3503	NA	NA
Tanezzuft	3665	4157	3690	3616	3657	6272
Hot Shale	NA	NA	4577	4414	NA	6265
Bir Tlacsin	NA	4517	4647	4474	NA	NA
Memuniat	4008	NA	4763	NA	NA	7323
Melaz Shuqran	NA	NA	4801	NA	4749	NA
Hawaz	NA	4595	NA	4518	5141	NA
(As Shabiyat)	4700	5225	5235	NA	NA	NA
Hasaounah	NA	NA	NA	NA	NA	NA
TD	4970	5450	5483	4882	5800	7700
Status	OIL	OIL	OIL	OIL	OIL	OIL

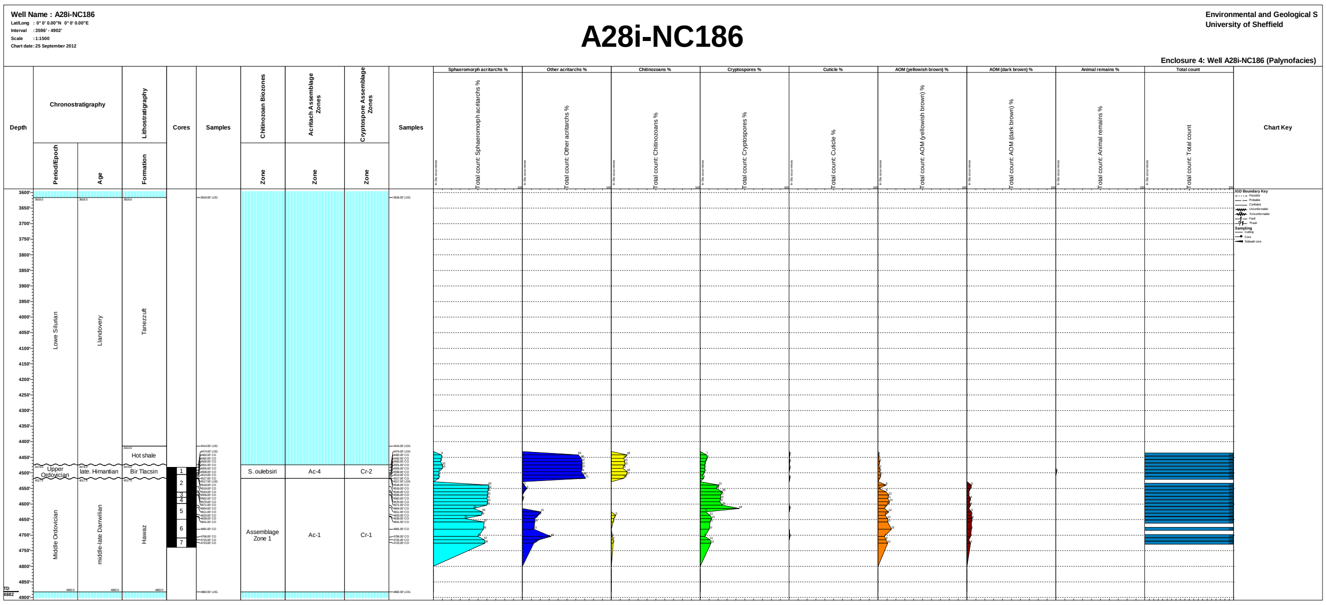
Appendix 3. Formation tops of the study wells.

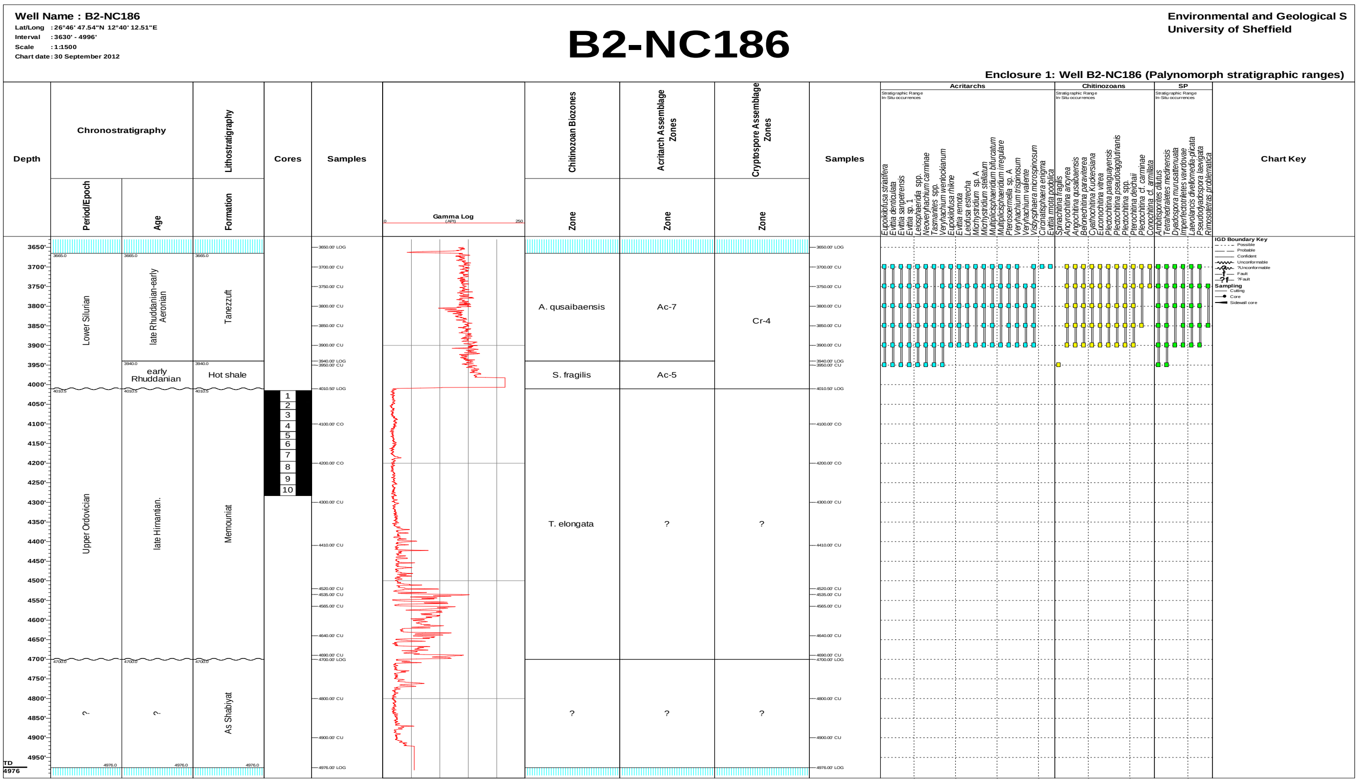
ENCLOSURES

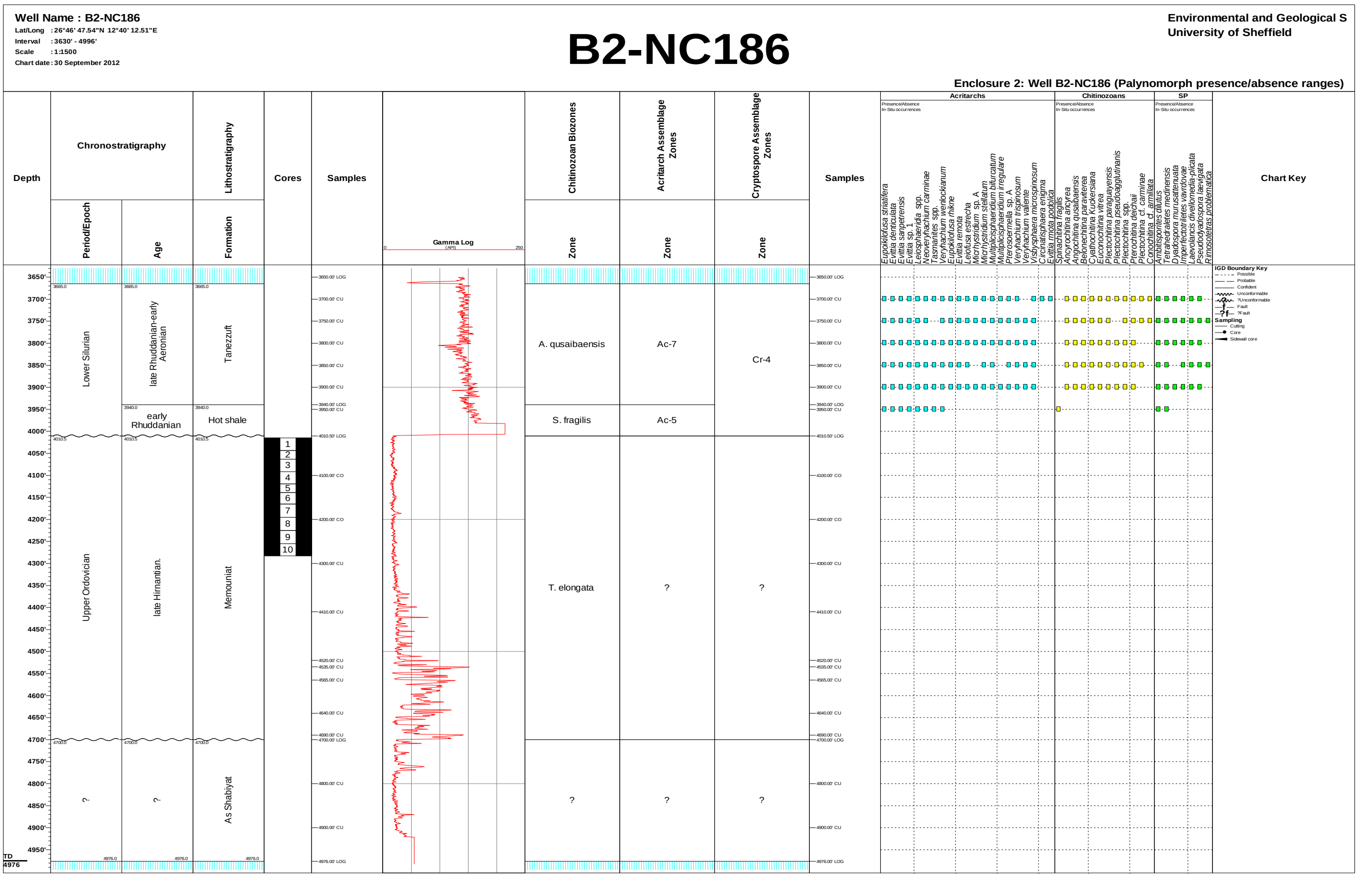

Well Name : A28i-NC186
Lat/Long : 0° 0' 0.00"N 0° 0' 0.00"E
Interval : 3596' - 4902'
Scale : 1:1500
Chart date : 25 September 2012
A28i-NC186
Environmental and Geological S
University of Sheffield
Enclosur 1: Well A28i-NC186 (Palynomorph stratigraphic ranges)
Depth
Chronostratigraphy
Period/Epoch
Age
Lithostratigraphy
Formation
Cores
Samples
Chitinozoan Biozones
Acritarch Assemblage Zones
Cryptospore Assemblage Zones
Zone
Acritarchs
Chitinozoans
Cryptospores
Chart Key
Lowe Silurian
Llandovery
Tanezzuft
Upper Ordovician
late. Hirnantian
Hot shale
Bir Tlacsin
Middle Ordovician
middle-late Darriwilian
Hawaz
S. oulebsiri
Ac-4
Cr-2
Assemblage Zone 1
Ac-1
Cr-1
TD 4882

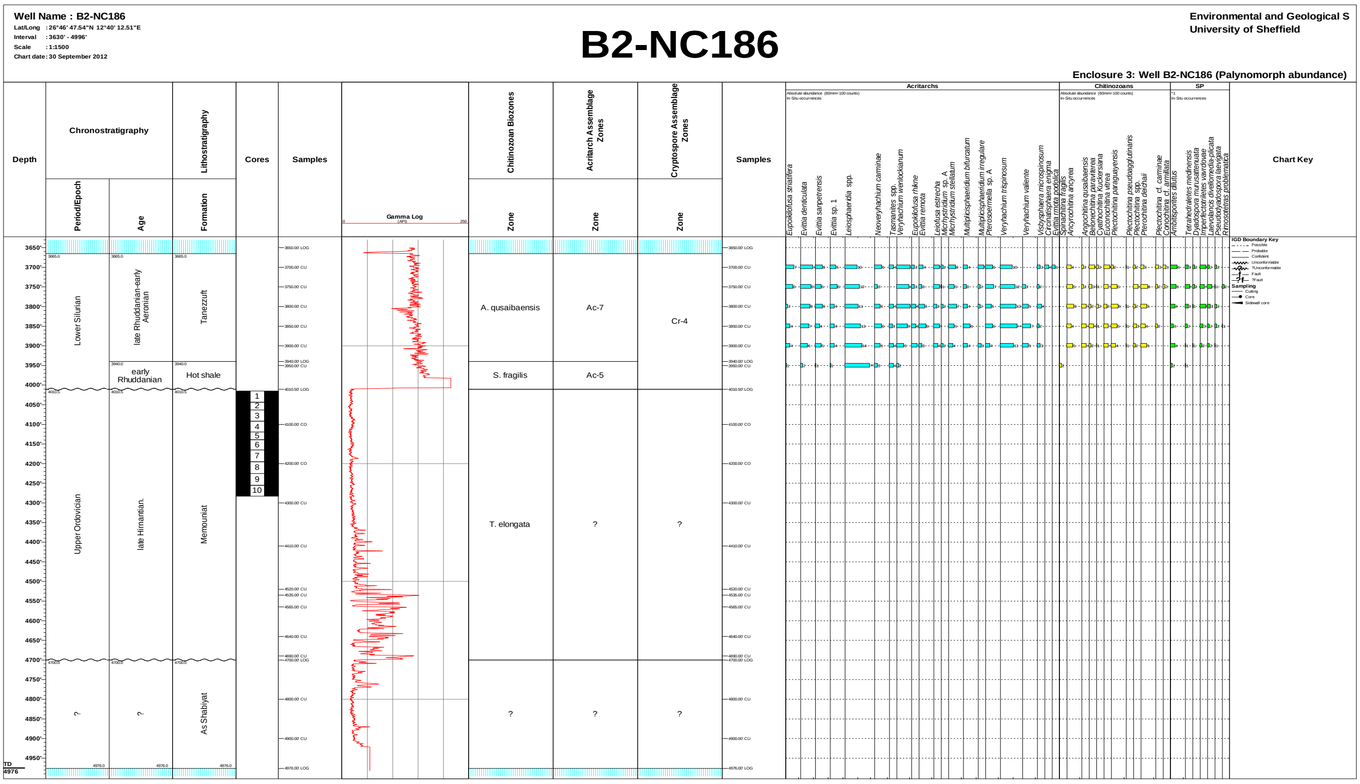

Well Name : A28i-NC186
Lat/Long : 0° 0' 0.00"N 0° 0' 0.00"E
Interval : 3596' - 4902'
Scale : 1:1500
Chart date : 25 September 2012
A28i-NC186
Environmental and Geological S
University of Sheffield
Enclosur 2: Well A28i-NC186 (Palynomorph presence/absence ranges)
Depth
Chronostratigraphy
Period/Epoch
Age
Lithostratigraphy
Formation
Cores
Samples
Chitinozoan Biozones
Acritarch Assemblage Zones
Cryptospore Assemblage Zones
Zone
Acritarchs
Chitinozoans
Cryptospores
Chart Key
Lowe Silurian
Llandovery
Tanezzuft
Upper Ordovician
late. Hirnantian
Hot shale
Bir Tlacsin
Middle Ordovician
middle-late Darriwilian
Hawaz
S. oulebsiri
Ac-4
Cr-2
Assemblage Zone 1
Ac-1
Cr-1
TD 4882


Well Name : A28i-NC186
Lat/Long : 0° 0' 0.00"N 0° 0' 0.00"E
Interval : 3596' - 4902'
Scale : 1:1500
Chart date : 25 September 2012
A28i-NC186
Environmental and Geological S
University of Sheffield
Enclosur 3: Well A28i-NC186 (Palynomorph abundance)
Depth
Chronostratigraphy
Period/Epoch
Age
Lithostratigraphy
Formation
Cores
Samples
Chitinozoan Biozones
Acritarch Assemblage Zones
Cryptospore Assemblage Zones
Zone
Acritarchs
Chitinozoans
Cryptospores
ALIN
Chart Key
Lowe Silurian
Llandovery
Tanezzuft
Hot shale
Upper Ordovician
late. Himantian
Bir Tlacsin
Middle Ordovician
middle-late Darriwilian
Hawaz
S. oulebsiri
Ac-4
Cr-2
Assemblage Zone 1
Ac-1
Cr-1
TD 4902

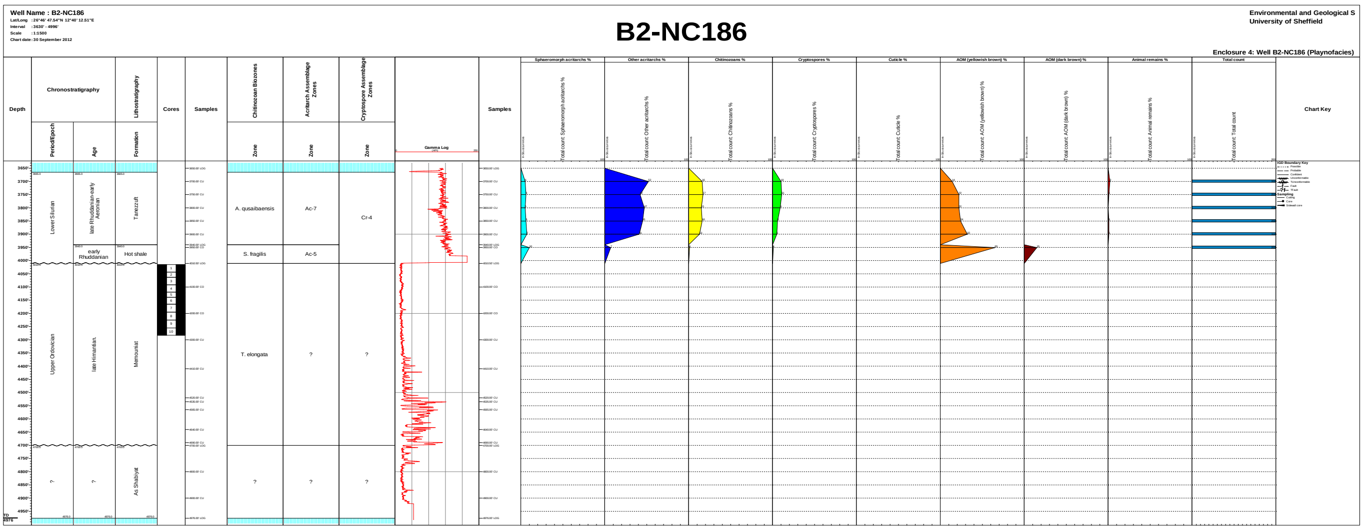

Well Name : A28i-NC186
Lat/Long : 0° 0' 0.00"N 0° 0' 0.00"E
Interval : 3596' - 4902'
Scale : 1:1500
Chart date : 25 September 2012
A28i-NC186
Environmental and Geological S
University of Sheffield
Enclosure 4: Well A28i-NC186 (Palynofacies)
Depth
Chronostratigraphy
Period/Epoch
Age
Lithostratigraphy
Formation
Cores
Samples
Chitinozoan Biozones
Acritarch Assemblage Zones
Cryptospore Assemblage Zones
Zone
Sphaeromorph acritarchs %
Other acritarchs %
Chitinozoans %
Cryptospores %
Cuticle %
AOM (yellowish brown) %
AOM (dark brown) %
Animal remains %
Total count
Total count: Sphaeromorph acritarchs %
Total count: Other acritarchs %
Total count: Chitinozoans %
Total count: Cryptospores %
Total count: Cuticle %
Total count: AOM (yellowish brown) %
Total count: AOM (dark brown) %
Total count: Animal remains %
Total count: Total count
Chart Key
Lowe Silurian
Llandovery
Tanezzuft
Hot shale
Upper Ordovician
late. Himantian
Bir Tlacsin
Middle Ordovician
middle-late Darriwilian
Hawaz
S. oulebsiri
Ac-4
Cr-2
Assemblage Zone 1
Ac-1
Cr-1
1
2
3
4
5
6
7
TD 4902


Well Name : B2-NC186
Lat/Long : 26°46' 47.54"N 12°40' 12.51"E
Interval : 3630' - 4996'
Scale : 1:1500
Chart date : 30 September 2012
B2-NC186
Environmental and Geological S
University of Sheffield
Enclosure 1: Well B2-NC186 (Palynomorph stratigraphic ranges)
Depth
Chronostratigraphy
Period/Epoch
Age
Lithostratigraphy
Formation
Cores
Samples
Gamma Log
Chitinozoan Biozones
Acritarch Assemblage Zones
Cryptospore Assemblage Zones
Zone
Acritarchs
Chitinozoans
SP
Stratigraphic Range
In-Situ occurrences
Eupoikilofusa striatifera
Evittia denticulata
Evittia sanpetrensis
Evittia sp. 1
Leiosphaeridia spp.
Neoveryhachium carminae
Tasmanites spp.
Veryhachium wenlockianum
Eupokilofusa rhikne
Evittia remota
Leiofusa estrecha
Micrhystridium sp. A
Micrhystridium stellatum
Multiplicisphaeridium bifurcatum
Multiplicisphaeridium irregulare
Pterosoermella sp. A
Veryhachium trispinosum
Veryhachium valiente
Visbysphaera microspinosum
Circinatisphaera enigma
Evittia rnota podolica
Spinachitina fragilis
Ancyrochitina ancyrea
Angochitina qusaibaensis
Belonechitina paraviterea
Cyathochitina Kuckersiana
Euconochitina vitrea
Plectochitina paraguayensis
Plectochitina pseudoagglutinanis
Plectochitina spp.
Pterochitina deichaii
Plectochitina cf. carminae
Conochitina cf. armillata
Ambitisporites dilutus
Tetrahedraletes medinensis
Dyadospora murusattenuata
Imperfectotriletes vavrdovae
Laevolancis divellomedia-plicata
Pseudodyadospora laevigata
Rimosotetras problematica
Chart Key
IGD Boundary Key
Possible
Probable
Confident
Unconformable
?Unconformable
Fault
?Fault
Sampling
Cutting
Core
Sidewall core
3650'
3700'
3750'
3800'
3850'
3900'
3950'
4000'
4050'
4100'
4150'
4200'
4250'
4300'
4350'
4400'
4450'
4500'
4550'
4600'
4650'
4700'
4750'
4800'
4850'
4900'
4950'
TD
4976
Lower Silurian
late Rhuddanian-early Aeronian
Tanezzuft
early Rhuddanian
Hot shale
Upper Ordovician
late Hirnantian.
Memouniat
?
?
As Shabiyat
1
2
3
4
5
6
7
8
9
10
A. qusaibaensis
Ac-7
Cr-4
S. fragilis
Ac-5
T. elongata
?
?
?
?
?

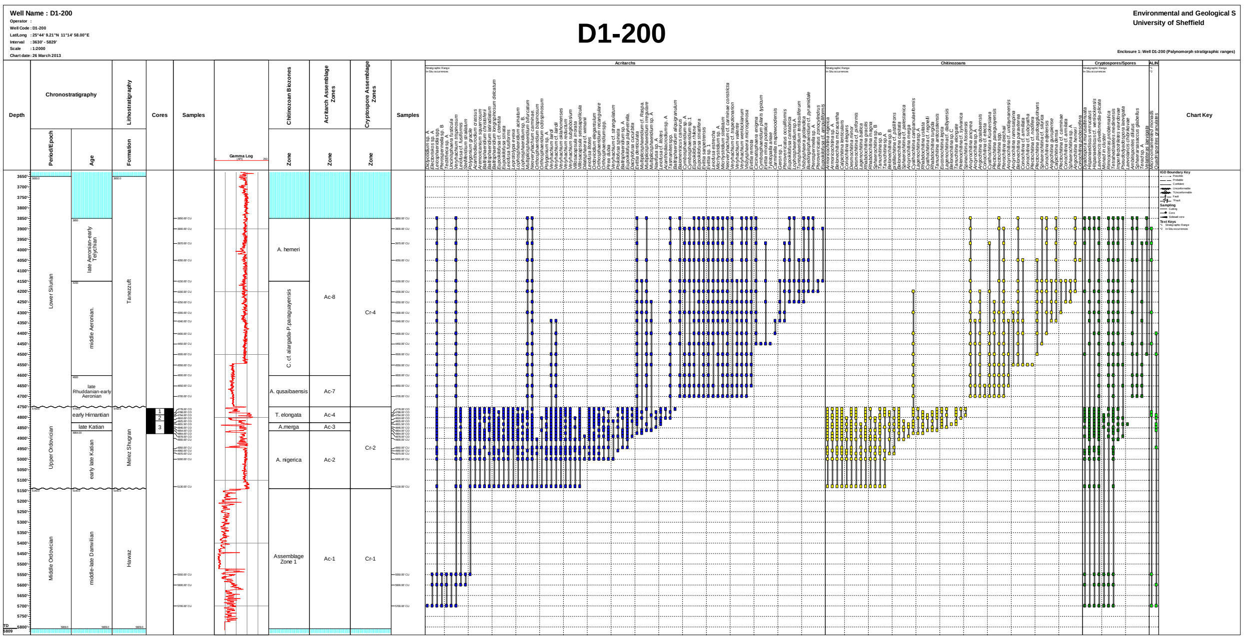

Well Name : B2-NC186
Lat/Long : 26°46' 47.54"N 12°40' 12.51"E
Interval : 3630' - 4996'
Scale : 1:1500
Chart date : 30 September 2012
B2-NC186
Environmental and Geological S
University of Sheffield
Enclosure 2: Well B2-NC186 (Palynomorph presence/absence ranges)
Depth
Chronostratigraphy
Period/Epoch
Age
Lithostratigraphy
Formation
Cores
Samples
Gamma Log
Chitinozoan Biozones
Acritarch Assemblage Zones
Cryptospore Assemblage Zones
Zone
Acritarchs
Chitinozoans
SP
Presence/Absence
In-Situ occurrences
Chart Key
IGD Boundary Key
Sampling
Lower Silurian
late Rhuddanian-early Aeronian
Tanezzuft
early Rhuddanian
Hot shale
Upper Ordovician
late Hirnantian.
Memouniat
?
?
As Shabiyat
A. qusaibaensis
Ac-7
Cr-4
S. fragilis
Ac-5
T. elongata
?
?
?
?
?
TD
4976

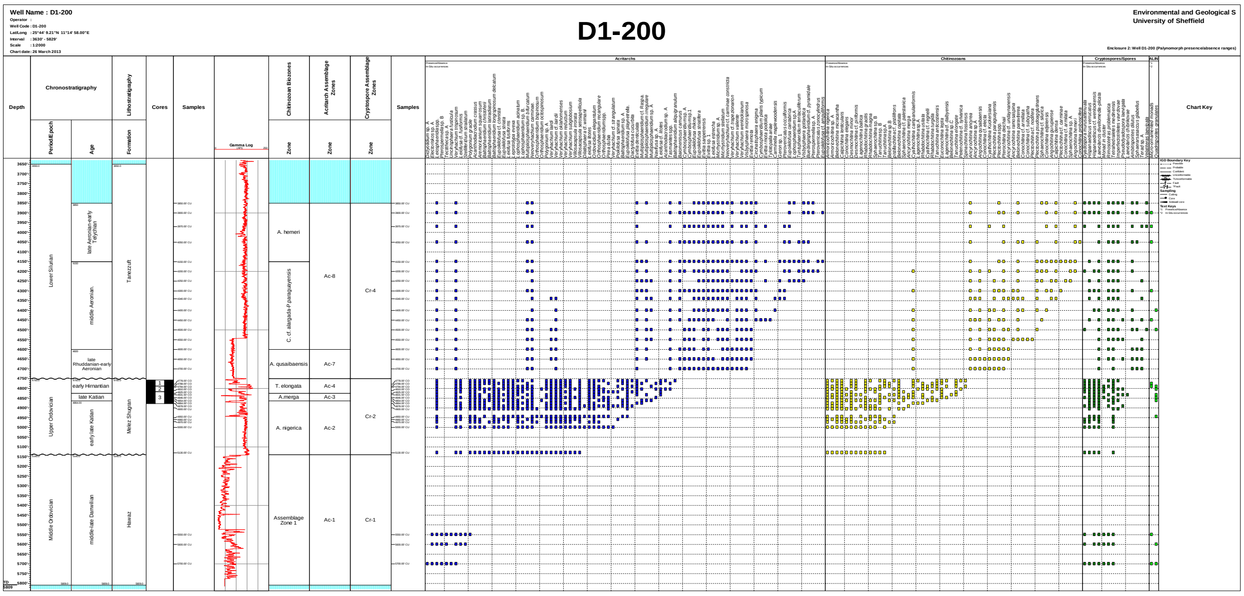


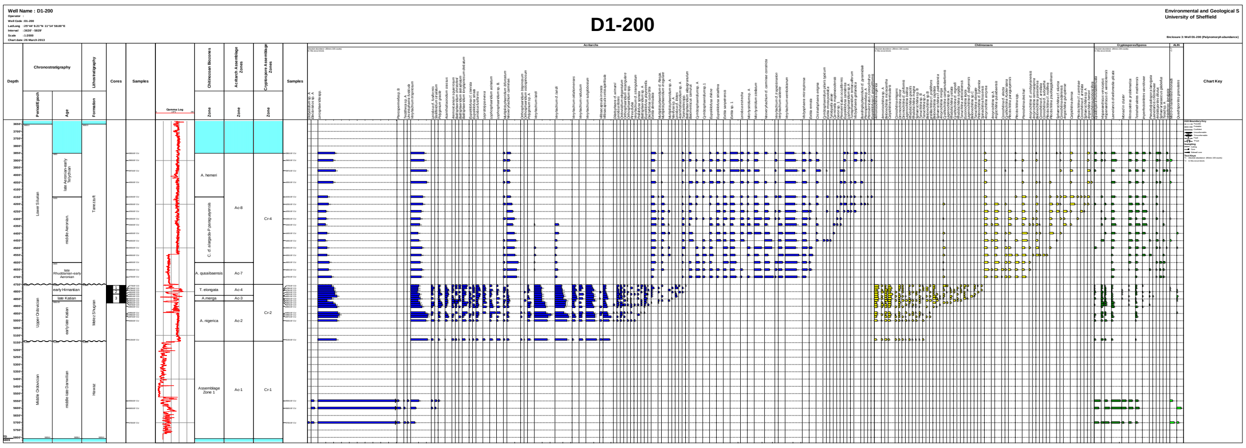
Well Name : B2-NC186
Lat/Long : 26°46' 47.54"N 12°40' 12.51"E
Interval : 3630' - 4996'
Scale : 1:1500
Chart date: 30 September 2012
B2-NC186
Environmental and Geological S
University of Sheffield
Enclosure 3: Well B2-NC186 (Palynomorph abundance)
Depth
Chronostratigraphy
Period/Epoch
Age
Lithostratigraphy
Formation
Cores
Samples
Gamma Log
Chitinozoan Biozones
Acritarch Assemblage Zones
Cryptospore Assemblage Zones
Zone
Acritarchs
Chitinozoans
SP
Chart Key
Lower Silurian
late Rhuddanian-early Aeronian
Tanezzuft
early Rhuddanian
Hot shale
Upper Ordovician
late Hirnantian
Memouniat
As Shabiyat
?
A. qusaibaensis
S. fragilis
T. elongata
Ac-7
Ac-5
Cr-4
3650'
3700'
3750'
3800'
3850'
3900'
3950'
4000'
4050'
4100'
4150'
4200'
4250'
4300'
4350'
4400'
4450'
4500'
4550'
4600'
4650'
4700'
4750'
4800'
4850'
4900'
4950'
TD
4976
1
2
3
4
5
6
7
8
9
10
Eupoikilofusa striatifera
Evittia denticulata
Evittia sanpetrensis
Evittia sp. 1
Leiosphaeridia spp.
Neoveryhachium carminae
Tasmanites spp.
Veryhachium wenlockianum
Eupoikilofusa malne
Evittia remota
Leiofusa estrecha
Michrystridium sp. A
Michrystridium stellatum
Multiplicisphaeridium bifurcatum
Multiplicisphaeridium irregulare
Pterospermella sp. A
Veryhachium trispinosum
Veryhachium valiente
Visbysphaera microspinosum
Cordobesia oblonga
Evittia crista-pottakia
Solisphaeridium nanum
Ancyrochitina ancyrea
Angochitina qusaibaensis
Belonechitina paravitrea
Cyathochitina kuckersiana
Eisenackitina vitrea
Plectochitina paraguayensis
Plectochitina pseudoagglutinans
Plectochitina spp.
Plectochitina dehrai
Plectochitina cf. carminae
Conochitina cf. armillata
Ambitisporites dilutus
Tetrahedraletes medinensis
Dyadospora murusattenuata
Imperfectotriletes vavrdovae
Laevolancis divellomedia
Pseudodyadospora laevigata
Rimosotetras problematica
IGD Boundary Key
Possible
Probable
Confident
Unconformable
Nonconformable
Fault
Fault
Sampling
Cutting
Core
Sidewall core

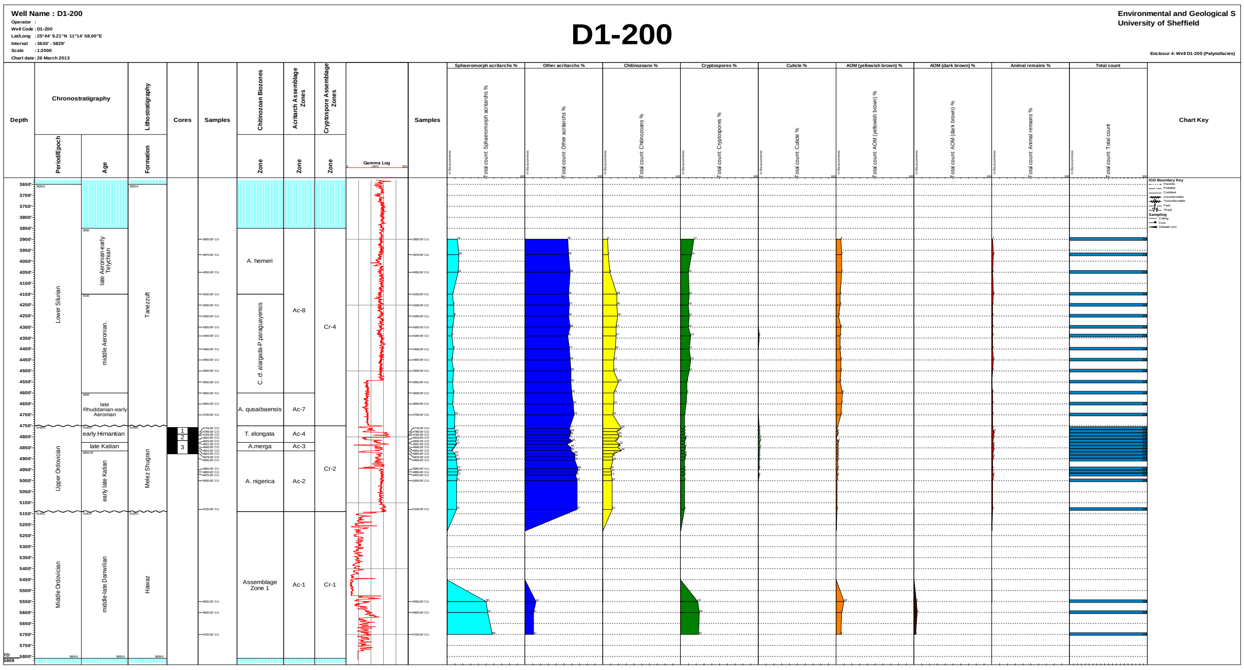


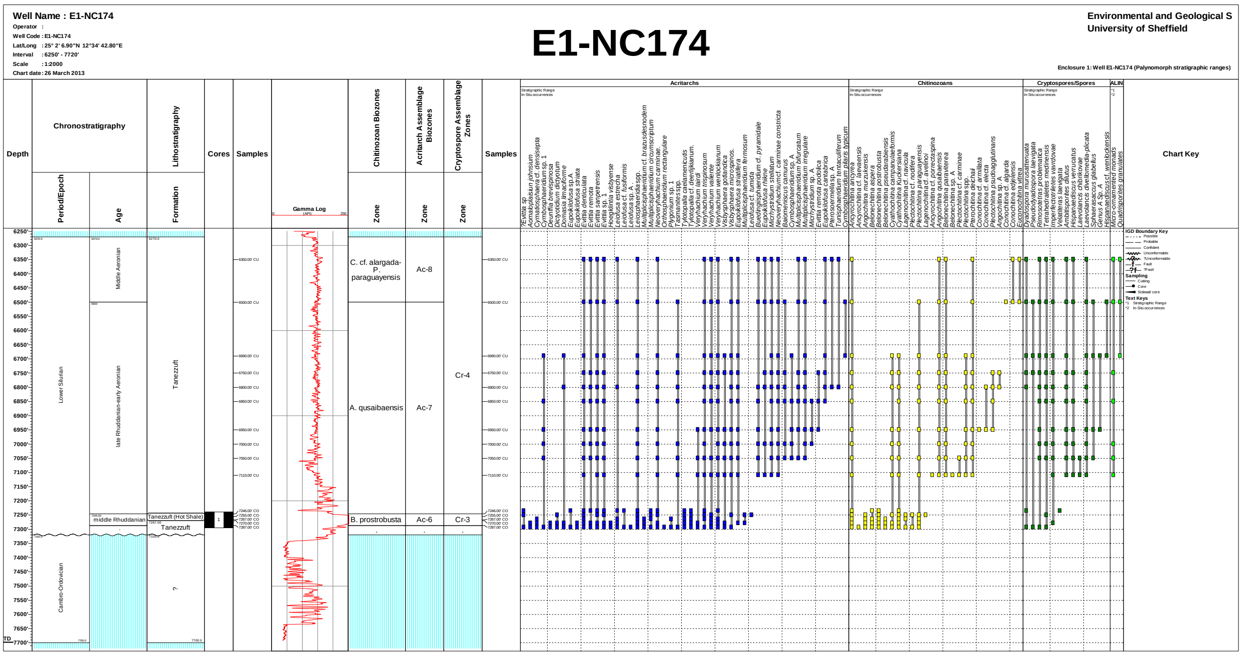
Well Name : B2-NC186
Lat/Long : 26°46' 47.54"N 12°40' 12.51"E
Interval : 3630' - 4996'
Scale : 1:1500
Chart date: 30 September 2012
B2-NC186
Environmental and Geological S
University of Sheffield
Enclosure 4: Well B2-NC186 (Playnofacies)
Depth
Chronostratigraphy
Period/Epoch
Age
Lithostratigraphy
Formation
Cores
Samples
Chitinozoan Biozones
Acritarch Assemblage Zones
Cryptospore Assemblage Zones
Zone
Gamma Log
Sphaeromorph acritarchs %
Other acritarchs %
Chitinozoans %
Cryptospores %
Cuticle %
AOM (yellowish brown) %
AOM (dark brown) %
Animal remains %
Total count
Chart Key
Lower Silurian
late Rhuddanian-early Aeronian
Tanezzuft
early Rhuddanian
Hot shale
Upper Ordovician
late Hirnantian
Memouniat
As Shabiyat
A. qusaibaensis
S. fragilis
T. elongata
Ac-7
Ac-5
Cr-4
?

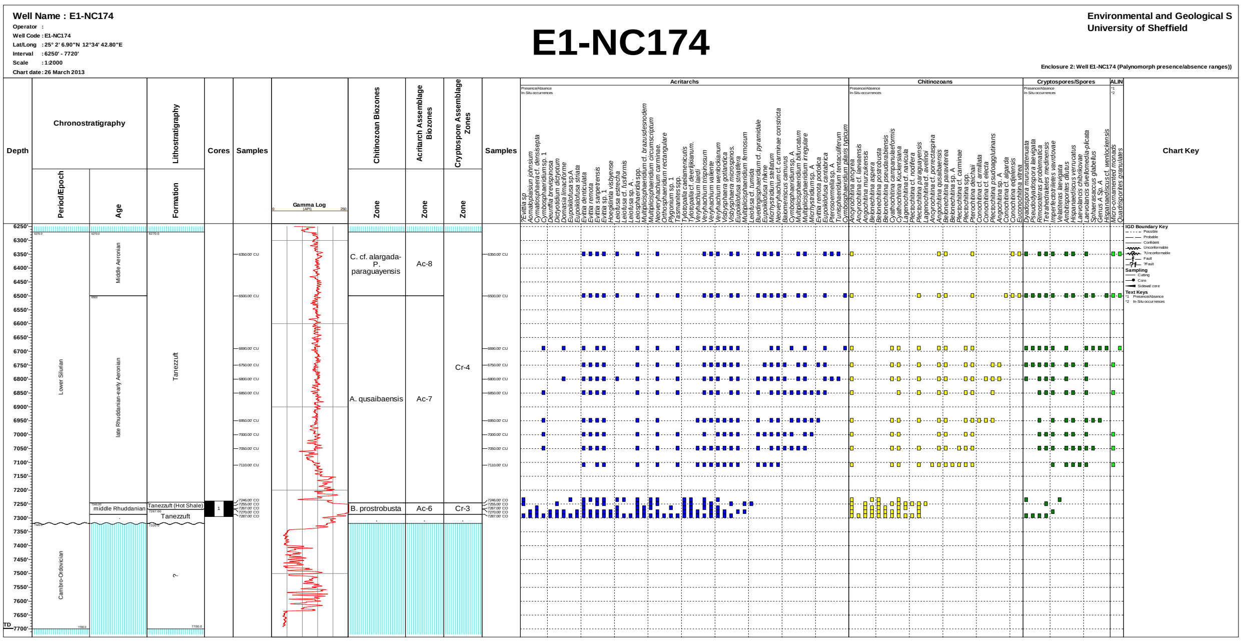

Well Name : D1-200
Operator :
Well Code : D1-200
Lat/Long : 25°44' 9.21"N 11°14' 58.00"E
Interval : 3630' - 5829'
Scale : 1:2000
Chart date : 26 March 2013
D1-200
Environmental and Geological S
University of Sheffield
Enclosure 1: Well D1-200 (Palynomorph stratigraphic ranges)
Depth
Chronostratigraphy
Period/Epoch
Age
Lithostratigraphy
Formation
Cores
Samples
Gamma Log
Chitinozoan Biozones
Acritarch Assemblage Zones
Cryptospore Assemblage Zones
Zone
Acritarchs
Chitinozoans
Cryptospores/Spores
ALIN
Chart Key
Lower Silurian
Upper Ordovician
Middle Ordovician
late Aeronian-early Telychian
middle Aeronian
late Rhuddanian-early Aeronian
early Hirnantian
late Katian
early-late Katian
middle-late Darriwilian
Tanezzuft
Melez Shugran
Hawaz
A. hemeri
C. cf. alargada-P. pamayuyensis
A. qusaibaensis
T. elongata
A.merga
A. nigerica
Assemblage Zone 1
Ac-8
Ac-7
Ac-4
Ac-3
Ac-2
Ac-1
Cr-4
Cr-2
Cr-1
IGD Boundary Key

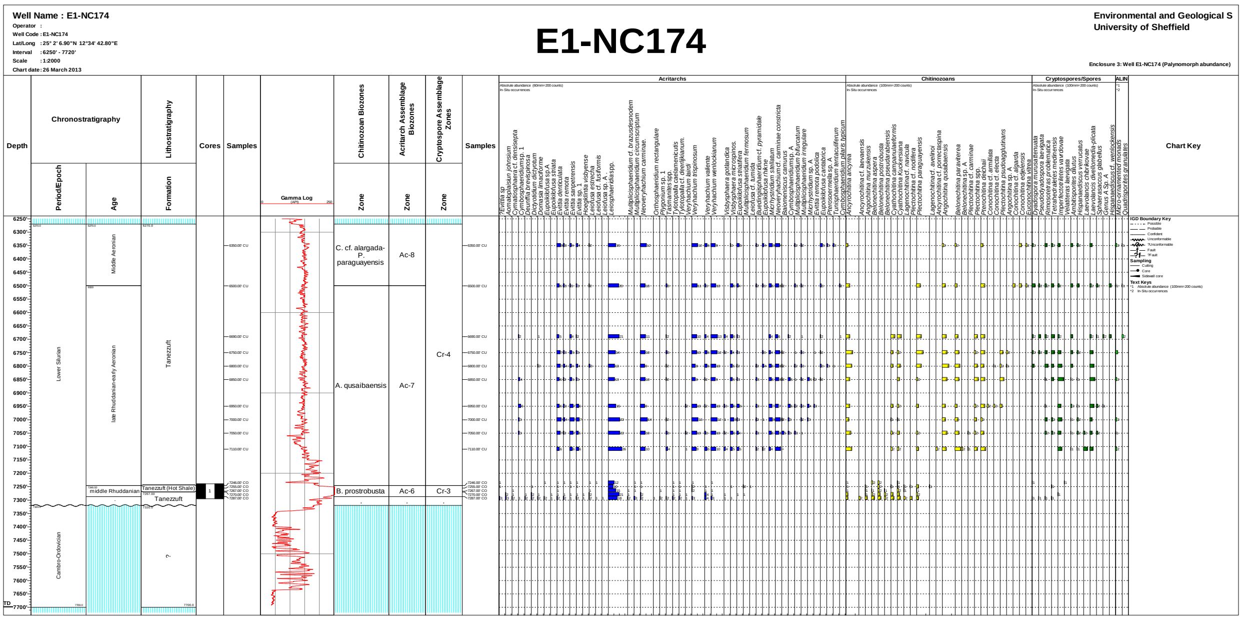

Well Name : D1-200
Operator :
Well Code : D1-200
Lat/Long : 25°44' 9.21"N 11°14' 58.00"E
Interval : 3630' - 5829'
Scale : 1:2000
Chart date : 26 March 2013
D1-200
Environmental and Geological S
University of Sheffield
Enclosure 2: Well D1-200 (Palynomorph presence/absence ranges)
Depth
Chronostratigraphy
Period/Epoch
Age
Lithostratigraphy
Formation
Cores
Samples
Gamma Log
Chitinozoan Biozones
Acritarch Assemblage Zones
Cryptospore Assemblage Zones
Zone
Acritarchs
Chitinozoans
Cryptospores/Spores
ALIN
Chart Key
Lower Silurian
Upper Ordovician
Middle Ordovician
late Aeronian-early Telychian
middle Aeronian
late Rhuddanian-early Aeronian
early Hirnantian
late Katian
early-late Katian
middle-late Darriwilian
Tanezzuft
Melez Shugran
Hawaz
A. hemeri
C. cf. alargada-P. pamayuyensis
A. qusaibaensis
T. elongata
A.merga
A. nigerica
Assemblage Zone 1
Ac-8
Ac-7
Ac-4
Ac-3
Ac-2
Ac-1
Cr-4
Cr-2
Cr-1
IGD Boundary Key

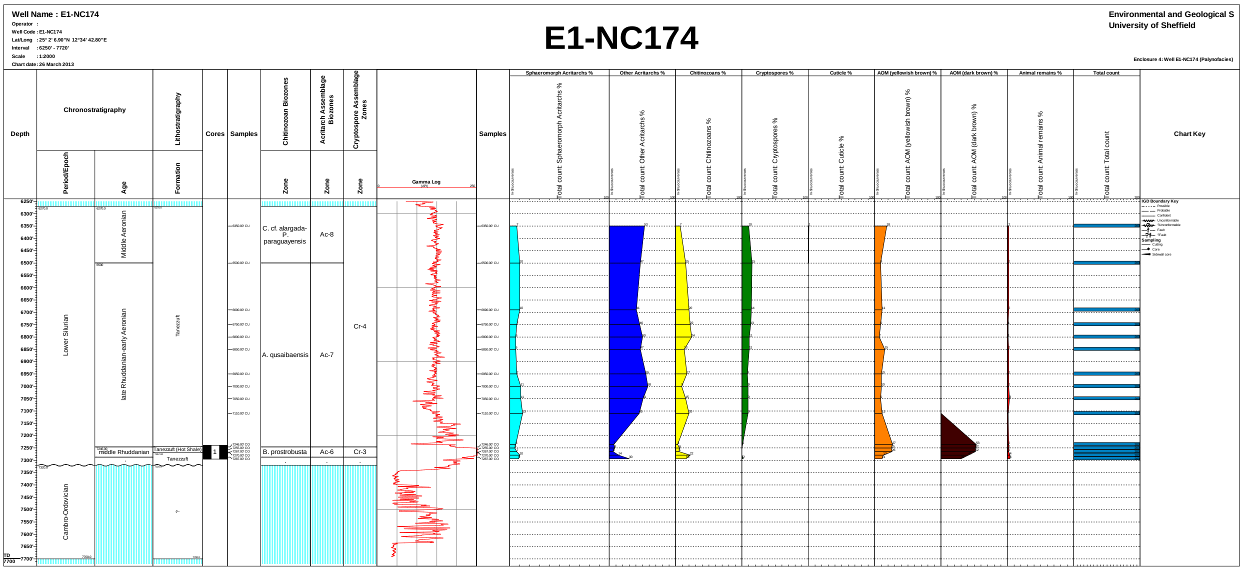

Well Name : D1-200
Operator :
Well Code : D1-200
Lat/Long : 25°44' 9.21"N 11°14' 58.00"E
Interval : 3630' - 5829'
Scale : 1:2000
Chart date: 26 March 2013
D1-200
Environmental and Geological S
University of Sheffield
Enclosure 3: Well D1-200 (Palynomorph abundance)
Depth
Chronostratigraphy
Period/Epoch
Age
Lithostratigraphy
Formation
Cores
Samples
Gamma Log
Chitinozoan Biozones
Acritarch Assemblage Zones
Cryptospore Assemblage Zones
Zone
Acritarchs
Chitinozoans
Cryptospores/Spores
Chart Key
Lower Silurian
Upper Ordovician
Middle Ordovician
late Aeronian-early Telychian
middle Aeronian
late Rhuddanian-early Aeronian
early Hirnantian
late Katian
early late Katian
middle-late Darriwilian
Tanezzuft
Melez Chograne
Hawaz
A. hemeri
C. cf. alargada-P. paraguayensis
A. quusibaensis
T. elongata
A. merga
A. nigerica
Assemblage Zone 1
Ac-8
Ac-7
Ac-4
Ac-3
Ac-2
Ac-1
Cr-4
Cr-2
Cr-1

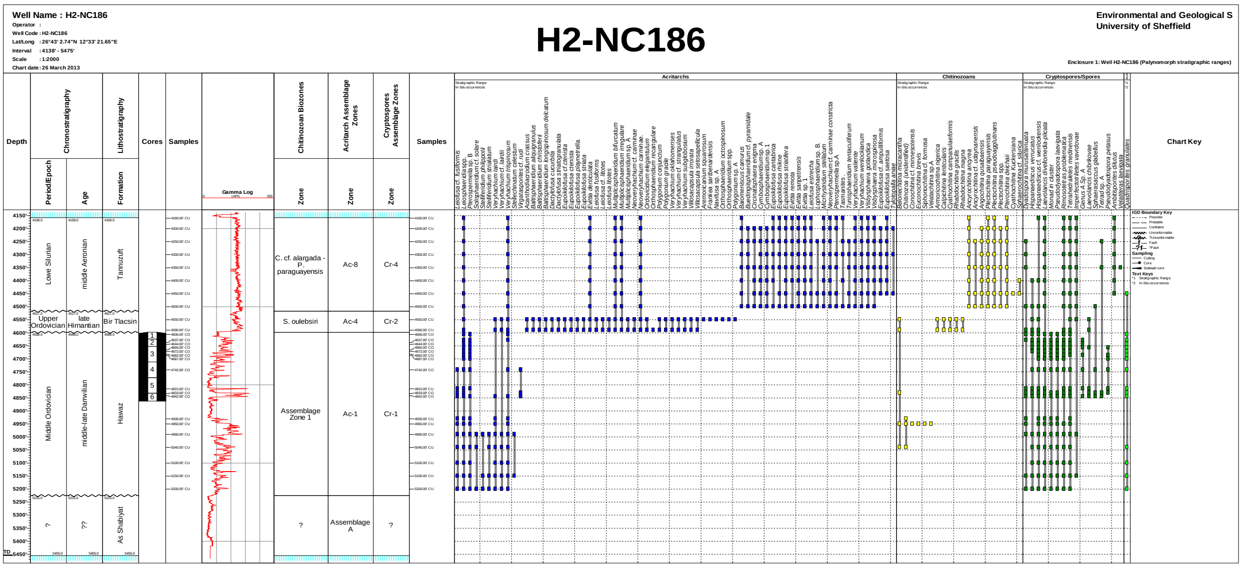

Well Name : D1-200
Operator :
Well Code : D1-200
Lat/Long : 25°44' 9.21"N 11°14' 58.00"E
Interval : 3630' - 5829'
Scale : 1:2000
Chart date: 26 March 2013
D1-200
Environmental and Geological S
University of Sheffield
Enclosur 4: Well D1-200 (Palynofacies)
Depth
Chronostratigraphy
Period/Epoch
Age
Lithostratigraphy
Formation
Cores
Samples
Chitinozoan Biozones
Acritarch Assemblage Zones
Cryptospore Assemblage Zones
Zone
Gamma Log
Sphaeromorph acritarchs %
Other acritarchs %
Chitinozoans %
Cryptospores %
Cuticle %
AOM (yellowish brown) %
AOM (dark brown) %
Animal remains %
Total count
Total count: Sphaeromorph acritarchs %
Total count: Other acritarchs %
Total count: Chitinozoans %
Total count: Cryptospores %
Total count: Cuticle %
Total count: AOM (yellowish brown) %
Total count: AOM (dark brown) %
Total count: Animal remains %
Total count: Total count
Chart Key
IGD Boundary Key
Possible
Probable
Confident
Unconformable
?Unconformable
Fault
?Fault
Sampling
Cutting
Core
Sidewall core
3650'
3700'
3750'
3800'
3850'
3900'
3950'
4000'
4050'
4100'
4150'
4200'
4250'
4300'
4350'
4400'
4450'
4500'
4550'
4600'
4650'
4700'
4750'
4800'
4850'
4900'
4950'
5000'
5050'
5100'
5150'
5200'
5250'
5300'
5350'
5400'
5450'
5500'
5550'
5600'
5650'
5700'
5750'
5800'
TD 5829
Lower Silurian
Upper Ordovician
Middle Ordovician
late Aeronian-early Telychian
middle Aeronian
late Rhuddanian-early Aeronian
early Hirnantian
late Katian
early late Katian
middle-late Darriwilian
Tanezzuft
Melez Chograne
Hawaz
1
2
3
A. hemeri
C. cf. alargada-P. paraguayensis
A. quusibaensis
T. elongata
A.merga
A. nigerica
Assemblage Zone 1
Ac-8
Ac-7
Ac-4
Ac-3
Ac-2
Ac-1
Cr-4
Cr-2
Cr-1

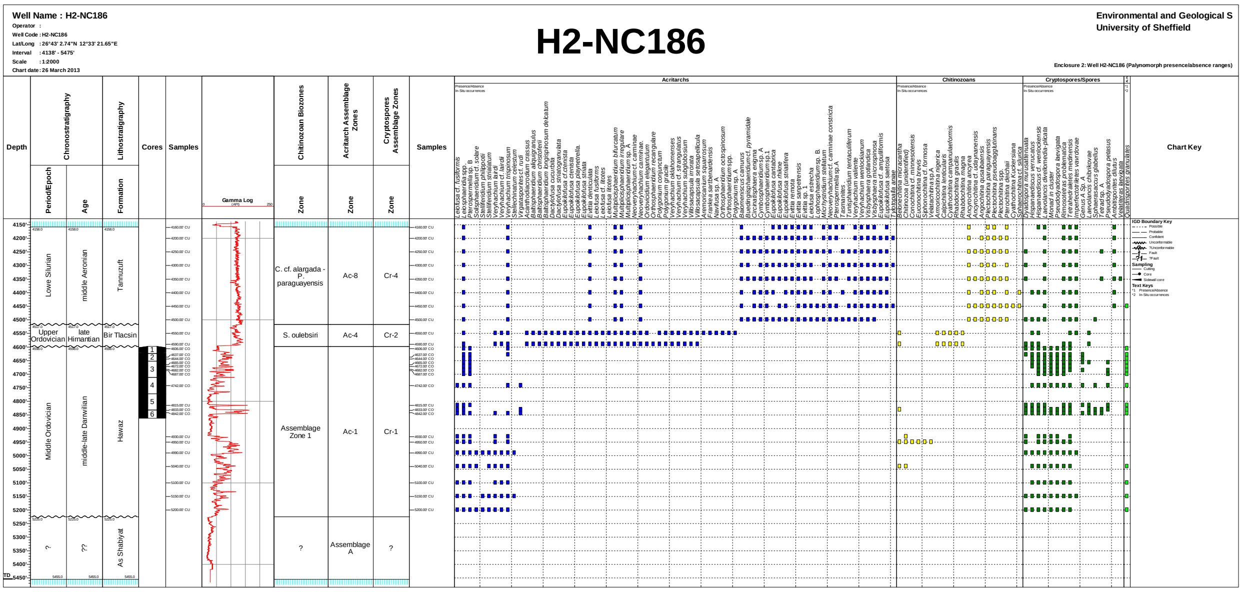

Well Name : E1-NC174
Operator :
Well Code : E1-NC174
Lat/Long : 25° 2' 6.90"N 12°34' 42.80"E
Interval : 6250' - 7720'
Scale : 1:2000
Chart date : 26 March 2013
E1-NC174
Environmental and Geological S
University of Sheffield
Enclosure 1: Well E1-NC174 (Palynomorph stratigraphic ranges)
Depth
Chronostratigraphy
Period/Epoch
Age
Lithostratigraphy
Formation
Cores
Samples
Gamma Log
Chitinozoan Biozones
Acritarch Assemblage Biozones
Cryptospore Assemblage Zones
Zone
Acritarchs
Chitinozoans
Cryptospores/Spores
ALIN
Chart Key
Lower Silurian
Cambro-Ordovician
Middle Aeronian
late Rhuddanian-early Aeronian
middle Rhuddanian
Tanezzuft
Tanezzuft (Hot Shale)
?
C. cf. alargada-P. paraguayensis
A. qusaibaensis
B. prostrobusta
Ac-8
Ac-7
Ac-6
Cr-4
Cr-3
TD

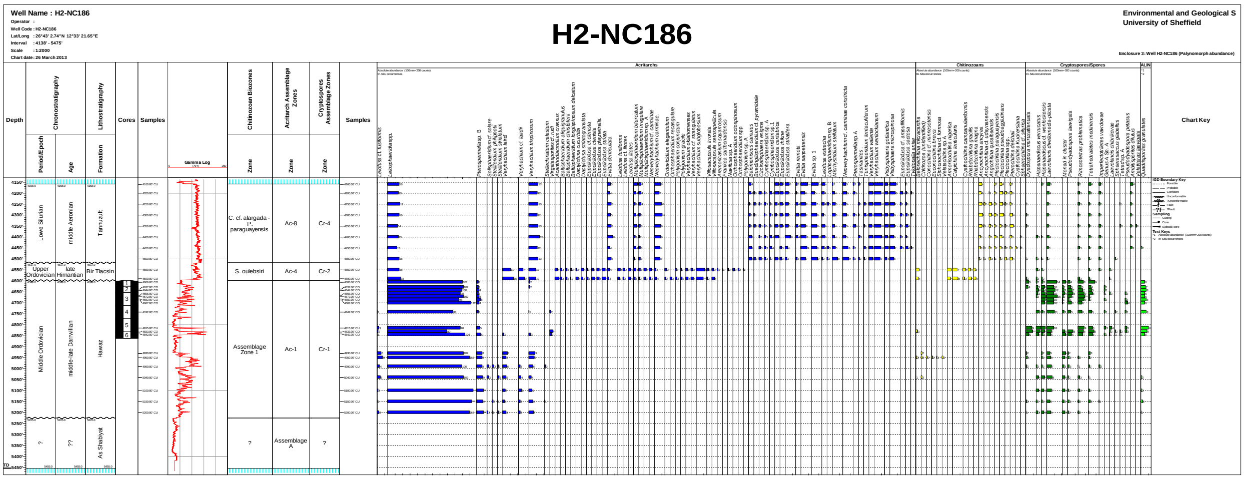

Well Name : E1-NC174
Operator :
Well Code : E1-NC174
Lat/Long : 25° 2' 6.90"N 12°34' 42.80"E
Interval : 6250' - 7720'
Scale : 1:2000
Chart date : 26 March 2013
E1-NC174
Environmental and Geological S
University of Sheffield
Enclosure 2: Well E1-NC174 (Palynomorph presence/absence ranges)
Depth
Chronostratigraphy
Period/Epoch
Age
Lithostratigraphy
Formation
Cores
Samples
Gamma Log
Chitinozoan Biozones
Acritarch Assemblage Biozones
Cryptospore Assemblage Zones
Zone
Acritarchs
Chitinozoans
Cryptospores/Spores
ALIN
Chart Key
Lower Silurian
Cambro-Ordovician
Middle Aeronian
late Rhuddanian-early Aeronian
middle Rhuddanian
Tanezzuft
Tanezzuft (Hot Shale)
?
C. cf. alargada-P. paraguayensis
A. qusaibaensis
B. prostrobusta
Ac-8
Ac-7
Ac-6
Cr-4
Cr-3
TD

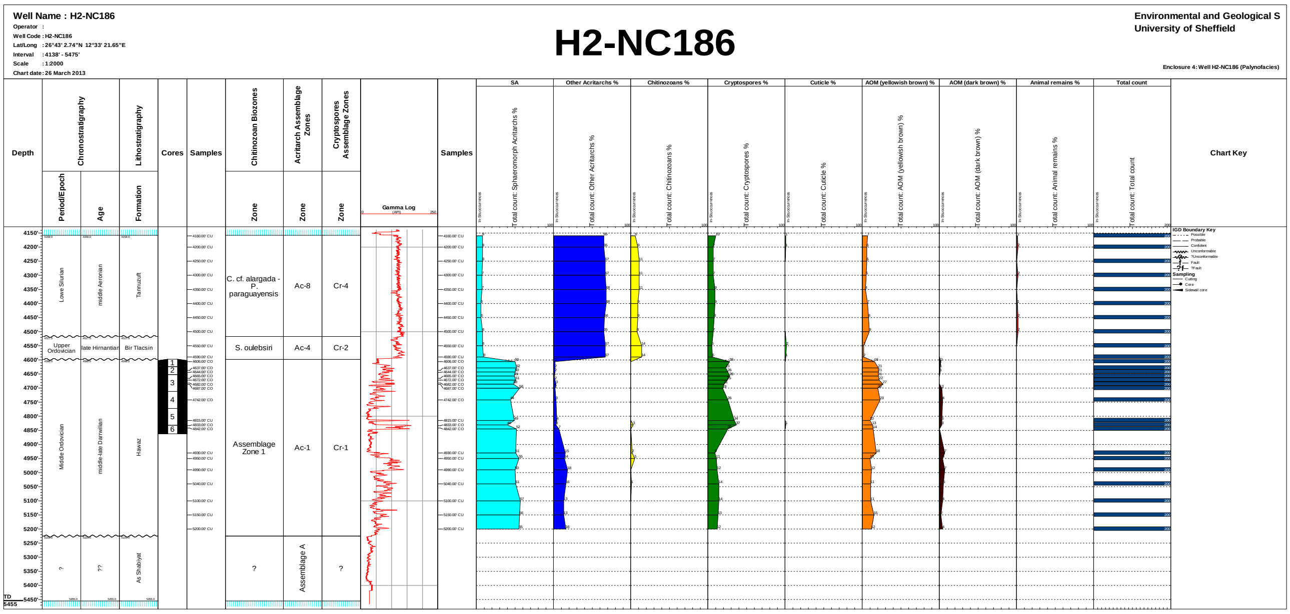

Well Name : E1-NC174
Operator :
Well Code : E1-NC174
Lat/Long : 25° 2' 6.90"N 12°34' 42.80"E
Interval : 6250' - 7720'
Scale : 1:2000
Chart date : 26 March 2013
E1-NC174
Environmental and Geological S
University of Sheffield
Enclosure 3: Well E1-NC174 (Palynomorph abundance)
Depth
Chronostratigraphy
Period/Epoch
Age
Lithostratigraphy
Formation
Cores
Samples
Gamma Log
Chitinozoan Biozones
Acritarch Assemblage Biozones
Cryptospore Assemblage Zones
Zone
Acritarchs
Chitinozoans
Cryptospores/Spores
ALIN
Chart Key
Lower Silurian
Cambro-Ordovician
Middle Aeronian
late Rhuddanian-early Aeronian
middle Rhuddanian
Tanezzuft
Tanezzuft (Hot Shale)
?
C. cf. alargada-P. paraguayensis
A. qusaibaensis
B. prostrobusta
Ac-8
Ac-7
Ac-6
Cr-4
Cr-3
TD
6250'
6300'
6350'
6400'
6450'
6500'
6550'
6600'
6650'
6700'
6750'
6800'
6850'
6900'
6950'
7000'
7050'
7100'
7150'
7200'
7250'
7300'
7350'
7400'
7450'
7500'
7550'
7600'
7650'
7700'

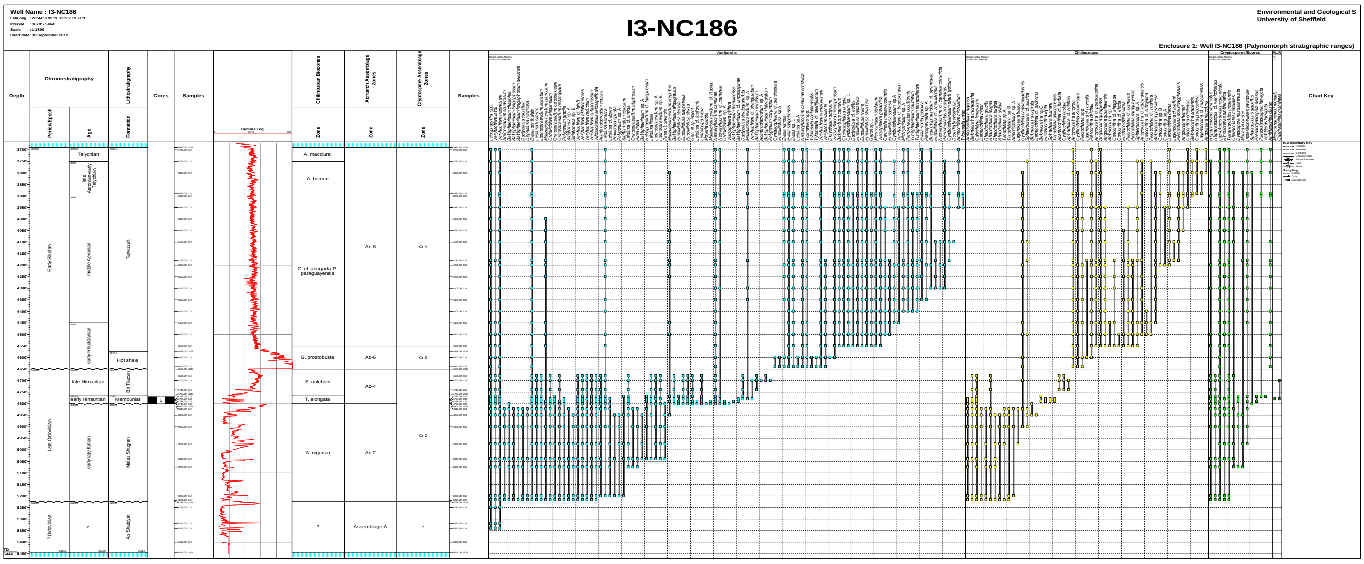

Well Name : E1-NC174
Operator :
Well Code : E1-NC174
Lat/Long : 25° 2' 6.90"N 12°34' 42.80"E
Interval : 6250' - 7720'
Scale : 1:2000
Chart date : 26 March 2013
E1-NC174
Environmental and Geological S
University of Sheffield
Enclosure 4: Well E1-NC174 (Palynofacies)
Depth
Chronostratigraphy
Period/Epoch
Age
Lithostratigraphy
Formation
Cores
Samples
Chitinozoan Biozones
Acritarch Assemblage Biozones
Cryptospore Assemblage Zones
Zone
Gamma Log
Sphaeromorph Acritarchs %
Other Acritarchs %
Chitinozoans %
Cryptospores %
Cuticle %
AOM (yellowish brown) %
AOM (dark brown) %
Animal remains %
Total count
Total count: Sphaeromorph Acritarchs %
Total count: Other Acritarchs %
Total count: Chitinozoans %
Total count: Cryptospores %
Total count: Cuticle %
Total count: AOM (yellowish brown) %
Total count: AOM (dark brown) %
Total count: Animal remains %
Total count: Total count
Chart Key
Lower Silurian
Cambro-Ordovician
Middle Aeronian
late Rhuddanian-early Aeronian
middle Rhuddanian
Tanezzuft
Tanezzuft (Hot Shale)
?
C. cf. alargada-P. paraguayensis
A. qusaibaensis
B. prostrobusta
Ac-8
Ac-7
Ac-6
Cr-4
Cr-3
TD
6250'
6300'
6350'
6400'
6450'
6500'
6550'
6600'
6650'
6700'
6750'
6800'
6850'
6900'
6950'
7000'
7050'
7100'
7150'
7200'
7250'
7300'
7350'
7400'
7450'
7500'
7550'
7600'
7650'
7700'

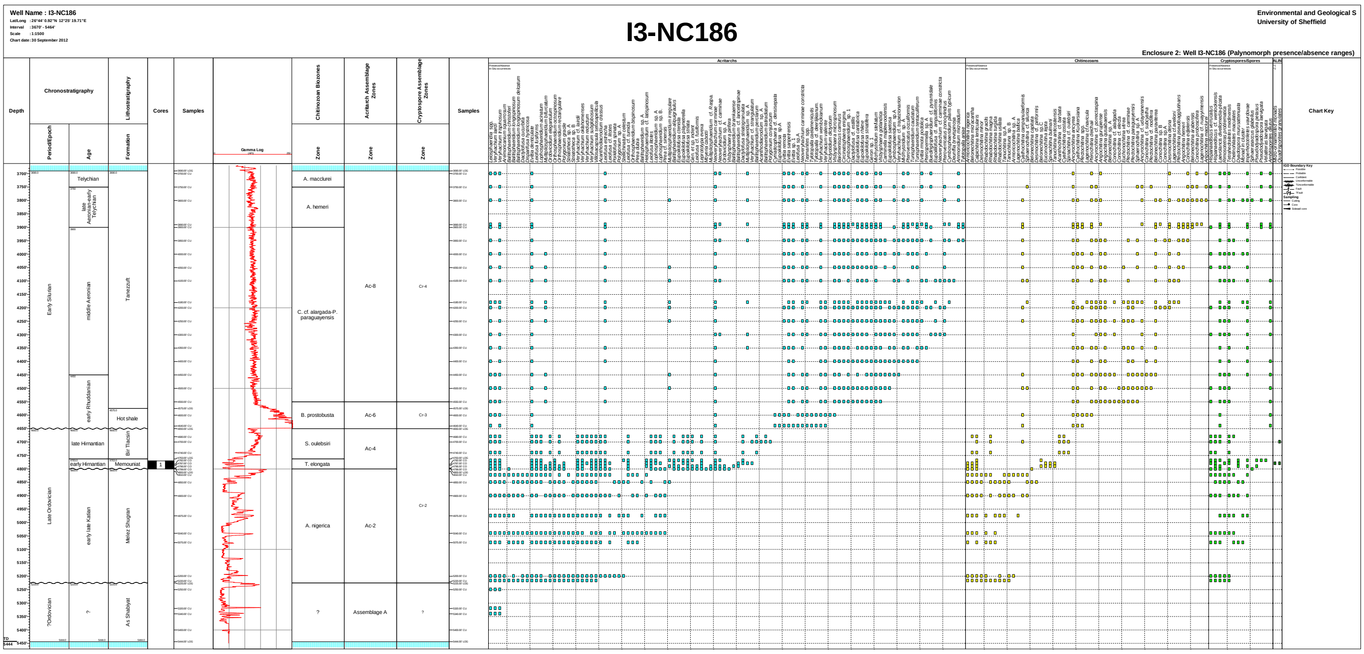

Well Name : H2-NC186
Operator :
Well Code : H2-NC186
Lat/Long : 26°43' 2.74"N 12°33' 21.65"E
Interval : 4138' - 5475'
Scale : 1:2000
Chart date : 26 March 2013
H2-NC186
Environmental and Geological S
University of Sheffield
Enclosure 1: Well H2-NC186 (Palynomorph stratigraphic ranges)
Depth
Chronostratigraphy
Period/Epoch
Age
Lithostratigraphy
Formation
Cores
Samples
Gamma Log
Chitinozoan Biozones
Acritarch Assemblage Zones
Cryptospores Assemblage Zones
Zone
Acritarchs
Chitinozoans
Cryptospores/Spores
Stratigraphic Range
In-Situ occurrences
Chart Key
Lowe Silurian
middle Aeronian
Tannuzuft
Upper Ordovician
late Himantian
Bir Tlacsin
Middle Ordovician
middle-late Darriwilian
Hawaz
As Shabiyat
C. cf. alargada - P. paraguayensis
S. oulebsiri
Assemblage Zone 1
Ac-8
Ac-4
Ac-1
Assemblage A
Cr-4
Cr-2
Cr-1
TD

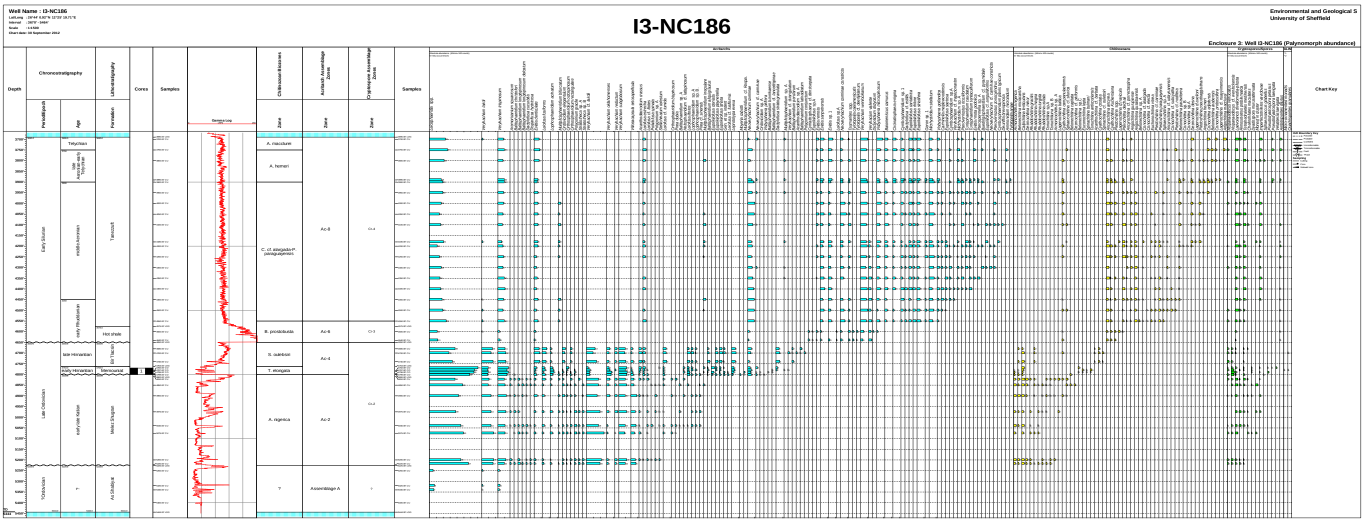

Well Name : H2-NC186
Operator :
Well Code : H2-NC186
Lat/Long : 26°43' 2.74"N 12°33' 21.65"E
Interval : 4138' - 5475'
Scale : 1:2000
Chart date : 26 March 2013
H2-NC186
Environmental and Geological S
University of Sheffield
Enclosure 2: Well H2-NC186 (Palynomorph presence/absence ranges)
Depth
Chronostratigraphy
Period/Epoch
Age
Lithostratigraphy
Formation
Cores
Samples
Gamma Log
Chitinozoan Biozones
Acritarch Assemblage Zones
Cryptospores Assemblage Zones
Zone
Acritarchs
Chitinozoans
Cryptospores/Spores
Presence/Absence
In-Situ occurrences
Chart Key
Lowe Silurian
middle Aeronian
Tannuzuft
Upper Ordovician
late Himantian
Bir Tlacsin
Middle Ordovician
middle-late Darriwilian
Hawaz
As Shabiyat
C. cf. alargada - P. paraguayensis
S. oulebsiri
Assemblage Zone 1
Ac-8
Ac-4
Ac-1
Assemblage A
Cr-4
Cr-2
Cr-1
TD

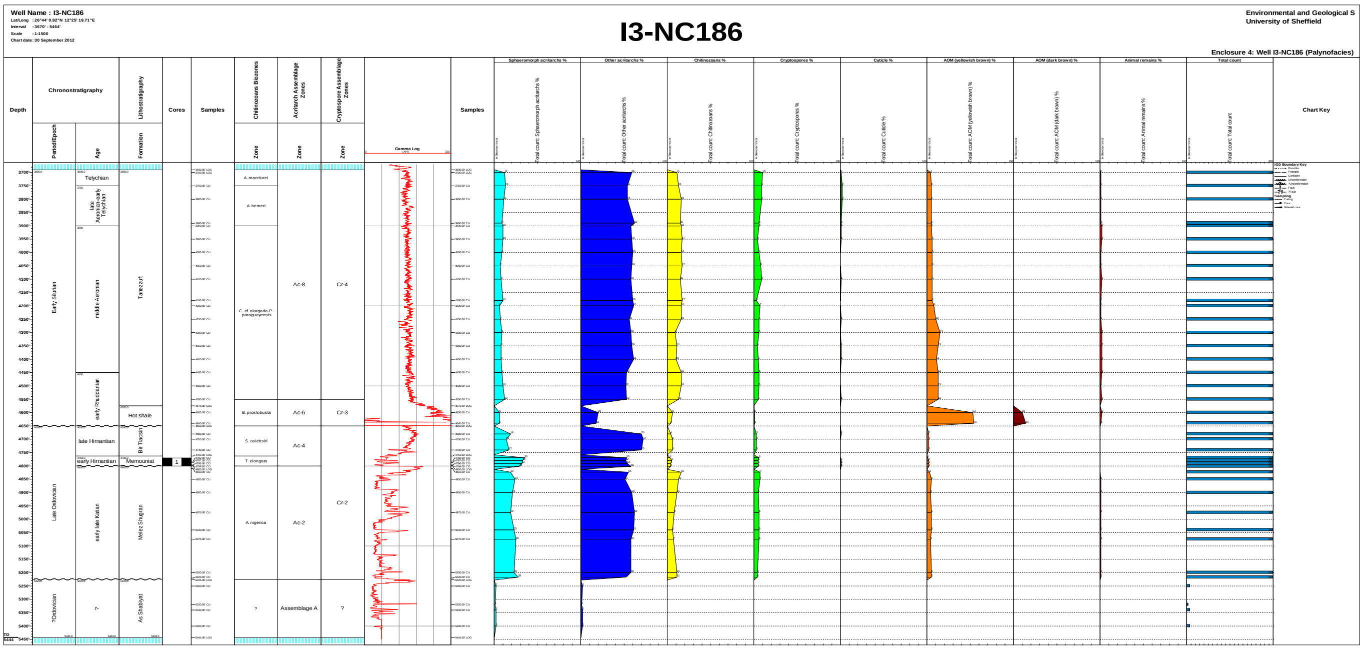

Well Name : H2-NC186
Operator :
Well Code : H2-NC186
Lat/Long : 26°43' 2.74"N 12°33' 21.65"E
Interval : 4138' - 5475'
Scale : 1:2000
Chart date : 26 March 2013
H2-NC186
Environmental and Geological S
University of Sheffield
Enclosure 3: Well H2-NC186 (Palynomorph abundance)
Depth
Chronostratigraphy
Period/Epoch
Age
Lithostratigraphy
Formation
Cores
Samples
Gamma Log
Chitinozoan Biozones
Acritarch Assemblage Zones
Cryptospores Assemblage Zones
Zone
Samples
Acritarchs
Chitinozoans
Cryptospores/Spores
ALIN
Absolute abundance (100mm=200 counts)
In-Situ occurrences
Chart Key
Lowe Silurian
middle Aeronian
Tanezzuft
Upper Ordovician
late Himantian
Bir Tlacsin
Middle Ordovician
middle-late Darriwilian
Hawaz
?
??
As Shabiyat
C. cf. alargada - P. paraguayensis
Ac-8
Cr-4
S. oulebsiri
Ac-4
Cr-2
Assemblage Zone 1
Ac-1
Cr-1
Assemblage A
4150'
4200'
4250'
4300'
4350'
4400'
4450'
4500'
4550'
4600'
4650'
4700'
4750'
4800'
4850'
4900'
4950'
5000'
5050'
5100'
5150'
5200'
5250'
5300'
5350'
5400'
5450'
TD


Well Name : H2-NC186
Operator :
Well Code : H2-NC186
Lat/Long : 26°43' 2.74"N 12°33' 21.65"E
Interval : 4138' - 5475'
Scale : 1:2000
Chart date : 26 March 2013
H2-NC186
Environmental and Geological S
University of Sheffield
Enclosure 4: Well H2-NC186 (Palynofacies)
Depth
Chronostratigraphy
Period/Epoch
Age
Lithostratigraphy
Formation
Cores
Samples
Gamma Log
Chitinozoan Biozones
Acritarch Assemblage Zones
Cryptospores Assemblage Zones
Zone
Samples
SA
Other Acritarchs %
Chitinozoans %
Cryptospores %
Cuticle %
AOM (yellowish brown) %
AOM (dark brown) %
Animal remains %
Total count
Total count: Sphaeromorph Acritarchs %
Total count: Other Acritarchs %
Total count: Chitinozoans %
Total count: Cryptospores %
Total count: Cuticle %
Total count: AOM (yellowish brown) %
Total count: AOM (dark brown) %
Total count: Animal remains %
Total count: Total count
Chart Key
Lowe Silurian
middle Aeronian
Tanezzuft
Upper Ordovician
late Himantian
Bir Tlacsin
Middle Ordovician
middle-late Darriwilian
Hawaz
?
??
As Shabiyat
C. cf. alargada - P. paraguayensis
Ac-8
Cr-4
S. oulebsiri
Ac-4
Cr-2
Assemblage Zone 1
Ac-1
Cr-1
Assemblage A
1
2
3
4
5
6
4150'
4200'
4250'
4300'
4350'
4400'
4450'
4500'
4550'
4600'
4650'
4700'
4750'
4800'
4850'
4900'
4950'
5000'
5050'
5100'
5150'
5200'
5250'
5300'
5350'
5400'
5450'
TD
5455


Well Name : I3-NC186
Lat/Long : 26°44' 0.92"N 12°25' 19.71"E
Interval : 3670' - 5464'
Scale : 1:1500
Chart date : 30 September 2012
I3-NC186
Environmental and Geological S
University of Sheffield
Enclosure 1: Well I3-NC186 (Palynomorph stratigraphic ranges)
Depth
Chronostratigraphy
Period/Epoch
Age
Lithostratigraphy
Formation
Cores
Samples
Gamma Log
Chitinozoan Biozones
Acritarch Assemblage Zones
Cryptospore Assemblage Zones
Zone
Acritarchs
Chitinozoans
Cryptospores/Spores
ALIN
Chart Key
IGD Boundary Key
Sampling
Early Silurian
Late Ordovician
?Ordovician
Telychian
late Aeronian-early Telychian
middle Aeronian
early Rhuddanian
late Hirnantian
early Hirnantian
early late Katian
?
Tanezzuft
Hot shale
Bir Tlacsin
Memouniat
Melez Shugran
As Shabiyat
A. macclurei
A. hemeri
C. cf. alargada-P. paraguayensis
B. prostobusta
S. oulebsiri
T. elongata
A. nigerica
Ac-8
Ac-6
Ac-4
Ac-2
Assemblage A
Cr-4
Cr-3
Cr-2


Well Name : I3-NC186
Lat/Long : 26°44' 0.92"N 12°25' 19.71"E
Interval : 3670' - 5464'
Scale : 1:1500
Chart date : 30 September 2012
I3-NC186
Environmental and Geological S
University of Sheffield
Enclosure 2: Well I3-NC186 (Palynomorph presence/absence ranges)
Depth
Chronostratigraphy
Period/Epoch
Age
Lithostratigraphy
Formation
Cores
Samples
Gamma Log
Chitinozoan Biozones
Acritarch Assemblage Zones
Cryptospore Assemblage Zones
Zone
Acritarchs
Chitinozoans
Cryptospores/Spores
Chart Key
Early Silurian
Late Ordovician
?Ordovician
Telychian
late Aeronian-early Telychian
middle Aeronian
early Rhuddanian
late Hirnantian
early Hirnantian
early late Katian
?
Tanezzuft
Hot shale
Bir Tlacsin
Memouniat
Melez Shugran
As Shabiyat
A. macclurei
A. hemeri
C. cf. alargada-P. paraguayensis
B. prostobusta
S. oulebsiri
T. elongata
A. nigerica
Ac-8
Ac-6
Ac-4
Ac-2
Assemblage A
Cr-4
Cr-3
Cr-2


Well Name : I3-NC186
Lat/Long : 26°44' 0.92"N 12°25' 19.71"E
Interval : 3670' - 5464'
Scale : 1:1500
Chart date : 30 September 2012
I3-NC186
Environmental and Geological S
University of Sheffield
Enclosure 3: Well I3-NC186 (Palynomorph abundance)
Depth
Chronostratigraphy
Period/Epoch
Age
Lithostratigraphy
Formation
Cores
Samples
Gamma Log
Chitinozoan Biozones
Acritarch Assemblage Zones
Cryptospore Assemblage Zones
Zone
Acritarchs
Chitinozoans
Cryptospores
Chart Key
Early Silurian
Telychian
late Aeronian-early Telychian
middle Aeronian
early Rhuddanian
Late Ordovician
late Hirnantian
early Hirnantian
early late Katian
?Ordovician
?
Tanezzuft
Hot shale
Bir Tlacsin
Memouniat
Melaz Shuqran
As Shabiyat
A. macclurei
A. hemeri
C. cf. alargada-P. paraguayensis
B. postobusta
S. oulebsiri
T. elongata
A. nigerica
Ac-8
Ac-6
Ac-4
Ac-2
Assemblage A
Cr-4
Cr-3
Cr-2
3700'
3750'
3800'
3850'
3900'
3950'
4000'
4050'
4100'
4150'
4200'
4250'
4300'
4350'
4400'
4450'
4500'
4550'
4600'
4650'
4700'
4750'
4800'
4850'
4900'
4950'
5000'
5050'
5100'
5150'
5200'
5250'
5300'
5350'
5400'
5450'


Well Name : I3-NC186
Lat/Long : 26°44' 0.92"N 12°25' 19.71"E
Interval : 3670' - 5464'
Scale : 1:1500
Chart date : 30 September 2012
I3-NC186
Environmental and Geological S
University of Sheffield
Enclosure 4: Well I3-NC186 (Palynofacies)
Depth
Chronostratigraphy
Period/Epoch
Age
Lithostratigraphy
Formation
Cores
Samples
Chitinozoans Biozones
Acritarch Assemblage Zones
Cryptospore Assemblage Zones
Zone
Gamma Log
Sphaeromorph acritarchs %
Total count: Sphaeromorph acritarchs %
Other acritarchs %
Total count: Other acritarchs %
Chitinozoans %
Total count: Chitinozoans %
Cryptospores %
Total count: Cryptospores %
Cuticle %
Total count: Cuticle %
AOM (yellowish brown) %
Total count: AOM (yellowish brown) %
AOM (dark brown) %
Total count: AOM (dark brown) %
Animal remains %
Total count: Animal remains %
Total count
Total count: Total count
Chart Key
IGD Boundary Key
Possible
Probable
Confident
Unconformable
?Unconformable
Fault
?Fault
Sampling
Cutting
Core
Sidewall core
Early Silurian
Telychian
late Aeronian-early Telychian
middle Aeronian
early Rhuddanian
Late Ordovician
late Hirnantian
early Hirnantian
early late Katian
?Ordovician
?
Tanezzuft
Hot shale
Bir Tlacsin
Memouniat
Melaz Shuqran
As Shabiyat
A. macclurei
A. hemeri
C. cf. alargada-P. paraguayensis
B. postobusta
S. oulebsiri
T. elongata
A. nigerica
Ac-8
Ac-6
Ac-4
Ac-2
Assemblage A
Cr-4
Cr-3
Cr-2
1
3700'
3750'
3800'
3850'
3900'
3950'
4000'
4050'
4100'
4150'
4200'
4250'
4300'
4350'
4400'
4450'
4500'
4550'
4600'
4650'
4700'
4750'
4800'
4850'
4900'
4950'
5000'
5050'
5100'
5150'
5200'
5250'
5300'
5350'
5400'
5450'