#### THE STRATIGRAPHY OF THE UPPER ORDOVICIAN OF CENTRAL PORTUGAL

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#### SUMMARY

The project has involved the revision of the stratigraphy of the upper part of the Ordovician succession in central Portugal. Using evidence derived principally from the study of measured sections, with some limited geological mapping, this thesis first considers a new lithostratigraphy of the upper Ordovician deposits. The scheme presented includes four groups, twelve formations and eleven members. Most of the elements of the scheme are described here for the first time.

The sedimentology of the deposits has been studied to allow an interpretation of the depositional environment. The history of sedimentation in the upper Ordovician is divided into three broad phases. In the first of these (phase A) storm-dominated deposition of detrital clastics took place on a wide, flat, shallow shelf. During the second phase (B) a localised area of igneous activity developed in the area of highest subsidence seen in the preceding phase. This igneous activity was accompanied by the deposition of some carbonate sediments. The third phase of deposition (C) is linked to the effects of the upper Ordovician glaciation.

A review of most of the macrofauna recovered is given. The faunas of Portugal form a highly distinct and homogeneous "province" with those of Armorica, Spain, Montagne Noire and Sardinia. The palaeoecology of the faunas collected during this

study are discussed. Thirteen broad associations (<u>sensu Lockley</u>, 1983) are identified. Factors other than latitude-related influences play an important role in controlling the diversity, abundance and taxonomic constitution of the palaeocommunities. Twelve biozones are erected to cover the range of fossiliferous Ordovician strata examined in this project. The correlation between the biostratigraphic scheme erected herein and the international standard is discussed.

An overview attempts to place the study area within the context of the peri-Gondwana shelf, and within the Variscan fold-belt.

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#### INTRODUCTION

#### 1) Outline of the thesis

The lithostratigraphy of the upper Ordovician deposits of central Portugal is revised in chapter 1 of part I of the thesis. The scheme presented includes four groups, twelve formations and eleven members. Most of the elements of the scheme are described here for the first time. The lithostratigraphy is related to the equivalent sequences in Brittany.

In cnapter 2 the description of the sequences is taken a stage further with the discussion of the depositional environment. The history of sedimentation in the upper Ordovician is divided into three broad phases. In the first of these (phase A) deposition took place on a wide, flat, shallow shelf. The sedimentary environment was strongly influenced by storm action, and the deposits are essentially detrital clastics. At discrete horizons colitic ironstones were widely developed during periods of reduced sedimentation. Differential subsidence during this phase resulted in the production of facies differences between "rise" and "basin" areas, although the palaeotopography was very slight.

During the second phase (B) a localised area of igneous activity developed in the area of highest subsidence seen in the preceding phase. This igneous activity was accompanied by the deposition of some carbonate sediments. The activity began with an explosive phase, and, after a period of quiescence, entered a period of extrusion of basaltic flows, together with the

intrusion of high-level, thick dolerite sills. All the extrusive activity seems to have been submarine.

The third phase of deposition (C) is linked to the effects of the upper Ordovician glaciation. The eustatic fall in sea level with the onset of the glaciation gave rise to regressive clastic sedimentation throughout much of the region. The area was covered by an icesheet at the height of the glaciation. During deglaciation eustatic sea-level rise preceded melting of the icesheet, decoupling the ice from the sea-floor and preventing the formation of fluvio-glacial deposits. One possible exception to this may be at the edge of the volcanic/carbonate build-up of the previous phase. However, in the absence of good dating evidence these channelled conglomerates could equally be due to the emergence of the build-up during the onset of glaciation. Continued melting of the icesheet led to the deposition of diamictites over a very wide area. In central Portugal the volcanics still represented a positive feature and were anot finally onlapped until the upper Silurian. After the rapid deposition during deglaciation, sedimentation in the period from close to the Ordovician/Silurian boundary to the upper Llandovery was greatly reduced. Sediments include pyrite- and organic-rich sandstones and mudflake-conglomerates. These sediments indicate a period of sediment reworking with little clastic input to the shelf. In the upper Llandovery sedimentation resumes a more rapid rate with the deposition of graptolitic mudstones.

The separation of the processes of allocating a fauna to a biozone, and of placing that biozone with respect to the international stratigraphical standard is considered essential

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The Ordovician faunas of Iberia have long been described as exhibiting low diversity, attributed to their high palaeo-latitude. Chapter 4 is devoted to examining the palaeoecology of the faunas collected during this study. Associations are markedly different from coeval faunas of the Anglo-Welsh province. Thirteen broad associations (sensu Lockley, 1903) are identified. These associations are grouped into five palaeocommunities. The first of these is found in the mudrocks of

the deeper-water facies of the middle and upper Ordovician. The associations of this palaeocommunity are dominated by trilobites, although brachiopods are also important elements. The representatives of this palaeocommunity have received little attention in this study. The second occurs in the mudrocks of the storm-dominated clastic sequences (facies 1 of phase A of chapter 2). This palaeocommunity has its preserved elements dominated by ostracodes and infaunal bivalves, although trilobites are also important. The third palaeocommunity occurs rarely in the sandstones of phase A, and is dominated by brachiopods, although again trilobites are important. This palaeocommunity is generally of very low diversity, and most assemblages ascribed to it have probably suffered more transport than the assemblages of any other association. The fourth palaeocommunity differs markedly from the first three by being dominated by suspension feeders, particularly brachiopods, bryozoans and echinoderms. This palaeocommunity occurs in oolitic ironstones and in carbonates of phases A and B. The fifth palaeocommunity covers an association from the basal sediments of phase C. It includes several brachiopods and a crinoid, and is of very low diversity. Thus the diversity of faunas is very variable. Factors other than latitude-related influences play an important role in controlling the diversity, abundance and taxonomic constitution of the palaeocommunities.

The final chapter, chapter 5, gives an overview of the development of central Portugal during the upper Ordovician, and attempts to place the study area within the context of the peri-Gondwana belt. The setting of the Ordovician shelf is considered,

and the influence of the palaeogeographic information thus obtained on constraints for tectonic interpretations of the Variscan events is discussed.

Part II of the thesis is concerned with some of the raw data on which the descriptions and discussions of part I are based. The first appendix (A) contains details of some of the geocnemical studies undertaken. The mineralogy of some of the deposits studied is discussed, and the results compared with those from similar research on the Armorican equivalents to the Portuguese strata. The second appendix (B) contains logs of all the measured sections, and giving details of the sampling localities. This section covers both the work undertaken in Portugal and that in Brittany.

Appendix C contains a review of most of the macrofauna recovered. The groups covered include rostroconchs, bivalves, brachiopods, trilobites and graptolites. The fauna from zones 1 to 7 is of a distinct south-west European aspect. Some similarity to faunas from Morocco, Bohemia, Turkey and Britain can be seen besides the close similarity to faunas from other parts of the Ibero-Armorican region. An influx of new elements in zones 5 to 11 reveals the increasing influence of northern European forms, but the faunas of Portugal, Armorica, Spain, Montagne Noire and Sardinia still form a nighly distinct and homogeneous "province".

#### 2) Previous studies in the area.

The upper Ordovician of central Portugal has received

relatively little study in the past. The first works to be published on the geology of Lower Palaeozoic rocks in Portugal are the papers by de Carvalho (1848), Sharpe (1849: on the geology of the Porto region) and Ribeiro (1853: on the geology of the Bucaço area).

During the latter part of the last century Delgado studied extensively both the stratigraphy and faunas of the Ordovician and Silurian, but published little of his findings apart from the classic "Système Silurique du Portugal" (1908). This volume provides faunal lists, and measured sections of many areas, but unfortunately the important faunal collections were never figured. Delgado's maps and collections formed the basis for further work on the Ordovician of central Portugal by Costa (1950) and Thadeu (1947).

The last 15 years have seen a greatly increased interest in the Ordovician of Portugal. In particular, the first half of the seventies saw important work on the Bucaco syncline by a group from Brittany, which has resulted in a series of important publications, mainly on palaeontological aspects (Elaouad-Debbaj, 1979, Henry and Morzadec, 1968, Henry and Thadeu, 1971, Henry et al. 1976, Henry et al. 1977, Paris, 1979, Paris 1981, Vannier, 1983a, Vannier, 1983b and Vannier and Schallreuter, 1983). Fields of research of other workers include stratigraphy (Perdigão, 1971 (Fajão, Unhais-o-Velho, Salgueiro do Campo and Penha Garcia), Mitchell, 1974 (Buçaco), Romano and Diggens, 1976 (Valongo) and Cooper, 1980 (Dornes)), and the trilobite faunas (Curtis, 1961, Henry and Romano, 1978, Romano, 1975, 1976, 1980). The extent of

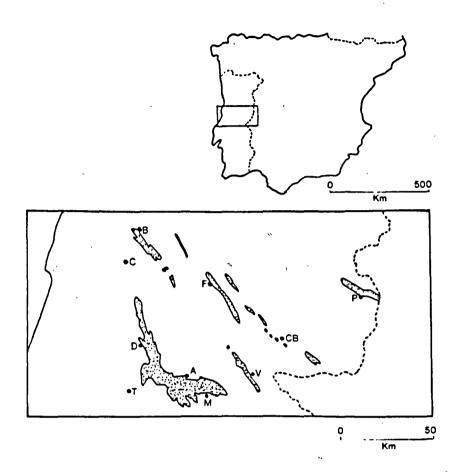


Figure 1. Location of the study area, showing the distribution of Ordovician rocks (including subsurface).

- . A: Amendoa
  - B: Buçaco
  - C: Coimbra
  - CB: Castelo Branco
  - D: Dornes
  - F: Fajão
  - M: Macão
  - P: Penha Garcia
  - T: Tomar
  - V: Vila Velna do Rodão

stratigraphical understanding and of international correlation prior to the start of this project is summarised in the reviews by Romano (1982b and <u>in Robardet et al. 1982</u>).

#### 3) Aims of the project

The deposits of the upper Ordovician in central Portugal often appear to be rather enigmatic in the existing literature. Most of the described sequences seem rather poor in fauna, and often have apparently barren clastic successions towards their tops. Exceptions to this picture include the locally richly fossiliferous volcaniclastics and carbonates of the Porto de Santa Anna Formation of Buçaco, estimates of the age of which range from lower Caradoc (Mitchell, 1974) to Ashgill (e.g. Paris, 1981). The stratigraphy and correlation of these deposits was therefore a major gap in the understanding of the Portuguese Ordovician.

In addition to the stratigraphic aims of the project, the study of the faunas of the upper Ordovician themselves was also an objective. Previous studies have indicated that the faunas of the Mediterranean Province are characteristically of low diversity, and this has generally been attributed to the high palaeolatitude, and hence low palaeotemperature. A survey, therefore, of the palaeoecology was undertaken, to examine if the effects of palaeolatitude could be identified. This is particularly important in view of the recent identification of glacimarine sediments in the upper Ordovician of the Ibero-Armorican region (Dangeard and Doré, 1971, Doré and Le Gall,

1973, Hamoumi, Le Ribault and Pelhate, 1901, Robardet, 1900 and Romano and Diggens, 1976).

#### 4) Approach to the project

The project has been based on the detailed study of sections through the upper Ordovician of the Buçaco, Fajão, Dornes, Amendoa, Mação, Vila Velna de Rodão and Penha Garcia areas. In addition, a limited amount of work has been done in the Arouca and Valongo areas north of the main study region. To accompany the study of the sections a limited amount of mapping has been undertaken in the Buçaco, Amendoa and Penha Garcia areas.

The sections studied have been examined from both sedimentological and palaeontological aspects. As the project progressed it became clear that a complete review of the lithostratigraphy of the area was essential before the other aspects of the project could be undertaken. The existing lithostratigraphical nomenclature has accordingly been revised, and many new units erected, to construct a lithostratigraphic scheme for the whole study area.

The palaeontological data derived from the project constitute a major reappraisal of the fauna, and its biostratigraphic implications. The faunas of the region, apart from the trilopites, were previously very poorly known. Indeed, even for the comparatively well-studied trilopites the detailed vertical distribution of many forms was unknown, largely because of the uncertainties in the existing lithostratigraphy. The project has revealed a much greater diversity of fauna than was

previously thought to exist in the area. In order that studies of the successions in this project should be well-founded, it was imperative that the faunas of the region should be documented. To this end it has become necessary to include within this thesis a substantial account of these largely undescribed faunas (appendix C), although it was not initially intended to be a full taxonomic study.

#### 5) Acknowledgments

This thesis is the result of research undertaken during tenure of an NERC research studentship. Grateful thanks are also extended to the Managers of the Harkness Prize Fund, University of Cambridge, who gave generous financial assistance towards the 1984 field-season, some of the results of which have been incorporated in this thesis. The 1984 season was also aided by the award of the Laverick-Webster-Hewitt Travelling Fellowship of the University of Sheffield to Mr. Paul Treble, who acted as field assistant. The enthusiasm of my supervisors, Drs. Mike Romano and Pat Brenchley was essential to the course of this project; equally the enthusiasm of "the French connection", Drs. Jean-Louis Henry, Jean Vannier and Florentin Paris provided for much useful discussion of common problems. Drs. J.-L. Henry and M. Melou also provided invaluable assistance in acquainting me with the Presqu'île de Crozon. Thanks are also due to Dr. Barrie Rickards for the identification and description of graptolites, and to Mr. B. Piggot for photographing the composites. Last, but by no means least I must extend my thanks to the Serviços Geològicos de Portugal for permission to work in their country.

#### CHAPTER 1 - The Lithostratigraphic Units

#### 1) Introduction

The area of central Portugal involved in this study, and its Ordovician outcrops are shown in fig. 1. Until recently the informal units described by Delgado (1908), and by Costa (1931,1950) formed the only available stratigraphic scheme for the region. These works contain a blend of lithostratigraphic (e.g. Grès de Louredo) and biostratigraphic (e.g. Schistes à Orthis riberoi) terms. Perdigão (1971) presented stratigraphical data for several outcrops in the region, including Penha Garcia and Fajão, but without erecting a formal lithostratigraphy.

Recent attempts to formalise the stratigraphical nomenclature have involved two separate areas; Buçaco (Mitchell 1974), and Dornes (Cooper 1900). Summaries of the current schemes are to be found in the reviews by Romano (Romano 1982, and Romano in Hammann et al., 1982). The present work aims to provide a unified lithostratigraphy for the succession above the Monte da Sombadeira Formation (Cooper 1980), incorporating elements of the schemes of Cooper and Mitchell, as well as new units where necessary. The correlation between the units used in this study and those of previous schemes is indicated in tables 1 and 2. This chapter gives a formal definition for each unit of this lithostratigraphy, describes the stratotype, and briefly states something of the fauna and age, although the faunas and biostratigraphy are dealt with in more detail in later chapters.

	Delgado, 1908	Mitchell, 1974	This work
\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	Schistes diabasiques	Porto do Santa Anna Ash Fm.	Porto de Santa Anna Fm.
	Schistes à <u>Dalmanites</u> <u>Dujardini</u>	Louredo Fm.	Louredo Fm.
	Grès de Loredo	. '	
			Carregueira Fm.
		· ·	Cabril Fm.
	Scnistes à <u>Homolonotus</u> <u>Oehlerti</u>	Cacemes Fm.	Fonte da Horta Fm.
			ণ্ড

Table 1. Correlatation with the stratigraphic units of Delgado and Mitchell, in the northern part of the Bucaco syncline.

	Delgado, 1908	Cooper		This work
		Vale da Ursa	Fm.	Vale da Ursa Fm.
20	Couches culminantes			Casal Carvalhal Fm.
			hal Fm.	Ribeira de Laje Fm.
	Schistes à <u>Orthis</u> <u>Berthoisi</u>		Carvalhal	Cabeço do Peão Fm.
		Bryozoa beds	оp	
		,	t e	Carregueira Fm. 3
			Monte	Capril Fm.
	Schistes à <u>Homolonotus</u> Oenlerti	Lameiros Mbr.		Fonte da Horta Fm.

Table 2. Correlelation with the stratigraphic units of Delgado and Cooper, in the Dornes/Amendoa area.

- 2) Description of lithostratigraphic units
- i The Cacemes Group

  (established name, Mitchell 1974, changed status)

The "Cacemes Formation" erected by Mitchell is here raised to group status. Included within this group are the brejo Fundeiro Formation and the Monte da Sombadeira Formation (both erected by Cooper 1900), together with the Fonte da Horta, Cabril, and Carregueira Formations erected in this paper. In the Dornes area Cooper (1980) identified the lower part of the Fonte da Horta Formation as his "Lameiros Member". This unit did not cover the whole mucstone interval, as represented by the new formation, and was based on a highly tectonised type section. Use of this name is therefore discontinued. It is felt that the lithological variation between these units is too great to warrant their inclusion in a single formation. The constituent formations do show related facies (see chapter 3) and their continued association at group level is desirable. The group is typically between 300 and 350m thick.

### a. The Fonte da Horta Formation(new term)

Stratotype- The unit stratotype is the interval 0 to 65m of the section at Cacemes, in the Buçaco syncline, as illustrated by log 1. This section, which was described by Paris (1961) as BU.B, lies on the east side of the Luso/Penacova road near km 47.1,

Chapter 1. 20.

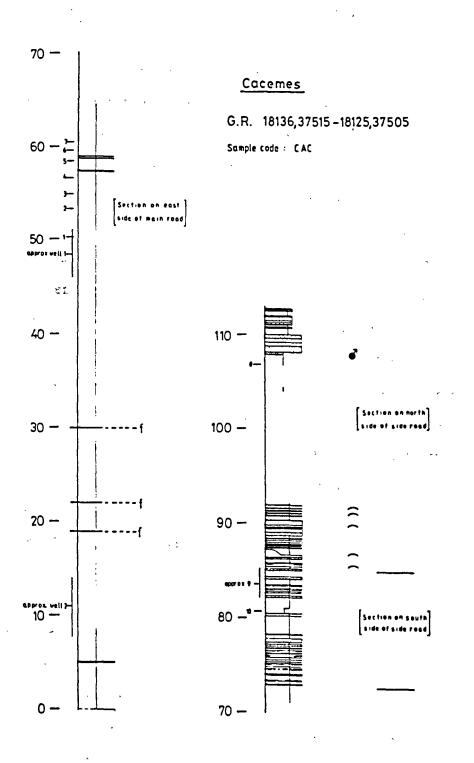
immediately south of the side road to Cacemes (map ref. 18136/37515 to 18125/37505).

Boundaries of the formation- The base of the formation is defined as the contact between the uppermost sandstone bed of the Monte da Sombadeira Formation and the overlying mudstones (Om on log 1). The top lies within the unexposed interval (63.6 to 70.8m) below the first visible laminated sandstones of the Cabril Formation.

Description of the type section— The formation consists primarily of mudstones with only very occasional sandstone beds. This is in marked contrast with the Monte da Sombadeira Formation and Cabril Formation which under— and overlie the formation respectively, for these units are dominated by sandstones. The formation is laterally equivalent to part of the Valongo Formation, of the Valongo/Arouca area, which was probably lithologically similar although it is now of a slightly higher metamorphic grade, being composed of slates. The arenaceous Cabril and Monte da Sombadeira Formations are not present in the Valongo area, and the Valongo Formation probably has an age range equivalent to that of the entire Cacemes Group.

Fauna and age- This formation bears a rich macrofauna (Ribeiro 1853, Delgado 1908, Mitchell 1974, Henry et al. 1976, 1977, Paris 1981, Vannier and Schallreuter 1983, Vannier 1984) dominated by bivalves and ostracodes. The fauna also contains abundant trilobites, brachiopods, gastropods, bellerophontids, orthocones, conulariids, hyolithids and rare graptolites. The fauna indicates an age from Zone 1 to Zone 3 for the formation.

Geographical extent and variation- The Fonte da Horta



Log 1. Cacemes.

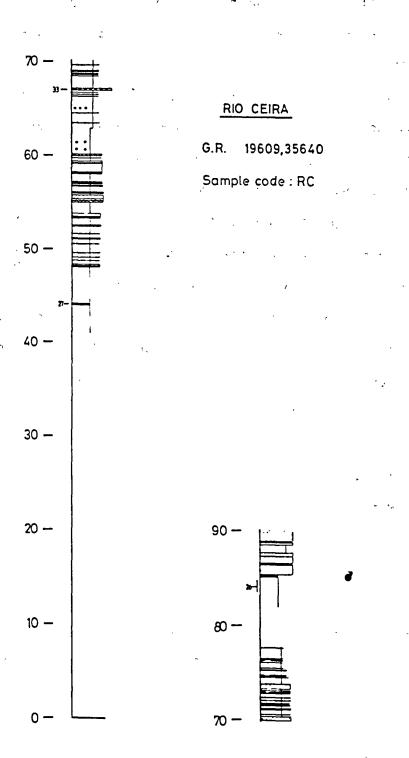
Chapter 1. 22.

Formation is recognised throughout the synclines of Bucaco, Dornes/Amendoa/Macao, Vila Velha do Rodão, Fajão and Penha Garcia. The formation thins southwards from the Bucaco and Fajao areas, where it is 65m thick, to less than 40m in the Amendoa/Vila Velha do Rodão area. Further south still, in the Macão area it thickens again to about 70m. In the Valongo and Arouca areas the Llanvirn to Llandeilo slates are all referred to the Valongo Formation. The Valongo Formation bears a very different fauna from the Fonte da Horta Formation in its type area (Romano 1982). The Fonte da Horta Formation of the Penha Garcia syncline yields a fauna containing elements common in northern Portugal such as the trilobites Salterocoryphe and Placoparia, as well as some elements more typical of central Portugal (e.g. Eorhipidomella musculosa).

b The Cabril Formation
(new term)

Stratotype- The type section for this formation is the cutting (map ref. 19609/35640) near the hamlet of Cabril, 2 km west of the village of Vila Nova do Ceira, towards the southern end of the Buçaco syncline. The formation lies in the interval 51 to 78m (approximately) of this section which is illustrated in log 2.

Boundaries of the formation- The base is defined as the base of the thin sandstone bed at 51m, which seems to mark the change from typical Fonte da Horta Formation fossiliferous mudstones to largely unfossiliferous laminated siltstones and sandstones. The



Log 2. Rio Ceira (Cabril).

Chapter 1. 24.

top lies in the unexposed interval 78 to 82m. The Cabril Formation is overlain in the type section by dark mudstones referred to the Carregueira Formation.

Description of the type section- In its type locality the formation consists of two pulses of sharp-based siltstone and sandstone beds, which commonly exhibit hummocky cross-stratification (HCS), within a background sediment of dark, laminated siltstones and mudstones. Between the two pulses are dark micaceous mudstones, which show bioturbation and yield a sparse fauna. A similar internal stratigraphy is recognisable throughout the Buçaco syncline.

Fauna and age- The mudstones between the two pulses of sandstones in the type area yield a sparse fauna of trilobites and bivalves. A similar fauna, but also including the brachiopods Heterorthina sp. A and Apollonorthis bussacensis occurs in conglomeratic beds (e.g at 66.9m in the type section). These faunas strongly resemble those of the Fonte da Horta Formation, so the Cabril Formation is likely to be of a similar age. The formation falls within Zone 3 of the macrofaunal zones erected in this thesis.

Geographical extent and variation— The Cabril Formation is recognised throughout central Portugal (Buçaco, Fajão, Vila Velha do Rodão, Dornes/Amendoa/Mação and Penha Garcia synclines). At present the formation is poorly characterised in the Penha Garcia syncline. The formation thickens towards the south, from less than 30m at Buçaco to almost 60m near Macão. Phosphatised conglomeratic beds occur in its upper part and these are particularly well developed in the Dornes/Amendoa/Mação area,

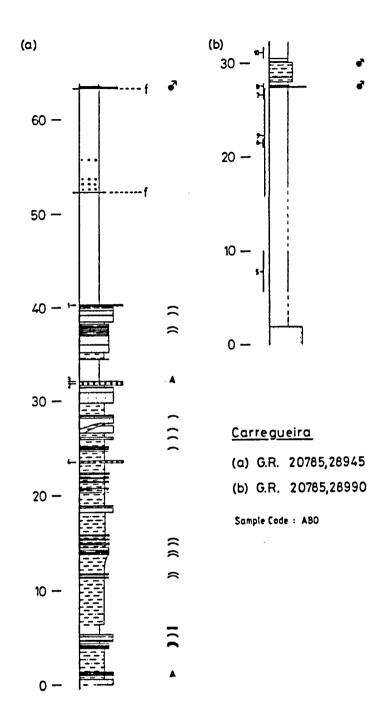
where individual phosphatic horizons may reach 60cm in thickness. The very top of the formation is often marked by a phosphatic bed, often accompanied by a bed of ferruginous sandstone.

c The Carregueira Formation (new term)

Stratotype- A road-cutting (map ref. 20705,28945) at Sitio da Vajona, 1 km west of Carregueira (near Maçao), provides the type section for this formation. The formation comprises the interval 40.6 to 64.5m of this section (log 3). There is some minor faulting within this section, and a second section to the north of the type on the same road provides further information, particularly on the upper part of the formation. The Carregueira Formation occupies the interval 3 to 29m of this second section.

Boundaries of the formation- The base is defined as the base of the mudstones at 40.0m in the type section, which lie on a conglomerate bed at the top of the Cabril Formation. The top of the formation is defined as the contact (at b4.5m) of the mudstones with the base of the oolitic ironstone bed, which marks the base of the Sanguinheira Group throughout central Portugal.

Description of the type section- The formation consists of dark mudstones, often pyritic and containing pyritic nodules. These mudstones are in marked contrast with the sandstones, siltstones and conglomerates of the underlying Cabril Formation, and with the ironstones and predominantly arenaceous sediments at the base of the Sanguinheira Group.



Log 3. Carregueira.

Fauna and age- Fauna occurs throughout the formation, and it is dominated by bivalves and trilobites, although brachiopods, crinoids, ostracodes and graptolites also occur. There is very great similarity between this fauna and that of the "Schistes de Veryac'h" (Babin and Melou 1972, Henry 1980, Henry et al. 1976) for which a basal Caradoc age has been proposed. This fauna is referred to Zone 4 in this study. The Carregueira Formation yields a graptolite closely comparable with Climacograptus bekkeri from the Kukruse stage in Estonia (Nemagraptus gracilis Zone).

Geographical extent and variation- This formation has been recorded from the Buçaco and Dornes/Amendoa/Mação regions of central Portugal. It is absent from the Penha Garcia syncline. The formation is thickest in the area of the type section (24m), and thins rapidly into the Dornes/Amendoa area (1.5m to 8m), before thickening again in the Buçaco syncline (upto 16m).

### ii. The Sanguinheira Group (new term)

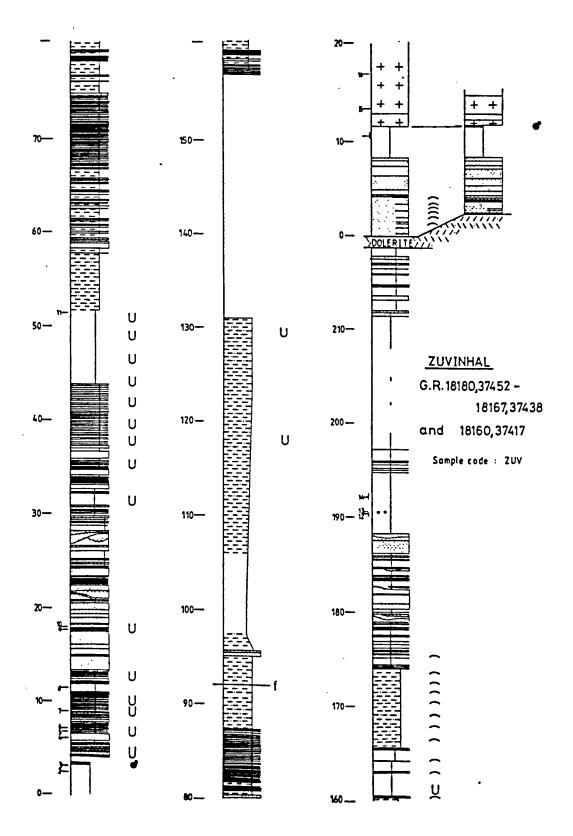
The Sanguinheira Group is erected here to embrace a sequence of predominantly arenaceous sediments lying above, and including, the Favaçal Ironstone bed. In contrast to the arenaceous formations of the Cacemes Group, the sandstones of the Sanguinheira Group are often highly bioturbated. Two formations are recognised within the group; the Louredo Formation in the northern part of the area (Buçaco, Fajão, Penha Garcia) characterised by the predominance of discrete sandstone beds

(often with HCS) and between 200 and 300m thick, and the Cabeço do Peão Formation to the south (Dornes/Amendoa/Mação), in which the sandstone beds and the mudstone interbeds have often been thoroughly mixed by bioturbation, giving a massive appearance to most of the formation, which is only 100 to 120m thick.

#### a The Louredo Formation

(established term, Mitchell 1974, first designation of stratotype)

Stratotype- The section selected for the type of this formation, which was erected by Mitchell (1974) without the designation of a stratotype, is the road cutting (map ref. 18180,37452 to 18167,37438) near K48.1 on the Luso/Penacova road in the Zuvinhal valley. This section was described by Paris (1979, 1981) as BU.D, and lies on the line of the section (a) described by Delgado (1908 pp. 31-33). The section starts on a small forestry track, and runs for 200m along the Luso/Penacova road to Galhano. The Louredo Formation is then cut by a largely unexposed dolerite sill, about 200m thick. The section resumes in a new road cutting (map ref. 18160,37438) on the road to Ponte da Mata, about 150m southwest of Galhano, where about 9m of the formation is visible below the base of the overlying Porto de Santa Anna Formation. The type section thus comprises the interval 0-216m below the sill, and 0-9.2m (old section) above it (0-11.6m new section), as illustrated by log 4. From comparison with other sections in the same area, it seems that very little of the upper part of the formation is missing on the line cut out by the intrusion of the dolerite sill.

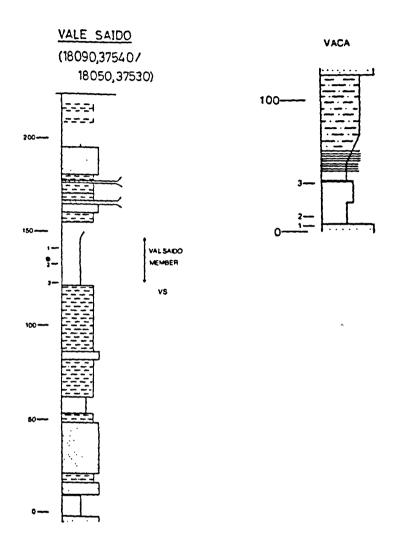


Log 4. Zuvinhal.

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Boundaries of the formation- The base of the formation was defined as the base of the of the colitic ironstone horizon which outcrops on the the edge of the village of Louredo. This same bed occurs in the interval 0-0.2m of the type section. The ironstone bed is herein named the Favaçal Bed (see below). The base of the overlying Venda Nova Group is similarly defined at the base of the colitic ironstone of the Leira Ma Member, which occurs in the type section of the Louredo Formation at 9.2 to 9.3m above the sill (old section).

Description of the type section- The Louredo Formation typically consists of sandstone beds 1 to 80cm thick, in a background of mudstones, although there are some intervals with mudstones without sandstone intercalations. Most of sandstones in the lower part of the formation are bioturbated except for the thickly bedded interval 10-23m in which the sandstone beds show parallel lamination. Towards the middle of the formation (approximately 120m above the base) the bioturbated sandstones grade upwards into bioturbated micaceous mudstones. These mudstones, the Vale Saido Member, are largely unexposed in the Zuvinhal section. Above the mudstones is a coarsening and thickening-upwards sequence, in which many of the sandstone beds display HCS. At 184.4m these sandstones are abruptly overlain by the mudstones of the Zuvinhal Member, which yield a sparse macrofauna. By 192m thin sharp-based sandstone beds reappear, and these thicken upwards until the interval 0-6.1m (old section) above the sill, which comprises beds upto 1m thick, with amalgamated HCS. Above these sandstones lies the 3m thick unit of dark mudstone, which constitutes the Galhano Member.



Log 5. Vale Saido.

Log b. Penna Garcia (Vaca).

Members- Four members of the Louredo Formation are erected here: n n n n

(new term)

Vale Saido Member - Micaceous mudstones in the interval 125-152m of the Vale Saido section (log 5) (map ref. 18075,37530)

(new term)

Zuvinhal Member - Mudstones in the interval 188-195m of the Zuvinhal section (log 4) (map ref. 18167,37439)

(new term)

Galhano Member - Mudstones 6.1-9.2m above the dolerite in the Zuvinhal section (log 4) (old section) (18160,37417)

Vaca Member (new term) - Mudstones at the top of the Louredo Formation in the Penha Garcia syncline. Defined on the exposure on the sides of the tracks 1600m east of the col near Bandonais (log 6, interval 5-35m).

Beds- The oolitic ironstone at the base of the Sanguinheira Group is here named the Favaçal Bed, with its type locality in a small track on the south side of the road leading into the village of Louredo.

Fauna and age- The basal colitic ironstone contains a well studied microfauna (Henry and Thadeu 1971, Henry et al. 1976, Paris 1979, 1981), which indicates a lower Caradoc age (top Costonian/basal Harnagian). The macrofauna, which includes trilobites and brachiopods, indicates a Zone 5 age. The microfauna from higher levels in the formation has not provided such precise dating, but Paris suggests a mid-Caradoc age for the Zuvinhal and Vale Saido Members, while the Galhano Member is suggested to be of Upper Caradoc age (Paris 1979,1951). The macrofauna of these members again provides supporting evidence. The two lower mudstone members of the Buçaco syncline yield a fauna similar to that of the "Schistes de Raguenez" of the Crozon Peninsula (Babin and Melou 1972), dominated by bivalves, ostracodes, brachiopods, and trilobites, which is attributed to Zone 7. The Galhano Member yields a similar but sparse fauna. The Vaca Member in the Penha Garcia syncline overlies fossiliferous sandstones containing brachiopods and trilobites, while it itself is also rich, particularly towards its base, in trilobites, brachiopods and ostracodes. The formation thus embraces Zones 5 to 7, and possibly part of Zone 8 of the zonal scheme erected below (chapter 2).

Geographical extent and variation- The Louredo Formation is present in the Buçaco, Fajão and Penha Garcia synclines, but is replaced in the Dornes/Amendoa/Mação region to the south by the Cabeço do Peão Formation. The formation is about 240m thick in the Penha Garcia syncline and the north of the Buçaco syncline, but thins rapidly southwards along the Buçaco syncline to about 160m near Vila Nova do Ceira. This thinning continues southwards with the Cabeço do Peão Formation, which is 105-140m thick. Three of the members defined in this paper are only recognised so far in the Buçaco syncline, while the fourth (the Vaca Member) is confined to the Penha Garcia syncline. The Favaçal Bed is recognised throughout the range of the Sanguinheira Group.

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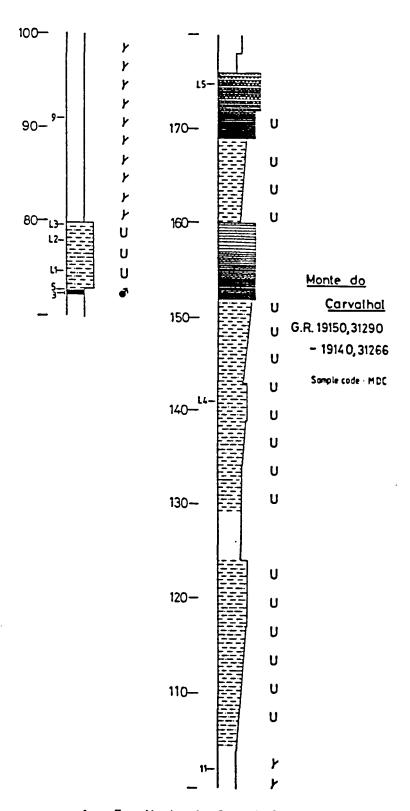
b The Cabeço do Peão Formation (new term)

Stratotype- The type section of this formation is the old road section (map ref. 19149,31290-19138,31265) at Monte do Carvalhal (Dornes), which Cooper used as the type for his "Monte do Carvalhal Formation". The Cabeço do Peão Formation stratotype comprises the interval 72 to 177m of log 7, and includes beds 7-12 of Cooper's section (Cooper 1980 fig. 15).

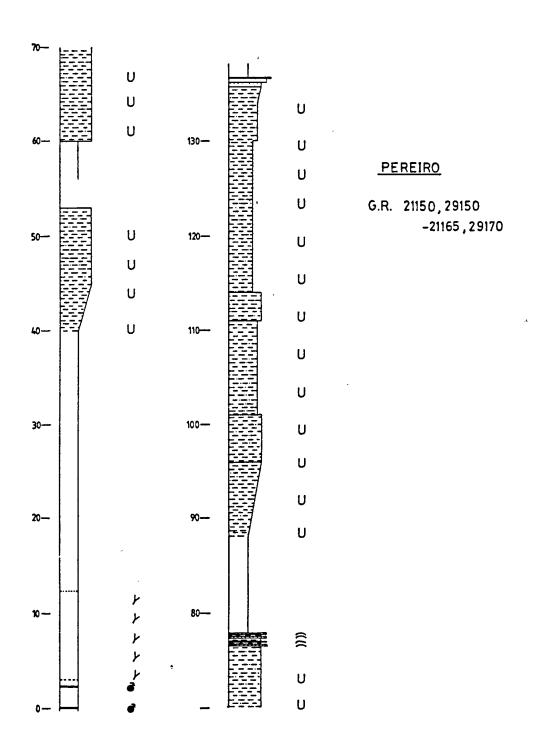
Boundaries of the formation- The base of the formation is drawn at the base of the oolitic ironstone (72m on log 7), and the top at the contact of the conglomeratic ferruginous sandstones with the overlying mudstones at 177m.

Description of the type section- The basal colitic ironstone horizon, correlated with the Favaçal Bed, is about 40cm thick, and grades upwards into ferruginous, bioturbated sandstone thick. These are overlain by 23m of micaceous mudstones, which bear a rich fauna dominated by bryozoans and echinoderms, the "bryozoa beds" of Cooper. These highly fossiliferous beds are here named the Queixopeira Member (see below). The interval micaceous siltstones 104-154m comprises bioturbated sandstones, while 154-162m contains more-distinctly bedded sandstones in beds 20-40cm thick. These are overlain (162 to 171m) by mottled green bioturbated siltstones. From 171 to 177m there are sandstones which are highly ferruginous, and frequently conglomeratic; these distinctive sandstones form the Serra do Cadaveira Member.

Members- The Serra do Cadaveira Member (established term, Cooper 1980, revised definition) is here given a new type



Log 7. Monte de Carvahal.



Log o. Pereiro.

section; the interval 171 to 177m of the Cabeço do Peão Formation type section. The type suggested by Cooper for this member has poor exposure, which has lead to problems with its definition, and its erroneous correlation with the interval 154 to 162m of the Monte de Carvalhal section. The importance of the recognition of this conglomeratic and ferruginous lithology at the top of the formation warrants the redescription of the member, and the allocation of a new, unambiguous stratotype in keeping with Cooper's original type locality.

The Queixopeira Member (new term) is here erected to include the micaceous mudstones in the lower part of the formation in the Dornes and Mação areas. The member is named after one of the richest fossil localities in this unit, which is located on the specimens in the collections of the "Servicos Geològicos" by reference to the hill "Queixopeira". The member includes the "Bryozoa Beds" of Cooper (1980) (this name will be used informally here for the fossiliferous parts of the Queixopeira Member), but also includes the lithologically similar, but unfossiliferrous mudstones above the bryozoa beds in the Dornes and Mação areas, together with those in the lower part of the Cabeço do Peão Formation in the Amendoa area. The Queixopeira locality (map ref. 20010,20930) does not provide a complete section through into the unfossiliferous beds above the faunally-rich horizons, so the type section for this member will be the section exposed on the hillside near Castelo, northeast of Mação (map ref. 21150,29150) illustrated in log 8. Queixopeira Member comprises the interval b-15m of this section.

Fauna and age- The basal oolitic horizon, the Favaçal bed,

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yields a similar macrofauna to that from the type locality of this bed in the Buçaco syncline, and is therefore believed to be of the same age (top Costonian/basal Harnagian, see above). The rich fauna of the bryozoa beds includes brachiopods and trilobites which indicate a Zone 6 age. The middle and upper parts of the formation yield elements known elsewhere from Zone 7.

Geographical extent and variation— The Cabeco do Peao Formation occurs in the Dornes/Amendoa/Mação syncline. The formation is thinnest in the area east of Amendoa (106m) and thickens southwards reaching 140m near Mação. Towards the south the ferruginous sandstones near the base of the formation in the type area are replaced by mudstones, often with minor development of an additional colitic ironstone horizon. The Serra do Cadaveira Member is present throughout the range of the formation. It is thickest in the Dornes area, and thins to only a few centimetres near Mação. In the area east of Amendoa it includes a minor component of ironstone coids, providing a lithological intermediate between the ferruginous sandstones of the type area of the member and the colitic ironstone of the Leira Ma Member.

iii The Venda Nova Group
(new term)

The Venda Nova Group is erected here to embrace the complex of volcanic and carbonate rocks overlying the Louredo Formation in the Buçaco and Fajão synclines. Two formations are

Cnapter 1.

distinguished; the Porto de Santa Anna Formation, consisting primarily of volcanics, and the Ferradosa Formation, in which massive carbonates predominate. These two formations seem to be broadly contemporary, with the volcanic facies thinnning towards the south-west. The carbonate facies locally replaces the thinned volcanic facies in the southern parts of the syncline.

a The Porto de Santa Anna Formation

(established term, Mitchell 1974, emended definition and new stratotype)

The "Porto do Santa Anna Ash Formation" was erected by Mitchell (1974). In this work it is recommended that the epithet ash be dropped from the name, as it does not accurately reflect the nature of the formation. The classic locality for the base of the formation has suffered some confusion over its name which has been variously quoted as "Porto de Santa Anna" (Sharpe 1850), "Porto de Sant'Anna" (Delgado 1906), "Porto de Sant'Ana" (Costa 1931), "Porto de Santa Ana" (Henry et al. 1976), "Porto do Santa Anna" (Mitchell 1974), and "Porto-do-Santa-Anna" (Paris 1979, 1981). The form "Porto de Santa Anna" will be used here.

Stratotype- Mitchell did not designate a stratotype for this formation, and at present there is no good continuous section through the formation. The section on the road to Ponte da Mata at Galhano (map ref. 18160,37417 to 18150,37400), continuing west from the type section of the Louredo Formation, and containing the section described by Paris (1981) as BU.H, was probably the most complete, but reconstruction of the road has obscured much

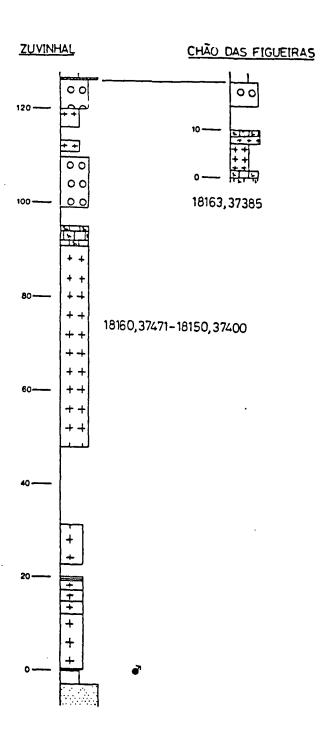
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of the formation. The upper part of the formation is better exposed some 400m south east (map ref. 18163,37385), on a field margin and irrigation channel at Chão das Figueiras. This section will be used in conjunction with the Galhano section as type, which thus comprises 0-126.5m of log 9, and 0-20m of log 10. Only the intervals 0-10m and 55-105m of the Galhano section are still visible, and the formational description is based partly on observations made before the building of the new road.

Boundaries of the formation- The base of the formation is drawn at the base of the thin collicities ironstone bed (Om on log 9, 9.2m on log 4), which lies on the mudstones of the Galhano Member. The top is defined as the contact of the uppermost volcanic horizon with the overlying mudstones at 20m on log 10.

Description of the type section- Above the basal colitic ironstone are 35m of sparsely fossiliferrous volcaniclastic sediments. These are followed by slightly coarser tuffs, which are overlain by a rather disturbed interval (92 to 99m) containing silicified beds, probably originally carbonates. Above this, 11m of a spheroidally-weathering lithology may represent a decomposed flow, and this is overlain by a sequence of thinnly-bedded fine-grained tuffaceous sediments, probably to be correlated with the thinly-bedded tuffs and limestones in the Chão das Figueiras section. Above these sediments in the Galhano section is another possible decomposed flow. At 126.5m in the Galhano section, above this possible flow, is a thin rottenstone band rich in orthocones. This bed is overlain (126.6m) by mudstones yielding Wenlock graptolites.

The Chão das Figueiras section (log 10) provides further



Log 9. Zuvinhal.

Log 10. Chão das Figueiras.

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information on the upper part of the formation, and as the contact with the overlying Wenlock mudstones is now covered in the Galhano section, it is used to define the top of the formation. The interval 0 to 1.5m contains a silicified limestone, and this is overlain by 5.5m of thinnly-bedded tuffs and limestones. Above this is 2.7m of massive silicified limestone. Above a break in exposure of about 5m, a massive, vesicular volcanic rock, badly altered, but probably a flow, is exposed for 5m upto the contact with the overlying mudstones at 20m.

Member- There is one defined member, the Leira Ma Member, erected here. This member includes the basal colitic ironstone horizon of the formation, and in the northern part of the Buçaco syncline the member also includes richly fossiliferous, iron-rich, but only sporadically colitic, beds lying immediately above. The member has no complete section exposed at present, but the type area is that between Louredo and Porto de Santa Anna, where Mitchell described (1974, p. 389, and fig. 3) a section (now destroyed) through this member. The Leira Ma locality lies within this type area. The colitic horizon, and the "60 cm thick fine-ash horizon" of Mitchell, together make up this member. The Leira Ma Member yields a rich fauna of Zone 8 age, and may be a lateral equivalent of the Serra da Cadaveira Member. It has not been recognised in Portugal outside the Buçaco syncline.

Fauna and age- The basal ironstone horizons, and the silicified beds which locally accompany them, bear a rich fauna of brachiopods, trilobites, bryozoa, orthocones, and gastropods. The brachiopods were attributed to the lower Caradoc by Mitchell,

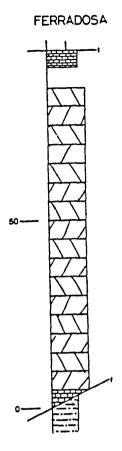
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but subsequent authors have assigned the trilobites to the upper Caradoc (Henry et al. 1976), and the microfauna to the basal Ashgill (Paris 1979,1981). The trilobites and brachiopods include several elements known from the "Bancos Mixtos" of the eastern Sierra Morena of supposed upper Caradoc or lower Ashgill age (Hammann, in Hammann et al. 1982). These elements are ascribed a Zone 8 (and possibly basal Zone 9) age in this study. The upper part of the Porto de Santa Anna Formation contains a fauna with bryozoans, echinoderms, rare trilobites and a wide variety of generally small brachiopods. These faunas range from Zone 9 to Zone 11 of the scheme erected in this thesis.

Geographical extent and variation- The Porto de Santa Anna Formation occurs in the northern part of the Buçaco syncline, and also in the Fajão syncline. At Buçaco the formation passes laterally into the Ferradosa Formation. Dolomites and limestones occur widely in the Buçaco syncline between Sazes and Venda Nova de Poiares, replacing the thin volcanic sequence which characterises the Porto de Santa Anna Formation south of Sazes.

# b The Ferradosa Formation (new term)

Stratotype- No good complete sections through this formation exist at present, despite the considerable exploitation of the dolomites in quarries north of Penacova, south of the Mondego, and near Poiares. The area approximately 500m east of the village of Ferradosa, south of the Rio Mondego near Penacova, is selected as type area (area centred on map ref. 18990,36620; fig. 2 and log 11). Exposure in this area consists of a series of small



Log 11. Ferradosa.

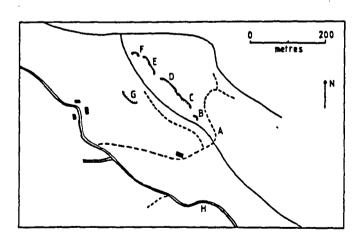


Figure 2. Location map for the type area of the Ferradosa Formation.

quarries, and a road section.

Boundaries of the formation- The lower boundary of the formation is not visible in the type area, and the contact between this and the Louredo Formation is faulted. Further south at Vila Nova de Ceira the base of the Porto de Santa Anna Formation is marked by an colitic ironstone with the same fauna as the Leira Ma Member, so it seems highly likely that the ironstone bed is continuous at the base of the Venda Nova Group in the Buçaco syncline. The top of the formation is the contact of the highest silicified limestones with the overlying mudstones. This contact is seen in the road cutting at locality H (fig. 2), but is highly tectonised.

Description of the type locality— The lowest beds of the formation seen in the type area are the decalcified beds visible in the small quarry (B). The main series of quarries (C-G) expose massive dolomites, probably about 100m thick. Locally these dolomites have clay-rich beds which contain a rich macrofauna of brachiopods, bryozoans and echinoderms. The upper part of the formation is exposed in the road-cutting (H), where 5m of deformed silicified limestones and tuffaceous sediments lie beneath a tectonised contact with mudstones of probable Silurian age.

Members- Two members of the Ferradosa Formation are erected here. The formational type area is the type area also for each of these members, and neither member has a complete visible sequence elsewhere in the syncline.

Poiares Member- this member comprises the decalcified beds which lie at the base of the formation from the Mondego to

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Vila Nova de Poiares. The contact of the member with underlying strata is not seen; at all localities the base is faulted. The member is seen to about 6m in the Ferradosa area, but in the Poiares inlier the 6.5m of the decalcified beds are interrupted by 9m of a highly weathered igneous rock 2.5m above the base.

Riba de Cima Member- The dolomites which form the bulk (probably about 100m) of the formation are allocated to this member. These dolomites preserve little of their primary structure except that in the lower part they sometimes contain clay-rich horizons which have not suffered as much from recrystallization and yield some poorly preserved fauna.

Fauna and age- The decalcified beds (Poiares Member) at the base of the formation in its type area and near Poiares contain elements of fauna in common with the lower part of the Rosan Formation, and with the lower part of the Porto de Santa Anna Formation; thus the observed base of the formation is probably of Zone 9 age. This fauna is rich in brachiopods, bryozoans, and echinoderms. The fauna from the main body of the dolomites is poorly preserved. The top of the formation yields a fauna with elements in common with that from the top of the Porto de Santa Anna Formation. The macrofaunal assemblages range from Zone 9 to (?)Zone 10.

Geographical extent and variation- The Ferradosa Formation is restricted to the southern part of the Buçaco syncline, from near Sazes to Vila Nova de Poiares. Throughout this range it is characterised by the massive, recrystallised dolomites of the Riba de Cima Member. The decalcified member (Poiares Member) at

the base of the formation in its type area, is persistently present in the area south of the Mondego, but has not been recorded to the north.

iv The Rio Ceira Group
(new term)

This group is erected here for a sequence of clastic sediments, of a generally regressive character, comprising the Ribeira da Laje Formation, the Ribeira do braçal Formation and the Ribeira Cimeira Formation. The group is of mid to upper Ashgill age, and occurs widely in central Portugal, particularly where the Venda Nova Group is absent. The group takes its name from the Rio Ceira inlier, in the south of the Bucaco syncline, where two of the constituent formations have their stratotypes. The deposits of the group may be upto 100m thick.

a The Ribeira da Laje Formation (new term)

Stratotype- The valley of the Ribeira de Laje, near Sanguinheira on the northern limb of the Amendoa/Mação syncline, provides the type section for this formation. Exposure occurs naturally in the stream, and on the west side of the valley, while there is a track section on the eastern side of the stream. It is the track section (map ref. 21500,29000 to 21469,29652) which is the stratotype.

Boundaries of the formation- The base of the formation is

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defined as the base of the micaceous mudstones in contact with the top of the conglomeratic sandstones of the Serra de Cadaveira Member at Om on log 12. The top is the top of the sandstones at 60m.

Description of the type section- This formation presents a coarsening-upwards sequence, starting with micaceous mudstones at the base, followed by bioturbated silty sandstones (5 to 25m). Above that there is an increase in the frequency in and thickness of discrete sandstone beds, often with HCS (25 to 40m), culminating in 9m of quartzites with bed thickness upto 1.5m. The quartzites are overlain by 5m of thinly-bedded bioturbated sandstones, and 4m of massive sandstones.

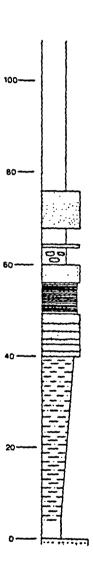
Members- The Serra do Amial Member

(established term, Cooper 1980, redescription)

Cooper erected this member for the quartzites exposed at Casal Carvalhal, within the upper part of his "Monte do Carvalhal Formation". The type area is retained here, but the stratotype is more precisely defined as the section in the valley at Casal Carvalhal (Dornes), on the southeast side of the outfall of the tributary running between Monte do Carvalhal and Serra do Amial (map ref. 19056,31283). It is below the high water level of the reservoir, but exposure is excellent, and the use of this section is considered more desirable than using the adjacent road section.

Fauna and age- The only fauna recovered from this formation is derived debris, probably from the Venda Nova Group, found within conglomeratic portions of the Serra do Amial Member. In its type area the youngest fossils found beneath the formation

RIBEIRA DA LAJE



Log 12. Ribeira da Laje.

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are of Zone 7 age (Serra do Cadaveira Member), and it is overlain by the Casal Carvalhal Formation of probable upper Ashgill age. Elsewhere (Penha Garcia) the formation overlies Zone 7 faunas, so the formation is probably mainly, or entirely of Ashgill age.

Geographical extent and variation- The Ribeira de Laje Formation occurs throughout the Dornes/Amendoa/Mação syncline, and in the Penha Garcia syncline. The lower, more fine-grained parts of the formation may be the lateral equivalent of the Ribeira do Braçal Formation of the Bucaco syncline. The Serra do Amial Member may similarly be equivalent to at least part of the Ribeira Cimeira Formation.

b The Ribeira do Braçal Formation (new term)

Stratotype- The track cutting immediately to the west of the valley of the Ribeira do Braçal, 2.5km north east of Serpins, provides the type-section for this formation (map ref. 19570/35610).

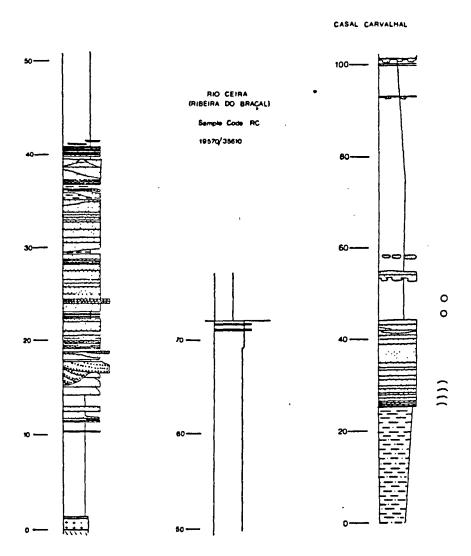
Boundaries of the formation- The base of the formation is taken as the contact of the decalcified crinoidal beds with the base of the overlying mudstones at 1.4m on log 13. The erosive base of the conglomeratic sandstone at 16.6m is taken as the base of the overlying Ribeira Cimeira Formation (for which this cutting is also the stratotype).

Description- This formation consists of an alternation of mudstones or siltstones with sharp-based beds of siltstone and sandstone. These coarser beds become progressively more coarse-

grained towards the top of the formation. The sandstone beds at the top of the formation have a very variable thickness laterally, and are probably nummocky cross-stratified. This is in contrast to the sharp based siltstone beds towards the base of the formation, which vary little in thickness, appear to be laterally persistent, and which do not show HCS; where they show any internal structure they appear to be parallel-laminated.

Fauna and age- The base of the formation in its type section yields a sparse fauna of echinoderm debris, while an exposure in the valley 50m north of the type section yields an abundant fauna of crinoids, ostracodes and brachiopods. This fauna is dated to Zone 12. The stratigraphic position of the formation beneath the Casal Carvalhal Formation, but (in the type section) above sediments of the Porto de Santa Anna Formation yielding Aegironetes tristis (known from the upper part of the Kraluv Dvur Formation of Czechslovakia), the index species for Zone 11, would also suggest a Rawtheyan or low Hirnantian age.

Geographical extent and variation—This formational name is applied at present only in the Buçaco syncline, and the formation is believed to be the lateral equivalent of the lower part of the Ribeira de Laje Formation of the Dornes/Amendoa/Mação and Penha Garcia synclines. Its distribution in the Bucaco syncline is very local, only occuring where the volcanic Porto de Santa Anna Formation is at its thinnest; including a small area just to the west of Sazes, another small region immediately south of the Mondego, and in the Rio Ceira inlier.



Log 13. Rio Ceira (Ribeira do Braçal).

Log 14. Casal Carvahal.

c The Ribeira Cimeira Formation (new term)

Stratotype- The type section for this new formation is in the track cutting between the Ribeira Cimeira and the Ribeira do Braçal, immediately to the west of the stratotype of the Ribeira do Braçal Formation (map ref. 19570/35010).

Boundaries of the formation- The base of the formation is taken as the base of the conglomeratic sandstone bed at 16.0m on log 13. This contact is erosive, and the sandstone downcuts considerably within the exposure in the cutting, and may cut out a further 10m of the underlying Ribeira do Braçal Formation in the valley to the north of the type section. The contact of this formation with the Casal Carvahal Formation is gradational, first with siltstone interbeds in the predominantly sandstone/ quartzite sequence, and then with thin sandstone horizons in the base of the overlying formation. The boundary between the two formations is placed at the top of the sandstone bed at 40.6m on log 13.

Description- The formation exhibits an overall fining and thinning upwards sequence, from the conglomeratic sandstones towards the base to the overlying pebbly siltstones of the Casal Carvalhal Formation. The sandstones of the formation are often very dark in colour. The conglomeratic beds yield fragments derived from the Venda Nova Group, including colitic ironstones, probably from the Leira Ma Member. If this identification is correct it indicates considerable erosion of the source of these pebbles.

Apart from the strongly cross-bedded conglomerate at the base of the formation, internal structures in the sandstones are hard to identify. The beds seem to be laterally impersistent, and scouring is common. Where mudstone interbeds occur, they are frequently rather massive. The facies of much of the formation suggests the facies 2d and e of the phase A deposits (see chapter 2).

Fauna and age- No <u>in-situ</u> fauna has been recovered from this formation. It does contain, in its conglomeratic parts, a large amount of fossiliferous material derived from the Porto de Santa Anna Formation. The only evidence for its age is therefore its stratigraphic position; it overlies sediments of the Porto de Santa Anna Formation of possible Rawtheyan age (see above), and underlies the "pélites à fragments" facies of the Casal Carvalhal Formation, which is proposed to be of Hirnantian age.

Geographical extent and variation- This formation is known only from the Buçaco syncline. It is the lateral equivalent to the Serra do Amial Member of the Dornes/Amendoa/Mação syncline to the south. This member may itself become conglomeratic locally (e.g. to the east of Amendoa), but never so importantly, or with such a coarse clast size as the Ribeira Cimeira Formation. The base of the formation rests erosively on the Ribeira do Braçal Formation in the areas to the west of Sazes, immediately south of the Mondego, but to the west and north-west of Covelo the formation rests directly on the Porto de Santa Anna Formation.

v The Casal Carvalhal Formation (new term)

Stratotype- The type section for this formation is the cutting for the Tomar/Sernache road at Casal Carvalhal, near Dornes, just above the type section of the Serra do Amial Member. The section was used by Cooper as part of his Serra do Amial section, and runs from map ref. 19032,31296 to 19064,31296.

Boundaries of the formation- The base of the formation is defined as the base of the massive spheroidally-weathering pebbly siltstones at 44m in log 14. The top is drawn at the contact of the mudstones with thin slumped sandstone beds, with the basal quartzites of the Vale da Ursa Formation, just before the retaining wall 300m east of the base of the section (100m on log 12).

Description- At the base of the formation are 8.5m of pebbly siltstones, which are massive and weather spheroidally. They closely resemble the Pélites à fragments Formation (Dangeard et al. 1962) of Normandy, and the lower part of the Cosquer Formation of Crozon, Brittany. The clasts are of siltstone, sandstone, limestone and oolitic ironstone. They may reach upto 150mm in diameter, but 2 to 20mm is more common. The siltstones also contain abundant isolated rounded quartz grains. These beds are overlain by 5.5m of siltstones with thick quartzites, showing "ball and pillow" structures. Above these are 25m of siltstones, sometimes bedded, but mainly massive and spheroidally-weathering. Micaceous siltstones and mudstones with sandy laminae and rare thin sandstone beds occur above. At the very top of the

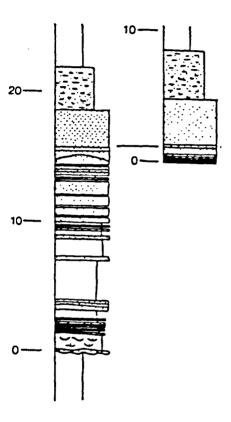
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formation are 2m of siltstones with thin slumped sandstone beds.

Fauna and age- No macrofauna has yet been recorded from this unit. Paris (1981) examined microfauna from this formation on the western limb of the Buçaco syncline, and found an enigmatic fauna of probably remanie chitinozoans. The clasts in the basal facies include a large proportion of material probably derived from the Venda Nova Group, and on the western limb of the Buçaco syncline the formation rests on the Ribeira Cimeira Formation, turn lies on the Porto de Santa Anna Formation. To the south the formation similarly overlies the much-attenuated Porto de Santa Anna Formation, but with both the Ribeira Cimeira and Ribeira do Bracal Formations between. The top of the Venda Nova Group is believed to be of Ashgill age (see above). The oldest dateable sediments above the Casal Carvalhal Formation are the sandstones of the Serra dos Aguilhões Member, which yield graptolites of lower Llandovery age. The Casal Carvalhal Formation thus seems to be of Ashgill age although it could be partly of basal Silurian age. Elsewhere the "Pélites à fragments" facies has been correlated with the upper Ashgill (Hirnantian) glaciation in Africa (Dangeard and Doré 1971).

Geographical extent and variation- This formation has been recorded throughout the Dornes/Amendoa/Mação syncline, and at some localities in the Buçaco and Fajão synclines. The basal pebbly facies is noticeably richer in clasts in the southern outcrops than at Buçaco or Fajão, and often at the very base of the formation in these southern outcrops there is a horizon of abundant small pebbles in a pyritic sand-grade matrix. The development of the thick quartzite beds within the formation is

## VALE DA URSA JUNQUEIRA



Log 15. Vale da Ursa.

Log 10. Junqueira.

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highly variable.

vi The Vale da Ursa Formation
(established term, Cooper 1980, redescription of stratotype)

Stratotype- The stratotype is that designated by Cooper, near Ponte Vale da Ursa, Dornes. The section (map ref. 19006,31208 to 19025,31211) lies in an old quarry and on a track, just east of the main road at the southern end of the bridge.

Boundaries of the formation- The base is defined as the base of the slumped horizon exposed in the track entrance by the bridge (Om on log 15), and the top as the contact of the bioturbated sandstones with the overlying muddy sandstones with mudstone clasts (the Junqueira Member), exposed at the top of the quarry at its southwestern end.

Description- The interval 0 to 9.5m of the section consists of quartzites and micaceous sandstones, which are often load-casted, particularly towards the base of the formation. The following interval from 9.5 to 15.7m comprises dark pyritous quartzites, with abundant pyrite nodules. The uppermost 2.8m of the formation (15.7 to 18.5m) are the dark laminated sandstones of the Serra dos Aguilhões Member. The lower part of this member is well laminated, with bedding planes often crowded with graptolites. Bioturbation, increases upwards so that the upper part is more massive. The base of the Junqueira Member follows conformably.

Members- The Serra dos Aguilhões Member (established term, Cooper 1980, redescription of stratotype) is the only defined

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member of this formation. Its type section is within the formational type section, and corresponds to the interval 15.7 to 15.5m of log 15. It consists of laminated sandstones, with the lamination progressively destroyed upwards by increasing bioturbation.

Fauna and age- The Serra dos Aguilhoes Member is the only part of the formation from which macrofauna has been recorded. It yields a graptolite fauna indicating a lower Llandovery age, possibly atavus Zone. The lower parts of the formation could thus be of basal Llandovery or upper Ashgill age.

Geographical extent and variation- The Vale da Ursa Formation has been found throughout the Dornes/Amendoa/Mação syncline, as well as in parts of the Fajão and Buçaco synclines. The detailed stratigraphy of the formation is known from relatively few sections, but it seems to show a fairly constant character. The Serra dos Aguilhões Member has only been recorded in the Dornes and Mação areas.

vii The Foz da Sertã Formation (established term, Cooper 1980)

Cooper erected this formation to include mudstones, siltstones and occasional fine-grained sandstone beds, lying between the quartzites of the Vale da Ursa Formation and those of the Vale de Serrão Formation. Only the base of the formation has been studied during the present work.

Stratotype- Cooper defined the formation by means of upper-, and lower-boundary stratotypes. Only the lower one is relevant to

Brittany

Cosquer Formation
Rosan Formation
Kermeur Formation
Postolonnec Formation
Gres de Kerarvail

Schistes de Raguenez Schistes de Kermeur Schistes de Veryac'h Portugal

Casal Carvalhal Formation
Porto de Santa Anna Formation
Louredo Formation
Cacemes Group
Monte da Sombadeira Formation

Vale Saido Member Zuvinnal Member Carregueira Formation

Figure 3. A correlation of lithstratigraphic units between Crozon and Buçaco.

Chapter 1.

the present study. This section lies at Foz da Serta (map ref. 19141,31095 to 19186,31117).

Boundaries of the formation- The base of the formation is defined as the contact of the bioturbated sandstones of the top of the Serra dos Aguilhões Member, and the highly organic muddy sandstones with mudstone clasts of the Junqueira Member.

Members- The Junqueira Member is erected here to include muddy sandstones with mudstone clasts at the base of the formation. The type section (map ref. 18900,30865) is at Junqueira, at K18.0 on the Tomar/Sernache road, 2km southwest of the Ponte Vale da Ursa, Dornes. The member is defined as the interval 5.3 to 8.8m on log 16. The base is coincident with the base of the formation, and the top is the contact of the muddysandstones with the overlying mudstones at 8.8m.

Fauna and age- In the Dornes area the Junqueira Member yields a graptolite fauna indicative of an upper Llandovery age. The base of the overlying mudstones yields a griestoniensis Zone fauna. Cooper indicates a probable centrifugus Zone age for a fauna less than 5m, and linnarssoni Zone 10-13m above the top of the Vale da Ursa Formation. About 40m above the base of the formation he records a fauna of nassa Zone age. The base of the formation, together with the top of the Vale da Ursa Formation, thus consists of a highly condensed succession, with the sequence from ?atavus Zone to griestoniensis only om thick.

Geographical extent and variation- The formation occurs in the Dornes region, where it was defined by Cooper, but the name is tentatively applied here (because of the present study being confined to the base of the formation) to the mudstones overlying Chapter 1. 62.

the Vale da Ursa Formation in the Amendoa/Mação area. The Junqueira Member has only been recognised in the Dornes and Mação areas.

viii The Sazes Formation
(established term, Paris 1981)

This formational name was used by Paris for mudstones with thin sandstone beds, which overlie the Porto de Santa Anna Formation on the eastern limb of the Buçaco syncline. This formation has not received a formal definition, and as its study is outside the scope of the present work, an informal use of the name is recommended.

3) The Lithostratigraphy of the Homologous Deposits in Armorica

#### i Introduction

The upper Ordovician of Brittany shows remarkable similarity to that of Portugal. Indeed the deposits of the Crozon Peninsula would be ascribed to the same formations as those of Buçaco were the areas adjacent. Despite this close similarity, in this study the Portuguese deposits have been referred to separate formations. It is felt that the continuation of two different schemes is preferable to the importation of terminology from one region to the other, which would result in the assignation of sequences to formations whose type localities are now 1000km distant. A brief account and history of all the stratigraphic terms used in Brittany is given by Babin et al. (1976b), and

further details on the elements of the current lithostratigraphy are given by Babin et al. (1976a). However, the sequences most directly comparable to those in Portugal, especially those of which sections have been studied in Brittany during this project, will be reviewed here, presenting new data where necessary. Correlations are summarised in fig. 3.

#### ii Discussion of lithostratigraphical units

#### a. The Postolonnec Formation.

This formation includes strata equivalent to the Cacemes Group. It forms the broadly middle Ordovician succession of the western part of the Median Synclinorium. The formation has been divided informally into several members, but none of these has been formally defined. The upper part of the formation includes the "Grès de Kerarvail" (Kerarvail Member of Babin et al. 1976a), a lateral equivalent of the Monte da Sombadeira Formation (Brenchley et al. in press), together with the so-called Upper Member (Babin et al. 1976a). This "Upper Member" is divided by Babin et al. (ibid.) into 3 subdivisions. The lowest of which (about 150m thick according to Babin et al.) is equivalent to the Fonte da Horta and Cabril Formations. In both the classic sections of Le Veryac'h and Postolonnec on the Crozon Peninsula the more coarsely-grained interval equivalent to the Cabril Formation is badly faulted, and it may be for this reason that it has been somewhat overlooked by the French stratigraphers. Above this unit lies the second of the subdivisions. This comprises less than 5m of mudstones, with thin sandstone beds in some sections (e.g. Le Veryac'h), and with phosphatised coquinoid beds. This unit is characterised by Marrolithus bureaui, and was known as the "Schistes de Kerarmor" (Kerforne, 1897). No equivalent of these beds is known from Portugal. The uppermost unit, probably almost 30m thick (Schistes de Veryac'h sensu Babin and Melou, 1972) is the equivalent of the Carregueira Formation of central Portugal. Some authors (e.g. Babin et al. 1976a) have included within the Postolonnec Formation the colitic ironstone more usually considered to form the lowest bed of the overlying Kermeur Formation.

In this project the sections through the upper part of this formation at Le Veryac'h and Postolonnec have been examined to provide information on the <u>Marrolithus bureaui</u> zone (<u>sensu</u> Henry, 1980).

The equivalent formation to the east, in the Laval Basin (north limb), is the Andouillé Formation. Towards the top of this formation the Marrolithus bureaui zone is again to be found. This has been studied in this project at the classic locality of La Touche. Here there is an colitic ironstone horizon apparently developed within the Marrolithus bureaui zone. The sequence is not completely exposed however, and the exact position of the outcrop with respect to the lithostratigraphy is not known.

#### b. The Kermeur and St.-Germain-sur-Ille Formations

The Kermeur Formation exhibits two strongly contrasting developments within the Crozon Peninsula. In the south (e.g. log 53 from Kerglintin/Raguenez) it is equivalent to the Louredo Formation, although there are important sedimentological differences. In the north of the peninsula however (e.g. log 54

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from Le Veryac'h), the formation is markedly different from any of the Portuguese successions, but somewhat similar in facies to the St.-Germain-sur-Ille Formation of the Ménez-Belair Synclinorium. The two facies are of very different thicknesses, with the northern development totalling about 190m, while the formation reaches about 300m in the south.

The lower part of the formation in both developments comprises some 40m of mud-rich bioturbated sandstones overlying an colitic ironstone. In both facies this is then overlain by bedded sandstones with mudstone interbeds. The southern facies exhibits much bioturbation of these sandstones, and there are several thick mudstone intercalations (Schistes de Raguenez and Schistes de Kermeur together with an unnamed unit at the top of northern facies the formation). The however shows no bioturbation, and no substantial mudstone intercalations. The upper half of the formation at Le Veryac'h comprises grey sandstones, and is apparently followed conformably by the base of the Cosquer Formation. The uppermost mudstones of the southern facies are overlain by the colitic ironstone at the base of the Rosan Formation.

This diffentiation across the Crozon Peninsula presents a major problem in correlation. Previous authors have assumed a single sandstone formation is present, and have even used the equivalent geometrical position of the Cosquer and Rosan Formations above the Kermeur Formation to indicate that the Cosquer and Rosan Formations are contemporaneous (e.g. Babin et al. 1976). Several possible explanations for the distribution of the Cosquer and Rosan Formations exist (e.g. discussion in Paris

et al. 1981). The evidence from the Portuguese homologues provides new constraints on the interpretation, as discussed elsewhere (chapters 1 and 5).

The St.-Germain-sur-Ille Formation is the term applied to a sandstone unit about 200m thick, in the central part of the Median synclinorium. It shows considerable similarity to the northern facies of the Kermeur Formation, and is overlain by the Pélites à Fragments Formation.

#### c. The Rosan Formation

The Rosan Formation ocurs in the southern Crozon Peninsula and as far east as Chateaulin. The formation comprises volcaniclastics with subordinate carbonates. In the Crozon Peninsula it conformably overlies the southern facies of the Kermeur Formation. The Rosan Formation includes two suites of volcanics.

Parts of the formation, particularly the carbonates near the base, and those interbedded with pillow lavas towards the top, are highly fossiliferous. These faunas have been studied very little, with interest to date being centred on the echinoderms (Chauvel, 1941, Chauvel and Le Menn, 1972) and conodonts (Lindstrom and Pelhate, 1971, Paris et al. 1981), with only a single brachiopod species having been described (Melou, 1971). There are indications of reasonable faunas in the literature (Babin et al., 1976, Kerforne, 1899, Durand, 1977), and therefore several sections (Lostmarc'h, fle de Rosan, Île de l'Aber/Pointe de Raguenez, Plage de Raguenez, Coat Garrec) were studied in this project (see logs 59-61). Large shelly faunas were obtained, and a

good correlation with the Venda Nova Group became possible. The basal colitic ironstone yields elements known from the Leira Ma Member, and the carbonates in the lower part of the formation contain a similar fauna to the Poiares Member. Some elements from the fauna of the carbonates at the top of the formation (e.g. at Rosan) have been found in the upper part of the Porto de Santa Anna Formation, and possibly also in the Riba da Cima Member of the Ferradosa Formation. A full discussion of the correlation and its implications is to be found in chapters 2 and 5.

One important implication of the shelly fauna is that the Coat Garrec locality belongs to the lower part of the formation (Zone 9 of the scheme erected in chapter 2). This implies that the structure of the Coat Garrec section may be simpler than some interpretations have indicated. The section appears to young northwards, from clastics of the Kermeur Formation, through the basal Rosan Formation carbonates (including the classic locality), through 20m of pillow lavas and then up into the volcaniclastics of the main body of the Rosan Formation.

### d. Cosquer Formation

This formation occurs in the northern part of the Crozon Peninsula, where it overlies, apparently conformably, the Kermeur Formation. The Cosquer Formation is best seen at present in the Veryac'h section. Here the base of the formation is laminated (thin sandstone and siltstone laminae in a fine siltstone matrix), and contains isolated small pebbles. It also contains small pyritic concretions. The formation fines upwards to become a uniform dark mudstone. Above this sandy beds and laminae

reappear, and the formation often appears to be contorted. There is considerable doubt to what extent this contortion is soft-sediment deformation, and to what extent it is tectonic. Photographs of the bay at Lamm-Saoz during a period of low sand-level indicate considerable faulting, with blocks of the Grès de Lamm-Saoz, and of fossiliferous Wenlock/Ludlow mudstones faulted down into the Cosquer Formation (F. Paris pers. com.). Although some of the deformation (e.g. the slump balls in the cliff just below the Grès de Lamm-Saoz) is convincingly of soft-sediment origin, the attribution of the major "slump-blocks" in the cliffs on the west of the bay to such an origin must be cosidered highly speculative.

A suggestion (Guillocheau and Rolet, 1984) that the whole sequence of the upper Kermeur Formation, the Cosquer Formation, and Grès de Lamm-Saoz has been affected by major Ordovician slumping, such that the Grès de Lamm-Saoz would be part of the Kermeur Formation thrust over the Cosquer Formation is backed by very little evidence. In this study it is believed that most of the deformation of the Cosquer Formation is tectonic in origin, and that the Grès de Lamm-Saoz represents a lower Silurian deposit.

The Cosquer Formation has been suggested to be the equivalent of the Pélites à Fragments of the eastern Median Synclinorium and of Normandy. Although pebbles are not common in the Cosquer Formation, and only occur in the basal few metres, this correlation seems highly plausible. A full discussion of the nature and context of these two formations is to be found in chapter 5.

# CHAPTER 2 - The Depositional Environment

#### 1) Introduction

The sediments of the middle and upper Ordovician of the study area fall into three broad depositional phases:

- A. (pre-Zone 1 to Zone 8 of biostratigraphic scheme erected in chapter 3) Shallow shelf environments, with clastic, mainly storm-dominated sedimentation. Hiatuses in the normal sedimentation resulted in the formation of phosphorites and colitic ironstones. The deposits are represented by the Cacemes and Sanguinheira Groups, together with the very basal part of the Venda Nova Group.
- B. (Zone 8 to Zone 11) Widespread hiatus in clastic sedimentation. Volcanic activity and carbonate deposition in localised areas. Deposits of this phase include those of the Venda Nova Group.
- C. (Zone 12 to basal Silurian) Initial regressive phase, resulting in deposition of clastic sequence culminating with coarse sandstone and conglomeratic sediments. Followed by transgressive sequence with the deposition of tilloids and later of mudstones. Final part of this phase includes the very widespread deposition of pyrite-rich sandstones. This phase saw the deposition of the Rio Ceira Group, together with the Casal Carvalhal and Vale da Ursa Formations.

These three phases will be discussed separately here, for the processes involved in each are distinct. Phase "A" seems too represent the sedimentary regime of the shelf without any major tectonic events. The wide extent of any change in sedimentation Chapter 2. 70.

during this phase suggests that the nature of deposition was influenced by large-scale, possibly even global events. In phase "B" on the other nand, both in the restricted area of this study, and in the Ibero-Armorican region as a whole, events are of a more localised nature, and are probably strongly influenced by local igneous and tectonic processes. The third phase, "C", represents a renewed influence of external control; in this case the effects, mainly the eustatic changes, caused by a glacial event. Later Silurian deposits of Wenlock and Ludlow age show a return to a stable shelf environment, probably not too unlike that of phase "A".

# 2) The Deposits of Phase "A"

## i The facies scheme for phase "A"

Within this period the sedimentary facies observed tend to be very widespread (e.g the Monte da Sombadeira Formation, Brenchley, Romano and Gutierrez-Marco in press), consequently lateral changes may be difficult to characterise. However some important lateral variations do occur within the study area, and seem to be related to long-lived areas of differential subsidence. This phase corresponds to the Cacemes and Sanguinheira Groups together with the basal bed of the Ferradosa Group, in terms of the lithostratigraphy of central Portugal erected in this study (see cnapter 1).

The deposits of this phase are divided here into o proad facies, with further arrangement into 3 facies groups:-

- 1 Mudstone facies
- 2 Interbedded mudstone/sandstone facies-group

- 2a Mottled muddy-sandstone facies.
- 2b Bioturbated interbedded sandstone/mudstone facies.
- 2c Interbedded sandstone/mudstone facies.
- 2d Amalgamated sandstone facies.
- 2e Lenticular sandstone facies.
- 3 Ironstones facies-group
  - 3a Oolitic ironstone facies
  - 3b Ferruginous sandstone facies

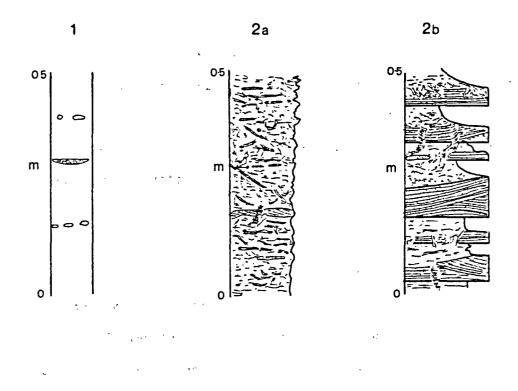
These facies are illustrated in fig. 4.

- ii Description of the facies
- a. Facies 1 Mudstone

This facies is an important element of the deposits of the Cacemes Group, but is less prominent in those of the Sanguinheira Group. It corresponds to facies 1 of Brenchley et al. (in press). The Fonte da Horta and Carregueira Formations develop this facies, as do the Zuvinhal, Vale Saido, Galhano and Vaca Members of the Louredo Formation. The Queixopeira Member of the Cabeço do Peão Formation is also a mudstone, but differs markedly from other members of this group in its fauna, and its relationships with other sedimentary facies.

The mudstones are now generally very weathered at outcrop, but where at all fresh they show evidence of a high pyrite content. The pyrite occurs disseminated in the mudstone, as well as concentrated in nodules and in replacement of calcareous fossil material. The mudstones themselves are illitic.

Body fossils occur concentrated on bedding planes, and in coquinoid layers, as well as dispersed in the otherwise rather



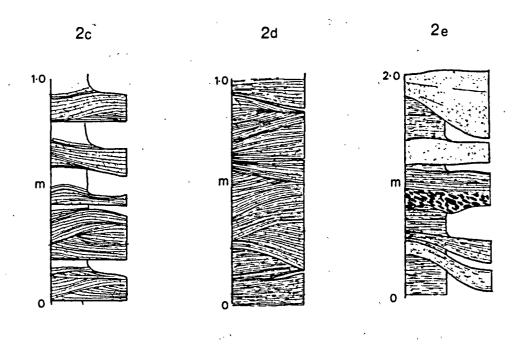


Figure 4. Schematic sedimentary logs of the clastic facies defined from Phase "A".

massive mudstones. Trace fossils, predominantly Palaeophycus, occur widely and are often preferentially pyritised. The macrofauna of this facies is usually dominated by ostracodes and infaunal bivalves, generally with abundant trilobites and some brachiopods. The Queixopeira Member of the Cabeço do Peão Formation consists of mudstones but differs from the other examples of this facies for it shows little or no sign of bioturbation, and where fossiliferous the fauna is dominated by bryozoans and echinoderms.

The Mudstone Facies may pass gradationally into thinly interbedded sandstone and mudstone (facies 2a, 2b or 2c) in vertical sequence. The facies commonly abruptly overlies thickly-bedded sandstones (facies 2d or 2e), and may be overlain sharply by colitic ironstones (facies 3a). The lateral variations of this facies are largely unknown; where this facies occurs it forms a blanket which persists over a large area, and those changes which are seen include changes of lower contact from gradational with facies 2c to abrupt with 2d/e, and the increasing occurrence of phosphatic beds in and below the mudstones with the thinning of the facies.

# b. Facies 2a - Mottled Mudstone/Sandstone

Highly bioturbated, muddy sandstone characterises this facies. The original sediment consisted of a background sediment of mud grade, with thin sand beds and laminae. This was reworked by a variety of organisms, partially or entirely destroying the original sedimentary fabric of the deposit. This facies is equivalent to parts of facies 3 of brenchley et al. (in press).

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This facies is well developed in the lower part of the Kermeur Formation in the section at Le Veryac'h, Crozon. Otner developments occur in the study area particularly within the Capeço do Peão Formation, but also in parts of the Louredo Formation. Minor occurrences of this facies form parts of the Capril Formation, although here the coarser fraction is often silty.

The trace fossil assemblages of this facies are often rich, dominated by <u>Palaeophycus</u>, <u>Planolites</u>, <u>Chondrites</u> and <u>Bifungites</u>. In contrast body fossils are scarce, generally occuring in the finer grained examples of the facies (e.g the upper part of the Cabeço do Peão Formation). These faunas include brachiopods, trilobites and cystoids. Bivalves occur only very rarely, in contrast to the faunas of the Mudstone Facies.

The lateral relationships of this facies are difficult to ascertain, largely due to the difficulties of detailed correlation of these unfossiliferous peds. However comparison of the Kermeur, Louredo and Cabeço do Peão Formations would suggest that this facies can pass laterally into well bedded sandstones of facies 2b, 2c or even 2e. In vertical section the facies is seen to intergrade with facies 1, 2b, and 3a, and to be abruptly juxtaposed with facies 2e.

# c. Facies 2b - Bioturbated Interpedded Sandstone/Mudstone

This facies is intermediate in nature beween 2a and 2c. It occurs when the rapidly-deposited sand beds are too thick to be completely reworked by the fauna and mixed with the intervening mud (as they were in facies 2a). The primary deposit was probably

similar to a deposit of facies 2c, but typically with sandstone bed thickness between 5 and 50mm. Where primary sedimentary structures are preserved symmetrical wave ripples occur rarely on the tops of beds, and parallel or low-angle cross lamination is seen within them.

The ichnofauna is not as abundant as in 2a, but may include some surface markings (usually indeterminate scratches), as well as burrows (<u>Planolites</u> is usually the dominant element). Body fossils are absent. Gradational contacts with facies 1, 2a, and 2c are seen in vertical section. This facies is particularly common in the Louredo Formation.

# d. Facies 2c - Interbedded Sandstone/Mudstone

This facies is sedimentologically very similar to 2b, but the effects of bioturbation are very much reduced. Usually this is associated with an increased thickness of the sandstone beds, typically to between 50 and 150mm. The facies is characterised by the prescence of sandstone beds in a laminated or mildly bioturbated mudstone background. The sandstone beds have sharp bases, but sole structures are absent. Sandstone beds are laterally persistent, only rarely being removed by scouring from above. The beds exhibit a low-angle cross-lamination, which can most often be seen to belong to the erosional type of hummocky cross-stratification. Towards the upper part of the bed the angle of cross-lamination often increases, and the top of the bed may be wave-rippled. These ripples are generally symmetrical, straight, parallel-crested, with wavelengths of 100 to 200mm. The rippled tops are most common where this facies grades into 2d,

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and there is only a very thin mud parting beween the sandstone beds. In vertical section the facies may pass into facies 1, 2a, 2b, 2d, or 2d. This facies is largely equivalent to facies 4 of Brenchley et al. (in press).

Facies 2c is found in the upper part of the Louredo Formation (together with its Armorican homologue, the Kermeur Formation), but its clearest development in the sequences studied is in the Cabril Formation, the bulk of which is in this facies. It is striking that the influence of bioturbation on the sandstone deposits of the Cacemes Group is much less than on those of the Sanguinheira Group.

# e. Facies 2d - Amalgamated Sandstone

This facies consists of sandstone beds with negligible mud partings, low angle cross-stratification (often HCS), a low degree of lateral persistence, and bed thickness of 0.1 to 0.4m (although the apparent bed thickness may be upto 2m because of the amalgamation). The internal structure of the beds of some examples referred to this facies (e.g the quartzites in the upper part of the Louredo Formation of the southern part of the Buçaco syncline) is unknown, so the amount of variation within the facies is not certain, particularly whether the thicker beds have the same structure as the thinner examples.

The facies is generally associated in vertical sequence with facies 2c, but may be abruptly overlain by facies 1. This facies is the equivalent of facies 6 of Brenchley et al. (in press).

#### f. Facies 2e - Lenticular Sandstone/Mudstone

This facies usually occurs in vertical sequence with facies 2c, with which it is closely related. Internal structure is rarely visible in the sandstone beds of this facies. These sandstones are more thickly bedded than in facies 2c, varying from 0.2 to 2m. The most obvious difference is the lack of lateral persistence of the beds of this facies, often lensing over a distance of only a few metres. Unlike facies 2c where changes in bed thickness are slight and mainly due to hummocky topography on the top surface of the bed, in this facies the variation is extreme, and almost entirely due to highly erosive bases. These scour surfaces may have a relief of upto 1m. The mudstone interbeds are generally laminated, and show little, or no signs of bioturbation. The lack of any fauna or ichnofauna in these mudstones, is an important and constant feature of this facies.

One important characteristic of this facies in the Cabril Formation is the development of conglomeratic beds upto 70cm thick. Both the matrix and the clasts of these conglomerates are highly phosphatic, with one specimen analysed indicating an apatite content for the whole-rock sample of about 36%. Often the clasts show a particularly phosphate-rich crust, with the inside being largely pyritic. This reflects the origin of the clasts as pyritic nodules, which are common in the facies 1 mudstones, that have been reworked and secondarily phosphatised. The clasts are generally discoidal, although some of the smaller clasts are sub-spherical. The clasts may reach 10cm in size, and may demonstrate a poorly developed imbrication.

The facies is found in the Louredo Formation, and to a lesser extent in the Cabril Formation. It may be gradational with 2c, and may occur beneath 1, with a sharp contact.

### g. Facies 3a - Oolitic Ironstone

The oolitic ironstones of the Favaçal Bed and Leira Ma Member form an almost insignificant proportion of the deposits of this phase (approximately 0.2% of the thickness). However this particular facies has great importance for the interpretation of the depositional processes, since it represents a major change in the sedimentary environment. The oolitic ironstones are also important in correlation, for they are found over very wide areas, and their onset is isochronous, at least at the current level of biostratigraphic resolution.

The ironstones consist of ooids of iron chlorite (chamosite) in a matrix consisting largely of the same mineral. Some specimens examined by XRD techniques show only a weak 14Å peak relative to the height of the 7Å peak. This suggests that the ironstones may contain a substantial amount of the mineral berthierine, which has a 7Å basal spacing instead of the 14Å of the chamosite. It seems likely that berthierine would have been the mineral forming the ironstone ooids initially, but it has transformed into the more ordered chlorite during burial (Odin and Matter, 1961; Velde et al. 1974). The bulk composition of the ironstone usually includes over 20% FeO (calculated for oxides on the results of XRF). The ironstones show variable amounts of quartz on XRD, and generally significant amounts of phosphate (upto about 12% apatite is suggested by XRD and XRF analyses).

This phosphate is concentrated in nodules; small nodules may be sub-spherical, but the larger ones (upto 30mm) are generally irregularly discoidal.

The distribution of ooids within the oolitic beds is irregular; the lower parts of the bed are often highly colitic, and contain large numbers of nodules, while the upper parts become progressively less colitic, with a higher clastic content. intensely bioturbated The oolitic horizons are often (Planolites), and they contain a sporadically distributed, but varied macrofauna of brachiopods, trilobites and cystoids. No indications of current action have been cross-stratification has been observed, trilobite carapaces are very commonly complete and articulated, and brachiopod shells are often articulated.

The base of the of the colitic ironstone facies generally lies on a thin nodular horizon at the top of the underlying mudstones. At some localities the basal part of the colitic ironstone bed contains large numbers of nodules suggesting reworking of such a nodular horizon. The development of nodules within the bed is highly variable. Some nodules from these horizons are pyritic, some phosphatic (see above), and many contain chamositic coids. Paris (1979,1981) records that the varied mineralogy of the nodules is matched by a variable microfauna, and invoked this as a sign of the reworking of previous sediments of slightly different ages. He identified a Zone 14 fauna in the matrix of the Favaçal Bed, but Zones 12 and 13 in the nodules. Similarly the Leira Ma Member colitic horizon yielded a Zone 18 fauna in the matrix, and a Zone 17 fauna in the

nodules. The stratigraphic evidence cited elsewhere in this work (chapter 2) suggests that any erosion below the ironstone horizons is probably minimal. The interpretation of the microfaunal evidence preferred here is that the ironstone horizon represents a phase of almost zero deposition. There may be a stratigraphic hiatus at the base of the ironstones, as represented by the nodular horizons on the contact of the two lithologies. The thin ironstone sequence overlying the break may itself have taken a long period of time to form. Nodules may be part of a crust formed diagenetically, before the formation of the ironstone, or may have grown within the ironstone during its formation. This gives the possibility of nodules preserving microfaunas from various intervals within the time represented by the hiatus and ironstone formation, while the ironstones themselves will yield microfauna of the periods of chamosite formation.

The two beds in this facies both lie on mudstones of facies 1, except for the Favaçal Bed in the Penha Garcia syncline which lies unconformably on the Cabril Formation. Both beds are also terminated vertically by gradual dilution with clastic material. Lateral variation within the upper horizon, that in the Leira Ma Member, is very marked, for it passes laterally into the ferruginous sandstones of facies 36.

# h. Facies 3b - Ferruginous Sandstone

Medium-grained sandstones with chamositic cement are characteristic of this facies. The sandstones often contain nodules, which are often phosphatic. The quartz grains show a

high degree of rounding and sphericity. At outcrop this lithology is often very weathered and presents merely a skeletal sandstone, with the chamosite entirely missing.

This facies only occurs once in the studied successions, and here it passes northwards into the Leira Ma oolitic ironstone. The actual passage is not seen, but the most northerly outcrops of this facies do display a significant amount of chamositic oolds within the ferruginous sandstones. Facies 2b and 2c underlie these deposits, while they are overlain, probably disconformably, by fine-grained sediments at the base of the phase "B" deposits.

## iii Discussion of phase "A" deposits

The clastic deposits of phase "A" can be seen as being influenced by the rate and amount of sediment input from a source of sand-grade clastic material. Variation of this factor produced a continuum of facies (1-2a-2b-2c-2d/e). The sedimentological evidence for the nature of this sediment input is detailed below:

- 1) HCS is a major sedimentary structure of some of the thicker interbedded sandstone beds. This structure has been interpreted as being formed by deep wave-, or combined wave/current activity during storm events, or during the waning of surge conditions induced by storm activity. Current-produced sedimentary structures are unknown, while the tops of sandstone beds commonly display symmetrical wave ripples.
  - 2) The sandstone beds do not generally show sole

structures, although the facies 2d may exhibit large scour structures of unknown 3-dimensional form.

- 3) When the deposition of sandstone beds starts in a section, the macrofauna disappears almost entirely in both the sandstones, and in the background mudstone deposits. Bioturbation is rare in sequences with sandstone beds above 200mm thick, coquinoid layers in sand beds are extremely rare (see chapter 4).
- 4) The periods of interbedded sandstone/mudstone deposition are synchronous over large areas.
- 5) In facies 1 the fauna is often reworked into coquinas, and some horizons display reworked nodules forming pebble horizons, suggesting the winnowing effects of storm action when not accompanied by a sand-deposition event.

These pieces of evidence all point to the major influence of periodical events, presumably storms. The mudstones of facies 1 show evidence of reworking, suggesting that they were deposited in depths above storm wave-base. The interbedded sandstone/mudstone sequences of facies 2c with their HCS again suggest deposition between storm and fair wave-base (Bourgeois, 1980; Brenchley and Newell, 1902; Brenchley et al., in press; Dott and Bourgeois, 1982; Hamblin and Walker, 1979; Harms et al. 1975). The depths suggested for HCS formation by various authors varies markedly (0 to 60m; Campbell in Dott and Bourgeois 1902, 5 to 80m; Harms 1979, 10 to 300m; Hunter and Clifton 1962, deeper than 10-15m; Wright and Walker 1981). The amalgamated sandstones and scoured units of facies 2d and 2e are more difficult to interpret in terms of depth, but would appear to

belong to shallower water than facies 2c. The overall depositional environment of these facies would thus seem to be water-depths of less than 80m. The facies would also appear to represent deposition below fair-weather wave-base (say 15m).

The stratigraphic profile of the deposits of phase "A" (fig. 9) shows considerable variation in thickness. The north to south thinning of these deposits across most of the area occurs in the same sense as the trends of the isopach maps of Bege (1970) and Romano (1982, fig. 5) for the lower Ordovician quartzites. The distribution of outcrop of upper Ordovician strata in central Portugal, and hence the distribution of isopach evidence, is too limited to confirm if the distribution of areas of high subsidence is the same for the upper, as for the lower Ordovician. All the available evidence from this study, and from the available published data for adjacent regions of Spain, does however suggest that this is the case. The data gained in this project from the Macao area is the first to suggest a thickening of strata to the south of the Amendoa/Dornes axis.

Evidence, largely taphonomical, has been presented by several authors (e.g. Hammann and Henry, 1978; Henry, 1980) to suggest that the Llandeilo deposits of Valongo and Martigné-Ferchaud were formed in deeper-water than those of Buçaco and Crozon. It remains difficult to separate the factors which may have influenced the distribution of fauna. The automatic correlation, for instance, of fauna similar to those from Valongo with deep water conditions elsewhere would be very dangerous. Thus the relative depth of water in various parts of the current study area is very difficult to evaluate.

The deposits of the Queixopeira Member may provide a clue to the palaeotopography of the lower Caradoc. These mudstones with their rich suspension-feeding fauna must surely be contemporary with the deposition of sandstones (in the lower part of the Louredo Formation) in the Buçaco syncline to the north. They occur at Dornes and to the west of Mação, but in the area to the east of Amendoa the rich fauna is generally lacking. This distibution of the faunally-rich beds to the south of the belt of maximum condensation of the Sanguinheira Group suggests that:

- 1) This belt may represent a palaeotopographic "high", and the suspension-feeding fauna lived in its lee, protected from storm action moving sand in from the north.
- 2) Alternatively the fauna may actually have lived on a "rise" (which would not in this model correspond to the belt of maximum condensation), onto which the mobile sands to the north (and potentially in this model to the south as well) could not encroach.

The evidence for palaeotopography is clearly rather sparse, in itself suggesting that any topography of the sea-floor was rather gentle. The belts with varying subsidence-rates themselves controlled the deposition and preservation of differing sediments, which cannot be held to be direct products of different water-depths alone. The pulses of sandstone deposition within phase A may have a rather complicated relationship with water-depth. The rate of deposition may have been greater during a phase of sandstone deposition, and hence, if this exceeds subsidence, lead to a local shoaling. If the original cause for the pulse of sandstone was a regressive event, then the shoaling

will be doubly marked. The nature of the origin of the sandstone pulses must await further analysis of their sources. The studies of Brenchley et al. (in press) indicate a possible source for the sands of the Monte da Sombadeira Formation across the Cordoba/Badajoz/Tomar fault from the Sierra Morena. The present position of this source area depends on the movement on the fault; the reconstruction favoured in this study is shown in fig. 12. This reconstruction would suggest that the source-area now lies north-west of Iberia, or west of Brittany.

The response of sedimentation to more drastic changes of relative sea-level (although probably still within the 15-80m range of depths indicated above) can probably be seen in the phosphorites and oolitic ironstones. The exact position of the formation of these deposits in a trangressive/regressive cycle is uncertain. The association of the conglomeratic phophorites with the thick sandstones of facies 2e suggests that they formed during some of the shallowest conditions experienced, with high-energy storm activity winnowing the sediment, and forming conglomeratic beds from the derived nodules. the These conglomerates are highly phosphatised, suggesting that they formed in conditions of very little sedimentation. The oolitic ironstones would similarly have required slow sedimentation rates to have formed (Van Houten and Purucker, 1984), but the exact conditions for their formation remains uncertain. The wide lateral extent of these ironstone horizons, their thin, tabular form, and the lack of any indication of current activity, would indicate that the models of inshore deposition (often seaward of deltas) derived for Mesozoic ironstones (e.g. Van Houten and Chapter 2. 86.

Purucker, 1984) do not apply here.

# 3) The Deposits of Phase "B"

#### i Introduction

The deposits of phase "B" as currently recognised are very restricted geographically. In Portugal they have only been identified in the areas of volcanic activity: the Buçaco and Fajão synclines.

The depositional facies in phase "B" have little in common with those of phase "A". Many of the deposits are very difficult to interpret in terms of a detailed sedimentary environment; particularly so the volcanic and volcaniclastic deposits which are so greatly affected by the deep weathering and alteration prevalant in the region. Eight facies are used here to describe the deposits of this phase:

# 3a. Oolitic ironstone

- 4. Well bedded "rottenstones"; presumably once carbonates, now generally silicified to a greater or lesser extent.
- 5. Massive cherts, sometimes cavernous; possibly a silicified equivalent to facies 4.
- 6. Massive coarsely crystalline dolomite; primary structure unknown.
  - 7. Massive grey limestones.
- 8. Fine-grained tuffaceous sediments, perhaps often originally calcareous; often with a sparse fauna.
  - 9. Thinly-bedded fine grained tuffs; often well laminated.
  - 10. Thickly-bedded coarser tuffs; sometimes with clasts upto

10cm.

11. Lava-flows; probably mainly basaltic.

## iii Description of Phase "B" Depositional Facies

#### a. Facies 3a - Oolitic ironstone

The colitic ironstone at the base of the Venda Nova Group has been included within the deposits of phase "A". However in the northern part of the Buçaco syncline there is an area where colitic ironstone beds occur above the earliest lava flow of phase "B". The section which used to be visible at Porto de Santa Anna presented an colitic ironstone passing up into a highly fossiliferous iron-rich bed with rare ironstone coids. At the Leira Ma locality, only 300m south-east, these same lithologies are visible, but separated by a flow at least 20m thick. The classic trilobite locality is actually in the sparsely colitic part of the Leira Ma Member above the lava. These beds above the flow are identical to the upper part of the Leira Ma Member at the Porto de Santa Anna locality, but pass upwards into a mudstone containing large (upto 20cm) lava blocks, and probably into another flow of similar lithology to the one beneath.

### b. Facies 4 - Well-bedded "Rottenstones"

This facies includes a range of lithologies of rather uncertain original composition. It seems likely that they were carbonates, and all are largely bioclastic. Some are now highly silcified, and form hard cherts; others are now represented by soft limonitic rottenstones. Fossil material is preserved in the form of moulds, sometimes partly infilled by quartz, particularly

in the cherty beds.

The examples of this facies include the Poiares Member, and beds within the Porto de Santa Anna in the Cabeço Pedrogão area. The Poiares Member exhibits considerable lateral persistence. It passes upwards into the massive dolomites of facies 4, but what underlies the facies is not seen, the base being everywhere faulted. The beds at Cabeço Pedrogão pass up into a massive, cavernous silicified unit (facies 3), possibly a silicified equivalent of the massive dolomites. The bedding in this facies appears to be parallel, and no current produced sedimentary structures have been seen. The fauna of the facies is rich, dominated by bryozoans, but also with abundant brachiopods and echinoderms; trilobites occur rarely.

### c. Facies 5 - Massive cherts

Within the upper part of the Porto de Santa Anna Formation there is a horizon of silicified beds, generally rather massive, and some are cavernous, particularly in the south, suggesting these may be a silicified equivalent of the dolomites of facies 4. No fauna has been recovered from these beds. They overlie tuffs (facies 8), and may be overlain by facies 2, 7 or 9.

### d. Facies b - Massive dolomites

The dolomites of this facies are generally massive, but may be bedded with beds 40cm to 100cm thick (e.g. in the quarries at Estrada). The original fabric of these rocks is largely obliterated by the recrystallisation they have undergone. They are now coarsely crystalline, and are cavernous with euhedral

dolomite growing into the cavities. No fauna has been recovered from the dolomites themselves, although near Ferradosa and at Poiares the lower part of the dolomites yields a few thin layers of partly dolomitised limestone with a high clay content which contain a fauna of bryozoans, echinoderms and brachiopods. These partly dolomitised beds are very similar in fauna and fabric to the decalcified beds of facies 2. The facies generally overlies beds of facies 2, and may be laterally equivalent to silicified beds of facies 3. In Spain the carbonates of equivalent age are frequently dolomitised (Hafenrichter, 1980).

# e. Facies 7 - Massive bioclastic limestones

This facies is only known from a single locality to the west of Sazes in the Buçaco syncline. The facies consists of grey, massive bioclastic limestones, containing bryozoan, echinoderm, brachiopod and trilobite material. The relationship of these limestones to other facies are unknown, for the single locality forms a fault-bounded block. The limestone shares with the dolomites of facies 6 the property of containing frequent cubes of magnetite.

# f. Facies 8 - Massively-bedded fine tuffaceous sediments

Towards the base of the Porto de Santa Anna Formation at some localities in the Buçaco syncline there occur fine tuffaceous sediments, which contain a varied but sparse fauna, particularly bryozoans. Some of these sediments may have been partly calcareous, but none are, at least at outcrop, now. The facies is poorly known, mainly because of the difficulties in

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recognising it when the deposits have suffered the intense weathering so common in the area. The weathering procedes with the formation of spherical cavities, often filled with chlorite, which mask the originally fine texture of the rock. This facies occurs above the colitic ironstone at the base of the formation, and below facies 8. The equivalent position in the Rosan Formation (as seen in the Raguenez area) is occupied by carbonates, with a high clastic (probably largely volcaniclastic) content.

# g. Facies 9 - Thinly laminated tuffs

This facies includes tuffs bedded on a scale of upto 10cm, and generally finely laminated. No fresh material of this facies has been recovered, but the fine parallel lamination with a lack of bioturbation and body fossils strongly suggests that at least a large part of this facies may be of primary origin. The tuffs of this facies may include occasional large lava blocks, although isolated blocks are more common in the tuffs of facies 8. The mode of origin of these deposits cannot be determined without better-preserved material, but primary air-fall tuffs must remain a very likely possibility. The close proximity in vertical sequence between this facies and silicified rottenstones (facies 2) strongly suggests submarine deposition for this facies.

#### h. Facies 10 - Coarse tuffs

The tuffs in this facies comprise a fine to coarse fragmental clastic deposit, often with isolated large blocks. Sorting of the deposits is very variable. Some of the

French examples are clearly graded, but other deposits are very poorly sorted (e.g the tuffs of the Porto de Santa Anna Formation at Cabril, in the Fajão syncline). Many of the fresh examples in Brittany show a calcite cement, sometimes partly silicified. Fragments within some of the deposits are highly angular, often with apparently fragile structures suggesting that these deposits at least may be primary. As with the previous facies too few examples of fresh lithologies are known to deduce much about the mode of origin of this facies.

One occurrence which suggests that more than one origin is likely for these deposits is the locality of Lostmarc'h on the Crozon Peninsula. This locality presents a sequence of pillow lavas passing up into hyaloclastites, which are in turn overlain by limestones. In the cliffs on the north side of the Pointe du Lostmarc'h these hyaloclastites are fresh and well exposed, while in the clifftops above the bay to the north of the headland, just 50m along strike, they are highly weathered and virtually indistinguishable from weathered airfall tuffs.

### i. Facies 11 - Lava flows

At several points within the the Rosan and Porto de Santa Anna Formations lava flows are developed. Most of the outcrops of these flows are heavily weathered and little information is available at present on the nature of the lavas. The lavas in the upper part of the Rosan and Porto de Santa Anna Formations are frequently pillowed. At Lostmarc'h the pillow lavas have an interstitial limestone, partly silicified, which yields a fauna of brachiopods, echinoderms, and bryozoans. Many individuals of

this fauna are remarkable for their large size compared with other assemblages of a similar age.

# iii Discussion of phase "B" deposits

The distribution of facies during this period is complex. This is largely due to the variation of the igneous activity, both geographically and temporally. The development of carbonates in the Ibero-Armorican area is almost entirely limited to this phase. Furthermore, in Portugal the carbonates are restricted to areas close to the volcanic activity. The appearance of the carbonates and volcanics coincides with the influx of a wide range of new fauna into the region.

The onset of this volcanic activity appears to vary from Zone 8 (e.g. Leira Ma) to Zone 9 (e.g. Coat Garrec and Raguenez). The earliest record is of a lava flow (Leira Ma). Deposition away from the flow itself seems to be a continuation of the colitic ironstone which was being formed at the end of phase "A". In the same area (Louredo/Leira Ma) tuffs were soon being deposited, while elsewhere (e.g. the southern part of the Buçaco syncline, Raguenez, Coat Garrec) carbonate sediments of facies 2 were formed during Zone 9. These carbonates are overlain by lavas (Coat Garrec) and graded (probably air-fall) tuffs of facies 8 at Raguenez. Coarse tuffs (facies 8) form the bulk of both the Rosan and Porto de Santa Anna Formations.

Towards the top of the phase "B" deposits both the formations show a tendency to return to the deposition of carbonates, lava flows and fine grained tuffs. The extensive dolerite intrusions into the upper Ordovician sediments in the

Buçaco and Crozon areas may belong to this phase of the igneous activity. The lateral variation in thickness, and the abrupt southern termination of the thick lava flow at the top of the Porto de Santa Anna Formation in the Louredo area may reflect the influence of a topography produced by the intrusion of these sills.

The relationship of the dolomites (facies 4) to the volcanic facies is still uncertain, but if the dolomites do indeed represent a lateral equivalent of the cherts (facies 3) then this suggests a possible interpretation. In this model the dolomites would postdate the main phase of explosive volcanism (as represented by the deposits of facies 8), but perhaps predate the later phase of lava extrusion and dolerite intrusion. The dolomites do contain small intrusive dykes, but only seem to contain fine tuff beds without any coarse debris, thus giving some backing to this interpretation. The silicified rottenstones of facies 2 present at the top of the Ferradosa Formation in its type area would seem to correlate with similar deposits towards the top of the Porto de Santa Anna Formation further north.

The deposits of this phase in Buçaco and Crozon show no clear indication of subaerial volcanic activity, and the sediments contain marine faunas. Furthermore, evidence for current activity is lacking. This suggests that the phase "B" deposits were formed under submarine conditions, probably below fair-weather wave base, as in phase "A". However, unlike in phase "A" the volcanic activity lead to a topography, which produced rapid local facies changes.

One of the major difficulties with the interpretation of

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deposits of this phase is the lack of any sediments away from the volcanic centre. It is possible that the basal part of the sediments of phase "C" of much of central Portugal could in fact belong to this period, but in the absence of any faunas in the phase "C" sediments of these areas the age of these basal deposits remains unknown. The existence of an important disconformity across most of central Portugal during phase "B" seems however to be most likely. The major evidence for this is the similarity of the sediments of the lower part of the Ribeira do Laje Formation of the Penha Garcia syncline, with the Ribeira do Braçal Formation of the Buçaco syncline. The Buçaco sediments overlie the Porto de Santa Anna Formation, and themselves contain a fauna of Zone 12 age. The Ribeira do Laje Formation in the Penha Garcia and Amendoa/Dornes/Macao areas, however, directly overlies deposits of the Sanguinheira Group placed in Zone 7, or just possibly the base of Zone 8. Despite the lack of macrofauna in other areas correlation may become possible in the future because reconnaisance sampling of the Ribeira do Braçal Formation has revealed a rich microfauna (principally acritarchs).

# 4) The Deposits of Phase "C"

## i Introduction

This phase marks a return to widespread clastic sedimentation in the area of the study. The interpretation of these sediments is hindered by the almost total lack of macrofauna. The youngest sediments of this phase are of lower Llandovery age, and contain graptolites (Serra dos Aguilhões Member). Some of the oldest deposits assigned to this phase

contain a shelly-fauna of Zone 12 age (base of the Ribeira do Braçal Formation). This phase would therefore appear to be largely of Hirnantian age, possibly together with the upper part of the Rawtheyan and the base of the Llandovery (see chapter 3 for the evidence placing Zone 11 in the Rawtheyan). This phase shows every sign of being very closely linked to the glacial event of the upper Ordovician, now recognised to be essentially Hirnantian in age.

The deposits are divisable into three:

- 1) A regressive sequence of clastics, from mudstones with occasional carbonate bands, overlain by mudstones with sharp-based siltstone beds (? turbidites), through bioturbated sandstone/ mudstone alternations, into thickly bedded sandstones with HCS and massive, possibly shoreface quartzites.
- 2) A transgressive unit, sometimes with pebbly sandstones at the base, of pebbly siltstones containing highly load-casted and slumped quarztite beds, grading upwards through massive siltstones into mudstones with thin sand laminae.
- 3) A widespread unit of pyritic sandstones and quartzites, generally showing much slumping and loading towards its base. At the top of this unit in some areas lies a highly condensed sequence through the lower and middle Llandovery, of laminated sandstones, and muddy sandstones with abundant mudstone clasts.

Above the deposits of phase C lies a sequence of mudstones and sandstones of upper Llandovery to Ludlow age. These include highly organic black mudstones, particularly in the lower part, as well as mudstone/sandstone alternations. These deposits indicate a return to a more stable sedimentary regime, not unlike

that of phase A.

- ii Description of the deposits
- a. Stage 1 The regressive sequence

Deposits of this sequence are known from the Buçaco, Dornes, Amendoa, Mação and Penha Garcia areas. The lower parts of this sequence suggest rather low energy depositional environments. In the Dornes, Amendoa and Mação areas the lower part of the Ribeira do Laje Formation consists of mudstones, but these are thin and overlain by bioturbated muddy sandstones. At Bucaco the equivalent mudstones are thicker, contain fossiliferous bands, and, especially at the base, seem to have been calcareous. These deposits are overlain at Bucaco by apparently unbioturbated mudstones with sharp-based siltstone beds, possibly of turbiditic origin. The lower part of the Ribeira do Laje Formation in the Penha Garcia syncline consists of dark mudstones with similar sharp-based intercalations to those at Buçaco. Some of these muds and silts show meandering surface trails including Nereites. These sediments seem to indicate an overall increase in depth of deposition from south to north, and to suggest that the depths involved were greater than those prevalent during the deposition of the sediments of phase "A".

The stage 1 succession indicates a shallowing of the depth of deposition, first with the spread of bioturbated muddy sandstones, and later with the appearance of sandstone beds with HCS. The top of the formation in the Dornes, Amendoa, Mação and Penha Garcia regions is marked by amalgamated, parallel-bedded quartzites with a possible shoreface aspect. In the Buçaco area

the equivalent deposits are truncated by the erosional base of the Ribeira Cimeira Formation, which cuts deeply into the previous sediments, probably even into the top of the Louredo Formation in places for the conglomerates contain clasts of the colitic ironstone horizon at the base of the Porto de Santa Anna Formation. Other material in the conglomeratic beds includes lavas and tuffs derived from the Porto de Santa Anna Formation. In the northwest of the Buçaco syncline the conglomerates lie directly on the volcanic deposits. The quartzites at the top of the regressive sequence further south (e.g Dornes) may also sporadically contain conglomeratic horizons. Both the top of the Serra do Amial Member and of the Ribeira Cimeira Member grade up into the Casal Carvalhal Formation with a thin interbedded sequence.

# b. Stage 2 - The tilloids and mudstones

These deposits overlie the top of the regressive sequence conformably, and apparently without any major break in deposition. The sediments of the earlier parts of the period consist of siltstones with isolated clasts. The clasts are of sandstone, colitic ironstone, silicified carbonates and are presumably of relatively local origin. Only in the upper member of the Sobredo Formation of the Valongo region (north Portugal) are clasts seen (granite) which cannot be matched with known strata in Portugal. Granite clasts are known from tilloidal beds (debris flow deposits?) in the upper part of the CXG of the Bucaco area, so even the pebbles from Valongo may possibly have an origin within the area. Even within the study area a great difference is seen between the nature of the pebbles at various

localities. At Buçaco they are almost entirely of a partly silicified decalcified limestone, with scattered chamosite ooids. This lithology occurs in the Leira Ma Member of the Rio Ceira Inlier, and although it has not yet been possible to identify any faunal elements in common, it would seem likely that the pebbles were derived from this horizon. A single pebble from the western limb of Bucaco is of a ferruginous sandstone, very close to the lithology of the Serra da Cadaveira Member. Further south (e.g at Dornes) however the clasts are predominantly sandstone and siltsone. The recognisable lithologies and local variation of clast type, suggest strongly that the clasts are of a local derivation. Similarly local derivation has been proposed for limestone and dolomite clasts in the Orea Formation, which overlies the eroded and karstified top of the Cystoid Limestone Formation in the Celtiberian Chain (Carls, 1975, Hafenrichter, 1980). The siltstones also contain small mudflakes and isolated rounded quartz grains. Similar quartz grains have been recorded from the Cosquer Formation and from the "Pélites à Fragments" Formation of Armorica (Hamoumi, Le Ribault and Pelhate, 1981).

These siltstones are massive, and weather spheroidally, giving a highly characteristic appearance at outcrop. Because of the lack of bedding within these deposits it is difficult to demonstrate conclusively the proposed dropstone origin for the clasts. The extremely isolated nature of the pebbles, the uniform nature of the siltstones, and the interbedding of the basal siltstones with the underlying sandstones and quartzites make a debris-flow origin for these tilloids very unlikely (cf. disussion in Dangeard and Doré, 1971). The basal deposits of this

phase in the Dornes and Amendoa regions also contain thick quartzite beds, which are highly load-casted into pillow structures.

The siltstones become progressively less pebbly upwards, and eventually pass into rather massive mudstones. The thickness of the siltstones varies from about 20m at Dornes, to about 30m at Buçaco, and further north to over 100m at Valongo. The overlying mudstones may contain further levels of spheroidally-weathering siltstones, but these rarely reach more than a few metres thick. The mudstone facies is unfortunately only well known in the Dornes region. Here it reaches 30-40m in thickness, gradually gaining thicker and more common sandstone intercalations. These start with laminae, often with delicate cross-lamination, but towards the top they form sandstone beds upto 30cm thick, often with load-casted bases. Eventually the sandstone beds are so frequent as to form a continuous sandstone formation; this forms the next phase of deposition.

# c. Stage 3 - The sandstones

The sandstones above the pelitic deposits described above form a widely recognised unit. They are thin (generally about 20m thick in the Dornes/Amendoa/Maçao area) and often pyritic. The sandstones show frequent load-casted horizons, some rippled surfaces, and are generally parallel laminated. The upper part of this unit in the Dornes/Amendoa/Maçao area consists of about 3m of finely laminated micaceous sandstones. The lower part of these contains an abundant graptolite fauna, but the higher parts are thoroughly bioturbated, and contain no body fossils. The

muddy sandstone with frequent mudstone clasts. This massive unitis about 3m thick. This sequence of laminated sandstones and muddy sandstones is overlain by organic-rich graptolitic mudstones. The base of the mudstones yields a graptolite fauna of upper Llandovery (griestoniensis zone) age, the muddy sandstones graptolites of middle to upper Llandovery age, and the fauna in the laminated sandstones is of lower Llandovery (atavus zone?) age. This indicates that 5 or 6 graptolite zones are represented by only 6m of sediments. This is in marked contrast to the underlying sediments which appear to have been deposited relatively rapidly.

# iii Discussion of phase "C" deposits

The beginning of phase "C" is marked by the change from carbonate to largely clastic sedimentation in the Bucaco area. The oldest phase "C" deposits do include some calcareous mudstones, and these yield a macrofauna, particularly brachiopods suggesting a relatively deep-water environment. Similar fauna occurs in the uppermost levels of the Porto de Santa Anna Formation in the north of the Bucaco syncline, but with additional elements suggesting a slightly shallower water origin. The disposition of phase "C" sediments around, and onlaping the thick volcanic deposits of phase "B" also indicates a topography inherited from the igneous episode. But the palaeotopography of the Bucaco region at any stage of phase "C" is very difficult to model. One major problem is to estimate the effect of the intrusion of the dolerite sills at shallow depth below the sea-

floor. The similarity of the faunas at the top of the Porto de Santa Anna Formation in the Louredo area and in the very south of the Buçaco syncline suggests that by the end of phase "B" the topography was subdued.

The essentially coarsening-upwards nature of the lower parts of the sequences of this age is attributed to the regression at the onset of the upper Ordovician glaciation. This would have lowered sea-level (e.g. Brenchley and Newell, 1980), and the top of the volcanic build-up presumably became emergent. The conglomeratic sandstones are seen as the products of the erosion of the emergent volcanics.

The tilloidal units can be seen as a transgressive deposit, with sea level rising as the ice cap melts. The apparently local origin of the dropstones suggests that there may have been glacial erosion within the study area. Previous attempts to explain the dropstones have tended to favour their derivation from icebergs rather than from a permanent ice sheet, but the ability of icebergs to erode and deposit debris locally is unproven. The existence of an ice sheet over the region seems much more plausible. If this sheet did exist then the melting process must be considered in more detail. During the early stages of melting fluvio-glacial processes might be expected. No deposits of this kind have been identified, although the channeled conglomeratic sandstones in parts of the Buçaco syncline, attributed above to emergence of the volcanic pile during the onset of glaciation, might be a possible candidate. However coarse fluvio-glacial melt facies would not be expected if during the earliest stages of melting eustatic sea-level rise Chapter 2. 102.

caused the decoupling of the ice-sheet from the sea floor. Examples of this process are known from the Ross Sea (Anderson et al. 1984).

The younger deposits of the phase suggest a slowing of the deposition rate. The quartzites of the Vale da Ursa Formation have a high organic and pyrite content, suggesting deposition in a restricted environment. It is possible that the period of deposition of these sands represents a period of subsidence on the shelf, with a very low rate of sediment input, and just relatively minor reworking of the sediments already on the shelf.

The resumption of major sediment input to the shelf in the upper Llandovery first produced the deposition of highly organic mudstones, but by the upper Wenlock sand grade clastic debris was again being moved across the shelf by storm activity. These deposits are rhythmic storm deposits, but snow more evidence of current action than those of the middle Ordovician. One possible explanation of this is that they were deposited in a slightly deeper environment where the effects of wave activity are reduced.

### CHAPTER 3 - BIOSTRATIGRAPHY

#### 1) Introduction

One of the main aims of this project has been to record the distribution of fauna in conjunction with a much more detailed study of the lithostratigraphy than has been attempted before. This has enabled the refinement and clarification of previous knowledge of the vertical ranges of many elements of the macrofauna. This chapter describes a series of macrofaunal biozones which are erected to allow correlation within the region. These zones are the result of the study of many different groups within the fauna. Trilobites and brachiopods are however the best-studied of these groups, and so it is their distribution which dominates the definition of the scheme.

A biostratigraphic scheme for correlation within the Ibero-Armorican area is highly desirable, for at present faunas are often referred directly to the international standard series and stages (e.g. Romano, 1982), or to the Bohemian regional stages (e.g. Gutierrez-Marco et al. 1984). Such attributions are often based on tradition and supposition as much as on "hard evidence". The establishment of a biozonal scheme would allow a more objective reference for faunas from the region, providing greater stability for stratigraphical studies. The positioning of the biozones on the international chronostratigraphic standard is thus a stage removed from the internal correlation of successions within the region.

A summary of the previous studies of the biostratigraphy of the Ordovician of Portugal was given in the review by Romano Chapter 3. 104.

(1982). One of the most important contributions to the understanding of the biostratigraphy of the region was the study of the chitinozoans of the Bucaco syncline by Paris (1979, 1981). In this study Paris erected a series of biozones which included much of the upper Ordovician. .. The sections studied by Paris have been reexamined in this project, allowing a close correlation between the chitinozoan biozones and parts of the macrofaunal biozonal scheme. Some important biostratigraphical studies have been undertaken in neighbouring regions. Foremost among these is the chapter on stratigraphy by Henry (1980 pp. 222-235), which indeed makes some reference to the biostratigraphy of the Bucaco syncline. He erected 4 faunizones and 4 biozones, recognised on basis of trilobites, within the "Llandeilo/Caradoc" the successions of Armorica. A further system of biozones was established by Gutierrez-Marco et al. (1984) in the Sierra Morena and Montes de Toledo, for the "Llanvirn/Llandeilo" of which the upper part coincides wih the lower horizons considered in this project.

# 2) A Macrofaunal Biozonal Scheme

# i Summary of the scheme

The macrofaunal biozones erected here cover most of the middle and upper Ordovician strata examined in this project. Only the topmost Ordovician has yielded no <u>in situ</u> macrofauna. The scheme is divided into 12 biozones, although these do not cover the entire succession. One of the biozones has been based on localities in Crozon, because the Portuguese faunas at this

horizon are rather poor. The boundaries of these biozones are often not yet located with a high degree of precision, and this reflects the logistical problem of providing adequate sampling cover over the whole of the central Portuguese Ordovician outcrop.

The Ordovician deposits of central Portugal tend to geographically widespread development of individual sedimentary facies at any given time (see chapters 2 and 5). This means that changes of fauna are often hard to resolve into evolutionary and ecological factors. It is therefore envisaged that as details of the upper Ordovician successions of other areas in western Europe become better known, and a greater variety of facies developments throughout the period are studied, so the potential refinement of a macrofaunal biozonal scheme will be increased.

To develop a series of biozones, the first step must be to select the basis on which the divisions can built. The characters usually thought to be desirable in "index" species include their wide geographical distribution with an ability to cross sedimentary facies boundaries (this usually means pelagic organisms are preferable to benthic ones), and a short, if possible geographically isochronous, total timespan, preferably due to rapid evolution within a single phylogeny. These parameters are hard to satisfy with the predominantly benthic faunas of the region. There are however a number of genera whose representative species occur widely in the Ibero-Armorican area, and it is to these that one must turn to seek the required index species. Such genera include the brachiopods Heterorthina, Aegiromena and Svobodaina with the trilobites Placoparia,

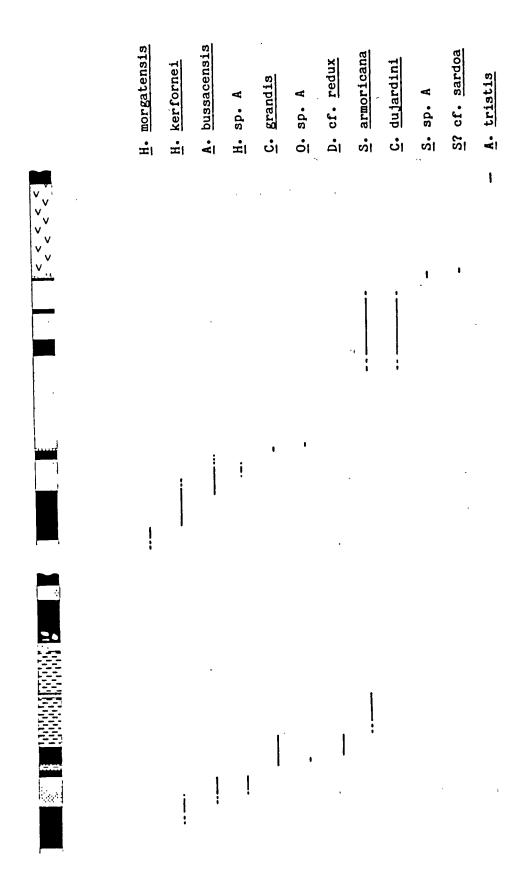


Figure 5. A range-chart for the biozonal index species of macrofauna, and other stratigraphically useful species. Upper chart for Buçaco, lower chart for Amendoa/Dornes/Mação. For explanation of the sections see tables 1 and 2.

## Crozonaspis and Deanaspis.

The biozonal scheme erected here has the following zones:

- 1. Total range Biozone of Heterorthina morgatensis Melou, 1974
- 2. Partial range Biozone of Heterorthina kerfornei Melou, 1974
- 3. Total range Biozone of <u>Placoparia</u> (<u>Coplacoparia</u>) <u>borni</u>
  Hammann, 1974
- 4. Concurrent range Biozone of Heterorthina n. sp. aff.

  kerfornei and Dalmanitina n. sp. aff. acuta Hammann, 1971
- 5. Local range Biozone of Onniella n. sp. A
- 6. Local range Biozone of <u>Drabovia</u> cf. redux (Barrande, 1848)
- 7. Total range Biozone of <u>Svobodaina</u> armoricana Babin and Melou,
  1972
- 8. Total range Biozone of Svobodaina sp. A
- 9. Total range Biozone of Strophomena? cf. sardoa Vinassa, 1927
- 10. Total range Biozone of Mcewanella? n. sp. A
- 11. Local range Biozone of Aegironetes tristis Havlicek, 1967
- 12. Local range Biozone of Plectothyrella sp. A

Where the index species is only or principally known from within the Ibero-Armorican region a total range biozone is indicated, otherwise a local range biozone is employed. Zone 2 and Zone 4 are based on a partial and a concurrent biozone respectively. The ranges of the index species, and other biostratigraphically important species, are illustrated in fig. 5.

The problems of the narrow range of facies available for examination in each of these zones is illustated by the table

below which indicates the facies from which faunas have been obtained during the present research:

	Mudstone	Storm sands	Oolitic	Carbonate/"Bryozoa	bed"
	Facies	Facies	Ironstone	Facies	
Zone					
1	X				
2	X				
. د	X	<b>X</b> ,.	Х		
4	X				
5			X		
b				X	
7	X	X			
ช '			X		
y				X	
10		,		X	
11				X	
12	X	,			

The problems of assessing possible facies control of faunas, together with the uncertainties due to the rather coarse sampling resolution over much of the succession, mean that this zonal system must not be regarded as more than a working model: a basis on which future refinement can be built, and within which many gaps remain to be filled.

- ii Descriptions of the macrofaunal zones.
- a. Zone 1: Heterorthina morgatensis Biozone.

This zone lies at the base of the sequence studied, and together with Zone 2 has not received a full investigation in this project. Parts of the zone have been examined in the Buçaco

and Penha Garcia synclines.

Basis of the zone - The index species for this zone is Heterorthina morgatensis Melou, 1974. The zone is defined as the total range of this species.

Limits of the zone - The index species may first appear below the Monte da Sombadeira Formation, in the upper part of the Brejo Fundeiro Formation (e.g. at Cacemes, in the Buçaco syncline, pers. obs.) and in the upper part of the lower member of the Postolonnec Formation (e.g. at Le Veryac'h, pers. obs., and pers. comm. Melou, 1982). The detailed analysis of the first appearance of the index species, and therefore the base of the zone is outside the scope of the present study. The top of the zone is marked by the replacement of H. morgatensis by H. kerfornei.

Discussion - The first appearance of P. (C.) tournemini is probably within Zone 1, as is the appearance of Crozonaspis struvei Henry 1968, and therefore the bases of the biozones of P. (C.) tournemini and C. struvei. (both sensu Henry 1980) lie within this zone.

# b. Zone 2: Heterorthina kerfornei Biozone.

Basis of the zone - Zone 2 is characterised by the prescence of <u>Heterorthina kerfornei</u> Melou, 1974, with the trilobite <u>Placoparia</u> (<u>Coplacoparia</u>) tournemini (Rouault, 1847).

Limits of the zone - The base of the zone is defined as the appearance of  $\underline{H}$ . kerfornei, and it is possible that this may occur before the disappearance of the last representatives of  $\underline{H}$ . morgatensis (Melou, pers. comm., 1952). If this overlap does

occur, and it is by no means certain, then it must be very short-lived. The upper limit of <u>H. kerfornei</u> is still unknown. Specimens of <u>Heterorthina</u> from within the range of <u>Marrolithus</u> <u>bureaui</u> are referred to <u>H. n. sp. A</u>, as are specimens from lower in Zone 3. Specimens from the very base of Zone 3 from the Buçaco syncline are still referable to <u>H. kerfornei</u>.

In Brittany the zone lies in the upper part of the biozone of Placoparia (Coplacoparia) tournemini (Rouault, 1847) sensu Henry, 1980. The top of Zone 2 is marked by the appearance of  $\underline{P}$ . ( $\underline{C}$ .) borni. This probably occurs with a slight degree of overlap with the range of P. (C.) tournemini (see Henry 1980, especially fig. 93). To date Placoparia from the Fonte da Horta Formation in Portugal has not been sufficiently well preserved for specific identification, but as in Brittany the levels with Apollonorthis contain much more abundant Placoparia than the lower parts of the sequence. In Brittany the change in abundance of Placoparia is associated with the change from tournemini to borni. This change in the trilobite fauna occurs at almost the same horizon as the appearance of the brachiopod Apollonorthis bussacensis (Sharpe, 1853). Indeed, at the present state of knowledge, whether A. bussacensis or P. (C.) borni appears first is not resolvable. It seems likely that in the Postolonnec Formation only a few metres separates these events, since P.(C.) tournemini, P. (C.) borni and A. bussacensis all occur in the material from the foundations of the villa "Les Atlantes" (Babin et al. 1976). The change in the species of Placoparia present is taken as the definition of the upper boundary of the biozone, for this might potentially allow correlation between the central and

northern Portuguese facies (Apollonorthis has not been recovered from the Valongo Formation), in other words between the developments of the <u>Placoparia</u> and <u>Praeleda</u> associations (see below chapter 4).

Discussion - The biozone of <u>Crozonaspis struvei</u> (<u>sensu Henry</u> 1980) includes Zone 2 of this scheme, and ranges both down into the upper part of Zone 1, and up into the lower part of Zone 3. The faunizone of <u>Morgatia hupei</u> (<u>sensu Henry ibid</u>.) overlaps the Zone 2/Zone 3 boundary, apparently including within it the zone of overlap of  $\underline{P}$ . ( $\underline{C}$ .) <u>tournemini</u> and <u>borni</u>.

## c. Zone 3: Placoparia (Coplacoparia) borni Biozone.

Basis of the zone - The characteristic species of this zone is  $\underline{P} \cdot (\underline{C} \cdot)$  borni. At present no difference has been resolved in the range of the index species and  $\underline{A} \cdot$  bussacensis, but the definition of the zone as the interval from the first appearance of  $\underline{P} \cdot (\underline{C} \cdot)$  borni to the first appearance of  $\underline{Dalmanitina}$  ( $\underline{Dalmanitina}$ ) n. sp. aff. acuta Hammann, 1977 will be adopted here.

Limits of the zone - The base of the zone is defined as the appearance of P. (C.) borni Hammann, 1971, as discussed above. The top of the zone is formed by the top of the Marrolithus bureaui zone (sensu Henry 1969,1980). The succession through the Zone 3/Zone 4 boundary appears to be continuous in the Crozon peninsula, and the fauna of the M. bureaui zone is replaced by a low diversity fauna of Zone 4 above the last of the phosphatised coquinoid layers. In central Portugal M. bureaui has not been

found, and the sedimentary facies close to the Zone 3/Zone 4 boundary suggest that it is disconformable, with the  $\underline{M}$ . bureaui biozone missing.

Discussion - The problem of the absence of specifically identifiable <u>Placoparia</u> from this horizon in central Portugal has been discussed above under Zone 2. In practice this means that the identification of this zone in the study area has been based on the prescence of <u>Apollonorthis bussacensis</u> (Sharpe), which seems to have a range very close to that of <u>P</u>.

The fauna from the M. bureaui zone in the Le Veryac'h section probably only contains one element not present in lower zone 3 faunas: M. bureaui itself. For this reason it does not seem advisable to erect a zone in the present scheme based on the biozone of M. bureaui (sensu Henry 1969,1980). This biozone will obviously still have immense use in correlation, even if it not accorded full zonal status in this scheme.

d. Zone 4: <u>Dalmanitina</u> n. sp. aff. <u>acuta/Heterorthina</u> n. sp. aff. kerfornei Biozone.

Basis of the zone - The range of co-occurrence of <u>Dalmanitina</u> (<u>Dalmanitina</u>) n. sp. aff. <u>acuta</u> Hammann, 1971 and <u>Heterorthina</u> n. sp. aff. kerfornei is used to define this zone.

Limits of the zone - Both these forms first occur above the biozone of Marrolithus bureaui in the sections of Le Veryac'h and Postolonnec. The details of the appearance of these forms are not known at present, partly because faunas are very sparse at this

horizon, and partly because the specimens from the mudstones are very poorly preserved. In Portugal both forms appear abruptly at the base of the Carregueira Formation, but as detailed elsewhere this contact is disconformable. The first appearance of  $\underline{D}$ . ( $\underline{D}$ .) n. sp. aff. acuta is defined as the base of the zone.

The problems over the definition of the base of this zone are mirrored by the problems with the definition of the top. The base of Zone 5 is defined as the incoming of a faunal element which occurs first in the colitic ironstone at the base of the Sanguinheira Group. This definition of the zonal boundary is adopted because the specific identification of Dalmanitina in the lower part of the Sanguinheira Group (Zone 6) is uncertain. It is possible therefore that D. (D.) n. sp. aff. acuta has a longer range than demonstrated at present. In contrast the range of H. n. sp. aff. kerfornei is better defined, for it occurs upto, but not above the base of the colitic ironstone horizon.

Paris (1981, p. 321) suggested that the colitic ironstone rested with considerable unconformity on the mudstones of Zone 4. He demonstrated that nodules within the colitic ironstone contain a different microfauna from the rest of the ironstone. His suggestion was that the nodules were derived by winnowing, during erosion of the underlying mudstones. As further evidence he cited the fact that different microfaunal zones were represented at the top of the mudstone at different localities. In this study however, the graptolite Climacograptus bekkeri Opik, 1927 has been found repeatedly in the upper part of the Carregueira Formation in the area studied by Paris at Buçaco. In the same sections as Paris studied this graptolite occurs particularly in

a single rich horizon, about 2cm thick, just below the top of the Carregueira Formation. This occurs at distances of 1.08-1.20m below the base of the colitic horizon in the Buçaco area, and in the Dornes and Amendoa areas a similar rich horizon occurs at 1.2m below the Favaçal Bed. Although the identification of these occurrences as representing a single event can only be tentative, the coincidence of these localities does strongly suggest that they do. If this is so, then it implies that if erosion did occur before the deposition of the Favaçal Bed then it must have been uniform. This in turn would imply that only a small amount of erosion would be likely, since major erosion would be unlikely to produce a planar surface.

The problems of the details of the top of the zone, and its relationship with the succeeding Zone 5, are however simplified by the fact that no Zone 4 macrofauna has been found in the nodules of the oolitic horizon. The break in the faunal succession between the zones is sharp. At present Colpocoryphe grandis (Snadjr, 1956) is the only element of the macrofauna known to cross the zonal boundary in the Portuguese sequences.

Discussion - This zone is important for the earliest deposits generally referred to the Caradoc in the Ibero-Armorican region, contain its characteristic fauna. This particular question will be addressed further in chapter 5. One aspect of the zone which must be emphasised here is the sequence of appearance of the fauna within the zone. Dalmanitina (D.) n. sp. aff. acuta, Crozonaspis chauveli, and Heterorthina n. sp. aff. kerfornei all appear in the lowest deposits of the zone in Portugal, and probably at the very base of the zone in Brittany. All these

forms seem to continue through to the top, although <u>C. chauveli</u> is rare towards the top. Two other elements of the fauna of this zone appear in the upper part of the zone: <u>Colpocoryphe grandis</u> and <u>Tyronella?</u> n. sp. A. These new elements seem to herald the apearance of the fauna of Zone 5. The graptolite <u>Climacograptus bekkeri</u> has been found as detailed above within the range of <u>Colpocoryphe grandis</u>, but also occurs lower down the sequence, in the beds with <u>Crozonaspis chauveli</u>. At all localities where this zone zone is recognised it contains a characteristic low-diversity fauna, the <u>Praeleda</u> association (phase 2) (see below chapter 4).

### e. Zone 5: Onniella n. sp. A Biozone.

Basis of the zone - This zone is characterised by Onniella sp. A, and comprises the known range of this species.

Limits of the zone - The nature of the base of this zone has been described in detail above. The index species occurs sporadically but persistently in the collitic ironstones of the Buçaco and Dornes areas. The lack of records of this species from the Amendoa and Mação areas probably reflects failure of collection, rather than absence. The top of the zone may still lie within the Favaçal Bed in the study area. No later fauna has been recovered immediately above the bed in its type area, in the Buçaco syncline. In the Dornes area fauna does occur in the upper, rather more clastic, layers of the bed, and just above it, and this is markedly different from that within the main colitic horizon. In particular Onniella n. sp. A has not been recorded

amongst this fauna. The characteristic species of Zone 6 <u>Drabovia</u> cf. <u>redux</u> (Barrande, 1848) does not however occur until several metres higher, above a further slightly colitic horizon, and thus possibly separated by a stratigraphic break. This raises a slight problem with the definition of the top of the zone. Until further study of the fauna of this interval (that between the Favaçal Bed and the Queixopeira Member, in terms of the lithostratigraphy of the Dornes area), that fauna will be placed in an interregnum between Zones 5 and 6.

Discussion - The recognition of the macrofauna of this zone is very important in correlation. This is partly due to the possibilities for long-distance correlation of the colitic facies itself, and partly because of the very precise dating suggested by the microfauna (Paris 1979, 1981, Henry and Thadeu 1971) from the Favaçal Bed in the Buçaco syncline and its homologue in Crozon (see chapter 5).

# f. Zone 6: <u>Drabovia cf. redux</u> Biozone.

Basis of the zone - This zone is based on the total range of Drabovia cf. redux (Barrande, 1848) in central Portugal.

Limits of the zone - The base of the zone has been discussed above, and probably does not directly follow Zone 5. The upper limit of the zone is represented by the disappearance of the index species from the study area. This is however related to facies change, so the total range of the index species is unknown.

Discussion - The difference in facies between the two main

developments of the Sanguinheira Group (the Louredo and Cabeço do Peão Formations) results in problems of recognising Zones 6 and 7 across the study area. The characteristic faunas of Zone 6 are closely related to the "bryozoa bed" facies (Cooper 1980), with its fauna of the <u>Drabovia</u> of redux association (see chapter 4), which is restricted to the Queixopeira Member, and this has only been recognised so far in the Dornes/Amendoa/Mação region. The faunas referred to Zone 7 are those of the <u>Calymenella</u> and Praeleda (phase 3) associations.

The museum of the "Serviços Geològicos" in Lisboa contains specimens of Blyskavomena cf. blyskavensis, and Rostricellula? sp. A (species known from the D. cf. redux association) from the lower part of the Louredo Formation of Buçaco. These specimens are from below the Vale Saido Member, and from below the first occurrence of Svobodaina armoricana in the syncline. In the southern part of the Buçaco syncline at Albegeria there is a thin intercalation of "bryozoa bed" facies in the lower part of the Louredo Formation, which yields the index species for this zone.

In the Cabeço do Peão Formation Svobodaina armoricana also occurs, but a considerable distance above the last occurrence of Drabovia cf. redux. This seems to suggest that although the faunas associated with Zones ó and 7 are to some extent facies-related, the zones do not overlap chronologically. The lack of continuity in fossiliferous sequences across the Zone 6/Zone 7 boundary means that the two zones cannot be considered as sequential, but until further faunas are found, the two zones remain separated in the scheme.

As outlined above the index species of the zone is part of a

facies-related fauna, but in Bohemia the genus <u>Drabovia</u> occurs in wide range of facies. The possibilities for correlation of this zone are unknown at present as there are no fossiliferous deposits which can be attributed to this zone outside central Portugal. Those sequences which contain deposits which can be attributed to this zone in other areas are unfossiliferous.

# g. Zone 7: Svobodaina armoricana Biozone.

Basis of the zone - The zone is based on the total range of the brachiopod Syobodaina armoricana Babin and Melou, 1972.

Limits of the zone - The base of the zone has been referred to above. Whether the first appearance of the index species is synchronous in the Louredo and Cabeço do Peão Formations is uncertain. The upper limit of the zone is not accurately defined (see below the definition of the base of Zone 8).

Discussion - The accompanying fauna in the two formations is very different, allowing correlation between the two facies. In the mudstones of the Louredo Formation S. armoricana is accompanied by the trilobites Dalmanitina (Dalmanitina) philippoti Henry, 1980, Crozonaspis dujardini (Rouault, 1847) and Plaesiacomia n. sp. aff rara Hawle and Corda, 1847, together with several bivalves, gastropods and ostracodes (the Praeleda association phase 3 of chapter 4). The bioturbated sandstones of the Cabeço do Peão Formation however yield Scotiella taouzensis and Calymenella of. boiselli at the horizons with S. armoricana (the Calymenella association of chapter 4).

h. Zone d: Svobodaina n. sp. A Biozone.

Basis of the zone - This zone is defined as the total range biozone of Svobodaina n. sp. A.

Limits of the zone - The base of the zone has only been studied in the Buçaco syncline. Here the first appearance of the index species recorded is in the collitic ironstone at the base of the Porto de Santa Anna Formation. The top of the zone has not been recorded in any of the sections in Portugal, where the species occurs in the Leira Ma Member, but not in the Poiares Member. In Brittany the species is found in the basal beds of the Rosan Formation, but does not occur more than about 1m above the collitic horizon.

Discussion - This zone may follow the previous zone only with a break. Similar problems to those encountered with the Zone 4/Zone 5 boundary are reported by Paris (1979,1981). An apparently remanie microfauna in the nodules of the colitic horizon was recorded, and a stratigraphic break between the Galhano and Leira Ma Members suggested. The top of the zone does appear to be followed directly by deposits with a Zone 9 fauna in Brittany, but in Portugal no continuously fossiliferous sequences are known. Thus the detailed distribution of the index species of Zones 8 and 9 across the zonal boundary has not yet been clarified.

# i. Zone 9: Strophomena? cf. sardoa Vinassa, 1927 biozone.

Basis of the zone - This zone is defined as the total range

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of  $\underline{S}$ .? cf.  $\underline{sardoa}$ . This species is a persistent element of faunas towards the base of the Rosan and Ferradosa Formations.

Limits of the zone - As discussed above the base of the zone has not been clarified in detail. The top of the zone is even more poorly known. The index species occurs at Aber upto the base of the unfossiliferous tuffs, occurs at Coat Garrec beneath the volcanics, and in Portugal it is known from the Poiares Member, but not from the Riba de Cima Member. Thus at present no fossiliferous sections are known which demonstrate the top of the zone.

#### j. Zone 9/10 Interregnum

Above the range of S.? cf. sardoa at Poiares there is an interval (probably about 4m) in which brachiopods are not as frequent as immediately below. The fauna of this interval includes several brachiopods and echinoderms known from Zone 9, as well as a great abundance of Bicuspina sp. A. This interval is overlain by the largely unfossiliferous dolomites of the Riba de Cima Member. This member does however yield, at Poiares, a rare fauna some 15m above its base, which is tentatively referred to Zone 10. The beds with a reduced fauna, including the absence of S.? cf. sardoa, contain no fauna conclusively indicative of Zone 10, so these beds are referred to an interregnum between Zones 9 and 10. This interval would correspond to the bulk of the unfossiliferous volcaniclastics of the Porto de Santa Anna Fm..

Further north in the Buçaco syncline there are silicified rottenstones (e.g. at Cabeço Pedrogão) with a diverse, but

poorly preserved fauna, which it has not been possible to place into any of the zones recognised here. The geometrical position of these rottenstones might suggest attribution to Zone 10, or the Zone 9/10 interregnum.

# k. Zone 10: Mcewanella? n. sp. A Biozone.

Basis of the zone - The index species for this zone,

Mcewanella? n. sp. A is only known at present from Brittany. The

zone is not yet recognised in Portugal.

Limits of the zone - The zone is based on the fauna of two localities: the calcareous tuffs at the top of the Rosan section, and the interstitial limestone of the Lostmarc'h pillow lavas. Thus neither the top nor bottom of the zone has been defined within continuously fossiliferous sections.

The faunas of this zone are distinctive both in their taxonomic elements, and in the large size of individuals of many of the brachiopod species found within the zone (<u>Dolerorthis</u>, <u>Nicollela</u>, <u>Hedstroemina</u>, <u>Porambonites</u>).

# i. Zone 11: Aegironetes tristis Biozone.

Basis of the zone - The zone is based on the local range of the index species.

Limits of the zone - The base of the zone has not been located within a continuous sequence. The index species has been found within the top few metres of the Porto de Santa Anna Formation, in the northern part of the Buçaco syncline. These

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beds overlie strata with a fauna tentatively atttributed to Zone 10. The upper limit of the zone is more precisely known although not in a single section. A zone 11 fauna has been recovered from the rottenstones below the the Ribeiro do Braçal Formation in the track-cutting in the Rio Ceira section. The base of the Ribeiro do Braçal Formation in the cutting has only yielded a single specimen of Plectothyrella, but an abundant Zone 12 fauna is known from the same horizon 50m to the north. At this second locality however, the underlying deposits of the Porto de Santa Anna Formation do not yield the Zone 11 fauna.

### 1. Zone 12: Plectothyrella sp. A Biozone

Basis of the zone - This zone is based on the local range of the index species.

Limits of the zone - The base of the zone is discussed above with the top of the <u>Aegironetes tristis</u> Biozone. As suggested above the faunal changes on the boundary may well be facies controlled. The top of the zone is poorly defined, for fauna disappears above this zone. The interval occupied by this zone in the sediments of the Ribeiro do Braçal Formation is only 0.5m at Rio Ceira and less than 2m near the Rio Mondego.

Discussion - At present knowledge of this zone is limited to two sections, both in the southern part of the Bucaco syncline, but about 7 km apart. The similarity of the fauna in the two occurrences, and its marked difference from the underlying Zone 11 fauna, makes a separate zone desirable despite the current paucity of information. The fauna of this zone includes only 3

articulate brachiopods, several poorly preserved inarticulates, an ostracode, and at least two crinoids. None of the articulate brachiopods (the best known elements of the fauna) have been recorded amongst the larger Zone 11 brachiopod fauna.

### 3) International Correlation of the Macrofaunal Biozones

#### i Introduction

The correlation of the zonal scheme cannot be undertaken directly, for none of the species studied in Portugal is known from the standard sequences in Britain. Two routes for indirect correlation do exist however. The first of these involves the use of the shelly fauna to correlate with other European Ordovician successions, which can in turn be correlated with the standard. The second method relies on the studies of the microfauna of the deposits in the Buçaco syncline (Elaouad-Debbaj, 1979, Henry et al. 1974, Henry and Thadeu, 1971, Paris, 1979 and 1981). These studies have suggested possible ages with respect to the standard for various parts of the Buçaco succession. The ages have mainly been derived by indirect routes, paricularly by reference to sequences on the Balto-Scandian platform.

The study of the shelly fauna with respect to other Mediterranean Province areas suffers from the problem that the correlation of even the best-known of these areas, the Barrandian region (Bohemia, Czechoslovakia), with the Anglo-Welsh standard sequences itself suffers from many questions and ambiguities. The use of the microfauna as an intermediate stage in correlation

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equally suffers from the problem that the microfauna (particularly chitinozoans) of the Anglo-Welsh type-sequences remains very poorly known.

# ii Correlation of macrofaunal with the chitinozoan zones

The correlation of these two biozonal systems has been attempted in the Buçaco syncline. The resulting scheme is illustrated in fig. 6. It has been possible in some cases to improve the resolution of Paris's zonal boundaries since lithological correlation between the sections used by Paris has been refined in this study. In any reference to Paris's zones they will be prefixed by "C" to avoid confusion with the macrofaunal zones erected in this chapter.

#### iii International correlation of the macrofaunal Biozones

Correlation of the biozones erected in this chapter with the international standard can be attempted via correlation with other European areas using both macro and microfaunal evidence. Both means of correlation are considered together here.

#### a. Zone 1

The boundary between Paris Zones C8 and C9 is rather poorly localised, and is indeed well below the lowest strata examined in this project. From the available evidence (Paris, 1981 and pers. obs.) it would seem that the appearance of Heterorthina

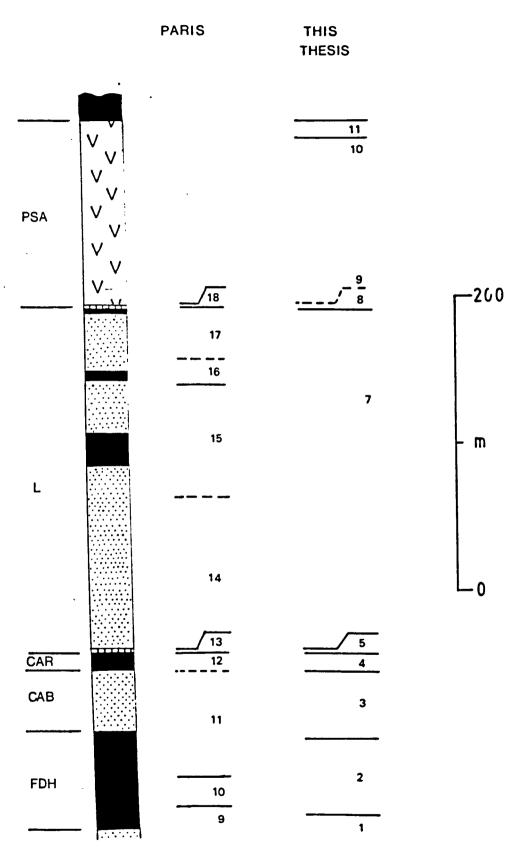


Figure b. Correlation between the macrofaunal biozones and the biozones based on chitinozoans (Paris, 1980) for the northern part of the Buçaco syncline

morgatensis is only a short distance (less than 20m?) above the last levels with <u>Didymograptus</u> <u>murchisoni</u>. The zonal boundary of C8/C9 probably lies not far from the base of Zone 1, which accordingly would seem to lie entirely within Zone C9. No graptolites are known from deposits of Zone 1. Paris did not provide any direct correlation of the chitinozoans.

The lower part of Zone 1 in Brittany (beneath the Gres de Kerarvail), has yielded a fauna of conodonts (Lindstrom et al. 1974). The age of this fauna was tentatively ascribed to close to, but (?) above, the teretiusculus/gracilis zonal boundary. This was based largely on the interpretation of the position of the elements found in hypothetical evolutionary sequences between previously discovered forms. Only one species previously recorded in Europe was identified in the study; Amorphagnathus inaequalis, known from the teretiusculus and (?) the lower part of the gracilis Zone of Wales. Distomodus? tamarae, known fron approximately the teretiusculus/gracilis boundary in Siberia was also found. The age given to this fauna was discussed by Henry (1980a, pp. 227-228), who points out that the different elements imply different ages, and the weight placed on each of these affects the estimate of age. Hence a lower Llandeilo age (teretiusculus zone) is not inconceivable for the conodont fauna.

### b. Zone 2

The appearance of <u>Heterorthina kerfornei</u> occurs within zone C9. The C9/C10 boundary lies within Zone 2, and the C10/C11

boundary close to the top of Zone 2. The zonal chitinozoans of this zone, and the zones above and below, have not been recovered from either Britain or Scandanavia, but the lower Llandeilo deposits of these regions do have many of the accessory species in common.

Graptolites have been recorded at several horizons within the zone (Henry et al., 1977, Paris, 1981). These authors recorded Gymnograptus linnarssoni Tullberg MS (Moberg) from the lower parts of Zone 2 and Glyptograptus cf. cernuus Jaanusson and ?Orthograptus propinquus (Hadding) from the top of the zone. On thebasis of these forms a lower Llandeilo age was ascribed. The interpretation of these graptolites is not, however, without problems. The material of ?0. propinguus is very poorly preserved. Henry et al. indicate (ibid. p. 277) that the dimensions of Gymnograptus from Bucaco do not coincide exactly with those of the Scandanavian material of G. linnarssoni. In a recent review of fauna from Bolivia, Finney and Branisa (1984) reject the Portuguese specimens from linnarssoni, prefering to refer the material to Lasiograptus. The problems of the identification of Glyptograptus cf. cernuus are discussed by Henry et al. (ibid.); the type material of Jaanusson is an incomplete rhabdosome. The evidence, therefore, on which to assign an age to this graptolite fauna is rather tenuous. In Scandanavia Glyptograptus cernuus occurs in the teretiusculus Zone, Gymnograptus linnarssoni in the lower part of the teretiusculus Zone, and Orthograptus propinquus <u>Didymograptus</u> <u>murchisoni</u> Zone to the <u>teretiusculus</u> Zone. The simplest solution, as adopted by Henry et al. (ibid.), is to Chapter 3. 128.

accept the graptolites as a fauna of <u>teretiusculus</u> Zone age. The uncertainties should not, however, be overlooked.

The shelly fauna allows correlation with the Armorican Massif (upper parts of the Postolonnec, Andouillé, and Pissot Formations) and with many parts of Spain. There is little to compare at specific level in the shelly faunas of Bohemia, or of Morocco.

#### c. Zone 3

The details of faunal distributions within Zone 3 are rather uncertain, largely because of the unfossiliferous nature of the storm-sands facies of the age in southern-central Portugal and in Crozon. Paris obtained only limited chitinozoan data for this interval. The zone seems to fall broadly into Zone C11, with the C10/C11 boundary close to the Zone 2/3 boundary. The position of the C11/C12 boundary is uncertain, indeed Paris records an assemblage with Lagenochitina ponceti from the Marrolithus bureaui Biozone of La Touche, and from a mudstone intercalation in the sandstones of the Tertre Chapon Formation, Domfront. This fauna shows some affinities with the Zone C12 fauna, without actually being referable to that zone.

The base of Zone 3 yields <u>Glyptograptus teretiusculus</u> at Bucaco according to Henry <u>et al</u>. (1977). The problems of accurately assigning species and ages to representatives of <u>Glyptograptus</u> are considerable, but the Buçaco material compares well with that from the Oslo region, according to these authors.

Two taxa from Zone 3 are known from the Dobrotivá Formation

of Bohemia; the zonal trilobite, <u>Placoparia</u> (<u>Coplacoparia</u>) <u>borni</u> (see Horbinger and Vanek, 1980), and the index chitinozoan from Zone C11, <u>Linochitina pissotensis</u> (see Paris, 1981). The occurrence of <u>P</u>. (<u>P</u>.) <u>borni</u> in Bohemia is at the top of the Dobrotivá Formation, within the upper part of the Bohemian graptolite zone of <u>Cryptograptus</u> <u>tricornis</u> (Horbinger and Vanek, 1980), which overlies the Bohemian range of <u>Glyptograptus</u> <u>teretiusculus</u> in the lower part of the Dobrotivá Formation (Havlicek and Vanek, 1966). The lack of overlap between <u>G</u>. <u>teretiusculus</u> and <u>P</u>. (<u>C</u>.) <u>borni</u> in Bohemia is in contrast to their co-occurrence in the Ibero-Armorican area (assuming the correct identification of this species in Portugal).

The shelly fauna of the zone is very similar to that of Zone 2, but there are some differences. Plaesiacomia oehlerti becomes much rarer in this zone in Brittany, and is absent in Portugal. The Faunizone of Morgatia hupei and the Biozone of Crozonaspis struvei (both sensu Henry, 1980) straddle the Zone 2/3 boundary, but neither of these trilobites occurs in later parts of Zone 3, including the Marrolithus bureaui Biozone. The appearance of Marrolithus bureaui represents the arrival of the first trinucleid in the Ibero-Armorican region, although earlier trinucleids are known from other Mediterranean areas (e.g. Montagne Noire and Bohemia - Dean 1966b, Havlicek and Vanek, 1966). In England and Wales Marrolithus is not known from post-Costonian strata (Thomas et al., 1984), and in Bohemia the genus occurs only in the Liben (Dobrotivá?) to Zahořany Formations.

The evidence for correlation of this zone is thus rather

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sparse, but it seems likely the base may still be within the teretiusculus Zone, while the upper parts range up into the gracilis zone. The age of the Marrolithus bureaui Biozone is uncertain, but the conventional view that it is still within the Llandeilo is not unreasonable.

#### d. Zone 4

The macrofaunas faunas of Zone 4 are markedly different from those of Zone 3. The chitinozoan faunas also show a major change (e.g. Paris, 1981, table 19). Sedimentological evidence is presented elsewhere in this study that the base of the deposits of this zone in central Portugal may be disconformable on Zone 3 deposits. The chitinozoan fauna of Zone 4 belongs to Zone C12. This fauna includes rare Cyathochitina kuckersiana, which first appears in the Kukruse stage of Estonia and in the lower Caradoc of Shropshire. The macrofauna also includes some elements with correlation potential; it includes the first appearance of the trilobite subgenus Dalmanitina (Dalmanitina) (the first appearance of D. (D.) is in the Liben Formation in Bohemia with cilinensis and in the Lower Ktaoua Formation in Morocco with socialis), and also the species Colpocoryphe grandis which is known from the lower Caradoc of Morocco (Lower Ktaoua Formation; Destombes, 1966), Turkey (Lower Shale Member, Bedinan Formation; Dean, 1984), Armorica (Henry, 1980a) and Bohemia (Šnadjr, 1956; where the species may occur as low as the Llandeilo).

The zone also yields <u>Climacograptus</u> <u>bekkeri</u>, a graptolite kown from the Kukruse Stage of Estonia and the <u>Ludibundus</u> Beds

(Jaanusson, 1960, Strachan, 1959). These occurrences are of gracilis Zone age. The balance of evidence would therefore suggest that this zone belongs to the Caradoc part of the gracilis Zone.

This still leaves the problem of where the base of the Caradoc lies within the sequences studied. The detailed study of the microfauna within Zones 3 and 4 in the apparently continuous sequences in Brittany will be needed to attempt to resolve this.

### e. Zone 5

The macrofauna of Zone 5 is more difficult to relate to contemporary microfauna than the other zones. This is because the oblitic ironstone yielding the Zone 5 fauna, the Favacal Bed, yields a variety of microfauna. Nodules from this bed yield faunas of Zones C12 and C13, while the matrix of the ironstone yields a C14 microfauna.

The macrofauna only includes one element which occurs in the faunas of Zone 4; the trilobite Colpocoryphe grandis, and this form continues up into Zone 6. The fauna also includes the first appearance of the genus Deanaspis, with a form referred to Deanaspis seunesi. The first appearance of Deanaspis in Bohemia is goldfussi in the Liben Formation.

The C12 microfauna has been discussed above. The succeeding C13 fauna is essentially the same but for the prescence of Lagenochitina dalbyensis. Indeed this species has been recognised by Paris from the top of the Zone 4 deposits. The index species of Zone C13 is Lagenochitina dalbyensis, known from the middle

part of the Dalby Formation in Sweden and the base if the Idaverian in Estonia. These occurrences correspond to a position very close to the <a href="mailto:gracilis/multidens">gracilis/multidens</a> zonal boundary (top Costonian or lower Harnagian).

The macrofauna does occur in nodules, but these are not usually the most highly phosphatic nodules. The detailed correlation between the macro and microfauna is not available. Much of the macrofauna (including all the specimens of Aegiromena of aquila praecursor recovered to date from the Favaçal Bed) does, however, occur within the colitic matrix of the bed. This matrix yielded to Paris (1981) a Zone C14 microfauna. This microfaunal zone is very poorly dated but Paris indicates that Sphaerochitina actonica from the Actonian is close to the index species.

The brachiopods of the Zone 5 fauna include Aegiromena cf. aquila praecursor and Gelidorthis cf. praepartita. The Bohemian species with which these two forms are compared occur together in the upper part of the Letná Formation.

### f. Zone 6

The brachiopod faunas which typify this zone in the Dornes/
Mação area of central Portugal, are only poorly represented in
the Buçaco syncline, so direct correlation with the chitinozoan
zones is somewhat tentative. The brachiopods (Blyskavomena cf.
blyskavensis, Drabovia cf. redux, Gelidorthis cf. partita,
Saukrodictya sp. A and Aegiromena cf. aquila praecursor) suggest
a correlation with the topmost part of the Letná Formation of

Bohemia. These forms, however, do seem to be strongly faciescontrolled in their Bohemian distribution.

The Zone 6 deposits yield a rich trilobite fauna with Deanaspis seunesi, Eccoptochile of clavigera, Echarpes macaoensis, Prionocheilus of pulcher, Eudolatites sp. A, Phacopidina? sp. A, Selenopeltis sp., Actinopeltis sp., Dalmanitina? sp., Dysplanus sp. and Colpocoryphe grandis. This fauna suggests a correlation with the Vinice Formation of Bohemia.

The rare occurrences of <u>B</u>. cf. <u>blyskavensis</u> are from near the base of the Vale Saido Member (possibly just below it - bed 15 of the Vale San Jorge section of Delgado, 1908, p. 40), this is close to the Zone C14/C15 boundary, and the species occurs with the index species of Zone 7, <u>Svobodaina</u> armoricana.

The faunas of Zone 6 would therefore seem to be of a broadly equivalent age to the Zone C14 microfauna, with a slight possibility of continuing into the base of Zone C15. the apparent coexistence of S. armoricana and B. blyskavensis raises the problem of correlation between the upper part of Zone 6, based on the Mação/Dornes area, with the base of Zone 7, based on the first appearance of S. armoricana in the Buçaco syncline. At present this has yet to be resolved.

Zone C14 faunas are known from the lower part of the Pont-de-Caen Formation, the Sangsurière Formation, the lower part of the St.-Germain-sur-Ille Formation, and the lower part of the Kermeur Formation (according to Paris, 1981).

#### g. Zone 7

The index species of this zone has been recorded from the Vale Saido, Zuvinhal and probably the Galhano Members of the Louredo Formation. These members have microfaunas of Zones C15, C16 and C17 respectively. Paris (1979,1981) has summarised the evidence for the age of these zones. Zone C15 is characterised by Rabdochitina? cf. gallica, a species which possibly occurs in the Gelli-grîn Group (Longvillian/Woolstonian).

The coexistence of <u>Belonochitina robusta</u> and <u>Conochitina homoclaviformis</u> defines Zone C16. <u>B. robusta</u> occurs in the type Marshbrookian (Paris, 1979), in the Baltic it occurs from the Idaverian to the Nabalaian, with its acme in the Rakverian (which is Marshbrookian in terms of the international standard), and in Sweden it ranges from the Dalby Formation to the Slandrom Formation, with its acme in the Skagen and Slandrom Formations (roughly the interval Longvillian to Actonian).

C17 is defined as the acme of Conochitina Biozone homoclaviformis. Belonochitina robusta is absent, and since this species disappears at the top of the Slandrom Formation in Sweden (end Onnian, Bergström, 1971) and at the top of the Nabalaian (close to the Actonian/Onnian boundary, Williams et al., 1972) in Estonia, a post-Actonian age is suggested. Other species which are important in the C17 fauna include C. (Calpichitina) lenticularis (known to be particularly abundant in the type Actonian; Paris, 1981) and Cyathochitina latipatigium (especially abundant in the type Onnian; Jenkins, 1967). Paris (1979) argued that Zone C17 (assemblage V) should not be younger

than basal Onnian since forms known to abundant in the Onnian elsewhere are absent.

The horizon in the St.-Germain-sur-Ille Formation which yielded the graptolites described by Skevington and Paris (1975), has also yielded a chitinozoan fauna similar to that of Zone C17, but lacking  $\underline{C}$ .  $(\underline{C}$ .) <u>lenticularis</u>. This suggests perhaps an age intermediate between Zones C17 and C16. The graptolite includes the following forms according to Skevington and Paris (ibid.): Orthograptus truncatus truncatus, O. truncatus abbreviatus, O. truncatus? pauperatus, O.? pageanus micracanthus, ?Diplograptus fastigatus, ?Climacograptus miserabilis. These authors attribute a D. complanatus Zone age to this fauna (upper Pusgillian). The graptolite fauna occurs in two quarries, and in both cases shelly faunas are also known. These faunas include the brachiopod Svobodaina cf. armoricana (pers. obs.), and the trilobites Calymenella bayani, and an echomalonotid. In both quarries the graptolites occur above the shelly fauna. In the better-studied quarry, "Barthelemy", the graptolites occur in a sandstone bed immediately above the mudstone intercalation yielding the possible Zone C17 microfauna, and about 1.5m above the sandstone with the shelly fauna, which in turn lies some 5m above a mudstone intercalation with a Zone C15 microfauna. This suggests that the upper part of Zone 7 might possibly be be even of lower Ashgill age, or alternatively the Zone C16 and C17 succession here might be highly condensed, and overlain by the graptolitic horizon.

h. Zone 8

Zone 8 deposits in the Buçaco syncline yield an important and diverse macrofauna. This fauna has considerable importance in correlation with other parts of the Ibero-Armorican region and with the Montagne Noire. The microfauna from the colitic ironstone horizon at the base of the Leira Ma Member exhibits a similar distribution to the microfauna of the Favaçal Bed; the phosphatic nodules yield a Zone C17 fauna, while the colitic matrix yields a fauana of Zone C18. The evidence for the age of the C18 zonal microfauna is rather sparse, but Paris (1979, 1981) indicates that Lagenochitina baltica is known from the linearis and complanatus zones elsewhere and C. latipatigium is known from the <u>linearis</u> and <u>clingani</u> zones. Paris therefore adopts the attribution of Zone C18 to the D. complanatus zone, however the evidence, even supported by some slight evidence from acritarchs (Elaouad-Debbaj, 1979), seems not to be sufficient to suggest a date more accurate than Onnian to Pusgillian.

The shelly fauna allows correlation with the "lumachelles terminales" of the Bancos Mixtos in the Sierra Morena (common occurrence of Svobodaina sp. A, Hedstroemina of mundae, Portranella? exornata, Prionocheilus costai (pers. obs. and Hammann, 1976)), with the upper part of the "clastic sequence" of the Montagne Noire (similarity of S. sp. A to S. feisti, P.? exornata to Paucicrura of fascicula, Porambonites (P.) magnus to Porambonites (P.) ribeiroi (Havlicek, 1981)) and probably with the upper part of the Huerva Member (Fombuena Formation) of Celtiberia (similarity of S. sp. A to S. ellipsoides (Villas,

1983)).

# i. Zone 9

The brachiopod fauna of Zone 9 is largely formed of elements already present in Zone 8. Indeed material in the collections of the "Serviços geològicos" suggests that rare examples of the zonal index (Strophomena? cf. sardoa) may occur in the uppermost levels with Svobodaina sp. A at Leira Ma. If this is a true overlap of ranges, the base will be taken immediately above the last occurrence of  $\underline{S}$ . sp. A. In the Buçaco area the zone includes a thin (3-4m) sequence of bioclastic, bryozoan-rich rottenstones, while in Crozon the Zone 9 sequence is thicker (at least 20m), and is generally markedly less bioclastic. Species common in this zone include Eridorthis angustisulcata (also known from the carbonate sequence, Montagne Noire), Dalmanella sp. A, D. sp. B, Nicolella sp. A, Leptestiina aonensis (also known from Celtiberia, Cystoid Limestone Formation), Leangella cf. anaclyta (also known (?) from the Cystoid Limestone Formation, Celtiberia) as well as the index, Strophomena? cf. sardoa (compared with a form from Montagne Noire and Sardinia).

The faunas compare closely with those from the calcareous marls at the base of the Cystoid Limestone Formation of Celtiberia. The Coat-Garrec fauna from the Crozon Peninsula belongs to this zone, and this correlation is strengthened by the occurrence of many of the echinoderms known from Coat Garrec (Chauvel and Le Menn, 1972) in the Poiares Member (Heliocrinites cf. minuta, H. helmackeri?, Conspectocrinus celticus,

Ristnacrinus cf. cirrifer and Aonodiscus spinosus). The occurrence of a similar fauna of echinoderms in Celtiberia is well-documented (Chauvel et al., 1975, Chauvel and Le Menn, 1979, and Melendez, 1959), and to judge from the comments by Villas (1983, p. 366) the forms known from Coat Garrec occur in Celtiberia within the same calcareous marls as the Zone 9 brachiopod fauna.

The dating of this zone is rather difficult, despite the diverse brachiopod and echinoderm faunas. No microfaunas are yet known, but the zone is bracketed between the Zone C18 chitinozoans, and the conodont/trilobite faunas known from the upper part of the Cystoid Limestone Formation in Celtiberia. Melou (1971) suggested that Leptestiina aonensis should be considered as contemporary or later than L. prantli (Kraluv Dvur Formation, Bohemia), but a review of L. prantli from Sweden (Sheehan, 1973) suggests that the difference between these two species is not so great as Melou suggested, invalidating Melou's arguments based on his evolutionary model.

## j. Zone 10

This zone is based on faunas from Crozon, as described above. The beds yielding the most abundant and diverse brachiopod faunas are towards the top of the section in the Rosan quarries. These decalcified, tuffaceous limestones overlie a pillow lava, and the limestones yielding the conodont fauna described by Lindstrom and Pelhate (1971).

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limestone of the pillow lavas at Pointe de Lostmarc'h. The fauna here is not identical to that of Rosan, but is similar enough to be attributed to Zone 10. The overlying hyaloclastites are truncated by an erosional unconformity (Paris et al., 1981), above which there are bioclastic limestones. These limestones yield bryozoans, brachiopods, ostracodes and trilobites (Cekovia munieri), as well as a conodont fauna described by Paris et al. (ibid.). This fauna can be attributed to the Amorphognathus ordovicious Zone, which according to Orenard (1980) has its base. in Cautleyan zone 2. The Lostmarc'h conodont fauna shows strong similarities with the condont faunas from the upper part of the Cystoid Limestone Formation of Celtiberia (Carls, 1975), the Calcaire des Vaux of Normandy (Weyant et al. 1977) and from the Urbana Limestone of the Sierra Morena (Fuganti and Serpagli, 1968). The prescence of Icriodina in the Lostmarc'h fauna was taken by Paris et al. (ibid.) as an indication that this fauna might be stratigraphically higher than the other occurrences listed.

The shelly faunas provide little evidence for the age of this zone. The species of <u>Nicolella</u> and <u>Dolerorthis</u> present are not specifically similar to any British forms. In Britain <u>Nicolella</u> has not yet been recorded from strata younger than the Rawtheyan, although it does occur rarely in the Hirnantian of the Oslo region (Brenchley and Cocks, 1982).

## k. Zone 11.

This zone is defined on brachiopod distributions in the upper

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part of the Porto de Santa Anna Formation. The exact relationship therefore of this zone to Zone 10 is uncertain. Further study of the faunal succession in the upper parts of the Porto de Santa Anna Formation is required to refine understanding of the base of this zone. The faunas include many genera present in Zone 10, but so far none has proved to be specifically identical. Brachiopod genera present include Aegironetes, Christiania, Dactylogonia?, Epitomyonia, Jezercia?, Leangella?, Leptaena, Nicolella, Skenidioides?, Platystrophia?, Protozyga, Saukrodictya and Triplesia. The trilobite Phillipsinella also occurs. This fauna is not easy to date, largely because the small amount of material available precludes detailed investigation of most of the faunal elements. The exception is Aegironetes tristis, which is abundant amongst the material from the south of the Buçaco syncline. This species is only known at present from the top of the Králův Dvur Formation (0.3-0.4m below the base of the Kosov Formation) of Bohemia, where it is probably of upper Rawtheyan age.

#### 1. Zone 12

The deposits yielding the fauna of this zone are the youngest macrofossiliferous horizons yet identified in the Ordovician of central Portugal. The fauna includes Horderleyella sp. B, Plectothyrella sp. A, and Bractoleptaena? sp. A. These elements have not been recorded in a restricted fauna such as this before. All the elements are similar to forms known elsewhere from strata of Hirnantian age. Such an attribution must, however, be treated very cautiously.

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Figure 7. Correlation of the Portuguese sequences with the international standard and with the Bohemian area.

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# 4) Summary and discussion of international correlation

The proposed correlation of the Ordovician of central Portugal with the standard and Bohemian successions is outlined in fig. 7. The scheme is very similar to the correlations proposed by Williams et al. (1972) and by Paris (1981), both of whom rely heavily on the earlier proposals by Havlicek and Vanek (1966). There are however a number of important points of difference. These will be taken in stratigraphic order and discussed here.

The identification of the teretiusculus Zone deposits is similar in these schemes, but they differ markedly in the interpretation of the gracilis Zone. Paris tentatively places the Dobrotivá/Liben formational boundary at the base of the Caradoc. The occurence of Placoparia borni at the top of the Dobrotivá Formation does not preclude a teretiusculus Zone age for the top of this formation, or at least an age only slightly younger than the base of the gracilis Zone. The Bohemian Liber and Letná Formations yield no graptolites (Havlicek and Vanek 1966). The strong similarity between the macrofauna of Zone 6 in Portugal (e.g the appearance of Selenopeltis buchi), with that of the base of the Vinice Formation suggests that the position accorded this formation by Paris may be a little too old. It is tempting to see the ironstone of the Favaçal bed (Zone 5) as correlating with the ironstone of the Nucice horizon at the base of the Vinice Formation. Such a correlation would allow the Libeň and Letná Formations to lie within the gracilis Zone, and possibly the peltifer Zone.

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Fauna from Zone 8 in central Portugal (<u>Svobodaina</u> sp. A, <u>Aegiromena</u> cf. <u>descendens</u>) shows some similarity to that of the Bohdalec Formation. This formation is correlated with the upper half of the Caradoc by both Williams <u>et al</u>. (1972) and by Paris (1981), but the evidence for this seems a little thin. The only graptolites providing useful evidence for correlation of this formation with the standard are finds of <u>D</u>. <u>clingani</u> low in the formation (Havlicek and Vanek, 1900). The evidence for the position of the base of the formation within the international standard is that <u>C</u> cf. <u>wilsoni</u> occurs in the Zahorany Formation (Havlicek and Vanek, 1900). A younger boundary between the two formations could be envisaged however, and this has the advantage of "stretching" the apparently short time-span of the Lodenice Substage in the Williams et al. correlation.

The age of the top of the Bohdalec Formation is equally problematical, and its position within the Ashgill seems likely, especially if the <u>complanatus</u> Zone age of the microfauna of the Zone 8 deposits is real. Correlation of deposits of younger Ashgill ages is very difficult; indeed the absence of graptolites in central Portugal at these norizons and the endemic nature of the shelly-fauna means it is virtually impossible. A single "tie-point" is the fauna of Zone 11 age which does seem similar to faunas of upper Královdvůrian age, supposedly equivalent to upper Rawtheyan (Havlicek and Mergl, 1982). The correlation of the glacial deposits with the Hirnantian seems plausible but unproven; they are merely bracketed by upper Rawtheyan, and <u>atavus</u> Zone deposits.

#### CHAPTER 4 - PALAEOECOLOGY

### 1) Introduction.

The faunas of the middle and upper Ordovician of the Mediterranean area, and of Iberia in particular, have been cited as having a distinct "low-diversity" composition probably due to their very high palaeolatitude. This view of Mediterranean Province (sensu Spjeldnaes, 1961) faunas was largely derived during a period when very little study of the fauna of the area had actually been undertaken. In the last few years several major pieces of research have been undertaken, and the whole concept of these so-called low-diversity faunas must be reviewed. The faunas of central Portugal studied in this project are amongst the first examples of entire macrofaunal assemblages to be described from the upper Ordovician of the area. This project has also attempted to examine the detailed stratigraphic occurrence of the faunal elements, and the biostratigraphic implications of the faunas are reviewed in chapter 3.

The faunas recovered fall into two broad suites; those largely dominated by infaunal bivalves, ostracodes, brachiopods and trilobites, and those dominated by assemblages of filter-feeders, brachiopods, bryozoans and echinoderms. These two suites of faunas follow the sedimentary facies very closely; the clastic deposits of phase "A" (see chapter 2) yield the first suite, while the phase "B" deposits together with the ironstones and other deposits with reduced sedimentation of phase "A" contain the filter-feeder dominated second suite. It would seem to be the first suite that has dominated the "classical"

impression of Mediterranean faunas.

The analysis of both the palaeoecology and the biostratigraphy of the region is hampered by the widespread nature of the sedimentary facies (see p. 69 above) and their contained faunas. This makes the resolution of faunal change into purely ecological and time-dependent factors rather dangerous. Nevertheless an attempt to derive a biostratigraphic scheme for the region is highly desirable, and this forms the subject of chapter 2. It will be necessary to examine the detailed faunal succession throughout other peri-Gondwana areas to realise the full biostratigraphic implications of the fauna.

The range of "correction factors" used by different authors to allow for moulting in ostracodes and trilobites is rather large (see discussion in Williams et al. 1981), so here the factors used by Williams et al. (ibid.) which have become the standard for much of the palaeoecological work on the Welsh Ordovician (e.g. Lockley 1983), have been used to derive the diversity and dominance indices.

The two suites of faunas contain assemblages which do not have equivalents within the palaeocommunities of the Anglo-Welsh area (e.g. Lockley, 1983). The first suite differs from any of the Welsh Ordovician faunas by the preponderance of infaunal (mainly nuculoid) bivalves and ostracodes. Its representatives do yield a high diversity of trilobites, and with the brachiopods usually dominated by a single heterorthid, this suite does show some remote similarity to the <a href="Tissintia/Pseudolingula">Tissintia/Pseudolingula</a> association. The brachiopod faunas of the second suite show greatest similarity at the generic level with the <a href="Nicolella">Nicolella</a>

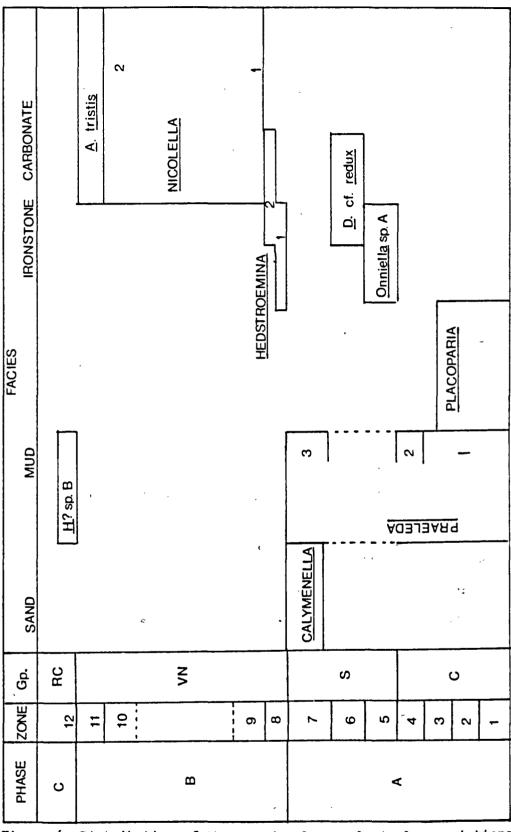


Figure 6. Distribution of the named palaeoecological associations with respect to sedimentary facies, and with respect to the biozonal scheme.

palaeocommunity of Lockley (1983). This simple comparison with Anglo-Welsh palaeocommunities serves to emphasise the distinct nature of these mediterranean faunas, rather than to provide any evidence of palaeoecological similarity between these areas.

## 2) Description of the Associations

- i Palaeoecology of the macrofaunal associations of Zones 1 to 4
- a. The Placoparia Association

DESCRIPTION - This association includes assemblages from the Valongo Formation, of Zones ?1 to 3. This formation is not formally studied in this work, but limited personal observation and the description by Romano (1982b, pp. 96,104, fig. 6) allow the recognition of a distinct association in these deposits. A brief comment is included here for comparison with coeval faunas from further south.

The association is characterised by the predominance of trilobites, including the genera Actinopeltis (Valongia according to Pribyl and Vanek 1984), Dionide, Eccoptochile, Echarpes, Mucronaspis, Neseuretus, Prionocheilus, Salterocoryphe and Zeliszkella, as well as the dominant Placoparia. Brachiopods are present, and in the sample counted at least, may constitute the dominant element. They include an indeterminate dalmanellid and Aegiromena? sp.. Bivalves are relatively rare and include Redonia. Ostracodes are present in the association, but do not occur as frequently as in the Praeleda association of a similar age to the south. Table 3 gives an analysis of an assemblage in the MR collection. The fauna may show some bias, as particularly

Assemblage from the Valongo Formation (? Zone 1) Sample 31/4 MR collection.

Species	count	individuals
Dalmanellid indet.	21	21
Placoparia (Coplacoparia) tournemini	78	19.5
Redonia sp.	4	2
Prionocheilus cf. mendax	5	1.25
Neseuretus (Neseuretus) tristani	5	1.25
Eccoptochile almadenensis	3	0.75
Illaenid indet.	2	0.5
Asaphid indet.	2	0.5
Eodalmanitina sp.	2	0.5
Salterocoryphe sp.	1	0.25
Crinoid indet. (ossicle)	1	0.1

Number of "individuals" - 47.0 Number of species - 11 Diversity - 2.5 Dominance - 0.20

# Trophic Nucleus

da]	Lmane:	llid indet.	_	44.1
P.	(C.)	tournemini	-	41.0
_				85.1%

### Proportions of major groups

Trilobites	_	52%
Brachiopods	_	44%
Bivalves	_	4%

Table 3.

fossiliferous slabs were collected, but probably approximates to a bulk collection.

The diversity index is low (2.6), while the dominance index is high (0.37). Superficial examination of other large collections from the Valongo Formation suggests that such low diversity is typical.

The association occurs in mudstones, with fossiliferous beds often separated by considerable relatively unfossiliferous

intervals (Romano and Diggens, 1976). Trilobite exoskeletons are very commonly articulated. Faunas from the Fonte da Horta Formation of the Penha Garcia syncline are very poorly known at present, but may provide an intermediate association between the Placoparia and Praeleda associations (see discussion below).

The <u>Placoparia</u> association contains the trilobites ascribed to "Association 2" by Henry (1980a) from the synclines to the south of Rennes. He also pointed out the frequent occurrence of entire carapaces, and undisturbed moults of trilobites, suggesting very low current activity.

DISTRIBUTION - This association occurs in the upper part of the Valongo Formation of the Valongo/Arouca area. It is very close to "Association 2" of Henry (1980a) from the upper part of the Traveusot Formation south of Rennes.

## b. The Praeleda Association (Phase 1)

DISCUSSION - This association characterises the mudstones of Zones 1 to 3 of the whole study are apart from the Penha Garcia syncline. Assemblages of this association are typically dominated by ostracodes and bivalves (Glyptarca, Praeleda, Redonia, Sluha? and Tancrediopsis). These two groups comprise about 60% and 20% of the individuals in the combined sample analysed in table 4. Trilobites are less important in this association (6% of the sample in table 4), and comprise a different assemblage to that present in the Placoparia association. Genera of trilobites present include Colpocoryphe, Crozonaspis, Ectillaenus?, Eodalmanitina, Kerfornella, Neseuretus, Nobiliasaphus, Morgatia,

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Phacopidina, Plaesiacomia and Selenopeltis. The species Plaesiacomia oehlerti is particularly characteristic of this trilobite assemblage, and has not been recorded from the Valongo Formation to the north. The brachiopods are of relatively low abundance (upto about 10% of the individuals in an assemblage) and diversity. Representatives of the genera Heterorthina (3 species), Apollonorthis (1 species) and Eorhipidomella (1 species) occur, but at no horizon are more than 2 species found together. In the combined sample analysed in table 4 brachiopods comprise slightly less than 10% of the estimated number of individuals.

## Trophic nucleus

Parapyxion? simplex	43.5%
Sluha? beirensis	10.8%
Heterorthina kerfornei	9.2%
Praeleda costae	5.7%
Quadrijugator marcoi	5.0%
Lardeuxella bussacensis	3.8%
Reuentalina ribeiriana	3.5%
	81.5%

## Proportions of major groups

Ostracodes	_	57%
Bivalves	_	20%
Brachiopods	-	10%
Trilobites	_	0%

Table 4. Analysis of combined CAC1/CAC2 samples

The trophic nucleus, as illustrated by table 4, contains four ostracodes, two bivalves and a brachiopod. This indicates a marked dominance of scavenging and deposit-feeding organisms, at least numerically. If this data is reinterpreted in terms of standing crop biomass, then the ostracodes become of relatively

An interesting observation from the relative abundances is that the proportion of the "minor" molluscan groups (rostroconchs, bellerophontids, nautiloids, gastropods and hyolithids) of the estimated total number of individuals is actually greater than the trilobites (about 7% compared to the 5.6% for trilobites). This gives some indication of the real importance of these often overlooked groups.

The faunas of this association show a marked difference in taphonomy to those of the <u>Placoparia</u> association. Faunas often show slight reworking, and concentration into coquinas; complete trilobite exoskeletons are rare, as are articulated specimens of brachiopods. A similar observation was made by Henry (1980a), whose "Association 3" contains similar or identical trilobites to this association. <u>In-situ</u> conjoined bivalve valves are fairly common, suggesting that deep sediment reworking by storm activity was generally uncommon. This is also supported by the fact that reworking of early diagenetic phosphatic or pyritic nodules is very rare in the Fonte de Horta Formation. It is perhaps significant however that the coquinas in the Postolonnec Formation of Le Veryac'h (Crozon, northern facies) frequently, indeed generally, do contain reworked nodules.

The mudstones of the Fonte da Horta Formation do not generally show sedimentary lamination between the coquinoid layers. This appears to be due to intensive bioturbation, although the preservation of burrows is infrequent. This observation is consistent with the shallow bioturbation expected to be produced by the large populations of deposit-feeding

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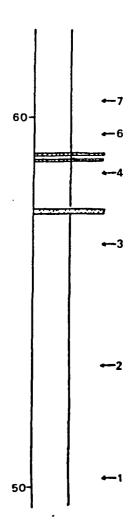
bivalves.

The faunas from the top of Zone 2 in the Buçaco syncline have been sampled in detail (table 5) to provide information on the nature of the fauna of the mudstones of this zone, and the effect of increasingly coarse sediment grain-size on the preserved fauna. The palaeoecological indices for the samples studied are represented graphically alongside the table. The decreased diversity, increased dominance and decreased density (although parameter can only be applied loosely) in coarser-grained sediments can be correlated with the increasing effect of storm-disturbance of the sedimentary environment. Indeed, in the Cabril Formation (principally of Sedimentary Facies 2c; see page 74) macrofauna is almost entirely absent, except in rare conglomeratic coquinas and in thin Facies 1 intercalations. This feature of faunal distribution, whereby any influx of storm- controlled sediments quickly reduces and then eliminates all macrofauna, even in the mudstones between the storm-sands, is also seen in Zone 7, and forms a characteristic property of the Ibero-Armorican storm-sand "packets". apparently similar sedimentary sequence in the type Caradoc (Brenchley and Newell, 1982) yields abundant fauna, both in frequent coquinoid beds within the storm-deposits, and in the mudstone interbeds (ibid. and Hurst, 1979).

DISTRIBUTION - This association is widely distributed in central Portugal (Buçaco, Dornes, Amendoa, Mação and Vila Velha do Rodão areas), in the Fonte da Horta Formation (Zones 1 to 3) and in the mudstone intervals within the Cabril Formation (Zone 3). In

Species	Sample					
	CAC1	CAC2	CAC3	CAC4	CAC6	CAC7
					<b>.</b>	
Parapyxion? simplex	682	662	-	-	84	-
Quadrijugator marcoi	64	30	-	-	4	-
Lardeuxella bussacensis	46	28	-	-	2	-
Sluha beirensis	46	40	1	-	1	2
Praeleda costae	28	16	-	-	1	_
Plaesiacomia oehlerti	24	2	-	1	2	1
Phacopidina micheli	11	6	-	-	-	-
Reuentalina ribeiriana	11	86	-	_	4	-
Heterorthina kerfornei	8	28	2	2	2	4
Neseuretus (Neseuretus) tristani	7	7	1	2	3	3
Ectillaenus sp.	7	1	1	-	1	-
Morgatia hupei	6	9	-	-	_	_
Glyptarca lusitanica	6	16	_	1	3	1
Tancrediopsis? ezquerrae	4	_	_	_	-	-
Crozonaspis struvei	3	2	1	_	2	_
hyolithid indet.	4	3	_	_	-	_
bellerophontid indet.	3	8	_	-	3	-
gastropod indet.	3	-	-	-	-	-
Myoplusia? sp.	3	1	_	-	-	-
graptolite indet.	2	1	-	-	-	-
Aegiromena? sp.	1	-	-	-		-
Bollia? sp.	_	41	-	-	1	-
Eodalmanitina destombesi	_	4	_	_	2	1
bryozoan indet.	_	_	-	_	3	1
Ribeiria pholadiformis	-	1	_	_	_	1
conulariid indet.	_	1	_	-	-	-
orthocone nautiloid indet.	_	5	-	_	_	-
Pseudolingula? sp.	-	-	2	-	-	-
Dominance	0.27	0.22	0.31	0.34	0.19	0.23
Diversity ((S-1)/Ln N)	3.9	<b>3.</b> 8	3.0	2.5	4.5	3.0
Number of species recorded	21	23	<u> </u>	4	17	88

Faunas from the upper part of the Fonte da Horta Formation, Buçaco syncline.



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Armorica similar faunas are known from the upper parts of the Andouillé and Postolonnec Formations.

## c. The Praeleda Association (Phase 2)

DISCUSSION - The mudstones of Zone 4 yield a similar fauna at all localities where they have been studied so far. Henry (1980a) records the trilobites which characterise this association (Colpocoryphe grandis, Dalmanitina n.sp. aff. acuta, Crozonaspis chauveli) from a wide geographical range in Armorica (Crozon, Laval, ?Martigné-Ferchaud, Ménez-Belair). In Portugal it seems that C. grandis and D. n. sp. aff. acuta occur principally in the upper part of the zone, while C. chauveli is dominant towards the base.

The fauna of the zone also contains bivalves and ostracodes, although these two groups are not always as dominant as they were in Phase 1 of the <a href="Praeleda">Praeleda</a> association. The trophic nucleus of an assemblage from the second phase of the association illustrated in table 6 shows a striking resemblance to the trophic nucleus of a sample assemblage from phase 1 in table 4. This probably hints at an association ecologically intermediate between the communities represented earlier by the <a href="Praeleda">Praeleda</a> association (Phase 1) and the <a href="Placoparia">Placoparia</a> association. Some connection with the earlier <a href="Placoparia">Placoparia</a> association is also suggested by the prescence of the ostracode genus <a href="Ogmoopsis">Ogmoopsis</a>, known at an earlier period from the Traveusot and Andouillé Formations, but not from the Fonte da Horta or Postolonnec Formation. The faunas also include graptolites (<a href="Climacograptus">Climacograptus</a>? <a href="Dekkeri">Dekkeri</a>, <a href="Corynoides">Corynoides</a> sp.), known elsewhere from shelf carbonate

environments. An interesting occurrence in the upper part of the zone in the Buçaco syncline are narrow tapering phosphatic tubes upto 15cm long, possibly produced by an annelid.

Table b gives an analysis of an assemblage from a thin nodular horizon within the Carregueira Formation of the Dornes area. This horizon lies near the top of the formation, but a

Species	Count	Individuals (Estimated)
crinoid indet.	956	5.0
smootn ostracode	79	19.75
Ogmoopsis sp.	b	1.5
Sluha? sp.	24	12.0
Praeleda sp.	28	14.0
Tyronella? sp.	14	14.0
Dalmanitina n. sp. aff. acuta	5	1.25
gastropod indet.	2	2
bellerophontid indet.	1	1
bivalves indet.	15	7.5
		78.0

## Trophic nucleus

smooth ostracode	- 25.03
Praeleda sp.	- 22.7%
Sluha? sp.	- 19.5%
Tyronella? sp. A	- 18.2%
	80.03

## Proportions of the major groups

Bivalves	-	42%
Ostracodes	-	203
Brachiopods	-	23%
Trilobites	_	21

Table 6. Analysis of an assemblage of the <u>Praeleda</u> association, phase 2, from the Carregueira Formation (Zone 4), sample AML1 from the Dornes area.

similar diversity of fauna is probably present throughout, although the taxa present vary slightly. The diversity index (1.8) is strikingly low, but as with the Phase 1 Praeleda association this diversity is not so dissimilar to values reported from the Tissintia/Pseudolingula association of Wales (Lockley, 1983). The brachiopods of this association (<u>Heterorthina</u> sp. aff. <u>kerfornei</u> and <u>Pseudolingula</u> sp.) also closely parallel those of the Welsh association. The abundant remains of crinoids (95b ossicles recorded from the sample in table 6, all of a single species) is a major difference from the faunas of phase 1 of the Praeleda association. These crinoid remains are often concentrated within certain intervals of the Zone 4 deposits, for instance in the lower part of the zone in the section at Le Veryac'h. The example given here is different from most examples, for it is only in the very top of the Carregueira Formation that Heterorthina sp. aff. kerfornei is replaced by Tyronella? sp. A as the dominant brachiopod.

The taphonomy of the faunas from this phase of the association is largely similar to those from phase 1. The occurrences of graptolites are generally limited to thin horizons. One of these occurs about one metre below the top of the Carregueira Formation (see p. 90), where the graptolites are almost alone. In other occurrences however, such as the lower part of the Carregueira Formation at its type locality near Mação, the graptolites occur amongst rich bedding plane assemblages of ostracodes, bivalves and trilobites.

DISTRIBUTION - Phase 2 of the Praeleda association is known from

the Carregueira Formation (Zone 4) of Buçaco, Dornes, Amendoa and Mação. In addition it is recorded from the uppermost Postolonnec Formation of Crozon. The trilobites of the association have been recorded (Henry, 1980a) from other areas within the Armorican Massif.

ii Palaeoecology of the macrofaunal associations of Zones 5 to 8 a. The Onniella? sp. A Association

DISCUSSION - This association occurs in the oolitic ironstones of the Favaçal Bed. The fauna includes trilobites, bryozoans and brachiopods, with rare cystoids. The trilobite Colpocoryphe grandis is present in most assemblages, and articulated carapaces are relatively common. Deanaspis seunesi occurs in this association, and a single specimen of Crozonaspis sp. has been recovered. Brachiopods are numerically dominant, and include Aegiromena cf. aquila praecursor, Triplesia sp. A and Onniella sp. A. At the top of the bed where the clastic content becomes higher Gelidorthis cf. praepartita becomes the dominant species.

Because of the low density of this association it has not been possible to undertake any numerical analysis. Slight variation in the constitution of assemblages of the association has been noted in the field, with <u>Aegiromena</u> cf. <u>aquila</u> <u>praecursor</u> noticeably more abundant in the faunas from Buçaco then in those from Dornes or Mação.

This association shows many faunal elements in common with the later <u>Drabovia</u> cf. <u>redux</u> association (<u>Colpocoryphe grandis</u>, <u>Deanaspis seunesi</u>, ?<u>Blyskavomena</u> cf. <u>blyskavensis</u>, <u>Aegiromena</u> cf. <u>aquila praecursor</u>, <u>Triplesia</u> sp. A and, at generic level,

Gelidorthis and (in France) Prionocheilus).

DISTRIBUTION - This association has been recovered from the Favaçal Bed (Zone 5) of the Buçaco, Dornes and Mação areas. Some elements of the association have been recorded from the equivalent bed at the base of the Kermeur Formation in the Crozon Peninsula.

# b. The Drabovia cf. redux association

DISCUSSION - It is this association which characterises, and gave rise to the name for, the "Bryozoa Beds" of Cooper (1980). The association occurs within a geographically restricted area, between Dornes and Mação. The abundance of bryozoa is the major difference between this association and the earlier Onniella? sp. A association. The brachiopods continue to be important, and are more diverse than in the earlier association, with eight species of articulate brachiopods (Aegiromena cf. aquila praecursor, Drabovia cf. redux, Gelidorthis sp., Saukrodictya sp. A, Triplesia sp. A, Blyskavomena cf. blyskavensis and Rostricellula? sp. A) and at least two inarticulates. The trilobites are also more diverse than in the Onniella? sp. A association, with eleven species recorded (Actinopeltis sp., Colpocoryphe grandis, Dalmanitina sp., Deanaspis seunesi, Dysplanus sp. A, Eccoptochile clavigera, Eoharpes macaoensis, Eudolatites Phacopidina? sp. A, Prionocheilus cf. pulcher and Selenopeltis cf. buchi). It is interesting to note that of the trilobite genera listed above, six are important genera in the earlier Placoparia association, while only one is prominent in phase 1 of

the Praeleda association.

The wealth of bryozoans in the association have not been studied in this project, and their abundance has prevented a numerical analysis of the fauna. Another group which is an important element of the fauna are the echinoderms. In addition to several crinoids, an important variety of cystoids occur. These include Rhombifera sp., Caryocystites sp., Corylocrinus sp., Calix? sp. and a conical diploporite. These cystoids remain in need of taxonomic revision.

There is considerable similarity between this association and the fauna of phase 2 of the <u>Hedstroemina</u> association, as indeed there is similarity between the sedimentological environments of the two associations.

Cooper (1980, p. 67) attributed the deposition of the "Bryozoa Beds" to turbidity currents, and believed the fauna had been transported for some distance. His claims that the bryozoa "are commonly rolled and fragmented" and that "the fossils are all disarticulated" must be strongly contested. Indeed fragile reticulate bryozoan colonies are very well preserved, trilobites are commonly articulated, and cystoids are more often preserved articulated, or at least associated, than not. The sediment enclosing the fauna of this association was described by Cooper (ibid. p. 67) as "several thick beds of fine-grained greywacke". The Queixopeira Member does infact comprise some 20-30m of highly micaceous mudstone. The bedding is purely the concentration of fauna at particular horizons, although micaceous laminae do occur rarely in the Dornes area. The sediments are interpreted here as being mudstones with an unusually high proportion of detrital

mica. The fauna is <u>in-situ</u>, and has not been transported. The high mica content can be correlated with the high detrital mica content of the deposits of the lower part of the Louredo Formation to the north, and indeed with the micaceous bioturbated interval in the lower part of the Kermeur Formation.

DISTRIBUTION - The association is restricted to the area between Dornes and Mação. A poorly exposed occurrence outside this range is at Albegaria, 5km southeast of the Rio Ceira section, at the southern extremity of the Buçaco syncline. The association is not known from Brittany, although fauna from the Riadan Formation includes some similar elements (Babin et al. 1976).

# c. The <a href="Praeleda">Praeleda</a> association (Phase 3)

DISCUSSION - This association occurs in a similar sedimentary environment to phase 1 of the association; it is found in mudstone intervals (Facies 1) between storm sand pulses (Facies 2c,d,e). It shows a strong taxonomic similarity to phase 1, although phase 3 of the association does not include as wide a range of species as phase 1 does.

The ostracodes of this phase of the association include Hastatellina normandiensis and Satiellina delgadoi. The trilobites present are Crozonaspis dujardini, Plaesiacomia n. sp. aff. rara, Dalmanitina philippoti and Deanaspis seunesi. All these species except the last are members of genera present in the earlier phases of the Praeleda association. The bivalves present, except for Praeleda ribeiroi, are not taxonomically close to the commoner bivalves of the earlier phases of this

phase 1 might be referable to Myoplusia. The other species present are Myoplusia of. bilunata perdentata, Myoplusia eschwegii and Concavodonta ponderata. Brachiopods are represented by Svobodaina armoricana and a rare indeterminate inarticulate. Other elements present include Plumulites sp., which is locally abundant on ostracode-rich bedding planes, and Anatifopsis sp., a rare homolozoan. This phase of the Praeleda association tends to be developed at a much lower density than the earlier phases, but the mudstone members of the Louredo Formation are close to the limit of their development (see chapter 5 below).

DISTRIBUTION - This association is known from the Vale Saido and Zuvinhal Members of the Louredo Formation of the Buçaco syncline (Zone 7). Similar faunas occur in the Schistes de Raguenez and the Schistes de Kermeur in the upper part of the Kermeur Formation (Babin and Melou, 1972). The association can also be recognised in the Sangsurière Formation (Cotentin) and the Pont-de-Caen Formation (Domfront), although the relative abundance of the various faunal elements may vary widely (Babin et al. 1976, Henningsmoen et al. 1965, Pillet and Robardet, 1968, 1969, 1970a, 1970b, Robardet et al. 1972a, 1972b, Vannier 1963a, 1983b).

### d. The Calymenella Association

DISCUSSION - This association differs from all the other

associations described in this study because it occurs in coarse clastic sediments (chiefly fine- to medium-grained sandstone). At present this association is poorly understood, but does appear to be of low diversity, with a variable taxonomic constitution. The assemblages here ascribed to this association typically consist of trilobites and brachiopods. Occurrences of the association in Zone 7 are usually characterised by the dominance of the brachiopod Svobodaina armoricana, while in an occurrence probably high in Zone 7 in the sandstones below the Vaca Member Hedstroemina sp. A is the dominant element. This occurrence in the Penha Garcia syncline also yields the brachiopods Rostricellula? sp. and Horderleyella? sp. A. The trilobites present include Calymenella (C. boisseli at Dornes, C. alcantarae at Penha Garcia, and C. bayani from St.-Germain-sur-Ille), Scotiella? taouzensis and Deanaspis of Seunesi.

The poor preservation, mainly due to the easily weathered clay-rich sandstones (Facies 2a) containing the fauna, associated with most assemblages of this composition in Portugal (e.g. that described by Cooper, 1900 from the Cabeço do Peão Formation, and that from the lower part of the Louredo Formation of Buçaco) has hampered analysis. Indeed, the specific identity of the dominant brachiopod is still open to discussion (see part II).

DISTRIBUTION - Faunas from sandstones containing the genus Calymenella are known from a wide geographical range. The genus is recorded from the Median Synclinorium of Brittany, Montagne Noire, various areas of southern Spain as well as from central Portugal.

# e. The Hedstroemina Association (Phase 1)

DISCUSSION - It has already been remarked above that Hedstroemina was important in the biota of coarse-grained sediments high in Zone 7. This genus also became important in mud environments close to the Zone 7/8 boundary. Thus the last examples of the Praeleda association (e.g the Galhano Member at Buçaco) have Svobodaina armoricana replaced as the dominant brachiopod by Hedstroemina cf. sp. aff. mundae. The genus however becomes even more important in the chamositic sediments (lower part of the Leira Ma Member) which overlies the Galhano Member. The lower part of the ironstone bed contains horizons which are only sparsely colitic, and in these there are shell beds dominated by Hedstroemina sp. aff. mundae. These assemblages are referred to phase 1 of the Hedstroemina association.

The composition of a typical assemblage of this association is illustrated by table 7. The diversity is very low, and apart from rare trilobite fragments, a few bryozoa and rare inarticulate brachiopods the fauna comprises just some four articulate brachiopods.

The fauna is clearly linked to that of the preceeding Praeleda association (prescence of Hedstroemina and Svobodaina), and is equally the precursor of the succeeding phase 2 Hedstroemina association (all the identified elements in phase 1 pass up into the more diverse phase 2 assemblages).

DISTRIBUTION - All the assemblages referred to this phase have been recovered from sparsely- or non-colitic horizons at the base Chapter 4.

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Hedstroemina sp. aff. mundae	42.5
Svobodaina sp. A	7.5
Dolerorthis? sp.	1.0
Porambonites ribeiroi	0.5
Bryozoa (stick form)	2.0
Total no. of "individuals"	53.5
Diversity	1.01
Dominance	0.65

Table 7. Analysis of a fauna from the oolitic ironstone in the Leira Ma Member, west of Louredo.

of, or within the lower part of the ironstone bed in the lower part of the Leira Ma Member of the Porto de Santa Anna Formation in the Buçaco syncline. These occurrences are of Zone 8.

# f. The Hedstroemina Association (Phase 2)

DISCUSSION - Above the colitic part of the Leira Ma Member there occurs a diverse <u>Hedstroemina</u> association. This association includes at least 15 species of brachiopod and 10 species of trilobite in the northern part of the Buçaco syncline. These elements are accompanied by a considerable fauna of bryozoans, and at some localities by cystoids (material in museum of "Serviços Geològicos"). The richest trilobite faunas (Leira Ma locality) occur in a chamosite-rich muddy sand, probably with some volcanic debris, occuring in association with the earliest volcanic deposits of the Porto de Santa Anna Formation. Some of the brachiopod-rich faunas occur in a silicified lithology in

lenses within the top of the colitic ironstone (e.e the fauna from "100m ouest de la fonte de Cassemes" in the museum of the "Servicos Geològicos")

The association shows some similarity in its composition to the earlier <u>Drabovia</u> cf. <u>redux</u> association, but differs in lacking abundant trilobites at most localities.

DISTRIBUTION - This association has only been found in Portugal within the basal part of the Porto de Santa Anna Formation in the Bucaco syncline. It occurs particularly in the Leira Ma Member of the Louredo area, but is also known from the same horizon in the Rio Ceira inlier. The association is also known from the carbonates at the base of the Rosan Formation at Raguenez. A fauna with several elements in common with this association occurs in the calcareous sandstones of the "Lumachelles terminales" of the Bancos Mixtos of the Sierra Morena (see p. 135). This spanish fauna is however much less diverse than that of the Leira Ma Member.

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The faunas from this interval are mainly to be found in carbonates. The faunas include many genera present in the diverse (phase 2) Hedstroemina association, but they are generally of a brachiopod/bryozoa/echinoderm composition so are markedly different from most previous associations.

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#### a. The Nicolella Association (Phase 1)

The use of Nicolella as the characteristic genus of this association is in no way intended to indicate close similarity or relationship with the Nicolella paleocommunity of Lockley (1983).

Phase 1 of the association occurs in the decalcified beds (Facies 4) at the base of the Ferradosa Formation. The major element of the association is the bryozoa fauna. This dominance of bryozoa, particularly in this facies where they are commonly fragmented, means that it has not been possible to quantify the association. A second development of the association occurs in less bioclastic calcareous muds (e.g in the lower part of the Rosan Formation at Coat Garrec), and in this facies the bryozoa are less important, while the cystoids may be more so. The brachiopod faunas of these two developments seem to be very similar. These brachiopod faunas are slightly less diverse than the earlier Hedstroemina association, with about 14 species. No large trilobite faunas have been recorded from this association, but the sparse finds are comparable to those from most Hedstroemina association localities. Only an illaenid and Nobiliasaphus sp. have been recorded in Portugal, but the Coat Garrec locality yields fairly common Onnia? sp.

DISTRIBUTION - This association is found in the rottenstones (facies 4) of the Poiares Member, in the Buçaco syncline (Zone 9). It also occurs in beds of a similar age at the base of the Rosan Formation. In Portugal the fauna of the strata in the Buçaco syncline assigned to the Zone 9/10 interregnum belong, at

least in part, to this association.

### b. The Nicolella Association (Phase 2)

DISCUSSION - This phase of the association is closely related to the first, but the elements are different at a specific level. Amongst the fauna of about 14 species of brachiopod so far recognised within this phase of the association 11 are members of genera known from phase 1. Like the assemblages of phase 1 this second phase may show a very variable importance of bryozoa, which are however always present. Echinoderms are generally not so important in phase 2. One striking difference between the assemblages of phase 1 and phase 2 is the large size of many individuals in phase 2 (e.g. the representatives of Nicolella, Dolerorthis, Rhactorthis?, Hedstroemina and the crinoids).

DISTRIBUTION - This association is known from the upper part of the Rosan Formation, where its assemblages form the basis for Zone 10. As mentioned above the two phases of the association are closely related, and the poorly known faunas from the Zone 9/10 interregnum (see p. 118) seem to be close in taxonomic composition and structure to the known examples of this association. Some of the poorly-known faunas from the Riba da Cima Member appear to belong to this association.

## c. The <u>Aegironetes tristis</u> Association

DISCUSSION - This association is markedly different from the representatives of the <u>Nicolella</u> Association which occur in earlier carbonates. The association is characterised by the

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presence of a moderately diverse (13 species) assemblage of generally rather small brachiopods, together with abundant bryozoa and crinoids, while trilobites and cystoids are rare. Of the identified trilobites and brachiopods (14 genera) only five are representatives of genera known from earlier deposits.

Some of the genera present (Aegironetes, Christiania, Epitomyonia, Leptaena and Jezercia) have been recorded elsewhere (Bohemia: Havlicek and Mergl 1982, Sweden: Sheehan 1973) from the "Foliomena Community". This "brachiopod community" is however normally a relatively minor constituent of a fauna dominated by vagile elements (trilobites of the "Stenopareia fauna" in Canada, Sheehan and Lesperance 1978, Cyclopyge fauna in Ireland, Harper 1980). This fauna from Zone 11 of the Bucaco area lacks abundant trilobites, but instead contains bryozoa and several brachiopod genera (e.g. Nicolella and Triplesia) generally considered to be atypical of a "deep-water" assemblage such as the Foliomena fauna. The palaeoenvironmental interpretation of this association should thus be approached with caution. The fauna should not be regarded as of a necessarily deep-water origin. One possible explanation for such a fauna existing in carbonate facies beds, is that it is showing the effect of a deteriorating climate prior to the Hirnantian glacial event. The first faunas to be affected by such changes might be expected to be the faunas of the shallow water carbonates, the Nicolella association, which was clearly related to northern European carbonate facies faunas.

DISTRIBUTION - The <u>Aegironetes tristis</u> association is only known from the uppermost sediments of the Venda Nova Group in the

Buçaco syncline (Zone 11) at present.

# d. The Horderleyella? sp. B Association

DISCUSSION - With the resumption of clastic sedimentation in the Bucaco syncline in Zone 12, there was a drastic change in the faunas present. It is not known whether there is a time interval between Zones 11 and 12, but they do seem to be continuous. The known macrofauna of the Zone 12 sediments comprises three articulate brachiopods, at least one inarticulate, an ostracode and two (?) crinoids. With the possible exception of the crinoids, none of these elements occur in the Aegironetes tristis association of Zone 11. The brachiopods occur in varying relative numbers at different localities. Near the Rio Mondego the fauna is rich in <u>Plectothyrella</u> sp. A and <u>Bracteoleptaena</u>? sp. A, while in the Rio Ceira inlier Horderleyella? sp. B is by far the most abundant form, accompanied by a high proportion of unidentified ostracode. The possible Hirnantian age of this low diversity fauna was discussed above (p.139).

DISTRIBUTION - This association is known from only a few localities in the southern part of the Buçaco syncline, all in the basal part of the Ribeira do Braçal Formation. They form the basis for the identification of Zone 12.

### 3) Discussion of the palaeoecology

The description of the associations of macrofauna given above provide a major part of the discussion of the palaeoecology of

this middle and upper Ordovician shelf. However, it is important to take into account those intervals which yield no macrofaunal body-fossils. There are four broad categories of such "barren" intervals in the succession studied.

The first of these is the important sedimentary facies 2a, which only in some of its coarser-grained developments yields macrofauna (Calymenella association). By definition this facies is highly bioturbated, but in Portugal it is rare to be able to study this bioturbation in the field.

The second important facies for ichnofossils are those deposits which consist of sandstone/mudstone alternations. This includes the storm-sand deposits of facies 2b and 2c as well as the sandstones of undetermined origin in the regressive deposits of Phase "C". Trace fossils known from facies 2b and 2c in the Kermeur Formation include Bifungites? sp. (Melou and Plusquellec 1975), and Rhabdoglyphus? (ibid.). The lower parts of the Louredo Formation yield Planolites, Palaeophycus, Chondrites and some small indeterminate "U" burrows. The facies 2c deposits in the upper part of the Louredo Formation yield a variety of indeterminate surface scratches and burrows. These bedded facies do not generally yield any body-fossils of macrofauna, although one sandstone bed in the Bucaco syncline has yielded a few indeterminate echinoderm fragments. The regressive deposits of phase "C" are often thoroughly bioturbated, particularly in the middle part of the sequence. The lowest, fine-grained beds of the Ribeira do Laje Formation of the Penha Garcia syncline (and possibly those of the lower part of the Ribeira do Braçal Formation of Buçaco according to Delgado 1908) contain bedding

planes with <u>Nereites</u>. The middle parts of the Ribeira do Laje Formation of Dornes, Amendoa and Penha Garcia are generally well bioturbated (cf. facies 2a of phase "A"), while the top resembles facies 2b, 2c and 2d (in ascending order) of phase "A", both in their overall sedimentology and in the general lack of biogenic structures apart from indeterminate surface tracks and scratches.

The third major interval lacking in body fossils is represented by the stage 2 of phase 3 (the diamictites and mudstones). These deposits have not yielded any signs of trace or body fssils in the study area, although body fossils have been recorded in similar deposits elsewhere (the Sobredo Formation of Valongo; a single brachiopod - Romano and Diggens, 1976 and the Pélites à Fragments Formation of the May syncline, Normandy; Mucronaspis sp. and ostracodes - Henry 1980a, Babin et al. 1976).

The volcanic deposits of the Venda Nova Group provide the final situation in which body-fossils do not generally occur. The barren beds are typically those which are interpreted as being primary tuff deposits.

The diagram in fig. 8 shows the stratigraphic distribution of those macrofaunal associations studied. One important aspect of this diagram is the close relationship of the successive associations present through each of the ironstone-deposition events. In the older event some of the faunas present in central Portugal afterwards show distinct generic similarity to those of earlier, supposedly deeper water deposits of north Portugal. These faunas are confined to situations, such as the Queixopeira

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Member, which are interpreted as having low rates of sediment deposition. The associations of environments with more active sedimentation are more stable (i.e. the <a href="Praeleda">Praeleda</a> association with its various phases, which lasts from Zone 1 to Zone 7). A similar situation is seen with the formation of the Leira Ma ironstone bed; faunas appearing at this horizon provide the basis for the later associations (i.e. the <a href="Nicolella">Nicolella</a> association) of carbonate environments, although the derivation of these forms from earlier deeper-water faunas cannot be demonstrated in this case. The <a href="Hedstroemina">Hedstroemina</a> association of the Leira Ma Member does however show distinct generic similarity to the <a href="Drabovia">Drabovia</a> of redux association of the Queixopeira Member.

This invokes the two broad divisions of faunal associations in the area mentioned in the introduction. The first suite of faunas, dominated by deposit-feeders and scavengers form the examples of the Praeleda association. In common with the taxonomically similar Tissintia/Pseudolingula association of the Welsh basin, this shows great taxonomic and structural stability over a long period of time. The second suite of faunas contain large numbers of filter-feeders such as bryozoa and echinoderms, as well as brachiopods. These faunas show a much greater range of developments, and seem to change much more quickly with time. These faunas show much more affinity with the classic "brachiopod associations" of Wales and elsewhere. In central Portugal however, these associations are not the usual inhabitants of the clastic shelf, but become dominant during periods of, and in regions of, reduced sediment influx and/or carbonate formation. They may be related to the faunas occupying the deeper, less disturbed parts of the shelf.

Taxa useful in international correlation are more abundant in the "filter-feeder suite". The faunas of the storm-dominated muddy parts of the succession, are more endemic. The extreme stability of this "deposit-feeder suite" is reflected in the similarity of such faunas in the middle Ordovician of the Ibero-Armorican area, with those of the lower Ordovician of the Anglo-Welsh region.

The question remains whether these faunas reflect the cold-water environment claimed bу several authors Spjeldnaes 1961). The existence of similar faunas in other regions well away from the palaeopole (e.g. the Welsh basin, the Appalachians: Bretsky, 1969, Bretsky and Bretsky, 1975) suggests that other factors may be important. One important difference between the areas of Wales, for instance, yielding classic brachiopod associations and the area of this study. is the lack of rapid lateral variability in the Portuguese area. It has already been remarked (pp. 69,144) that the facies, both bio- and litho-, developed in the Portuguese Ordovician tend to be very widespread, due to the extremely low palaeotopography. It is surely significant that the periods with evidence for lateral variability, during Zones 6 and 8-11, are precisely those when the closest approach to those classic types of brachiopod association occur.

Although any conclusion must be tentative until there has been a full analysis of the palaeoecological evidence from the Mediterranean Province, it does seem likely that the palaeogeography, particularly the very widespread, shallow shelf

sea, with its low-topography floor, may be largely responsible for the palaeoecology observed. The climate may not have been the all-important factor that some authors have seen it to be.

# CHAPTER 5 - SYNTHESIS

### 1) A Dynamic Stratigraphy

The deposits of the upper Ordovician in central Portugal have yielded the sedimentological and palaeontological evidence detailed in chapters 1 to 4 above; the purpose of this chapter is to place these various aspects in the context of the regional setting. The first part of the chapter attempts to synthesise a history of the area through the upper Ordovician, while the later sections review the implications of this model for the interpretation of upper Ordovician palaeogeography and subsequent tectonic history.

#### i Phase "A" (Zone 1 to Zone 8)

The deposits of Zone 1 studied in this project form a rather uniform unit of mudstone across the whole study area. The faunal and taphonomic evidence suggests that there was a palaeoslope to the north. The deeper water deposits of north Portugal had a fauna of low diversity, dominated by brachiopods and trilobites, while the shallower sea to the south contained a benthos dominated by infaunal, deposit feeding bivalves and ostracodes. These conditions lasted until the early part of Zone 3, when there was an influx of sand onto the southern part of the shelf during storm events. Only during a few short breaks in this periodic storm activity did a benthos become re-established in the area. Most of the sediments yield neither body- nor trace-fossils. This increased sand deposition probably coincided with, and may have been caused by, a shallowing of the water depth. There is a hiatus occupied by conglomerates of reworked,

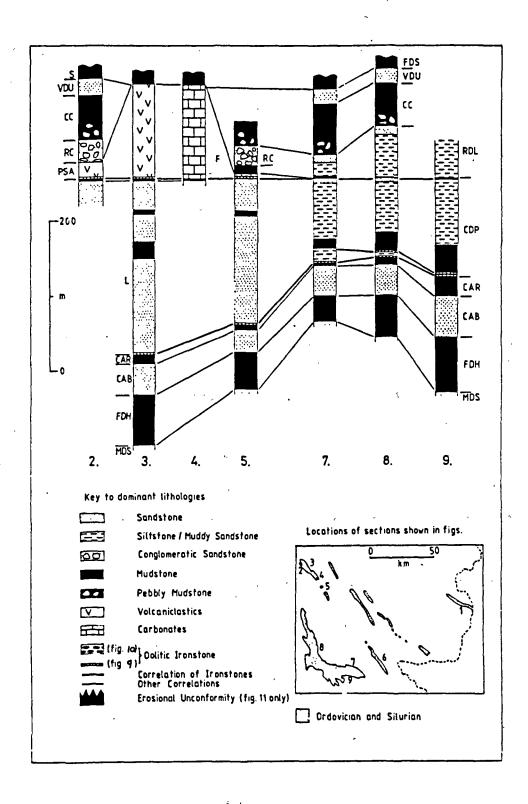


Figure 9. Upper Ordovician sequences from central Portugal, illustrating the influence of the Dornes/Amendoa rise on sedimentation.

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phosphatised diagenetic nodules in the upper part of Zone 3, and there may be a considerable non-sequence below the earliest deposits of Zone 4. This hiatus is particularly marked on the crest of the Amendoa/Dornes "rise" where Zone 4 may be virtually absent, and the conglomerates are best developed. In the regions of higher subsidence (such as Crozon) the transition from Zone 3 to Zone 4 may be almost continuous, and in these areas the uppermost part of Zone 3 is occupied by the Marrolithus bureaui Biozone.

The deposits of Zone 4 mark a return to the uniform deposition of fine-grained clastics. The depth of water may have been greater than in Zones 1 and 2, for there are few coquinoid beds, faunal diversity is low, and graptolites are not uncommon. The rate of sedimentation slowed abruptly at the end of Zone 4, and a complex ironstone bed was laid down across the whole of central Portugal. The colitic ironstone includes reworked nodules and crusts, and probably represents a major condensed sequence. Above the oolitic bed coarse clastic sedimentation began again abruptly. This renewed clastic input spread across the shelf in a rather different pattern from the coarse-clastic intervals of earlier zones. In contrast to the rather uniform north-west thinning of the Monte da Sombadeira and Cabril Formations, the sands which came to form the Louredo and Kermeur Formatations appear to have been funnelled along the basinal areas. It is possible that it was the condensed sequence of Zone 5 that allowed the differential subsidence of the Buçaco/Fajão belt to form a topographic feature, rather than being masked by sediment.

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This different sedimentary environment for the "basin" and "rise" areas is most marked during Zone 6, when the "Bryozoa Bed Facies" developed in the Dornes/Mação region, at the same time as a major period of deposition of storm-sands in the "basin" to the north. Later on, in Zone 7, coarse clastic deposits spread to the "rise" area, although they are developed generally in a bioturbated facies rather than the more barren sandstones with HCS to the north.

At the end of Zone 7 the sea seems to have shallowed again, producing pulses of storm sands, not unlike those of Zone 3. In the basinal areas, again like Zone 3/4 there are amalgamated sandstone beds with HCS abruptly overlain by dark mudstones with graptolites. Like the earlier event, these mudstones are thickest in Crozon, and are not present on the Dornes/Amendoa rise. In a similar way to the Zone 4/5 transition, these mudstones are followed by an colitic ironstone horizon.

# ii Phase "B" (Zones 8 to 11)

This second collitic ironstone event passes up into carbonate facies, where the sedimentary sequence is complete, but at many localities in the Crozon/Buçaco/Fajão "basin" the sedimentary history is interrupted by a phase of volcanic activity. At first this was largely explosive, but later phases saw the formation of basic pillow lavas and hyaloclastites (Zone 10). In both Zones 9 and 10 where and/or when the influence of volcanicity was low carbonate deposition continued. The later basic igneous phase was accompanied in both Crozon and Buçaco by the intrusion of a major suite of doleritic sills. Zone 11 saw the return to a

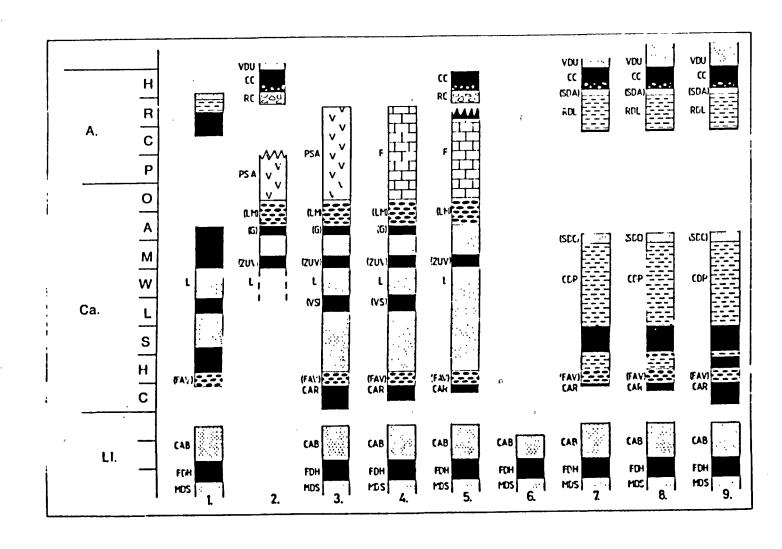


Figure central 10. Time Portugal. distribution See figure y figure of for factes for selected areas ဝ္ဌ

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reduced carbonate deposition, although a few pillow lavas are found at this horizon. Phase "C" also saw a marked faunal change-over, perhaps reflecting increased communication between Europe and Baltica at this time.

Elsewhere, in the "rise" areas, there appears to have been no deposition during this phase, so that at the onset of phase "C" the topography had been reversed; the "basinal" areas were now largely occupied by positive volcanic accumulations.

# iii Phase "C" (Zone 12 to basal Silurian)

This phase of deposition saw the major upper Ordovician glaciation. The deposits of this phase have already been described in chapter 2, so further comment here is not needed. Faunas are essentially unknown during this phase, and there is evidence for the development of an ice-sheet even within the study area. The prescence of a low-diversity fauna in sediments immediately older than the glacial deposits is important; most of the occurences of the <a href="Hirnantia">Hirnantia</a> fauna in Europe are postglaciation (e.g Bohemia, Morocco), so the prescence of a related fauna in this context may be relevant to the discussion of the origins of this widespread <a href="Hirnantia">Hirnantia</a> fauna.

The widespread development of pyritic sandstones at, or just above the Ordovician/Silurian boundary is typical for the Ibero-Armorican area, as is the mid- to upper Llandovery onset of graptolitic mudstone deposition. The causes of these widespread sedimentary phenomena are important in understanding the process of eustatic sea-level rise during, and apparently after deglaciation, but are beyond the scope of this work.

2) Implications for the regional setting

# i Phase "A" (Zone 1 to Zone 8)

This period saw the deposition of shallow-water shelf sediments in the region that is now central Portugal. Similar sedimentary facies have been recorded throughout Armorica and Spain, while less well known, but broadly similar sequences occur in Sardinia, Montagne Noire and the Aquitaine Basin (Mullan 1984). South of the Mediterranean there are large areas showing Ordovician shelf sediments of this age, the best-known of which are the Ordovician sediments of the Moroccan Anti-Atlas.

Within the study area there is a marked thinning of the Phase A succession over a belt running from Vila Velha do Rodão in the southeast towards Figueiro dos Vinhos in the west (see fig. 9). This study does not provide enough data to plot this line accurately, but studies on the "Armorican Quartzite" (Bege, 1970, Romano, 1982b) show isopachs trending parallel to this line, delineating several "basins" and "rises". The evidence outlined above (p. 82) suggests that belts of differential subsidence may not have formed marked topographic features, although the line of the rise on the "Amendoa/Dornes axis" may have been shallower than the area to the north during this phase. Those wave-ripple trends measured seem to parallel this trend and Komar et al. (1972) suggest that such occurrences will parallel the strike of a palaeoslope. This trend is also parallel to the Tomar/Cordoba Fault.

It was indicated in chapter 2 that changes in the nature of deposition were very widespread, indeed Hammann et al. (1982)

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suggest a series of broad sedimentary facies which characterise the Ordovician of southwest Europe as a whole. In chapter 3 it was suggested that it may be possible to correlate the Favaçal Bed with the Nucice iron-ore horizon in Bohemia. This ability to trace facies changes over long distances must surely be indicative of tectonically stable conditions during this phase. This stability is also attested by the thin development of the Ordovician over almost the whole region, and certainly in central Portugal. Local areas of volcanicity are recorded from the middle and upper Ordovician of Europe. In particular Havlicek (1981a) documents the development of volcanic centres in areas of high subsidence within the Prague basin. This has important implications for the interpretation of Phase B in central Portugal (see below).

The source of clastic sediment is unknown, but as outlined in chapter 2 would seem to have lain to what is now the south of the study area, in a region subsequently moved away from the study area by the action of the Tomar/Cordoba Fault.

Faunal affinities are with Bohemia, Britain, Morocco and Turkey. The similarity of Ordovician facies and faunas from the various parts of Europe southwest of the Tornquist line suggest that they formed part of a single area of stable shelf, and the affinities with the north African, and northern South American faunas suggest that this area was directly adjacent to, if not part of, Gondwana.

In order to learn more of the palaeogeography, and perhaps of the dynamics of this area of shelf it would be necessary to understand how the fragments of this large shelf which remain 183. Chapter 5.

within the Hercynian belt were originally assembled. The Phase 1 deposits can provide evidence for such an assembly through the study of facies belts. The distribution of trilobite faunas in Armorica (Henry, 1980) suggests that if belts such as those seen in the "basins" and "rises" of Phase A in Iberia do exist in Armorica, then they should be oriented close to East/West. Such a direction for a Phase A palaeoslope is supported by the direction of wave-ripple trends in Crozon, and indeed by the direction of the differentiation between the northern and southern facies within the Crozon Peninsula.

By placing the Buçaco region (truncated by the Tomar/Porto Fault) and the Crozon region (which lies close to the South Armorican Shear Zone) close together (for these two regions have almost identical geological successions, facies and faunas) a rough reconstruction of the Armorican and central Portuguese areas can be made. Such a reconstruction places those areas with a predominantly arenaceous sedimentation during Phase A in Normandy in the same direction relative to the more muddy deposits of Brittany, as the supposed source relative to the sediments of central Portugal.

#### ii Phase B (Zones 9 to 11)

This second phase of deposition in central Portugal, with its localised volcanic centre is best seen in the context of the volcanic activity described from the Prague basin by Havlicek (1981a). Here the maximum volcanic deposition took place in some of the thickest parts of the sedimentary basin, but itself lies along the pre-Ordovician Komarov Fault. It seems reasonable to

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suggest that the Fajão/Buçaco/Crozon/Chateaulin volcanic complex lies within the belt of highest subsidence in Phase A, while also straddling the Porto/Tomar fault. This perhaps suggests that this Hercynian faultline follows an older fracture. Such a hypothesis receives support from the fact that the Tomar/Cordoba Fault parallels the Phase A "basin and rise" belts.

The other aspect of Phase B worthy of merit in a regional context is the development of carbonate facies. This is sporadic in Portugal, but more widespread in Spain (Celtiberia and Sierra Morena) as well as Sardinia, Montagne Noire, and also occurs in limited areas of Armorica (Crozon, southern Normandy). Carbonate production also rises in other areas of Britain and the Baltic during the lower part of the Ashgill. The causes of such an event must be sought in a palaeoclimatic or marine-chemical change, and as such are outside the scope of this discussion.

# iii Phase C (Zone 12 to basal Silurian)

During this third phase of sedimentary history glacio-marine sediments were deposited across the study-area, except for the volcanic centres of Phase B, which seem to have formed positive areas, and received no further deposits until they were finally covered by mudstones in the Wenlock. The sediments themselves have been discussed above, and further comment is unnecessary, except to indicate that many of the other fragments of the former Ordovician shelf in southern Europe yield similar deposits.

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# 3) Tectonic models for the evolution of the Ibero-Armorican arc

In southwest Europe the Hercynian orogenic belt includes large arcuate regions on either side of the Bay of Biscay. These two segments together form a single large structural unit known as the Ibero-Armorican arc. The origin of this structure has attracted much debate over the last 15 years, but the arguments have been dominated by the geophysical and structural evidence. Palaeontologists have shown the great faunal similarity between parts of the Iberian Ordovician and of Brittany, but comparison of Ordovician facies between the two has been hindered by the lack of precision in the knowledge of the Portuguese sequences.

Much of the controversy in the seventies centred on the origin of the large high-grade mafic/ultramafic metamorphic complexes of northwest Spain and northern Portugal (Anthonioz 1972, Engels 1972, Matte and Ribeiro 1967, Ries and Shackleton 1971, Van Calsteren 1977, Van Overmeeren 1975). Over the last decade these have increasingly been accepted to be klippen, thrusted over autochthonous Palaeozoic low-grade metamorphic strata (Bayer and Matte 1979, Burg et al. 1981, Lefort and Ribeiro 1980, Pin and Vielzeuf 1983).

A second controversy concerned the possible secondary nature of the arc (Ries et al. 1980, Perroud and Bonhommet 1981). A primary origin implies that the arc always had the same curvature, whereas a secondary origin would imply oroclinal bending of the arc. Recent palaeomagnetic studies, although small in scope do suggest that much of the curvature of the arc may be secondary (Ries et al. 1980, Perroud and Bonhommet

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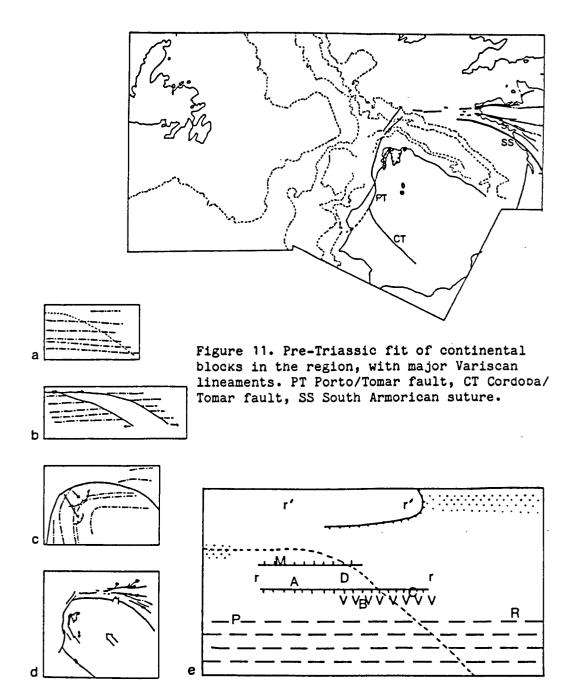


Figure 12. a-d Evolution of the Ibero-Armorican arc.

- a Lower Palaeozoic facies belts.
- b Mid/Late Devonian extension.
- c Late Devonian compression, formation of suture and exotic nappes of northwest Iberia.
- d Late Carboniferous compression, tightening of arc, indenting action of central Iberia.

Figure 12e. Schematic reconstruction of central Portugal and adjacent parts of Armorica for the Ordovician. A Amendoa, B Bucaco, D Dornes, P Penha Garcia, R Rennes. V Ashgill volcanism, stippling: zone 2 sandy, shading zone 2 with Placoparia Assn., r-r Dornes/Amendoa rise, r-r South Normandy rise.

1981).

Further debate arose from the discovery of blueschist facies metamorphic rocks in the south of Brittany, which led to attempts to describe the geology of the southern Armorican Massif in terms of paired metamorphic belts of circum-Pacific type (Peucat et al. 1978). At the same time interest in the shear-zones of the Ibero-Armorican are increased, in particular in the Coimbra-Cordoba shear zone (Bladier 1974, Bladier and Lauret 1974, Chacon 1974, Laurent 1974). A large movement on this shear-zone was recognised, and a major role in controlling the evolution of the arc was proposed for it (Lefort and Ribeiro 1980, Burg et al. 1981). It could also be seen as an explanation for the fundamental differences between the Ossa-Morena and Luso-Alcudian zones, which had been recognised for a long time (e.g. Robardet 1976).

The result of these intensive studies has been the development of a model for the nature and timing of the Hercynian orogenic activity, although the mechanism and tectonic setting of the events remain still hotly debated. The points of concensus are:

- 1 A mid(?)-Devonian event, including large movements on the Coimbra/Cordoba shear-zone, emplacement of the high-grade complexes of northwest Iberia, and high-pressure metamorphism in southern Brittany. Possibly preceded and/or accompanied by intrusion of alkaline plutons.
- 2 A mid-Carboniferous event (300-340 Ma) involving further movement on the shear-zones, much brittle deformation and the emplacement of the leucogranite batholiths. High-grade

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metamorphics, including eclogites, formed in this phase (Group 2 Granulites of Pin and Vielzeuf) are often found on deep-seated lineaments which acted as micro-plate boundaries during Alpine events. This phase has been interpreted as representing tightening of an existing intracontinental discontinuity in the southern Armorican Massif (Lefort et al. 1982), and the model proposed by Lefort and Ribeiro (1980) for the evolution of the whole are also suggests that the tightening phase is intracontinental.

It is thus apparent that a major stumbling block in the interpretation of Hercynian events in western Europe is the lack of a pre-Devonian palaeogeographic reconstruction for the diverse continental fragments now present in the area. The palaeomagnetic data for this period is very sparse; only four data points are presented by Perroud and Bonhommet (1981). Any attempt at unravelling the pre-Carboniferous history of the region must therefore seek evidence from the distribution of sedimentary facies and faunas. Some limited work on this topic has appeared, particularly studying the distribution of trilobite sub-provinces (Henry 1980).

4) The implications of the distribution of fauna and sedimentary facies for tectonic models.

Most of the tectonic models for the region do not consider in detail its evolution during the Lower Palaeozoic. However the existence of a pre-Devonian "South Armorican Ocean" is at least acknowledged by many authors. The clearest exposition of this

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proposed ocean is by Lefort and Ribeiro (1980). In this model an ocean opened between Armorica and northern Iberia sometime in the Lower Palaeozoic (Upper Cambrian?) and closed again leading to a mid-Devonian collision. Thus the median synclinorium of the Armorican Massif would be far from the central Iberian domain during the Ordovician and Silurian in this model. This is precisely the period for which the evidence for the close proximity of these two areas is at its greatest. An alternative explanation for the tectonic data, compatible with the evidence from the Ordovician rocks themselves, must therefore be sought. If the faunal and sedimentological evidence is considered sufficient to repudiate previous tectonically-derived models, then an alternative model must be provided to help bridge the gap between the interpretations.

Peninsula and that of the Buçaco syncline is taken alone it is striking, but taken in the context of the distribution of faunas as illustrated in figure 12, it becomes compelling evidence for the close proximity of these two regions before the Devonian movements. This demands a bulk dextral displacement on the line of the Coimbra/Cordoba and South-Armorican shear-zones. The movement on the Coimbra/Cordoba shear-zone is often described as sinistral, but evidence for the sense of movement before the mid-Carboniferous orogenic phase is lacking, and the model proposed by Lefort and Ribeiro (1980) does suggest an earlier dextral period of movement. What the data on figure 12 suggests is that an early dextral movement may have been more important than the later sinistral phase.

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### 5) Synthesis

The evidence strongly suggests that a limited reconstruction of the relative positions of Portugal and parts of Brittany during the Ordovician is feasible. A full reconstruction for southwest Europe would involve unravelling the complex history of the Hercynian orogen. However, several general points can be made. Firstly, during the Ordovician the Ibero-Armorican region was a stable shelf. Local linear belts of differential subsidence are superimposed on a general picture of very slow subsidence during the middle and upper Ordovician. Models invoking a major rifting phase, with production of oceanic crust between parts of this shelf during the Ordovician (e.g. Lefort and Ribeiro, 1980) seem incompatible with this stability.

The post Ordovician deformation has fragmented the original shelf, involving the rotation of fragments and forming arcuate shear zones. Subsequent tightening of the orogen was responsible for the formation of large-scale structures, such as the Ibero-Armorican arc. Features attributed to oceanic sutures, such as the "South Armorican Suture" may rather be the resuturing, the welding together of the rotated and deformed remnants of the pre-Hercynian stable block, on which the Ordovician of south-west Europe had been deposited.

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## Appendix A. - Geochemistry

## 1) Introduction.

In order to further the understanding of the sediments involved in this study some 31 samples were selected for study by X-ray diffraction techniques, and all but one of these samples were then examined by X-ray fluorescence. The samples were selected to provide data on a wide variety of lithologies, in particular the fine-grained rocks; the mudstones and oolitic ironstones. All the analyses were undertaken on the equipment in the Department of Geology, the University of Sheffield.

The work was largely undertaken as a reconnaissance study, in advance of a forthcoming research project. This project will examine the sedimentary geochemistry of the European Ordovician, with particular reference to the development of colitic ironstones. In view of this more detailed study to come, the geochemical results will be presented simply in tabular form here, with a few general comments on mineralogy. These results will be intended to permit comparison with other studies, rather than being presented here as an end in themselves.

#### 2) Discussion of mineralogy.

There are two suites of samples which are particularly worthy of comment. these are the "normal" mudstones (ZUV7, VS2, FAV1, ZUV29, ABO5, CW1, CW2) and the oolitic ironstones (VER30, QXP1, LOR1, RAG20, RC31, ABO8, RC29, MDC5).

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#### a Mudstones.

The dominant minerals in most of these mudstones (ABO5, which has been more extremely heated excepted) are quartz and illite. This is similar to the results from Brittany (e.g. Dabard, 1983), however Dabard did not see the same pyrite content as is evident from the freshest portuguese samples (e.g. CW2 9.6% Fe203, 3.8% SO3). This high iron content is extremely significant in the interpretation of the ironstones (see below). Chlorite is present in the mudstones, but in relatively small amounts.

#### b Oolitic Ironstones.

This lithology is relatively unimportant volumetrically, but the facies has important palaeogeographical consequences because of its widespread distribution. the iron-mineral present is predominantly chamosite (a chlorite), but the widely varying relative intensity of the 7A and 14A XRD peaks hints that berthierine or kaolinite may also be present. The colitic ironstones are frequently phosphate-rich (e.g. RC 31b). No siderite or other carbonate phase has yet been identified in the ironstones.

#### c Other specimens.

The other material sampled includes several samples from the supposed glaci-marine deposits of the Casal Carvalhal Formation.

This includes quite a large amount of fine-grained feldspars.

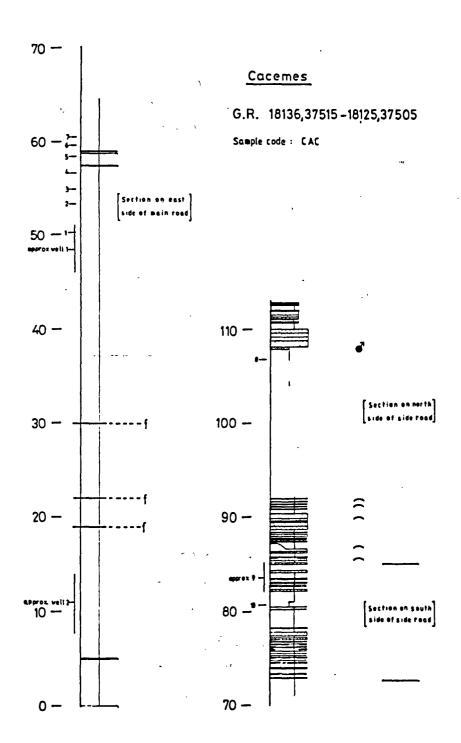
A phosphatised conglomerate from the Cabril Formation comprised (CAC9) almost 36% apatite.

Sample SiO2 TiO2	A1203 Fe203	MnO I	MgO CaO	Na20	K20	P205 S03	Total	
VED 20 1 22 70 0 84	10 01 01 67	0.00		======	======			
VER30] 32.79 0.81	19.21 24.67		3.49 5.47		1.67			Oolitic ironstone
QXP1 J 41.10 0.88	18.50 26.37		2.85 0.00	0.00	1.11			Oolitic ironstone
LOR1 ] 28.78 1.07	22.64 27.32		3.20 2.32	0.05	1.46	-	-	Oolitic ironstone
RAG20 J 44.47 1.20	22.95 8.30		3.47 4.89	0.32	3.67			Oolitic ironstone
RC31CJ 33.66 1.99	12.45 33.49		1.84 0.03	0.05	0.64			Oolitic ironstone
RC31BJ 55.32 0.29	5.99 5.57		0.52 13.57	0.00	*			Oolitic ironstone
RC31A] 38.47 1.42	15.70 25.30	-	3.41 1.02	0.00	0.94		-	Oolitic ironstone
ABO8 ] 42.56 0.86	21.25 22.91		3.23 0.31	0.13	2.17			Oolitic ironstone
RC29 ] 26.05 0.97	20.18 26.50		3.93 6.25	0.11	1.63			Oolitic ironstone
MDC5 J 49.38 0.53	14.43 19.33		2.33 3.68		0.98			Oolitic ironstone
MDCL3] 60.49 0.71	15.03 11.85		0.94 0.00	0.06	2.08	0.11 0.03	] 91.37	Muddy sandstone
MDCL4J 70.20 0.88	14.93 3.70		0.72 0.00	1.12	3.50	0.06 0.01	J 95.10	Muddy sandstone
MDCL1] 77.08 0.44	10.79 5.20		0.63 0.00	0.67	1.66	0.08 0.02	] 94.12	Muddy sandstone
MDC9 J 55.09 1.01	22.10 7.57		1.77 0.00	0.09	4.94	0.11 0.01	] 92.69	"Bryozoa bed"
MDC11] 68.54 0.28	8.09 15.86	0.01	1.84 0.69	0.00	0.01	0.80 0.00	J 96.07	Chamositic Sst.
ZUV7 ] 67.32 1.02	18.28 2.33	0.00	0.68 0.00	0.00	4.25	0.06 0.03	] 93.89	Mudstone
VS2 J 56.80 1.04	21.40 6.81	0.02	1.32 0.00	0.03	4.66	0.14 0.02	1 92.21	Mudstone .
FAV1 J 52.12 1.00	23.60 7.35	0.01	1.94 0.00	0.02	5.68	0.13 0.03	-	
ZUV29] 59.11 0.95	20.65 4.37	0.00	1.48 0.00	0.04	6.37	0.12 0.02		
MDC12] 76.27 0.75	10.26 4.95	0.08	0.67 0.19	1.11	2.26	0.18 0.34		
AML J 72.01 0.80	14.70 1.75	0.00	0.66 0.00	0.52	4.49	0.11 0.01		
VDU1 ] 85.57 0.45	6.79 0.42	0.00	0.12 0.06	0.17	1.81			Black sandstone
VDU ] 56.98 1.23	23.72 3.32	0.00	1.55 0.04	0.02	6.58	0.21 0.00		
FDS1 ] 70.27 0.86	16.84 0.45	0.00	0.55 0.00	0.00	4.30			Sandy mudstone
CW2 ] 52.41 1.03	22.87 9.54		1.95 0.00	0.29	4.39			Fresh mudstone
CW1 J 53.42 1.19	22.39 8.61		2.00 0.09	0.81	3.40	-		Fresh mudstone
CAC9 ] 48.18 0.25	5.58 4.06	0.00	0.27 19.83	0.04	1.09			Phosphorite
AB05 J 55.75 1.13	24.09 4.29		1.45 0.07	0.55	4.98	0.23 0.00		
POR6 ] 12.26 0.90	7.34 1.67		5.50 23.45	0.03	1.97	3.30 0.00	-	
POR2 ] 64.58 0.90	13.21 11.83		0.35 0.07	0.00	3.04			"Rottenstone"
=======================================	=======================================	======		:=====	=====	:=======::	:======	, ,
Si02 Ti02	A1203 Fe203	MnO	MgO CaO	Na20	K20	P205 S03	Total	

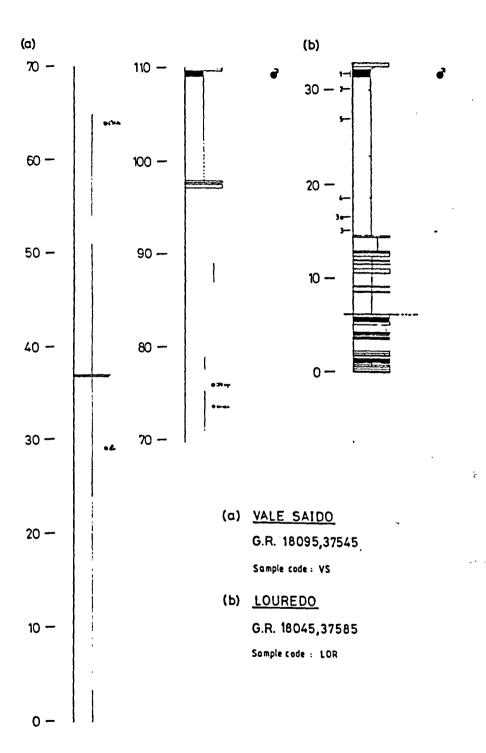
#### Appendix B. - Measured Sections

#### Contents

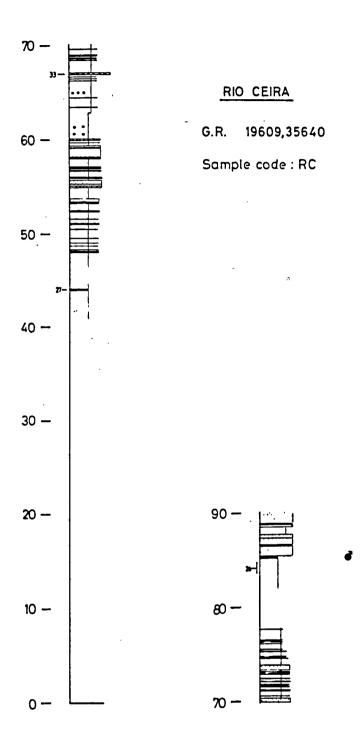
- Log 17. Cacemes, Buçaco, upper part of Cacemes Group.
- Log 18. Vale Saido, Buçaco, upper part of Cacemes Group.
- Log 19. Louredo, Buçaco, Carregueira Fm.
- Log 20. Rio Ceira (Cabril), upper part of Cacemes Group.
- Log 21. Rio Ceira, Louredo Formation.
- Log 22. Rio Ceira (Ribeira do Braçal), Rio Ceira Gp..
- Log 23. Zuvinhal, Buçaco, Louredo Formation.
- Log 24. Zuvinhal, Porto de Santa Anna Formation.
- Log 25. Chão das Figueiras, Porto de Santa Anna Formation.
- Log 20. Porto de Santa Anna, base of Porto de Santa Anna Fm..
- Log 27. Favaçal, Buçaco, Louredo Formation.
- Log 20. Vale Saido, Buçaco, Louredo Formation.
- Log 29. Ferradosa, Buçaco, Ferradosa Fm..
- Log 30. Covello, Buçaco, Ribeira Cimeira/Casal Carvalhal Fms.
- Log 31. Carvoeiro, Bycaco, Ribeira Cimeira/Casal Carvalhal Fms.
- Log 32. Lameiros, Dornes, upper part of Cacemes Gp..
- Log 33. Monte de Carvalhal, Dornes, upper part of Cacemes Gp..
- Log 34. Monte de Carvalhal, Dornes, Cabeço do Peão Formation.
- Log 35. Sanguinheira, Amendoa, Cabeço do Peão Formation.
- Log 30. Ribeira da Laje, Amendoa, Cabeço do Peão Formation.
- Log 37. Balancno, Amendoa, Capeço do Peão Formation.
- Log 38. Ribeira da Laje, Amendoa, Cabeço do Peão Formation.
- Log 39. Aboboreira, Mação, Cabeço do Peão Formation.
- Log 40. Amendoa, Cabeço do Peão Formation.
- Log 41. Pereiro, Mação, Cabeço do Peão Formation.
- Log 42. Carregueira, Mação, Carreguiera Formation.
- Log 43. Ribeira da Laje, Amendoa, Ribeira da Laje Formation.
- Log 44. Casal Carvalhal, Dornes, Ribeira da Laje and Casal Carvalhal Formations.
- Log 45. Vale da Ursa, Dornes, Vale da Ursa Formation.
- Log 46. Junqueira, Dornes, Foz da Serta Formation.
- Log 47. Foz da Sertã, Dornes, Vale da Ursa Formation.
- Log 46. Cabeço da Pena, Dornes, Vale da Ursa Formation.
- Log 49. Casal de Rio, Dornes, Vale da Ursa Formation.
- Log 50. Penha Garcia (Bandonais SW limb), entire.
- Log 51. Penha Garcia (Bandonais NE limb), Cacemes Gp.
- Log 52. Penha Garcia (Vaca), upper part of Louredo Fm.
- Log 53. Raguenez, Kermeur Fm.
- Log 54. Le Veryac'h, Kermeur and Cosquer Fms.
- Log 55. Le Veryac'h, Schistes de Veryac'h.
- Log 50. Postolonnec, Schistes de Veryac'h.
- Log 57. Raguenez, base of Kermeur Formation.
- Log 58. La Touche, upper part of Andouillé Formation.
- Log 59 and 59a. Pointe de Raguenez (Aber), Rosan Fm.
- Log oo. Rosan Quarry, Rosan Formation.
- Log b1. Raguenez (Plage de Raguenez), Rosan Formation.



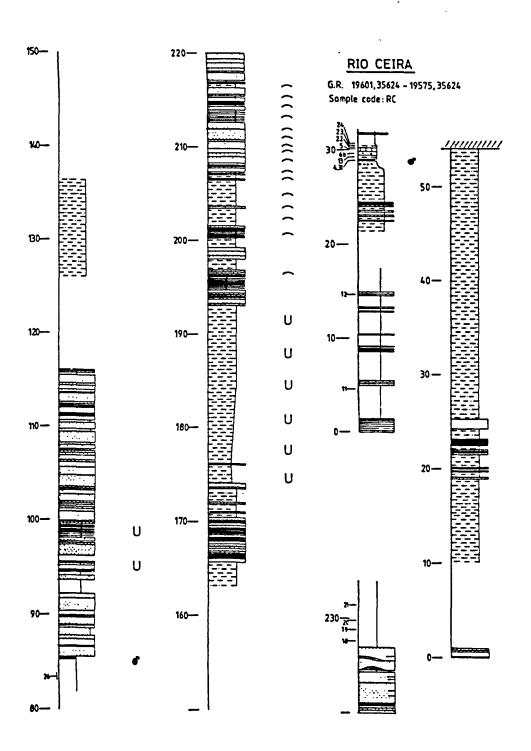
Log 17. Cacemes.



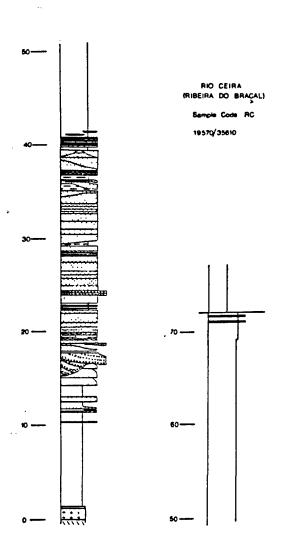
Log 18. Vale Saido.
Log 19. Louredo.



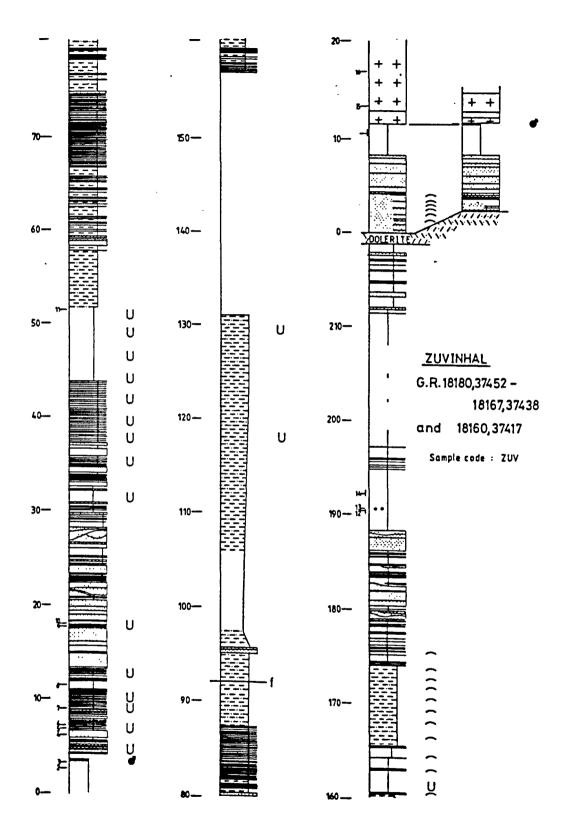
Log 20. Rio Ceira (Cabril).



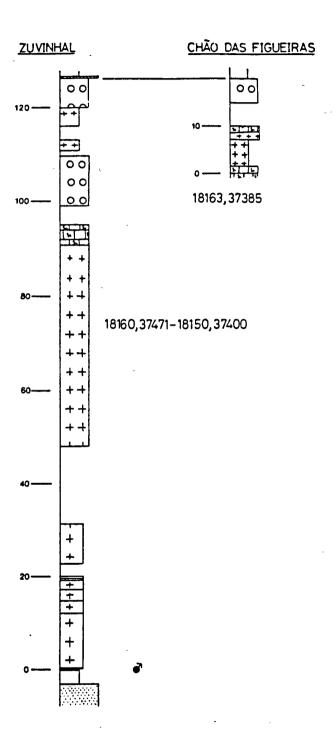
Log 21. Rio Ceira.



Log 22. Rio Ceira (Ribeira do Braçal).



Log 23. Zuvinhal.

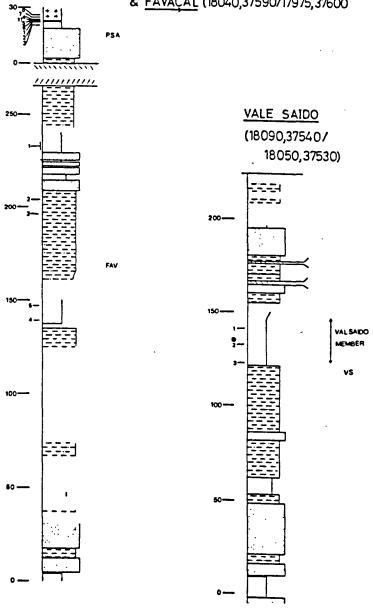


Log 24. Zuvinhal.

Log 25. Chão das Figueiras

## PORTO DE SANTA ANNA

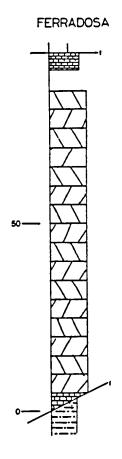
## & FAVACAL (18040,37590/17975,37600

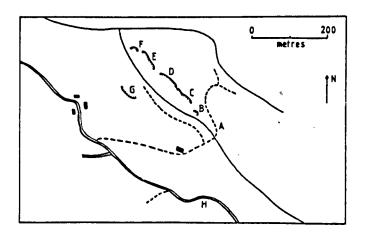


Log 26. Porto de Santa Anna.

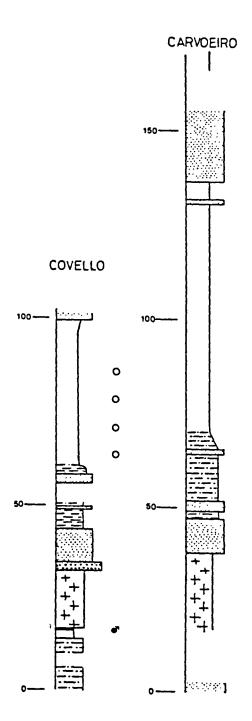
Log 26. Vale Saido.

Log 27. Favaçal.



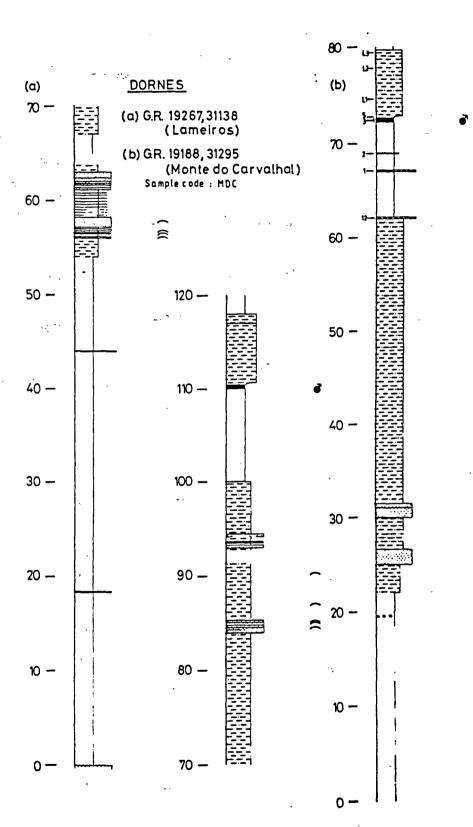


Log 29. Ferradosa.



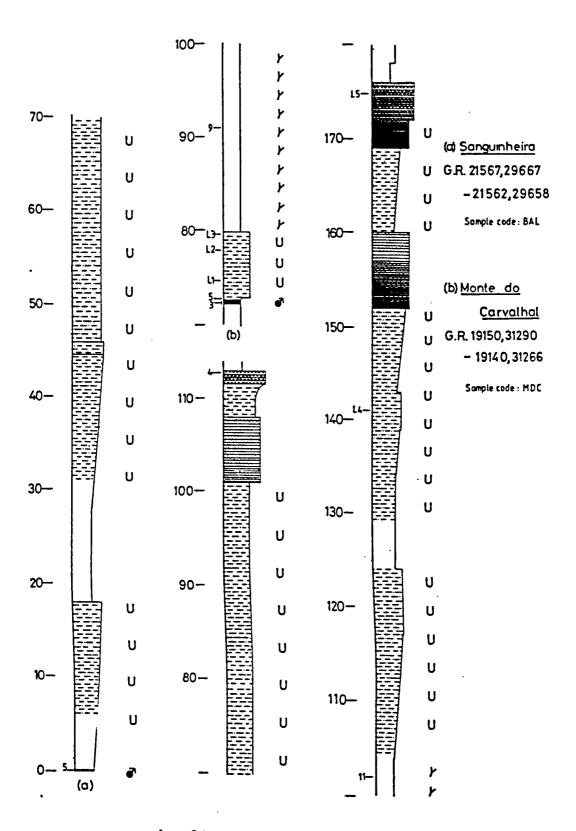
Log 30. Covello.

Log j1. Carvoeiro.



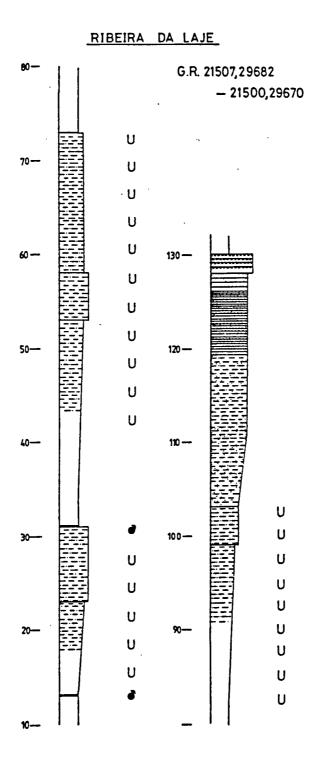
Log 32. Lameiros.

Log 33. Monte de Carvalhal.

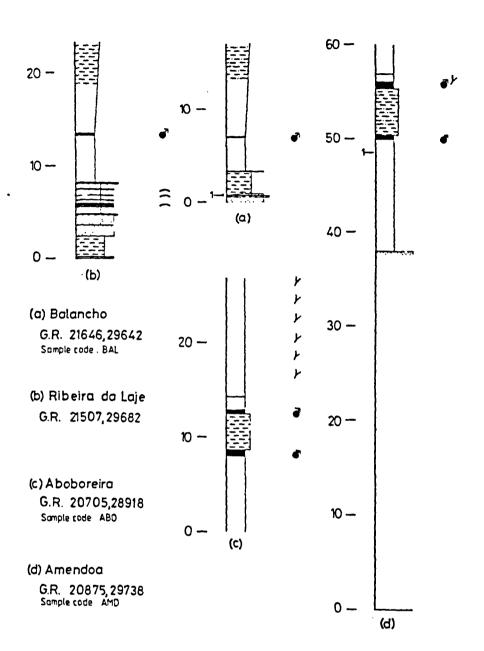


Log 34. Monte de Carvalhal.

Log 35. Sanguinheira.



Log 30. Ribeira da Laje.

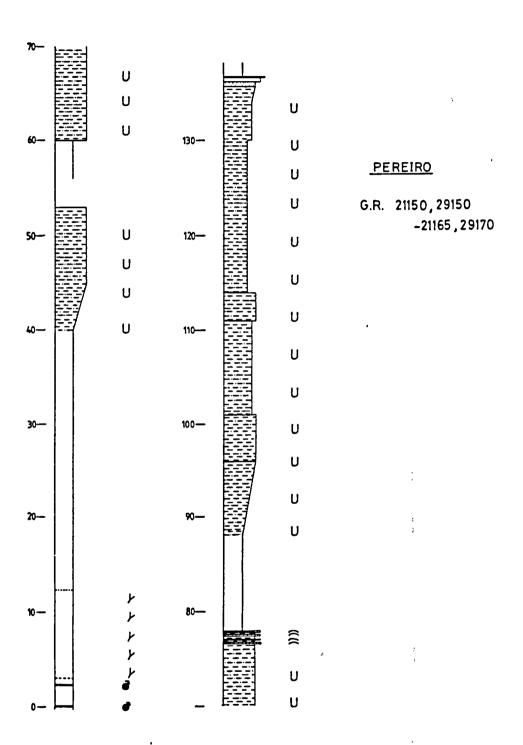


Log 37. Balancho.

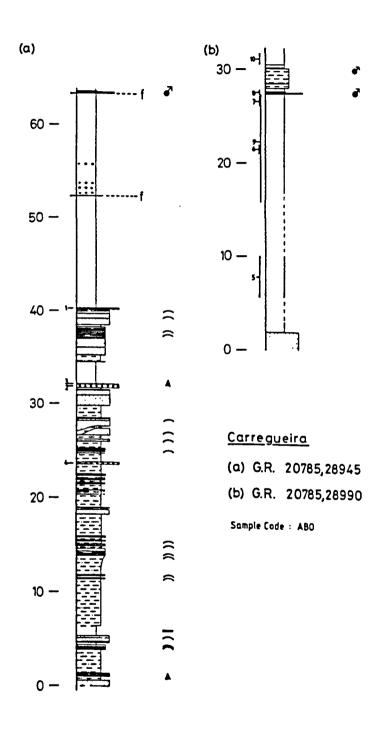
Log 30. Ribeira da Laje.

Log 39. Aboboreira.

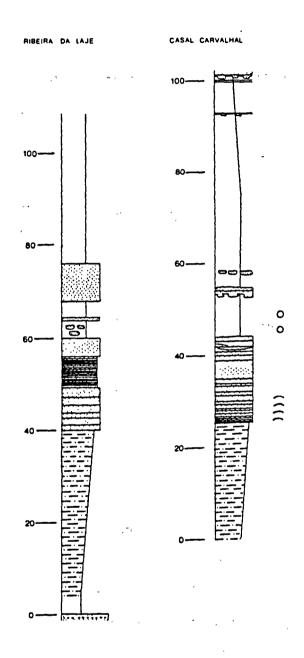
Log 40. Amendoa.



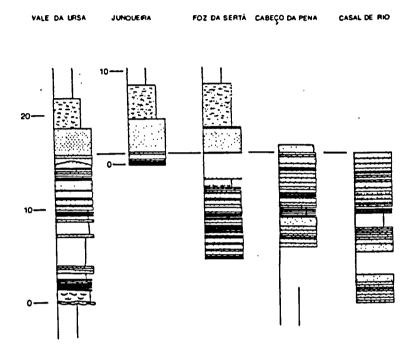
Log 41. Pereiro.



Log 42. Carregueira.



Log 43. Ribeira da Laje. Log 44. Casal Carvalhal.



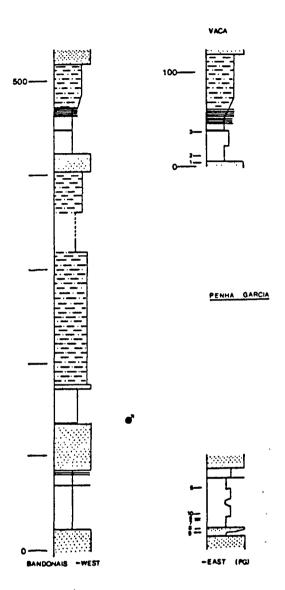
Log 45. Vale da Ursa.

Log 46. Junqueira.

Log 47. Foz da Sertã.

Log 45. Cabeço da Pena.

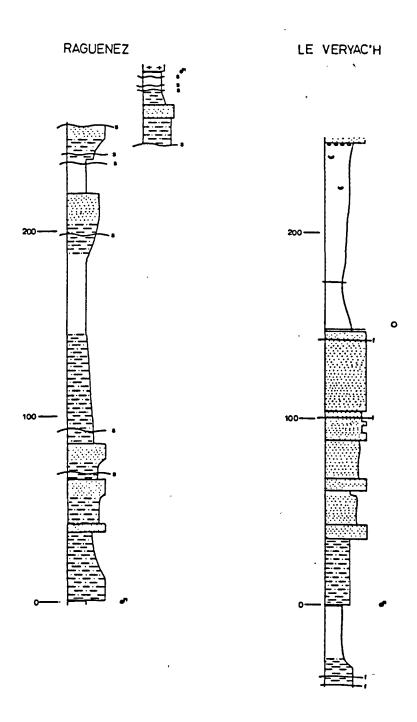
Log 49. Casal de Rio.



Log 50. Penha Garcia (Bandonais - SW limb).

Log 51. Penha Garcia (Bandonais - NE limb).

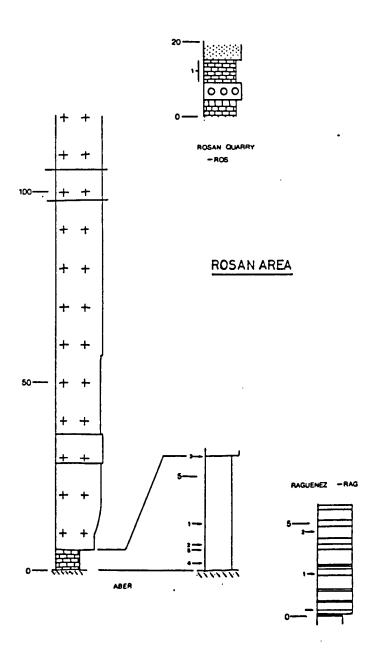
Log 52. Penha Garcia (Vaca).



Log 53. Raguenez.

Log 54. Le Veryac'h.

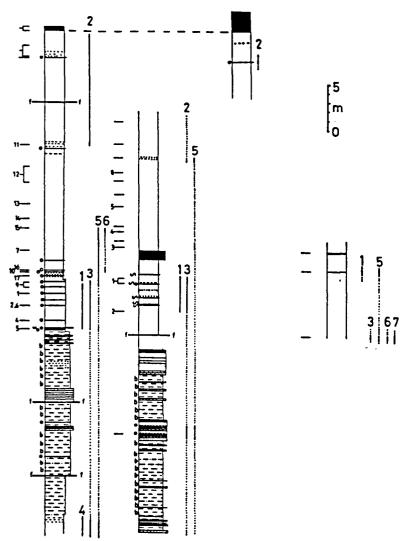
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Log 59 and 59a. Pointe de Raguenez (Aber).

Log 60. Rosan Quarry.

Log 61. Raguenez (Plage de Raguenez).



Le Veryac'h Postolonnec Raguenez La Touche

7 Tyronella? p A
Nescurelus (Neseurelus) tristeni
Applianorthis bussacensis
Neterorthina app.
Placaparia berni
Aegiromena mariana

Log 55. Le Veryac'h.

•

Log 56. Postolonnec.

Log 57. Raguenez.

Log 58. La Touche.

# Appendix C. - The fauna

This appendix comprises a summary of the brachiopods, rostroconchs, bivalves, graptolites and trilobites recovered from the studied successions.

The brachiopods of the Portuguese Ordovician were particularly poorly known, so during this study some emphasis has been placed on the description of their constitution and distribution. There has not been sufficent opportunity for the complete description of all the forms recovered, but an attempt has been made to provide a comment on each element of the fauna, with full descriptions wherever possible.

The molluscan groups outlined here consist largely of previously-described forms, so in most cases full descriptions have not been provided. It has been possible, however, to clarify the use of some of the specific names erected by Sharpe.

Dr R.B. Rickards has kindly provided descriptions of one Ordovician and three Silurian graptolites, and these are included in full here. Dr. Rickards also drew the accompanying line drawings.

As a group the trilobites are much more fully known than the other elements of the portuguese fauna. Because of this the main contribution of the section on trilobites is to clarify their geographical and stratigraphical distribution.

Phylum Brachiopoda Dumeril, 1806

Class Inarticulata Huxley, 1809

Order Lingulida Waagen, 1885

Superfamily Lingulacea Menke, 1828

Family OBOLIDAE King, 1846

Subfamily Obolinae King, 1846

Obolinid gen. et sp. indet. A

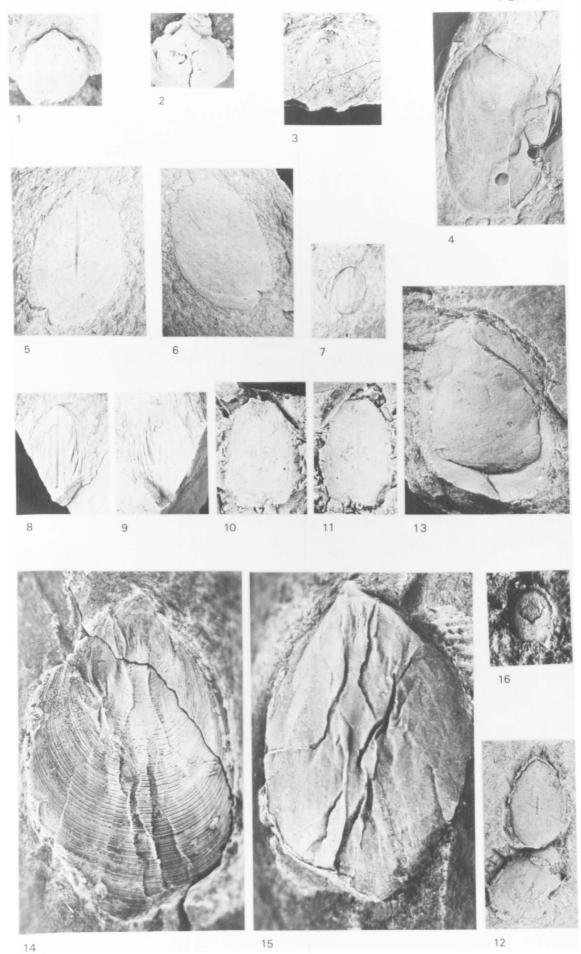
(Plate 1, figs. 1,2)

MATERIAL. Internal moulds of two brachial valves, one with corresponding external with some adhering shell material.

DESCRIPTION. Brachial valves of sub-circular outline; ornament unknown; shell relatively thick; well-developed dorsal interarea with strongly ridged median groove; anterior margin of groove recessed posteriorly from anterior margin of lateral parts of interarea.

DISTRIBUTION. Both of the available specimens are from the Favaçal Bed, one from the Buçaco syncline (LOR1) and the other from the Dornes area (MDC5). Both are thus of zone 5.

DISCUSSION. The relatively thick-shelled, moderately convex valves seem to belong to the Obolinae, but assignation to a genus within the subfamily is more difficult. Schmidtites Schuchert and Le Vene, 1929 seems close to the present material.



Subfamily Glossellinae Cooper, 1956

Genus <u>Pseudolingula</u> Mickwitz, 1909, emend. Williams, 1974

Type species: <u>Pseudolingula quadrata</u> (Eichwald, 1829).

## Pseudolingula spp.

(Plate 1, figs. 3-12)

MATERIAL. This material comprises four brachial valves, all rather poorly preseved, from the Cabril Formation (samples CAC10, RC33), together with a large amount of fragmented shell material, together with nine valves from the Carregueira Formation (AB05,6,7,9), again flattened and deformed.

DESCRIPTION. Tear-drop shaped valve about 65% as wide as long.

Maximum width at about 60% of valve length. A low ridge runs

Plate 1.

Obolinid gen. et sp. indet. A Internal moulds of brachial valves, x3; fig. 1 MDC5, fig. 2 LOR1.

Pseudolingula spp.
Fig. 3 partly exfoliated ?brachial valve, ABO7, fig. 4 external mould of ?brachial valve, ABO9, figs. 5,6 internal and external moulds respectively of brachial valve, ABOb, fig. 7 internal mould of brachial valve, ABO7, figs. 8,9 partly exfoliated internaland external moulds of brachial valve, ABO9, figs. 10,11 partly exfoliated external and internal moulds of brachial valve, CAC10, fig. 12 internal moulds of two brachial valves, CAC9. All x3.

Lingulid indet. A

Fig. 13, internal mould of ?pedicle valve of conjoined pair, QXP2, x3.

Lingulid indet. B

Fig. 14, external and internal moulds of ?brachial valve,. RC12, x4.

Paracraniops sp.

Fig. 1b internal mould of brachial valve, RC11, x7.

from approximately 15% of valve length from umbo to 65%. External ornament composed of concentric growth lines (about 8/mm Carregueira Formation), faint fine radial ornament (fila 20/mm on midline of a specimen from the Carregueira Formation) visible on internal, and on well preserved externals. Maximum pedicle valve length 14.5mm

DISTRIBUTION. The material described here from the Cabril Formation of the Buçaco syncline (zone 3) occurs in the mudstones of the formation, as well as reworked in the phosphatic coquinas and conglomerates. The material from the Carregueira Formation (zone 4) is from the Mação area.

DISCUSSION. Given the poor state of knowledge of this poorly preserved material, comparison with other forms is not possible.

Lingulid indet. A (Plate 1, fig. 13)

An internal mould of conjoined valves of a specimen of an indeterminate Lingulid was recovered from QXP2, Zone 6.

Lingulid indet. B Plate 1, fig. 14)

A single large specimen of an unidentified lingulid was found in Zone 12 deposits of the Riberia do Braçal Formation of the Rio Ceira inlier (RC12).

Family CRANIOPSIDAE Williams, 1963

Genus Paracraniops Williams, 1963

Type species: Paracraniops pararia (Williams, 1962)

Paracraniops sp. indet.

(Plate 1, fig. 16)

The Zone 11 deposits in the south of the Buçaco syncline (Rio Ceira inlier) have yielded several specimens of <u>Paracraniops</u>.

Order Acrotretida Kuhn, 1949

Suborder Acrotretidina Kuhn, 1949

Superfamily Acrotretacea Schuchert, 1893

Family ACROTRETIDAE Schuchert, 1893

Genus Conotreta Walcott, 1889

Type species: Conotreta rusti Walcott, 1889.

Conotreta sp.

(Plate 2, figs. 1,2)

MATERIAL. Internal moulds of two brachial valves, and two pedicle valves. Material is disassociated, so it remains uncertain whether these valves do belong together.

DESCRIPTION. Shells minute, but great variation in size of available material (brachial valves about 0.5mm diameter, pedicle valves about 1.5mm); ventral valves acutely conical, about as high as basal diameter; pedicle opening probably small,

sub-apical (preservation makes this uncertain); sides of cone slightly concave in profile; dorsal valve low; approximately circular; with prominent medium septum, continuous with depressed median platform; propareas well developed.

DISTRIBUTION. All of the available specimens are from from decalcified peoples within the diamictite of the Casal Carvalhal Formation on the western limb if the Buçaco syncline, at Covelo. The age of this material is therefore uncertain. The lithology of the silicified rottenstone containing the specimens, with its dispersed ironstone ooids suggests derivation from the oolitic ironstone of the Leira Ma Member (zone 8).

DISCUSSION. The general form of the available material strongly suggests this material could be placed in <u>Conotreta</u>, but better material of the ventral valve and confirmation that these valves are indeed from the same species are needed before a specific assignation can be made.

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Plate 2.

Conotreta sp.

Fig. 1 internal mould of pedicle valve, fig. 2 internal mould of brachial valve, both x12, COV1.

Schizocrania sp. A

Fig. 7 internal mould of brachial valve, CACWELL1, x3.

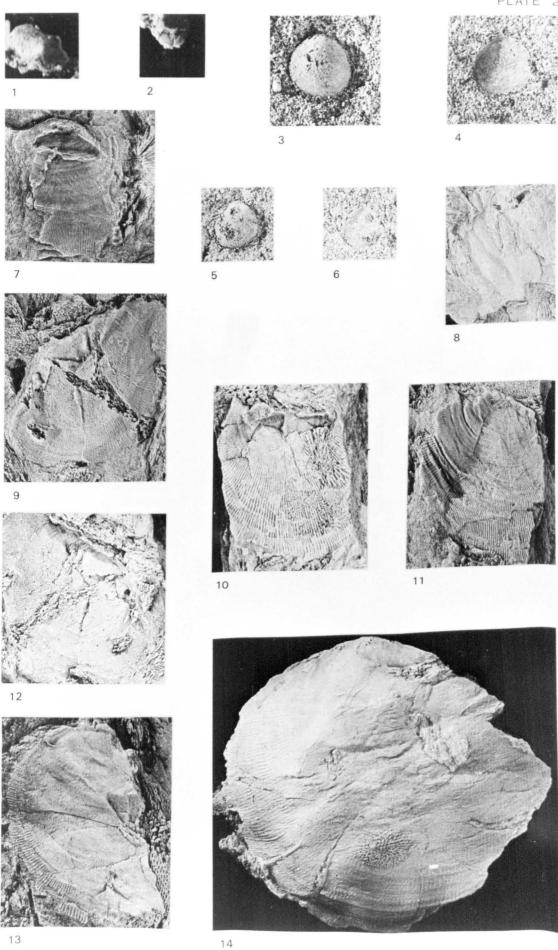
Schizocrania sp. B

Figs. 3,4 internal and external moulds of a brachial valve, figs. 5,6 internal and external moulds of a brachial valve, both specimens BAL1, x3.

Trematid gen. indet. sp. A

Figs. 0,9 external moulds of pedicle valves, fig. 12 latex cast of specimen in fig. 9, figs 10,11 external moulds of brachial valves, figs. 13,14 internal moulds of brachial valves. All specimens x3, QXP2.

PLATE 2



Superfamily Discinacae Gray, 1840 Family TREMATIDAE Schuchert, 1893

Genus <u>Schizocrania</u> Hall and Whitfield, 1875

Type species: <u>Schizocrania</u> filosa (Hall, 1847).

Schizocrania sp. A
(Plate 2, fig 7)

MATERIAL. A single poorly preserved valve.

DESCRIPTION. The single specimen is of a sub-circular convex, presumably brachial valve, approximately 20mm in diameter. Only the outside of the valve is visible, and this has a radial ornament of dichotomous ribs, and a concentric ornament of lamellae and wrinkles; the latter exaggerated by the compaction of the sediment.

DISTRIBUTION. This specimen is from the Fonte da Horta Formation of the Bucaco syncline (CACWELL1).

Schizocrania sp. B (Plate 2, figs. 3-6)

MATERIAL. Two brachial valves, both partly exfoliated.

DISTRIBUTION. These two specimens are from a ferruginous sandstone at the top of the Cabril Formation, in the area to the east of Amendoa.

DISCUSSION. The preservation does not allow further description of these specimens.

Trematid gen. indet. sp. A

(Plate 2, figs. 8-14)

MATERIAL. Four internal moulds of brachial valves and two external (?) of pedicle valves.

DESCRIPTION. Subcircular in outline; all material flattened, preserved as moulds; ventral valve with ornament of concentric ribs, as well as fila, at anterior margin of valve (12mm diameter) 10 ribs/mm, 6 fila/mm; dorsal valve shows only radial ornament, this is and 7/mm slightly thickened, and one specimen gives a suggestion of a pair of dorsal valve 15mm.

DISTRIBUTION. This material is from the Queixopeira Member from the area to the west of Mação (QXP2), and is of zone ó age.

DISCUSSON. This material has been kept under open nomenclature for although the genus <u>Schizocrania</u> is very similar, the difference in ornament between the two valves is striking. The discovery of further material may aid to resolve this point.

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Order Orthida Schuchert and Cooper, 1932

Suborder Orthidina Schuchert and Cooper, 1932

Superfamily Orthacea Woodward, 1852

Family ORTHIDAE Woodward, 1852

Subfamily Productorthinae Schuchert and Cooper, 1931

Genus Nicolella Reed, 1917

Type species: Orthis actoniae Sowerby, 1839.

<u>Nicolella</u> sp. A (Pl. 3, figs. 1-13)

MATERIAL. 9 internal and 8 external moulds of pedicle valves with 1 internal and 3 external moulds of brachial valves, all from sample ROS1.

DESCRIPTION. Concavo-convex shell, with highly convex pedicle valve at least 30% as deep as long, brachial valve concave and often slightly resupinate; shell outline varies markedly during ontogeny: in juvenile specimens the shell is strongly mucronate, with the maximum width of the shell at the hingeline, with the length 75% of the maximum width, after the length exceeds about 20mm the cardinal angle gradually approach an obtuse shape, and the maximum width lies at about 40% of the shell length anterior of the hingeline, in large specimens the length increases to 85% of the maximum width (see Pl. 3 figs. 2 and 7); in large specimens both valves may become geniculate; ventral interarea flat, anacline, dorsal interarea low, ana- to hypercline;

ornament costellate, 10 primary costae on brachial valve, typical branching pattern includes early internal costellae from ribs 1 and b, with externals from 2, 3, 4, b, tertiary ribs are commonly developed in the area of costae 3, 4, 5; typical rib counts are 11 at 5mm, 20 at 10mm, 44 at 20mm anterior of umbo; density of ribs at anterior margin of large valves 4 ribs/mm; fine growth lines are present, as are lamellae, with typically 7 or 8 lamellae distributed across the shell, with the geniculate anterior margins of large specimens extremely lamellose.

Ventral interior with teeth supported by receeding dental plates; ventral muscle field sub-pentagonal, 20% of valve length long, diductors do not enclose adductor scars anteriorly; vascular system unknown except for prominent vascula media anterior of medial lobes of diductor scars.

Dorsal interior with widely divergent brachiophores, with simple pits postero-laterally; cardinal process ridge- or boss like, on slightly developed notothyrial platform which extends anteriorly into median ridge for 35% of valve length; muscle field poorly impressed; vascular system unknown.

DISTRIBUTION. This species has only certainly been recorded from the Rosan quarries and road-cutting, but similar material with a

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Plate 3.

Nicolella sp. A

Pedicle valves: figs. 1, 3, 4, 5, 0 - internal moulds, figs. 2, 7, 8 - external moulds. Brachial valves: figs. 10, 11 external moulds, fig. 9 internal mould, figs. 12 and 13 counterparts - internal and external moulds respectively.

All specimens from sample ROS1. All x1.5 magnification.

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concave brachial valve, and similar ribbing pattern on the brachial valve, has been recovered from the upper part of the Porto de Santa Anna Formation of the Buçaco syncline. The firm specific attribution of the Portuguese material must await the discovery of more material.

DISCUSSION. Separation of this species from N. sp. B is discussed under that species (see above). Nicolella sp. A is close in general form to N. decemcostata Dreyfuss 1948, but the details of any change of valve outline with growth are unclear from Havlicek's plates and description (1981). However the two species differ in details of rib-branching; Havlicek describes the simultaneous appearance of inner secondaries in the brachial valve, and outer secondaries in the pedicle valve, at 7-10mm from the umbo. He does not describe the prescence of a later generation of ribs.

Nicolella sp. B
(Pl. 4, figs. 1-8)

v 1908 Orthis actoniae Sowerby: Delgado p 61.

MATERIAL. Description based on internal moulds of 2 brachial, and 5 pedicle valves from the Poiares Member (samples POR2,3), together with that of 1 pedicle valve from Coat Garrec (GAR1). A slightly larger number of external moulds were also available from the same localities.

DESCRIPTION. Plano-convex shell of sub-circular outline; pedicle

valve with strongly incurved umbo, ventral interarea low anacline, dorsal interarea low hypercline; shell mucronate, becoming less-so in larger specimens; brachial valve about as long as wide; ornament costellate, pedicle valve with 11 primary ribs, with a further pair of costae developing along posterior margin, on available specimen no division of costae within 6mm of umbo; brachial valve with 10 or 12 primary ribs, with a further pair arising from flanks, some valves exhibit a median rib arising 0.5mm from umbo, secondary ribs variably developed, but typically ribs 2, 3, 4, 5 develop internal secondaries at about 4mm, 4mm, 6mm, 6mm respectively; surface of shell covered with growth lines which often become lamellose, particularly after 7mm growth stage when the shell becomes highly lamellose; maximum observed width 15mm.

Ventral interior with stout teeth supported by recessive dental plates; ventral muscle field bilobate, sub-pentangular, with adductor track on narrow low median ridge.

Plate 4.

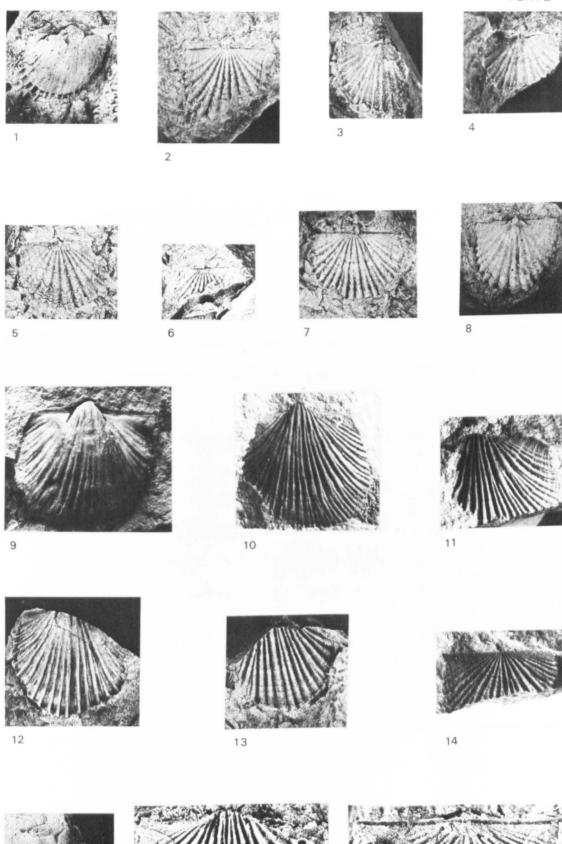
## Nicolella sp. B

Fig. 1 internal mould of pedicle valve, POR2, x1.5, figs. 2, 5, 7 external moulds of brachial valves, POR2, x1.5, fig. 6 external mould of brachial valve, GAR1, x1.5, figs. 3, 4 internal moulds of brachial valves, POR2, x1.5, fig. 8 latex cast of internal mould of brachial valve, POR2, x1.5.

### Nicolella sp. C

Fig. 9 internal mould of pedicle valve, SGL 2907, Leira Ma, x1.5, figs. 10, 11 external moulds of pedicle valves, SGL 2907 and 2900 (1 of) respectively, Leira Ma, x1.5, figs. 12 and 13 internal and external moulds of a pedicle valve, ABER4, x1.5, fig. 14 external mould of bracnial valve, SGL 2906 (1 of), Leira Ma, x1.5, fig. 15 internal mould of pedicle valve, ABER4, x1.5.

Figs. 16 and 17 external moulds of pedicle and brachial valves of conjoined pair, B135, x4.0.





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Dorsal interior with widely divergent low ridge-like brachiophores; cardinal process boss-like with median ridge on posterior face; notothyrial platform thickened, extending anteriorly into short median ridge; crural closed by low ridges at distal ends of brachiophores.

DISTRIBUTION. The material referred to this species originates from the lower part of the Venda Nova Group, in the Poiares Member, and from the lower part of the Rosan Formation. All these occurrences are Zone 9. Poorly preserved <u>Nicolella</u> from the silicified beds at Cabeço Pedrogão and near Palmazes (both south of Sazes) may also belong here (Zone 9/10 interregnum).

DISCUSSION. The separation of this species from Nicolella sp. A (see above) is difficult because there is little overlap in the size range of the available material. However the concave brachial valve of  $\underline{N}$ . sp. A is a feature not generally seen in the available material of  $\underline{N}$ . sp. B. There are also differences in the observed ribbing patterns, but these are highly variable within the two poulations and their value as a distinguishing character is uncertain.

<u>Nicolella</u> sp. C (Pl. 4, figs. 9-15)

The separation of this material from  $\underline{N}$ . sp. B is at present rather tentative. Very little material of this form has been recovered during this present study (2 pedicle valves from

AbER4), but the museum of the "Serviços geológicos" contains several specimens of Nicolella from Leira Ma (Zone 8, Bucaco syncline), which show several differences from the Zone 9 material described as  $\underline{N}$ . sp. B. These differences include earlier formation of secondary ribs, better developed dental plates, and a larger number of ribs inserted along the hingeline of the brachial valve.

Nicolella sp. indet.
(Pl. 4, figs. 10, 17)

A single specimen from the upper part of the Porto de Santa Anna Formatation (Zone 11) of the Buçaco syncline exhibits a higher number of ribs and earlier rib division than is seen on other material. This may represent a different member of the genus.

Family DOLERORTHIDAE Opik, 1934

Subfamily Dolerorthinae Opik, 1934

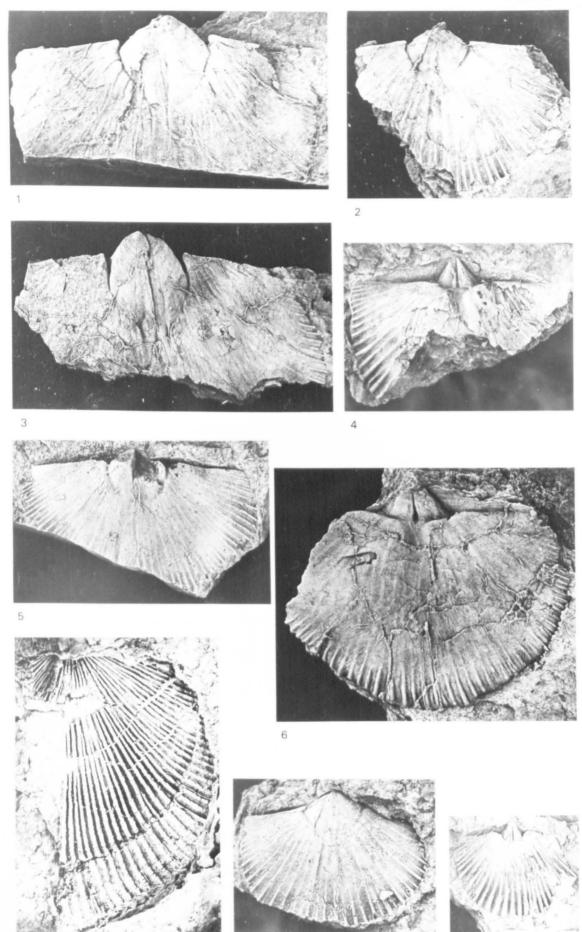
Genus <u>Dolerorthis</u> Schuchert and Cooper, 1931

Type species: Orthis interplicata Foerste, 1909.

# Dolerorthis sp. A

(Pl. 5 figs. 1-9, Pl. 6 figs. 6, 7, D. cf. sp. A Pl. 6 figs. 1-5)

MATERIAL. Internal moulds of 4 brachial and 4 pedicle valves together with 9 external moulds, all from sample ROS1, provide the basis for this species. In addition 3 pedicle valve, and 2



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brachial valve internal moulds, and several fragmentary external moulds from the Lostmarc'h locality may also belong here (see discussion below).

DESCRIPTION. Shell biconvex, sub-semicircular in outline, both valves 75-80% as long as wide, dorsal valve convex in both cross-section and longitudinal profile, ventral valve about 12% as deep as wide, convex in cross section but with an almost straight longitudinal profile, cardinal angles obtuse with maximum width of valve just posterior to midlength, in large valves hingeline is about 85% of maximum width; ventral apsacline, flat, smooth, delthyrium open; dorsal interarea flat, anacline, smooth, extending for about 10% of valve length, notothyrium open; shallow sulcus in dorsal valve, flattening anteriorly. Ornamentation ramicostellate, with high rounded ribs, about 16 primary ribs at ventral umbo, with a further 14 additional costae appearing postero-laterally on each flank of mature valve: rib density typically 9 per 5mm, 5mm anterior of umbo, and 1 per mm near anterior margin; one pedicle valve yielded the following rib count: 26 at 3mm stage, 29 at 5mm and 49 at 10mm stage; on pedicle valves the median costae typically developing costellae on both sides at 6mm, rib 2 produces costellae on both sides at about 10mm, ribs 3-7 produce single

Plate 5.

Dolerorthis sp. A

Pedicle valves: figs. 1, 2, 3, 5, 8 - internal moulds, fig. 7 external mould. Brachial valves: figs. 4, 6, 9 - internal moulds. All x2.0, ROS1.

internal costellae at between 4 and 7mm, although occasionally the costella may be external, rib 8 often produces both internal and external costellae, and rib 9 an external at about 12mm; the costae on the postero-lateral part of the shell may sometimes produce costellae, on one pedicle valve rib 19 produced an external at 16mm, and rib 20 an internal at 20mm, on this valve ribs 19, 20, 21, and 22 arose on the posterior border at 9, 10, 13, and 15mm from the umbo respectively. Tertiary ribs are seen on larger valves, typically arising from the region of ribs 0 and 7 and their costellae, these arise at about 25mm from the umbo.

Pedicle valve interior with strong teeth supported by recessive dental plates, which merge with the bounding edge of the ventral muscle scar, the plates have an undercut base (a feature at the same distance from the floor of the valve is also seen on the inner faces of the brachiophores, and occasionally on the inner face of the ventral interarea); muscle field sub-pentangular, with adductor scars slightly shorter than diductor scars, which extend anteriorly for about 30% of valve length; vascula media seen immediately anterior to adductor scars, and vascula genitalia observed over large region of flank, with elements cutting ridge bounding diductor scars laterally,

Plate 6.

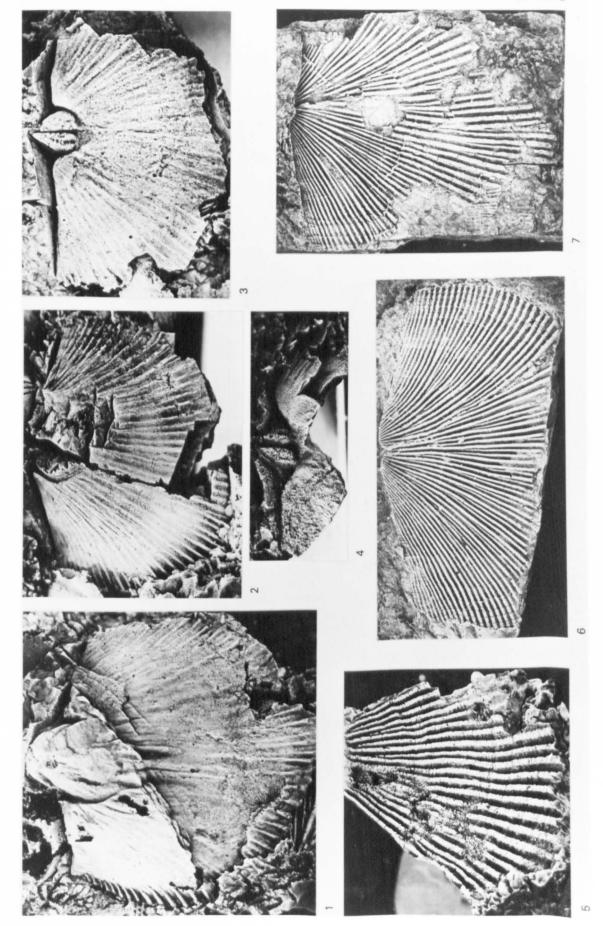
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Dolerorthis sp. A

Figs. b and 7 external moulds of pedicle valves, ROS1, x2.0.

<u>Dolerorthis</u> cf. sp A

Figs. 1, 2 internal moulds of pedicle valves, LM10, x2.0, figs. 3, 4 internal moulds of brachial valves, LM10, x2.0, fig. 5 fragment of external mould. LM10, x2.0.



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and also with elements running dorso-laterally on inner face of interarea.

Brachial valve interior with simple ridge-like cardinal process on thickened notothyrial platform, platform extends anteriorally into low median ridge running to 55% of valve length; brachiophores simple, undercut at base of inner face, strong fulchral plates define small pit; dorsal muscle field poorly defined, extending anteriorly for 60% of valve length; vascula genitalia poorly defined but covering large part of flanks of larger valves.

DISTRIBUTION. This species is an abundant element of the fauna from the upper part of the Rosan Formation from Rosan (in the limestones, and in the overlying tuffaceous beds).

DISCUSSION. The interstitial limestone of the pillow lava at La Pointe de Lostmarc'h yields very similar material to this species; this will be referred in this work to <u>Dolerorthis</u> cf. sp. A. This material seems to be indistinguishable from the Rosan species on internal criteria. The ornament is, however, slightly different; being much coarser, with about 40 ribs at the margin of a valve 30mm long, compared with 80-90 on a valve of similar size from Rosan. The ribs themselves in the Lostmarc'h material are narrower than the interspaces, which bear radial striae, while in the Rosan material the ribs are wider than the corresponding interspaces, until at least the 25mm growth stage. This species shows little similarity with contemporary British forms. The ribbing is considerably coarser than most of the known

Ashgill forms, but is comparable with <u>D. inequicostata</u>. However the rib branching patterns are totally different in the two forms. The Rosan material is probably closest in ornament to <u>D. duftonensis prolixa</u> Williams, 1963 from the Longvillian of Bala. The Rosan material also shows some similarity with <u>D. cf. maxima</u> (Vinassa, 1927) from the upper Ordovician of the Montagne Noire (itself noted to be similar to <u>D. duftonensis prolixa</u> by Havlicek, 1961). The species from the Montagne Noire differs from the Breton material in details of the ornament.

Dolerorthis sp. indet.

(Plate. 7, figs. 1,2)

Material from the top of the Ferradosa Formation in its type area (FERo) yields a <u>Dolerorthis</u> of uncertain specific affinity.

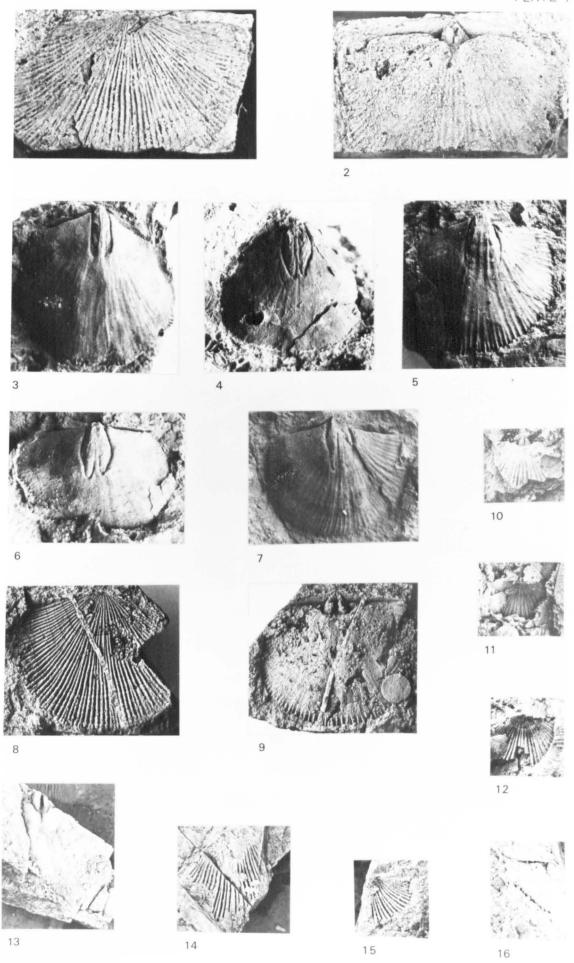
Plate 7.

## Dolerorthis sp. inact.

Figs. 1 and 2, external and internal moulds of a brachial valve, x2 magnification, FERo.

#### Dolerorthis? sp.

Figs. 3-7 internal moulds of pedicle valves, fig. 3 SGL 3331, 100m O. Fonte de Cassemes, fig. 4 SGL 3332, locality as 3, fig. 5 SGL 2916 (1 of), Leira Ma, fig. b SGL 3333 locality as 3, fig. 7 SGL 2916 (1 of), Leira Ma. Figs. b,9 external and internal moulds of a prachial valve, BM.B 85006 (part of type material of Orthis bussacensis Sharpe, 1853), figs. 10-12 internal mould, latex cast of internal mould and external mould of brachial valve, Louredo, figs. 13,14 internal mould and fragment of external mould, PSA4, figs. 15,16 external and internal mould of a pedicle valve, RAG1. All material x2.0.



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# Dolerorthis? sp.

# (Plate 7, figs 3-16)

This material from Zone 8 includes brachial valves of appearance similar to <u>Dolerorthis</u>. The pedicle valves believed to belong with them are of Dolerorthid type, but have a distinctively narrow muscle field, with anteriorly sub-parallel dental plates.

Genus <u>Apollonorthis</u> Mitchell, 1974

Type species: Orthis bussacensis Sharpe, 1853

# Apollonorthis bussacensis (Sharpe, 1853) (Plate 8, figs. 1-10)

- v\*1853 Orthis Bussacensis n.s.: Sharpe pp. 153-154; pl.VIII, fig 3.
  - 1908 Orthis Bussacensis Sharpe: Delgado pp. 35,43,61
- v 1974 Apollonorthis lusitanica gen. nov. sp. nov: Mitchell pp. 392-393; pl I, fig 7-12.
  - 1976 Apollonorthis bussacensis (Sharpe) 1853: Melou pp.694-698; pl I, figs 1-11; pl 2, figs 1-15.

MATERIAL. This study has yielded two fragmentary valves from the Fonte da Horta Formation, 3 internal moulds of brachial valves, 1 of a pedicle valve and several fragmentary valves from the Cabril Formation, together with 3 internal moulds of brachial and 1 of a pedicle valve from the Marrolithus bureaui zone at La Touche,

with some fragmentary material from the same horizon at Le Veryac'h. The material from the Fonte da Horta Formation was supplemented by about 10 valves from Buçaco in the collections of Dr. Romano (Sheffield University). In addition the material collected by Sharpe and Mitchell in the British Museum was examined.

DESCRIPTION. This species has been fully described by Mitchell (1974) and by Melou (1976), so will not be redescribed here.

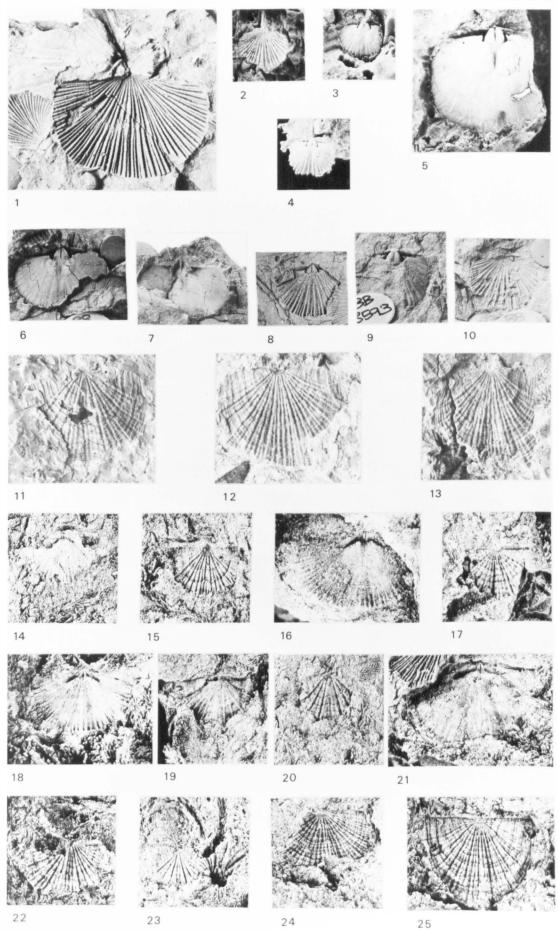
DISTRIBUTION. The species occurs in the upper part of the Fonte da Horta Formation, and throughout the Cabril Formation. In the Crozon Peninsula it occurs in those parts of the Postolonnec Formation corresponding to its range in Portugal, but in addition it is found in the Marrolithus bureaui zone. It also occurs in

Plate b.

# Apollonorthis bussacensis (Sharpe, 1853)

Fig. 1 external mould of pedicle valve, BM.B 83005, fig'd Sharpe pl. VIII fig. 3, holotype. Also note internal mould of brachial valve, figs. 2,4 external and internal mould of a brachial valve, coquinoid bed, La Touche, figs. 3,5 internal moulds of brachial valves, locality and horizon as 2, figs. b and 7 internal mould of brachial valve and latex cast, fig'd Mitchell pl. I figs. 10,11, BM.B 35591, fig. 8 internal mould of brachial valve, Vale Saido, MR coll., figs. 9,10 internal and external moulds of a brachial valve, BM.B 35593 and 35592 respectively, external is holotype of Apollonorthis lusitanica Mitchell, 1974. All x2.0.

Eridorthis of angustisulcata Havlicek, 1977
Figs. 11 to 13, external moulds of brachial valves, SGL 3349 (3 of), 100m 0. Fonte de Cassemes, figs. 14,15 internal and external moulds of a brachial valve, ABER5, fig. 10 internal mould of a brachial valve, ABER3, figs. 18,19,21 internal moulds of brachial valves, figs. 17,20,22,23 external moulds of brachial valves, figs. 24,25 external moulds of pedicle valves, figs. 17-25 all ABER5. All x2.0.



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this zone in the Laval area (La Touche).

DISCUSSION. Melou quotes Sharpe's type series as:

BM.B 83002: missing- the internal mould of a pedicle valve from Porto dos Malhadas.

BM.B 83003 : external mould from Serra de Mucela.

BM.B 83004: internal mould of brachial valve, Serra de Mucela.

BM.B 83005 : Sharpe's figured specimen, Serra de Mucela.

BM.B 83006: only an artificial cast- not A. bussacensis.

BM.B 83007 : missing.

BM.B 83006 is infact represented by internal and external moulds of a dolerorthid (?), and BM.B 83007 is an internal mould of a <u>Heterorthina</u>? sp. B, all from the Porto de Santa Anna Formation. Thus only BM.B 83002-83006 are conspecific, and of these it is recommended that BM.B 83005 be erected lectotype as this was the specimen illustrated by Sharpe (1853).

Subfamily Glyptorthinae Schuchert and Cooper, 1931

Genus <u>Eridorthis</u> Foerste, 1909

Type species: Plectorthis (Eridorthis) nicklesi Foerste 1909.

Eridorthis cf. angustisulcata Havlicek, 1981
(Plate 8, figs. 11-25)

v?1908 Stricklandinia sp. indet: Delgado p. 60 (partim.)

cf1981 Eridorthis angustisulcata sp. n.: Havlicek, pp. 8-9, pl.

2, figs. 1-5.

cf1983 Eridorthis angustisulcata Havlicek: Villas pl. 2 figs.

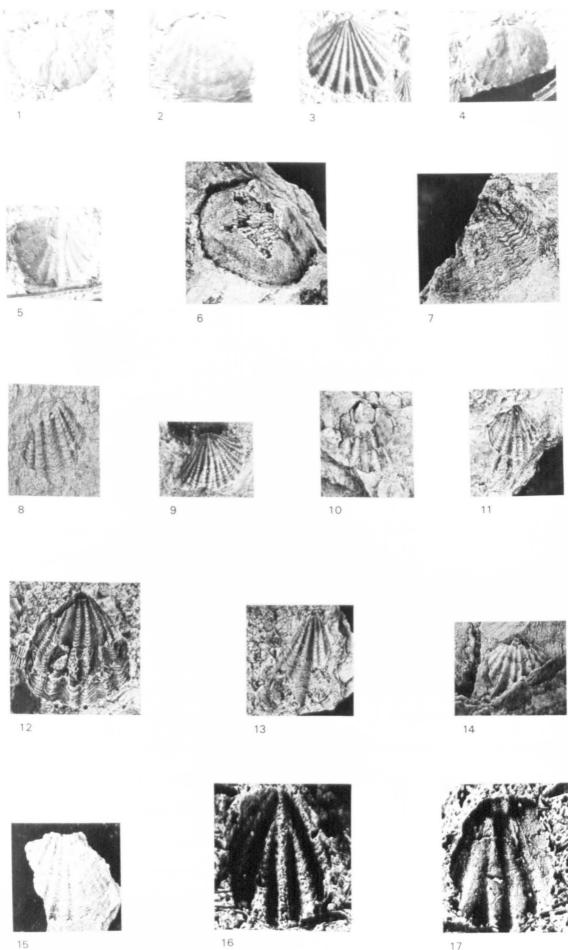
7, 10, 14.

MATERIAL. 9 external and 3 internal moulds of brachial valves were recovered during this study. In addition the collections of the "Serviços Geológicos" contain external moulds of three brachial valves from the locality "100m. O. de Fonte de Cassemes" (SGL.3349 - 3 specimens labelled "Stricklandinia?").

DESCRIPTION. The material found agrees with the description of Havlicek. The lack of pedicle valves provides a problem which must be overcome before this species can be meaningfully studied.

DISTRIBUTION. During this study material of this species has been recovered from the lower part of the Rosan Formation, as well as from the Leira Ma and Poiares Members in the Buçaco syncline. The species would thus seem to occur in Zones o and 9.

DISCUSSION. Eridorthis occurs in the Caradoc of North America, and rarely in the Caradoc of Ireland (Pomeroy; Mitchell, 1977). It is also recorded from the Silurian of Wales (Bassett, 1972), but has only once been recorded from the Ordovician of Europe; the species with which the Portuguese material is compared (Havlicek, 1961). This occurrence is in the upper Ordovician of the Montagne Noire, with a fauna showing manysimilarities to the upper Ordovician faunas of Portugal. The genus may possibly occur in the upper Ordovician of Sardinia (Orthis nodulata Vinassa; see Havlicek, 1981 p. 9).



Genus <u>Ptychopleurella</u> Schuchert and Cooper, 1931

Type species: Orthis bouchardi Davidson, 1847.

## Ptychopleurella sp. A

(Plate 9, figs. 1-5)

MATERIAL. This species is based upon material (SGL.3342: 3 internal moulds of brachial valves, SGL.3348: 1 internal mould of pedicle valve and two external moulds of brachial valves) from the Leira Ma Member (Porto de Santa Anna Formation) from the collections of the "Servicos Geológicos".

DESCRIPTION. The material has not been fully studied so a description will not be given here. The distinguishing criterion between this and P. sp. B is the even size of the ribs.

DISTRIBUTION. The material from the "Serviços Geológicos" is all

## Plate 9.

Ptychopleurella sp. A

Figs. 1,2 internal moulds of brachial valves, SGL 3342 (2 of), 100m 0. of Fonte de Cassemes, figs. 3,4 external and internal mould of brachial valve, SGL 3348 (1 of) and SGL 3342 (1 of) respectively, locality as 1, fig. 5 internal mould of pedicle valve, SGL 3348, locality as 1. All x2.0.

Ptychopleurella cf. sp. B

Figs. 6,7 internal and external moulds of pedicle valve, ABER3, fig. 8 external mould of brachial valve, ABER3, fig. 9 external mould of brachial valve, GAR1. All x2.0.

Ptychopleurella sp. B

Figs. 12,13 external moulds of pedicle valves, figs. 10,11 internal and external moulds of a pedicle valve, fig. 14 internal mould of a pedicle valve, fig. 15 external mould of a brachial valve. All specimens from ROS1, all x2.0.

Ptychopleurella sp. indet.

Figs. 16,17 external and internal moulds of a brachial valve, B135, x7.0.

from the locality "100m 0. de Fonte de Cassemes". This locality is believed to within the Leira Ma Member, although the lithology containing the fossils is siliceous, possibly a silicified carbonate. The fauna from the locality includes <u>Svobodaina</u> sp. A, <u>Drabovia</u> sp. A, <u>Porambonites</u> (P.) <u>ribeiroi</u> and <u>Eridorthis</u> sp. A so is representative of zone 8.

## Ptychopleurella sp. B

(Plate 9 figs. 10-15, P. cf. sp. B: plate 9, figs. b-9)

MATERIAL. 4 external moulds and 1 internal mould of a pedicle valve from Rosan (ROS1) form the basis for this species. Further material here compared with sp. B has been recovered from the lower part (Zone 9) of the Rosan Formation.

DESCRIPTION. This material is not sufficiently well known for a full description, but is distinguished from  $\underline{P}$ . sp. A by its unequally-sized ribs.

DISTRIBUTION. This species is known only from the upper part of the Rosan Formation (Rosan quarries-tuffaceous beds above the pillow lava, Pointe de Lostmarc'h-interstitial limestones of the pillow lavas).

# Ptychopleurella sp. indet. (Plate 9, figs 10,17)

Material referable to this genus occurs in deposits of Zone

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11 in the Bucaco syncline. It is not sufficiently well known to establish its specific affinities.

Family PLECTORTHIDAE Schuchert and Le Vene, 1929

Subfamily Orthostrophiinae Schuchert and Cooper, 1931

Genus Gelidorthis Havlicek, 1968

Type species: Orthis partita Barrande, 1879.

Gelidorthis cf. praepartita Havlicek, 1977
(Plate 10, figs. 1-11)

- cf1968 Gelidorthis partita (Barrande, 1879): Havlicek p. 125; pl. 2, figs. 1-7.
- cf1971 Gelidorthis partita (Barrande, 1879): Havlicek p. 42; pl. 7, figs. 12-18.
- ? 1974 Gelidorthis cf. partita: Mitchell pp. 388,391.

MATERIAL. Eight brachial and seven pedicle valves from the upper part of the Favaçal Bed of the Dornes area.

DESCRIPTION. Ventri-biconvex shell of sub-rectangular outline, maximum width at about midlength in adult valves; length about 75%-80% of width, small valves with maximum width on hingeline, adult valves may rarely be alate, but hingeline is never maximum width. Ornament costellate, with irregular swellings on ribs, and growth lines in furrows; in adult valves the ornament is barely, if at all, visible on the internal surfaces of the valves; ventral interarea high apsacline, horizontally striated, dorsal

interarea low, anacline; delthyrium and notothyrium open.

Ventral interior with teeth supported by short divergent dental plates extending anteriorly for 15% of valve length; muscle field 90% as wide as long in adult, with slightly raised triangular adductor track between the similarly sized, but fractionally longer, diductor scars; scar tends to be lamellose; vascular system often well impressed.

Dorsal interior with simple cardinal process consisting of ridge with slight swelling postero-ventrally; brachiophores divergent, supported by plates which converge onto ridge beween posterior ends of muscle scars; small fulchral plates present, parallel to hingeline; muscle field and vascular system poorly impressed.

DISTRIBUTION. This species is known at present from the upper part of the Favaçal Bed of the Dornes region. Fragmentary material from the Favaçal Bed in the Buçaco syncline may also belong here, as may the material mentioned by Mitchell form this same bed.

Plate 10.

Gelidorthis cf. praepartita Havlicek, 1977

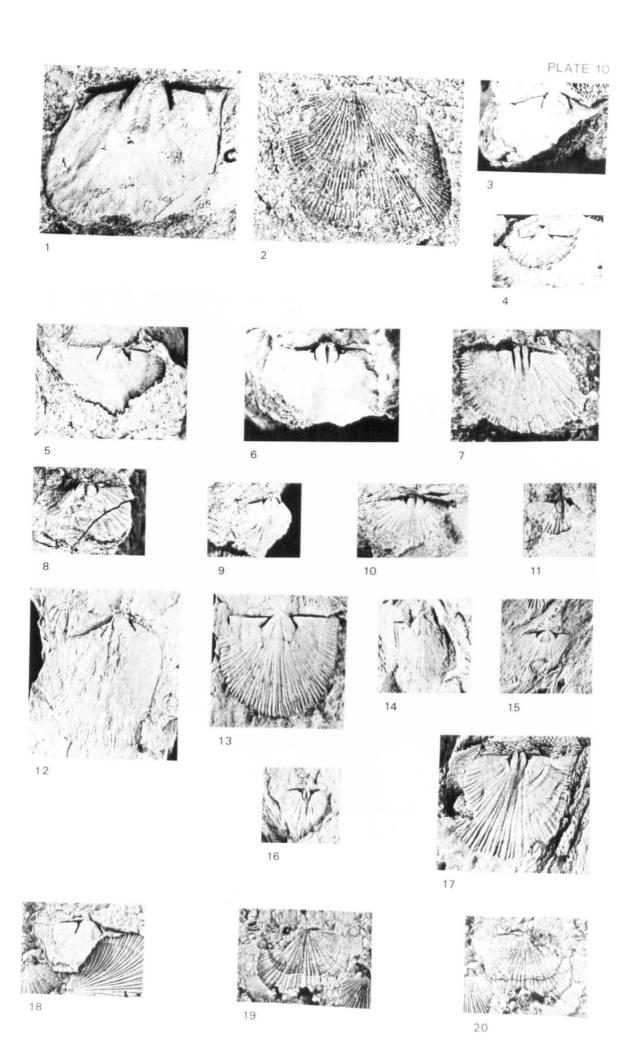
Figs. 1,2 internal and external moulds of a pedicle valve, Lameiros, figs. 3-5 internal moulds of pedicle valves, MDC5, figs. 6-11 internal moulds of brachial valves, MDC5, all x3.0.

Gelidorthis sp. A

Figs. 12,13,15 internal moulds of pedicle valves, MDC4, fig. 14 internal mould of pedicle valve, QXP2, fig. 16 internal mould of brachial valve, MDC4, fig. 17 internal mould of brachial valve, QXP2. All x3.0.

Tazzarinia sp.

Figs. 16-20 internal and external moulds of pedicle valve, with latex cast of external mould, Louredo, x3.0.



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DISCUSSION. This material is very close to the species <u>G</u>.

<u>praepartita</u> described by Havlicek (1977) from the Letná Formation
of Bohemia and the lower Ktaoua Formation of Morocco. The current
material does differ from Havlicek's description on several
counts; firstly the discovery of alate adult valves is not usual
for this species, and also the prescence of lamellae on the
exterior of the valves was a rare feature for Havlicek, but is
common among the material here. Despite this, however, the
Portuguese material is close to Havlicek's species, and provides
another link between the faunas of the Favaçal Bed, the topmost
beds of the Letná Formation, and the Lower Ktaoua Formation.

#### Gelidorthis sp. A

(Plate 10, figs. 12-17)

MATERIAL. Material is limited to four internal moulds of pedicle valves and two of brachials, together with several fragmentary external moulds.

DESCRIPTION. Ventri-biconvex shell of sub-semicircular outline, approximately 90% as long as wide; slightly alate, particularly in small specimens; pedicle valve carinate, particularly posteriorly; dorsal interare anacline, low, ventral interarea tall, apsacline; ornament of rounded costellae, with very prominent growth lines; ribbing visible on interior of valves.

Ventral interior with sub-pentagonal muscle-field; diductor scars fractionally longer than adductor tracks; each diductor scar triangular, and roughly the same size as the adductor scar;

the adductor field is very slightly raised on pad; teeth strong and supported by divergent dental plates.

Dorsal interior with widely divergent brachiophores, supported by plates converging onto very low notothyrial platform; cardinal process simple ridge; socket pits simple with vestigial fulchral plates; vascular system unknown.

DISTRIBUTION. This species is based upon material from the Queixopeira Member of the Dornes (sample MDC9) and Mação areas (QXP2).

DISCUSSION. The relationship between this species and  $\underline{G}$ . cf.  $\underline{praepartita}$  is close. Exactly how similar they are is difficult to define, because of the different modes of preservation; the earlier species being preserved with little compression compared to the Queixopeira Member material. However, the prescence of strong growth-lines and the impression of ribbing on the interior of the valves serves to distinguish this species from  $\underline{G}$ . cf.  $\underline{praepartita}$ .

Genus <u>Tazzarinia</u> Havlicek, 1971

Type species: <u>Tazzarinia</u> <u>drotae</u> Havlicek, 1971.

Tazzarinia sp.

(Plate 10, figs. 16-20)

? 1974 Tazzarinia cf. drotae Havlicek: Mitchell pp. 368,391.

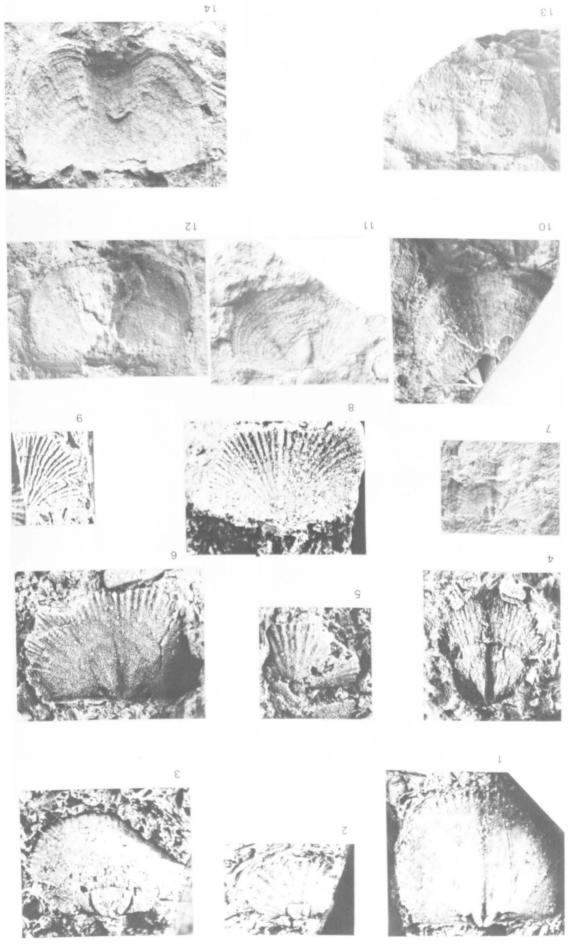


PLATE 11

Appendix C. 280.

A few fragments of a plectorthinid with very slight dorsal cardinalia forming a tiny notothyrial chamber from the Favaçal Bed of Buçaco and Dornes seem comparable to the material described as <u>T</u>. <u>drotae</u> by Havlicek (1971). Further material must be obtained before the identification of this form can be clarified.

Subfamily Chrustenoporinae Havlicek and Mergl, 1982

Genus <u>Jezercia</u> Havlicek and Mergl, 1982

Type species: <u>Jezercia ostiaria</u> Havlicek and Mergl, 1982

# Jezercia sp. A

(Plate 11, figs. 1-6,8,9)

Material close to <u>Jezercia</u> <u>ostiaria</u> has been recovered from Zone 11 deposits in the Buçaco syncline. The characteristic coarse perforations in the shell are visible in many of the moulds. A full study of this species, which may well prove to be important in both biostratigraphical and palaeogeographical fields has yet to be undertaken.

Plate 11.

Jerzercia sp. A

Figs. 1,2,5 internal moulds of pedicle valves, figs. 4,0 internal moulds of brachial valves, fig. 8 external mould of brachial valve, fig. 9 fragment of external mould of ?pedicle valve, all from B135 (near Cacemes), all x7.0.

Platystrophia? sp. A

Figs. 7,10,12,13 internal moulds of brachial valves, figs. 11 and 14 external moulds to specimens in figs. 13,12 respectively. All specimens from bed 2 of Delgado's "Val San Jorge" section, all are in SGL.

Subfamily Platystrophiinae Schuchert and Le Vene, 1929

Genus <u>Platystrophia</u> Schuchert and Le Vene, 1929

Type species: <u>Platystrophia</u> biforatus (von Schlotheim, 1820).

Platystrophia? sp. A
(Plate 11, figs. 7,10-14)

v 1908 <u>Spirifer antiquissimus</u> Salt. (cf. <u>Strophomena</u> <u>spiriferoides</u> McCoy): Delgado pp. 38,60.

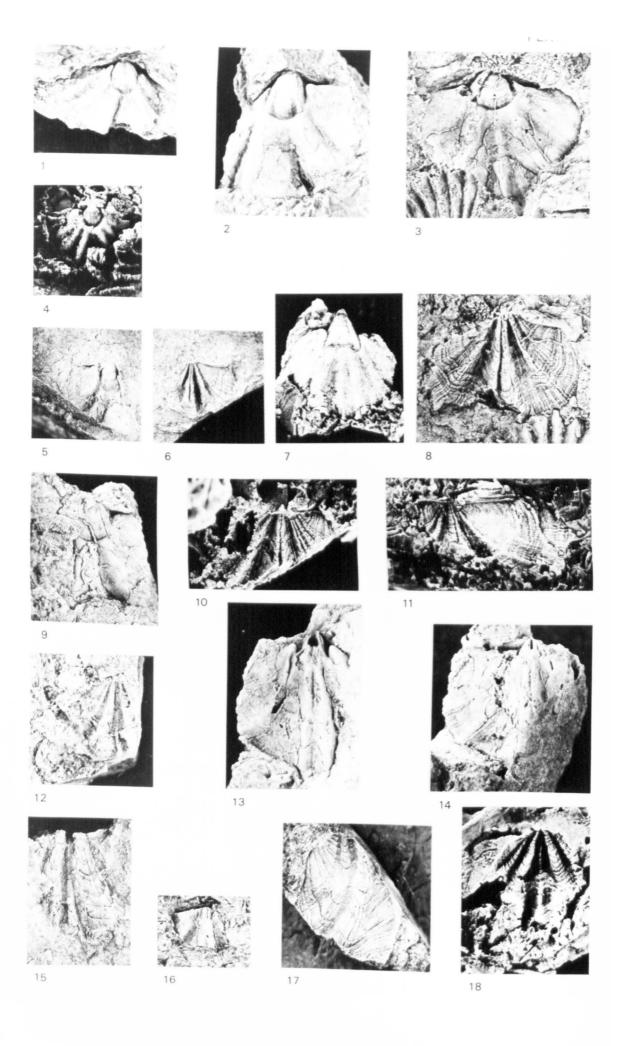
Several specimens close to <u>Platystrophia</u> are in the collections of the "Serviços Geológicos", and form the material described by Delgado as <u>Spirifer antiquissimus</u>, and <u>Athyris?</u> from bed 2 of the Val San Jorge section. The material is characterised by a very high ventral muscle-platform, with prominent papillae on the valve floor along the antero-lateral margins of this platform. This is similar to the feature described by Hiller from <u>Platystrophia anomala</u> Hiller, 1980. The ornament of the material is finely costellate, quite unlike that of most <u>Platystrophia</u>.

Genus <u>Mcewanella</u> Foerste, 1920

Type species: Mcewanella fernvalensis (McEwan, 1919).

Mcewanella? sp. A (Pl. 12, figs. 1-15)

MATERIAL. About half a dozen internal and external moulds of each valve.



DESCRIPTION. Biconvex shell, subcircular in outline, maximum width just anterior of hingeline, cardinal angles obtuse or very slightly alate, valves 80% as long as wide, ventral interarea curved, apsacline, dorsal interarea curved, anacline and lower than ventral, delthyrium and notothyrium open; strong dorsal fold and ventral sulcus, ornament of two prominent subangular costae on each flank of brachial valve, pedicle valve with single costa in sulcus and two costae on each flank, flanks of both valves with superimposed costellae numbering 2-3 per mm near anterior margin, concentric ornament of fine growth lines (approx 12 per mm), superimposed on lamellose ornament with lamellae about 1mm apart; maximum observed valve length 20mm.

Pedicle valve interior with stout teeth, supported by slightly ventrally convergent dental plates which confine raised muscle platform, muscle platform extends forward for 30% of valve length, muscle field continues onto inner face of dental plates. Brachial valve interior with stout brachiophores, extending for 15% of valve length, which together with fulchral plates delimit small sockets; cardinal process ridge-like, continued anteriorly by small septum merging anteriorly (at 60% of valve length from

Plate 12.

Mcewanella? sp. A

Pedicle valves; figs. 1, 2, 3, 9 internal moulds, ROS1, figs. 4, 7 internal moulds, LM10, figs. 5, 6 internal and external moulds of a valve, ROS1, fig. 8 external mould, ROS1, figs. 10, 11 external moulds, LM10.

Brachial valves; figs. 12, 15, 17 external moulds, ROS1, figs. 13, 14, 16 internal moulds, ROS1, fig. 18 external mould, LM10.

All x2.0.

umbo) with median interspace; dorsal muscle field weakly impressed, reaching 60% of valve length from umbo, quadripartite, with posterior scar twice as long as anterior.

DISTRIBUTION. This species is an important member of the fauna from the upper part of the Rosan Formation at Rosan (tuffaceous beds at the top of the succession) and Pointe de Lostmarc'h (interstitial limestone of the pillow lavas). These occurrences are of Zone 10.

DISCUSSION. The generic assignation of this form is uncertain. The ornament differs from that of most <u>Mcewanella</u>, but is closest amongst the Platystrophinae to that genus.

Subfamily Rhactorthinae Williams, 1963

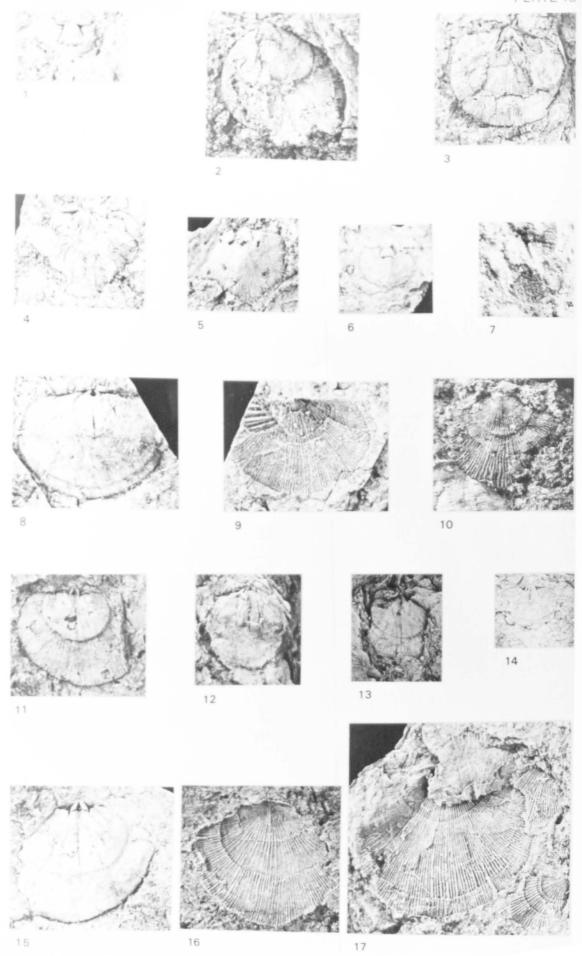
Genus Rhactorthis Williams, 1963

Type species: Rhactorthis crassa Williams, 1963.

Rhactorthis? sp. A
(Plate 13, figs. 1-17)

MATERIAL. Internal moulds of 7 brachial and 7 pedicle valves, most with corresponding external moulds, plus several other external moulds.

DESCRIPTION. Biconvex shells, subcircular in ouline, 75% as long as wide, with short hingeline 50% of maximum shell width, maximum width occurs 30% of shell length anterior to hinge; pedicle valve



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carinate, particularly in small specimens. gentle sulcus in brachial valve reaching to just beyond midlength of valve; ventral interarea low, apsacline, dorsal interarea low ortho- or anacline; ornament costellate with typically 4 ribs per mm both 5 mm anterior of umbo and at anterior margin, costellae arising mainly from exterior splitting, growth lines fine and dense, lamellae present, often 3 or 4 to an adult valve; exopunctae present in widely-spaced concentric arcs.

Ventral interior with short divergent dental plates supporting small teeth; ventral muscle-field triangular, elevated on marked platform, which is prolonged in specimens greater than 4mm long into a pseudospondylium reaching anteriorly for 20% of valve length, it is probable that only the adductor scars are substantially elevated by this platform; vascular system not impressed except perhaps in floor of valve beneath pseudospondylium where 5 parallel elements (of vascula media?) are present.

Dorsal interior with divergent brachiophores extending for 12% of valve length, and strong fulchral plates defining small sockets, cardinal process narrow in young specimens, but widening in larger ones, bilobed and crenulated, prolonged into ridge

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Plate 13.

Rhactorthis? sp. A

Figs. 1-6 internal moulds of pedicle valves, ROS1, fig. 7 internal mould of pedicle valve, bed 2 of "Val San Jorge" sectoion of Delgado, in SGL, figs. 8,9 internal and external moulds of a brachial valve, ROS1, fig. 10 latex cast of an external mould, ROS1, figs. 11-14 internal moulds of brachial valves, ROS1, figs. 15,16 internal and external moulds of a brachial valve, ROS1, fig. 17 external mould of a brachial valve, with fragments of several others, ROS1. All x2.0.

extending to midlength of valve; muscle field poorly impressed extending anteriorly for about 50% of valve length;

DISTRIBUTION. This species has only been recorded from the tuffaceous beds above the pillow lava in the Rosan quarries (upper part of the Rosan Formation), Zone 10.

DISCUSSION. It may be this species that has given rise to the accounts of <u>Bicuspina</u> from the Rosan locality, for <u>Bicuspina</u> has not been recorded there in this project.

#### Rhactorthis? sp. B

Material probably referable to <u>Rhactorthis</u> occurs in various Zone 8 and 9 deposits (e.g. Leira Ma Member, Poiares Member and the lower part of the Rosan Formation. The specimens are generally very small, and have not yet been studied.

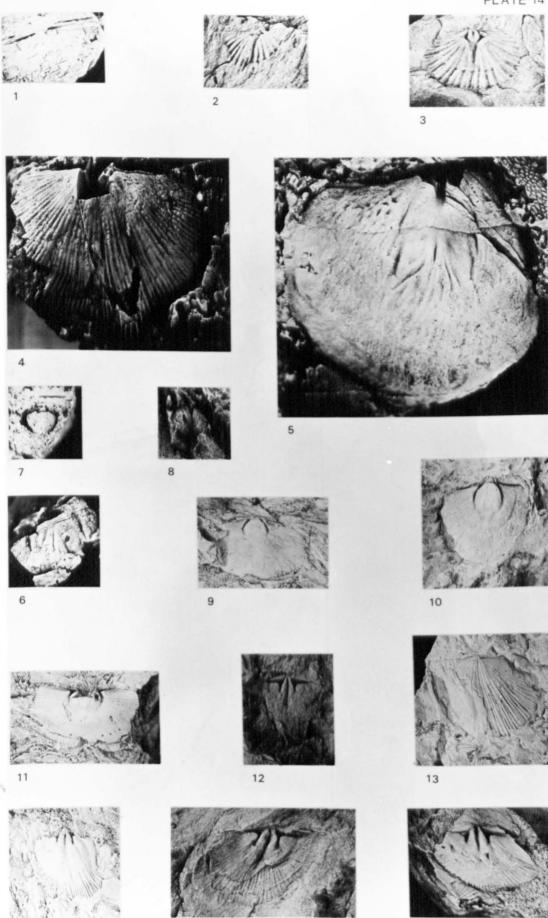
Family SKENIDIIDAE Kozlowski, 1929

Genus <u>Skenidioides</u> Schuchert and Cooper, 1931

Type species: <u>Skenidioides billingsi</u> Schuchert and Cooper, 1931

Skenidioides? sp. indet.
(Plate 14, figs. 7,8)

Material referred to this genus has been recovered from the Zone 11 deposits of the Rio Ceira Inlier, Buçaco syncline. The material consists of a single internal mould each of a pedicle



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and of a brachial valve. It is not yet possible to compare this with representatives of the genus.

Orthacean indet. A

(Plate 14, figs. 1-3)

Material of a coarse ribbed brachiopod of plectorthinid affinity occurs in the deposits of Zone 5 (uppermost part) nad Zone 6. Insufficient material has been recovered to date for generic assignment.

Orthacean indet. B

(Plate 14, figs. 4-6)

Three brachial valves have been recovered from the interstitial limestone of the pillow lava at Lostmarc'h. None of the valves shows well preserved cardinalia, and no contender for the equivalent pedicle valve has been found. The material does however show a characteristic muscle field outline.

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Plate 14.

Orthacean indet. A

Figs. 1,2 internal moulds of brachial valves, MDC4, x3.0, fig. 3 internal mould of brachial valve, x2.0.

Orthacean indet. B

Figs. 4-b internal moulds of brachial valves, LM10, x2.0.

Skenidioides sp.

Fig.7 internal mould of pedicle of a brachial valve, both RC11, x4.0.

<u>Drabovia</u> cf. <u>redux</u> (Barrande, 1848)
Figs. 9,11 internal moulds of pedicle valves, QXP2, fig. 10 internal mould of pedicle valve, MDC4, figs. 12,15 internal moulds of brachial valves, MDC4, figs. 14,16 internal moulds of QXP2. All x2.0.

Superfamily Enteletacea Waagen, 1884

Family ENTELETIDAE Waagen, 1884

Subfamily Draboviinae Havlicek, 1950

Genus <u>Drabovia</u> Havlicek, 1950

Type species: Orthis redux Barrande, 1848.

<u>Drabovia</u> cf. <u>redux</u> (Barrande, 1848)

(Plate 14, figs. 9-16)

- cf1848 Orthis redux Barr.: Barrande, p. 49, pl. 18, fig. 7.
- cf1879 Orthis redux Barr.: Barrande, pl. 62, case III, figs.
  4, 12, 13.
- cf1932 Pionodema redux (Barrande): Schuchert and Cooper, pl. 23 figs. 2,4.
- cf1951 <u>Drabovia redux</u> (Barrande, 1848): Havlicek, p. 46 and 117 pl. 9, fig. 4; pl. 10, figs. 5, 6, 8.
- v 1980 <u>Drabovia</u> cf. <u>redux</u> (Barrande, 1848) : Cooper pp. 342-345; pl. 29, figs. 4-7; pl. 30, fig. 1.

MATERIAL. Material of this species is relatively abundant, although most of it is rather deformed.

DESCRIPTION. Cooper described material of this species from Dornes, and in general it is very close to Barrande's species. To take the description of this species further would require the statistical analysis of the deformed material, and this has not been attempted here.

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DISTRIBUTION. This species is the most abundant brachiopod in the Queixopeira Member (Cabeço do Peão Formation) of Dornes and Mação. Its first recorded appearance is in the very top of the Favaçal bed of the Dornes area, and in the same area it has been seen last about 30m above the base of the formation. This species is the dominant brachiopod in the <u>Drabovia</u> cf. redux association (see p. 132). It is also the index species for Zone 6 (see p. 99).

DISCUSSION. <u>Drabovia</u> <u>redux</u> (Barrande) occurs in Bohemia in the middle part of the Letná Formation, in a sandstone facies.

# <u>Drabovia</u> sp. A (Plate 15, figs. 1-4)

- v 1908 Pentamerus cf. pelagicus Barr.: Delgado p. 60
- v 1908 Stricklandinia sp. indet.: Delgado p. 61 (partim.)
- v 1908 Orthis aff. basalis Dalm.: Delgado p. 61

MATERIAL. Knowledge of this species is based mainly on the specimens housed in the collections of the "Serviços Geológicos" (SGL.3330 (2 specimens), 3345 (3 specimens), 3327 (3 specimens), 3329 (1 specimen)). In addition 2 internal, and 3 external moulds of this species were found in this study, none of which were of sufficiently good preservation to aid description..

DESCRIPTION. There was not opportunity in this project to undertake full study of the museum material in Delgado's

collection. The material is therefore illustrated here without description.

DISTRIBUTION. <u>Drabovia</u> sp. A occurs in the lower parts of the Porto de Santa Anna and Rosan Formations. The material in the "Serviços Geológicos" collections is all from the locality "100m.

O. de Fonte de Cassemes", which is at the base of the Porto de Santa Anna Formation, probably within the Leira Ma Member. The detailed palaeoecology and internal stratigraphy of this member is not fully understood; hence the restricted distribution of this material remains enigmatic.

Genus Kinnella Bergstrom, 1968

Type species: Kinnella kielanae (Temple, 1965)

Kinnella? sp. indet.

(Plate 15, figs. 11,12)

Two internal moulds of pedicle valves from Zone 10 deposits at Lostmarc'h appear to belong to <u>Kinnella</u>.

Plate 15.

Drabovia sp. A

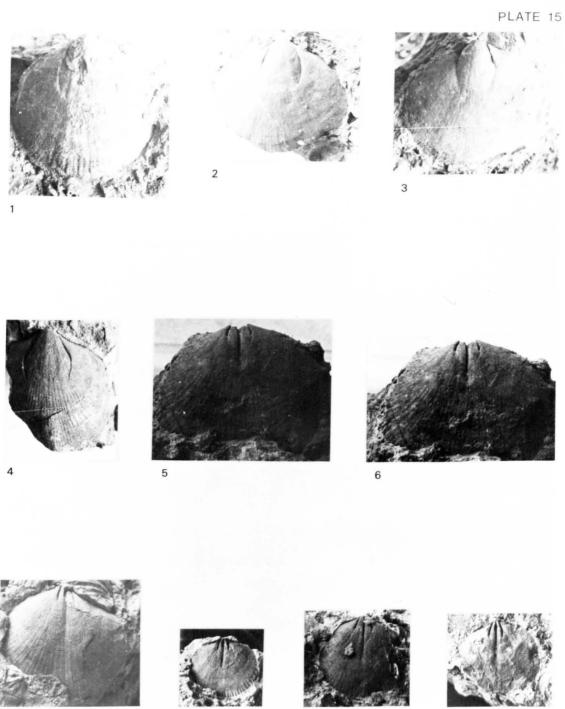
Figs. 1-4, internal moulds of pedicle valves, all from "100m 0. de Fonte de Cassemes", all x2, figs. 1,2,4 SGL 3327, fig. 3 SGL 3329 (1 of). Figs. 5-10 internal moulds of brachial valves, x2, same locality, figs. 5-7 SGL 3330, figs. 8-10 SGL 3345.

Kinnella? sp. indet.

Figs. 11,12 internal moulds of pedicle valves, x2, LM10.

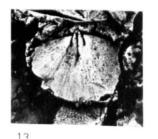
Draboviid gen. et sp. indet.

Fig. 13 internal mould of brachial valve, x2, LM10.









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Draboviniid indet.

(Plate 15, fig. 13)

The internal mould of a brachial valve from Lostmarc'h (Zone 10), would appear to belong to either <u>Drabovia</u> or <u>Hirnantia</u>.

Details of its cardinalia are unknown.

Family DALMANELLIDAE Schuchert, 1913

Genus <u>Dalmanella</u> Hall and Clarke, 1892

Type species: <u>Dalmanella</u> testudinaria Dalman, 1828

Dalmanella sp. A
(Plate 16, figs. 1-11)

MATERIAL. The material illustrated in plate 16 comprises the total material found of this species to date.

DESCRIPTION. The valves have a sub-circular outline, ventri-biconvex, dorsal valve with narrow sulcus, hinge-line roughly 50% of maximum width of valve, cardinal angles rounded, ventral interarea low, curved, apsacline (often almost orthocline), dorsal interarea very low, anacline; ornament finely costellate, with large puctae, running posteriorly and at a low angle to the shell surface, from major growth imbrications, paricularly from the median rib of the pedicle valve (see pl. 16 fig. 5).

Ventral valve with short dental plates running for less than 20% of valve length, enclosing a small delthyrial chamber;

ventral muscle field confined to this chamber in young specimens, but extending anteriorly for upto 25% of valve length in large specimens, muscle field triangular to cordate; shell floor raised anterior to medial part of field, and slightly raising adductor field, vascula media usually form marked depressions on either side of this "pad" of shell material, other parts of mantle canal system unknown, small pedicle callist present.

Interior of dorsal valve with small to minute notothyrial chamber with small cardinal process, details of which are unknown; short brachiophores supported by convergent plates fused with low median ridge anterior of cardinal process, brachiophore-supporting plates also fused to low divergent ridges passing outside posterior adductor scars, muscle field sub-rhombic, extending for about 35% of valve length. Fulcral plates present.

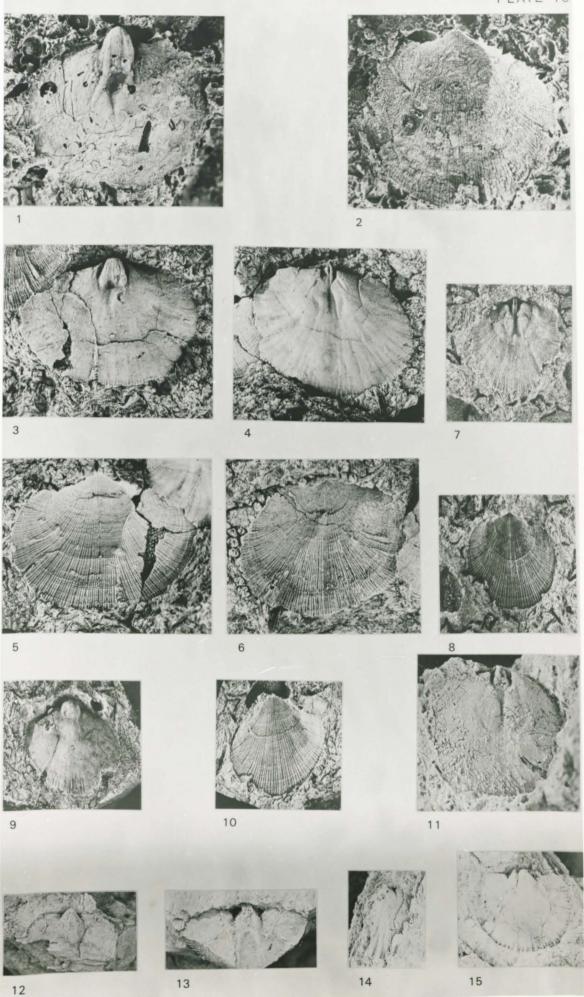
DISTRIBUTION. This species has been found in the lower part of the Ferradosa Formation (Zone 9 or 9/10 interregnum) and in the lower part of the Rosan Formation (Zone 9) at Coat Garrec.

Plate 16.

Dalmanella sp. A

Figs. POR10, figs. 3,5 internal and external moulds of a pedicle valve, FER10, valve, internal and 9,10 external and internal moulds of a pedicle valve, GAR1, fig. 11 internal mould of a brachial valve, POR11. All x2.0.

<u>Dalmanella?</u> sp. B Figs. 12-15 internal moulds of pedicle valves, ROS1, x2.0.



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#### Dalmanella? sp. B

(Plate 16, figs. 12-15, plate 17, figs. 1-4)

MATERIAL. This species is fairly abundant in the upper part of the Rosan Formation (Zone 10) of Rosan quarry (tuffaceous decalcified beds above the pillow lava). The only other locality yielding this species is the iron-mine west of Louredo in the upper part of the Porto de Santa Anna Formation, in which two specimens have been found.

DESCRIPTION. Ventri-biconvex shell, of sub-circular outline, pedicle valve 90% as long as wide, hinge line 85% of maximum width of valve; brachial valve sulcate; ventral interarea low, flat, apsacline, dorsal interarea low, flat, anacline; ornament costellate, rib division predominantly internal, rib density 6/mm 1mm from umbo and 5/mm 5mm from umbo; shell substance punctate, punctae converge onto inner surface below rib crests, with occasional rows of punctae perpendicular to interior of shell along interspaces.

Pedicle valve interior with small teeth supported by receeding dental plates; well developed pedicle callist; ventral muscle field bilobed, about 30% as long as valve; prominent canals of vascula media extend anteriorly from diductor scars, other parts of system unknown.

Dorsal interior with small, divergent brachiophores extending anteriorly for 12% of valve length, weak fulchral plates present defining pits; cardinal process with crenulated bilobed myophore, notothyrial platform thickened; dorsal muscle

field extending anteriorly for 35% of valve length.

DISTRIBUTION. This description is based on material from the upper part of the Rosan Formation (Rosan quarry, tuffaceous beds above the pillow lava). Further probably conspecific material has been recovered from the upper part of the Porto de Santa Anna Formation (west of Louredo).

Dalmanella? cf. sp. B

(Plate 17, figs. 5-12)

Material from the Poiares member closely resembles  $\underline{\mathbb{D}}$ ? sp. B, but is of a much smaller size. No statistical work has yet been undertaken on this fauna, but casual inspection suggests that the shell outline, and the disposition of the brachiophores may differ slightly from the Rosan species.

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Plate 17.

Dalmanella? sp. B

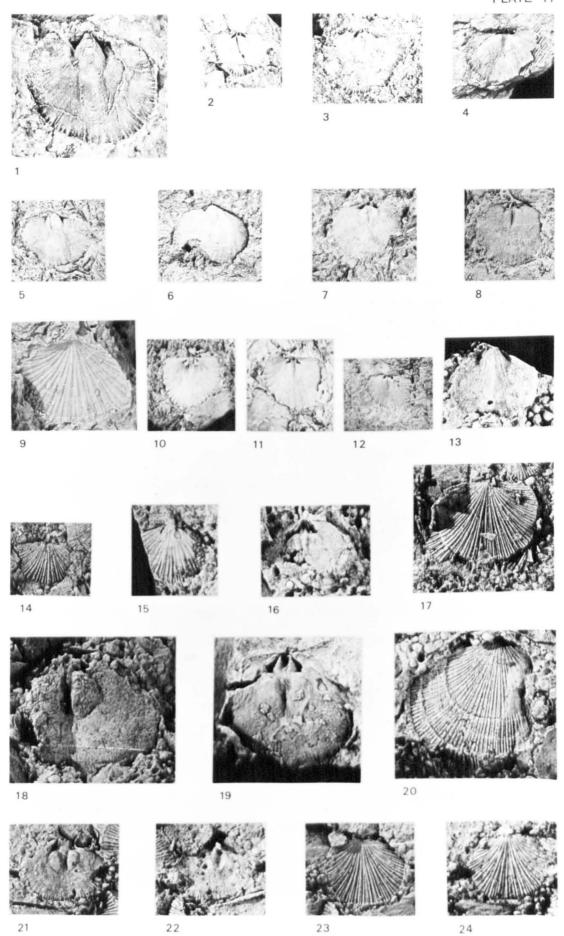
Fig. 1 internal mould of pedicle valve, ROS1, figs. 2-4 internal moulds of brachial valves, ROS1, x2.0.

Dalmanella? cf. sp. B

Figs. 5,6 internal moulds of pedicle valves, figs. 7,8,11,12 internal moulds of brachial valves, fig. 9 external mould of brachial valve, fig 10 latex cast of internal mould of brachial valve in fig. 11. All POR3, x2.0.

Onniella sp. A

Figs. 13,15 internal moulds of pedicle valves, Louredo, fig. 14 latex cast of external mould of pedicle valve, Louredo, fig. 15 internal mould of brachial valve, Louredo, fig. 17 latex cast of external mould of brachial valve, Louredo, figs. 18,20 internal and external moulds of brachial valve, Louredo, figs. 21,23 internal and external moulds of a brachial valve, Louredo, with respect latex casts figs. 22,24, fig 19 internal mould of brachial valve, fig. 19 internal mould of brachial valve, Louredo. All x3.0.



Genus <u>Onniella</u> Bancroft, 1928

Type species: <u>Onniella broggeri</u> Bancroft, 1928

Onniella sp. A
(Plate 17 figs. 13-24)

? 1974 Onniella sp.: Mitchell p. 388.

MATERIAL. Material of this species is relatively abundant, but infrequently well-preserved.

DESCRIPTION. Convexo-planar shell of transversely sub-quadrate outline; hingeline about 60% of valve maximum width, which occurs at about mid-length; ornament costellate, not analysed, btu with median interspace on brachial valve; brachial valve with marked sulcus, pedicle valve slightly carinate.

Ventral interior with strong dental plates extending for about 20% of valve length; muscle often poorly marked, cordate, pedicle callist present. Dorsal interior with strongly impressed muscle field, transversely elliptical in outline extending to about 55% of valve length; short stout brachiophores divergent, supported by short plates running along posterior margin of muscle field to fuse with low median ridge; fulcral plates absent; cardinal process bilobed, but details uncertain.

DISTRIBUTION. This species has only been recovered from the Favaçal Bed, but it occurs widely at this horizon (Buçaco, Dornes, Mação).

DISCUSSION. This species forms the zonal index for Zone 4 of the scheme oulined in this thesis.

Genus <u>Portranella</u> Wright, 1964

Type species: <u>Portranella angulocostellata</u> Wright, 1964.

Portranella? exornata (Sharpe, 1853)
(Plate 18, figs. 1-13)

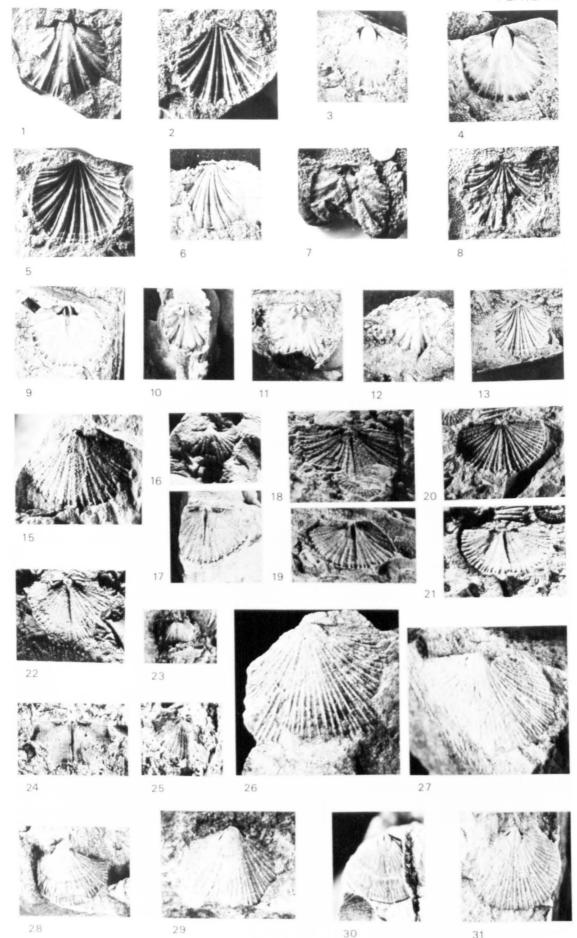
- v\*1853 Orthis exornata n.s.: Sharpe pp.142, 153; pl. VIII, fig. 2.
- v 1900 Orthis exornata Sharpe: Delgado pp. 31, 39, b1.

same Member in the Rio Ceira inlier.

1974 Portranella? exornata (Sharpe): Mitchell p. 389.

MATERIAL. Abundant material in the form of moulds from the Leira Member, mostly from the north part of the Buçaco syncline (Leira Ma and Porto de Santa Anna localities9, but also occurs in the

DESCRIPTION. Ventri-biconvex shell, of subcircular outline, pedicle valve 90% as long as wide, brachial valve 80% as long as wide; sulcate brachial valve; ventral interarea apsacline, low, with open delthyrium; dorsal interarea anacline, low, horizontally striated, open notothyrium filled by posterior face of cardinal process which extends well behind hingeline; shell substance finely punctate; ornament costellate, with very feint growth-lines, and sporadic more marked growth-lines; 10 primary costae on brachial valve, generally first splitting occurs about



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appear just before equivalent externals from costae 2, 3, 4 and 5, costa 6 appears late and is generally weakly developed, rib 1 only produces an internal secondary until much later, giving a rib count of 25 5mm anterior of umbo; 9 primary costae on pedicle valve, ribs 4 and 5 develop both internal and external secondaries early, ribs 2 and 3 develop externals early and internals later (about 2mm), while rib 1 produces secondaries on each side early on, tertiary ribs are developed in sectors 1 and 2 at about 5mm from the umbo.

Ventral interior with large teeth supported by divergent dental plates, which continue anteriorly into convergent ridges which bound the muscle field antero-laterally; muscle field bilobed, subtriangular; canals of vascula media run from anterior ends of diductor scars to near anterior margin of shell, distal

Portranella? exornata (Sharpe, 1853)
Figs. 1,2 internal and external moulds of a pedicle valve,
BM.B 82987, internal ?figured Sharpe pl. VIII fig. 2d, figs. 3,4
internal moulds of pedicle valves, PSA9, fig. 5 external mould
of a pedicle valve, BM.B 82989, ?figured Sharpe pl. VIII fig.
2c, fig. 6 latex cast of external mould of pedicle valve in fig.
4, PSA9, figs. 7,8 internal and external moulds of a brachial
valve, BM.B 82988 and 82986 respectively, fig'd Sharpe pl. VIII
figs. 2b and 2a respectively, fig. 9 internal mould of brachial
valve, PSA9, figs. 10-12 latex casts of internal moulds of
brachial valves, PSA9, fig. 13 external mould of pedicle valve,
PSA9. All x2.0.

Tyronella? sp. A

Fig. 15 internal mould of pedicle valve, PEN1, fig. 16 internal mould of pedicle valve, AML1, fig. 17 internal mould of brachial valve, PEN1, figs. 18,19,21,22 internal moulds of brachial valves, AML1, fig. 20 external mould of specimen in fig. 21, AML1. All x4.0.

Epitomyonia? sp.
Fig. 23 internal mould of brachial valve, RC11, figs. 24,25 internal moulds of brachial valves, B135.

Horderleyella sp. B
Figs. 26-29 internal moulds of pedicle valves, RC12, figs. 30,31 internal moulds of brachial valves, RC12, all x4.0.

ends of canals seen on lateral valve margins.

Dorsal interior with divergent stout horn-like brachiophores; cardinal process stout, shaft short, with medianly cleft myophore, which has a tendency to become trilobed in larger specimens, myophore protrudes beyond hinge-line, brachiophores remain seperate from cardinal process- no fusion observed; notothyrial platform thickened and extending anteriorly into prominent ridge reaching 70% of valve length from hinge-line, ridge bisects dorsal muscle field, muscle field extends 50% of valve length from hinge line, anterior scars twice as long posterior scars.

DISTRIBUTION. This species has been recorded from the Leira Ma Member in the Buçaco syncline (samples RC 31, PSA4), and from the base of the Rosan Formation, Raguenez (Crozon) (RAG1, ABER4). It is also found in the "Bancos Mixtos" of the Sierra Morena (sample from Corral de Calatrava).

DISCUSSION. The species Orthis exornata Sharpe was placed in Portranella Wright, 1964 by Mitchell (1974). This genus is distinguished by the trilobed myophore with lateral lobes extending over the posterior faces of the brachiophores. It was originally thought to be impunctate, but subsequent work by Hiller has shown it to be punctate. Mitchell erected the genus Diplonorthis (1977) for an apparently impunctate stock, with a bilobed myophore, externally similar to Portranella. However Mitchell gave a note of caution that Diplonorthis could prove to be synonomous with Portranella, as the impuncate nature of the

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shell was not proven, and in large specimens the myophore showed a tendancy to become trilobed. Havlicek (1981) assigned Orthis fascicula Vinassa, a form from the ?Upper Caradoc of Sardinia and the Montagne Noire very close to Orthis exornata to the genus Paucicrura Cooper, 1956. This species seems to differ from Portranella? exornata by a more elongate outline, a character observed in some of the material from the Rosan Formation, and by in the ornament, particularly the order differences development of costellae. The Portuguese species with its punctate shell, and bilobed myophore with a tendancy to become trilobed is clearly close to Portranella, but is distinguished from the described species by its myophore being contained between the posterior ends of the brachiophores. The Portuguese material has an ornament very similar to that of Portranella sp. from Glyn Ceirog (N. Wales) (Hiller 1980), but differs in having a more circular overall shape.

Family DICOELOSIIDAE Cloud, 1948

Genus Epitomyonia Wright, 1978

Type species: Epitomyonia glypha Wright, 1978.

Epitomyonia? sp. (Plate 18 figs. 23-25)

Material referable to Epitomyonia has been recovered from Zone 11 deposits in the north of the Buçaco syncline (B135) and from the Rio Ceira inlier (RC11). The material does not permit comparison with other species, but it is interesting to note

that the other occurrences in the Ordovician of Europe (Glyn Ceirog (Hiller 1981), Boda (Wright 1908) and Bohemia (Havlicek and Mergl 1902) are all of Ashgill age.

Family HARKNESSELLIDAE Bancroft, 1928

Genus <u>Horderleyella</u> Bancroft, 1928

Type species: <u>Horderleyella</u> plicata Bancroft, 1928.

### Horderleyella sp. A

MATERIAL. Two poorly preserved internal moulds of brachial valves.

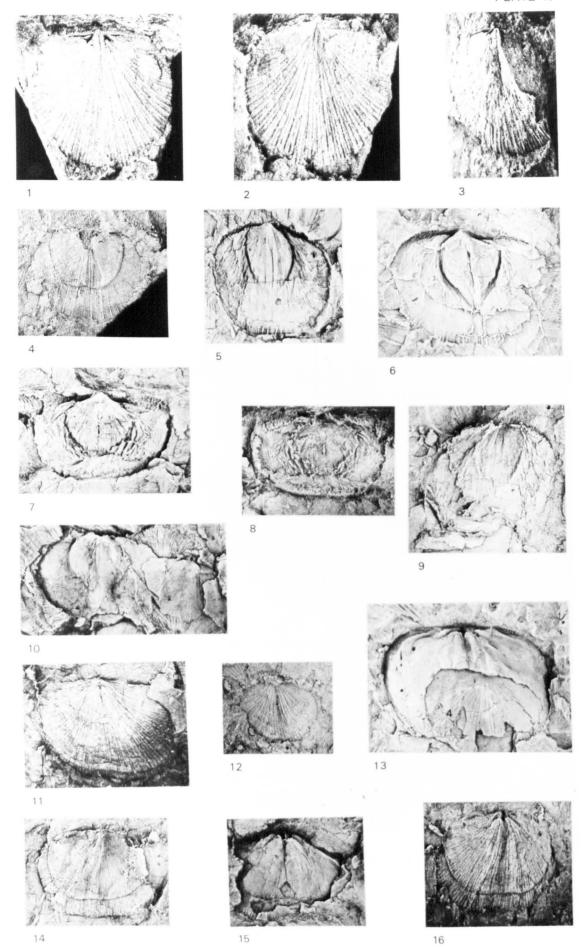
DESCRIPTION. Deep pits between the brachiophores and their supporting plates suggest this material belongs in <a href="Horderleyella">Horderleyella</a>. The poor preservation in a coarse sandstone does not permit further detailed description.

DISTRIBUTION. This species has only been recorded from a single locality (VACA1) in the Penha Garcia syncline, where it occurs in the upper part of the Louredo Formation.

#### Horderleyella sp. B

(Plate 18 figs. 26-31, plate 19 figs. 1-3)

MATERIAL. Several dozen moulds. The probably originally slightly calcareous mudstone contains these specimens is rather soft, and most of the material is poorly preserved in the form of



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composite moulds. Some rare specimens (e.g. plate 18, fig. 30) are well preserved in a harder, concretionary lithology.

DESCRIPTION. Ventri-biconvex shells, with both valves of fairly low convexity, cardinal angles rounded, widest point about 40% of valve length anterior of hingeline, valves about 90% as long as wide. Ornament costellate.

Ventral interior with widely divergent dental plates extending anteriorly for 12-15% of valve length, muscle field poorly impressed; dorsal interior with divergent brachiophores, supporting plates slightly convergent and extending for just over 20% of valve length anteriorly, deep conical pits present between plates and brachiophores, cardinal process narrow and simple, mantle canal system ?saccate.

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Plate 19.

Horderleyella sp. B

Figs. 1,3 internal moulds of brachial valves, fig. 2 external mould of specimen in fig. 1. All RC12, x4.0.

Eorhipidomella musculosa (Melou, 1976)

Fig. 4 latex cast of external mould of pedicle valve, figs. 5,9 internal mould of pedicle valve, and its latex cast, fig. b internal mould of pedicle valve, figs. 7,b internal mould of pedicle valve and its latex cast, fig. 10 internal mould of pedicle valve, figs. 11,12,1b latex casts of external moulds of brachial valves, fig. 14 latex cast of external mould of pedicle valve, figs. 13,1b internal moulds of brachial valves. All PG7, x2.0.

DISTRIBUTION. This species is known from the lower part of the Ribeira do Braçal Formation (Zone 12 - for which it is the index species) of the Buçaco syncline (samples RC 12/13 and PEN2).

DISCUSSION. This species is a member of an interesting fauna (with <u>Plectothyrella?</u> sp. A and <u>Bracteoleptaena</u> sp.) which seems to show a relationship to the classic Hirnantia fauna. The Hirnantia faunas from Poland, Wales (Temple, 1965) and Morocco (Havlicek, 1971) yield <u>Horderleyella?</u> cf. <u>bouceki</u> (Havlicek, 1950), to which the present form shows considerable similarity. Until a full statistical analysis of the Portuguese material has been undertaken, this assignation will not formally be made.

Family HETERORTHIDAE Schuchert and Cooper, 1931

Genus <u>Heterorthina</u> Bancroft, 1928

Type species: <u>Heterorthina</u> praeculta Bancroft, 1928.

This genus provides several species which form the major part of the brachiopod faunas of central Portugal in Zones 1 to 3. The genus is the dominant brachiopod of the phases 1 and 2 of the Praeleda association, and may also occur in the sandstone facies of the same age in southern Spain (Valencia de Alcantara, persobs.) and indeed in central Portugal (Monte da Sombadeira Formation of the Penha Garcia syncline). The diversity of the genus is shown here to be greater than previously indicated. This situation is somewhat similar to the distribution of various species of Svobodaina in Zones 7 and 8).

## Heterorthina morgatensis Melou, 1975 (Plate 20, figs. 1-13)

- v?1974 <u>Cacemia</u> gen. nov. sp. nov. : Mitchell pp. 388, 394; pl. 1, figs. 5, 6.
- v 1974 Fascifera sp.: Mitchell p. 388.
  - 1975 Heterorthina sp. A: Babin et al.
  - 1975 Heterorthina sp. A: Racheboeuf
- \* 1975 <u>Heterorthina morgatensis</u> nov. sp.: Melou pp. 192-203; pl. 20, figs. 1-9; pl. 21, figs. 1-12; pl. 22, figs. 1-5.
  - 1979 Heterorthina morgatensis Melou: Hurst pp. 268,269.
- ? 1983 Heterorthina morgatensis Melou: Villas pl. 2 fig. 11.

MATERIAL. Several moulds of immature material from the lower part of the Fonte da Horta Formation of the Buçaco syncline. In addition material from the same area from below the Monte da Sombadeira Formation as outlined below. Mitchell's collections contain much referred here to this species, including many specimnes from below the Monte da Sombadeira Formation (e.g. his locality 1).

DESCRIPTION. This species was described in detail by Melou (1975), and so will not be redescribed here. All the material recovered from the Fonte da Horta Formation is immature, but corresponds well with topotype material from Brittany. More mature specimens have been recovered from the lower part of Zone 1 (Brejo Fundeiro Formation) of the Buçaco syncline, but this

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horizon is outside the scope of the present study.

DISTRIBUTION. This species has been found in the lower part of the Fonte da Horta Formation of the Bucaco syncline (CACWELL2), and at the same stratigraphic level in the Penha Garcia syncline.

DISCUSSION. Material from Buçaco probably referable to this species was collected by Mitchell, and was described by him as Cacemia sp. nov.. This material is housed in the British Museum, and is labelled as <u>Cacemia mistura</u>. Specimens also collected by Mitchell, described (1974) as Fascifera sp., are also present in the British Museum collections labelled Pionodema fasciferoides, and these also seem to belong, at least in part, to  $\underline{H}$ . morgatensis Melou.

Plate 20.

Heterorthina morgatensis Melou, 1975

Mitchell's material labelled Pionodema fasciferoides, all from loc'y 4, x2.0. Figs. 1,3 internal and external moulds of a brachial valve with corresponding latex casts, figs. 2,4 respectively, BM.BB 73257a and b respectively, figs. 5,6 internal moulds of brachial valves, BM.BB 73250 and 73255 respectively.

Mitchell's material labelled <u>Tissintia</u> convergens transversa, all from loc'y 1, all x2.0. Figs. 7-9 internal moulds of brachial valves, BM.BB 73117, 73135 and 73132 respectively, fig. 12

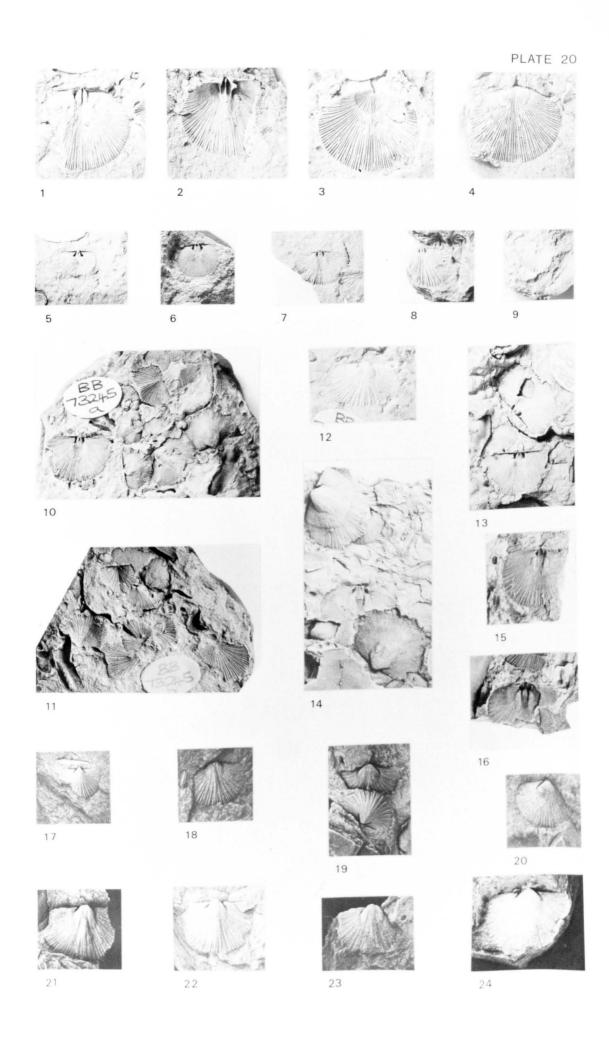
internal mould of pedicle valve, BM.BB 73130.

Mitchell's material labelled <u>Cacemia</u> <u>mistura</u>, all from loc'y 3, all x2.0. Figs. 10,11 part and counterpart bedding planes with several internal and external moulds, BM.BB 73245 a and b, fig 13 internal moulds of two brachial valves, upper specimen fig'd Mitchell, 1974 as Cacemia sp. nov. (pl. 1, fig. 5).

Heterorthina kerfornei Melou, 1975 Mitchell's material labelled <u>Tissintia</u> convergens, loc'y 3, x2.0. Fig. 14 internal moulds of several valves, BM.BB 73217a, fig. 15 internal mould of a brachial valve, BM.BB 73217b, fig. 16 internal mould of a brachial valve, BM.BB 73217b.

Internal moulds of pedicle valves; figs. 17-24. Figs 22,24

CAC3, others CACWELL1, all x2.0.



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### Heterorthina kerfornei Melou, 1975 (Plate 20, figs. 14-24, Plate 21, figs. 1-7)

- v?1974 Tissintia cf. convergens Havlicek: Mitchell p. 388.
  - 1975 Heterorthina sp. B : Babin et al.
  - 1975 Heterorthina sp. B: Racheboeuf
- \* 1975 <u>Heterorthina kerfornei</u> nov. sp.: Melou p. 203-207; pl. 23, figs. 1-14; pl. 24, figs. 1-13.
- ? 1980 <u>Horderleyella</u> cf. <u>plicata</u> Bancroft, 1928 : Cooper p. 346-348; pl. 27, fig. 1; pl. 30, figs. 2-7.
- ? 1983 Heterorthina kerfornei Melou: Villas pl. 2 figs. 9, 10.

MATERIAL. A large number of specimens of this species, mainly disarticulated valves, have been recovered.

DESCRIPTION. A full description was given by Melou (1975) so further comment here is unnecessary.

DISTRIBUTION. This species is abundant in the Fonte da Horta Formation, from about 20m above the base to the top of the formation. Specimens have been recovered from the Buçaco, Dornes/Amendoa/Mação, Fajão and Vila Velha do Rodão synclines in Portugal. Further material has been collected from the upper part of the Postolonnec and Andouillé Formations of Brittany (Crozon peninsula, Laval syncline). Further information on the distribution of this species at localities in Brittany not visited in this study is given by Melou (1975).

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DISCUSSION. Heterorthina kerfornei was placed in synonomy with  $\underline{H}$ . <u>praeculta</u> Bancroft by Hurst (1979). The French species can however be distinguished by the prescence of a pair of shallow pits in the notothyrial platform just posterior to the muscle scars.

# Heterorthina sp. aff. kerfornei Melou, 1975 (Plate 21, figs. 16-21)

MATERIAL. About 10 reasonably well preserved internal moulds, with a large number of moulds of poorly preserved specimens.

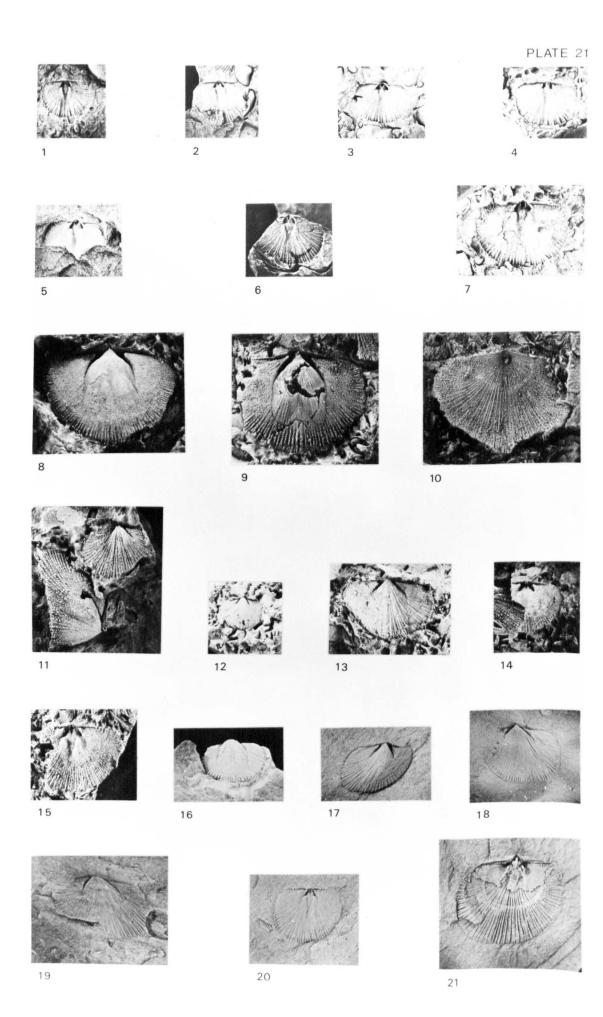
DESCRIPTION. Most of the reasonable material of this species comes from the Carregueira section, which unfortunately has suffered rather more deformation than most localities. This makes direct comparison of shape with <a href="kerfornei">kerfornei</a> difficult. The distinguishing features of the new species are its large ventral muscle field (rather like <a href="morgatensis">morgatensis</a> and sp. A), and probably a less transverse outline. The overall appearance of the shell in size and ornament is similar to <a href="kerfornei">kerfornei</a>. The internal features

Plate 21.

Figs. 1-7 internal moulds of brachial valves, CACWELL1, x2.0.

Heterorthina sp. A
Figs. 6,9,11,12,13 internal moulds of pedicle valves, fig. 10
external mould of pedicle valve, figs. 14,15 internal moulds of brachial valves. All from La Touche, x2.0.

Heterorthina sp. aff. kerfornei Melou, 1975 Figs. 10-19 internal moulds of pedicle valves, figs. 20-21 internal moulds of brachial valves, all from ABO5 except 19 (ABO9), x2.0.



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of the brachial valve seem close to <u>kerfornei</u>, although the two pits in the notothyrial platform characteristic of that species have not been seen in this material.

DISTRIBUTION. This species occurs in the Carregueira Formation of Portugal (Buçaco, Dornes, Mação), and in the "Schistes de Veryac'h", the uppermost part of the Postolonnec Formation, of the Crozon peninsula (sections at Le Veryac'h and Postolonnec).

DISCUSSION. The material described here is very poorly known at present and more collecting is necessary to provide material well-enough preserved to enable its relationship to other Heterorthina to be evaluated.

#### Heterorthina sp. A (Plate 21, figs. 8-15)

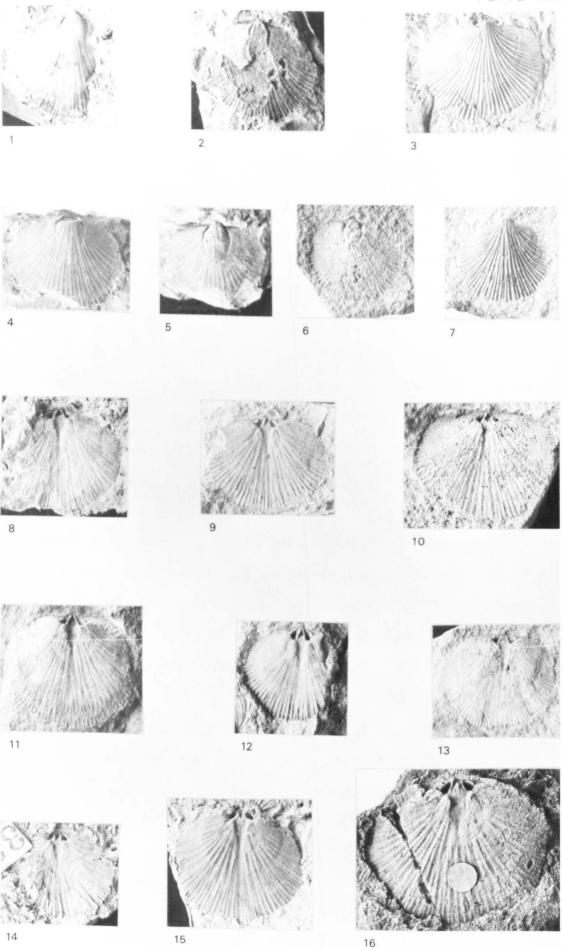
MATERIAL. This species is represented by about 10 internal and external moulds of each valve from La Touche, as well as more fragmentary material from several localities in the upper part of the Cabril Formation in central Portugal.

DESCRIPTION. Although this species is very similar to Heterorthina kerfornei Melou, there are several small, but significant differences to justify the erection of a new species. This material has a slightly more transverse outline than Melou's species; having length/width ratios of 0.73 (mean for 4 pedicle valves) and 0.69 (mean for 4 brachial valves), against 0.79 and

0.72 as mean ratios quoted by Melou for H. kerfornei. The new species differs also in the arrangement of the dorsal cardinalia; the shaft of the cardinal process is more differentiated from the notothyrial platform and it lacks the two small pits present in kerfornei in the platform. Similarly there is not as much secondary shell material on the inside of the brachiophores, leaving them with a more divergent, narrower appearance. The major difference is the ventral valve; in the new species thisis more strongly developed, reaching over 70% of the length of the valve. Also the new species does not possess as marked a pedicle callist as does H. kerfornei. Instead the delthyrial cavity narrows posteriorly, giving into a delthyrium with an acutely angular floor, as opposed to the "U" shaped delthyrium of the older species.

DISTRIBUTION. Material referred to this species was recovered from a ferruginous coquina within the Marrolithus bureaui zone of La Touche, Andouillé, Brittany. Further material from the Cabril Formation is also referred to the species, although the amount of material available for study is very small.

DISCUSSION. This species is very close to <u>Heterorthina</u> <u>kerfornei</u> Melou, and differs from it in only a few details. Unfortunately there is a substantial stratigraphic gap between the oldest specimens of this species and the youngest of Melou's species recovered from Portugal, so the transition between the two species is unknown.



## Heterorthina? sp. B (Plate 22, figs. 1-16)

MATERIAL. Only two poorly preserved internal and external moulds of brachial valves were recovered from Leira Ma in this project. In contrast good material is available in the collections of Delgado and Sharpe, made in the last century.

DESCRIPTION. As almost all the well preserved material is in the collections of the Servicos geologicos it is not possible to here provide a full description. The overall form of the valves, the reflexed setae, the ventral muscle field, and the form of the bilobed cardinal process appear to justify inclusion of this species in Heterorthina.

DISTRIBUTION. This species is an important member of the fauna from Leira Ma in the collections of the "Serviços Geológicos".

Plate 22.

#### Heterorthina? sp. B

Pedicle valves: fig. 1 internal west of "Fonte de Cassemes", fig. 2 internal mould, SGL 3355 (1 of), 100m west of "Fonte de Cassemes", fig. 3 external mould, SGL 3051, Leira Ma, fig. 4 internal mould, SGL 3741 (1 of), 100m west of "Fonte de Cassemes", fig. 5 internal mould, SGL 3355 (1 of), 100m west of "Fonte de Cassemes", figs. 6 and 7 internal and external moulds of a valve, SGL 3050, Leira Ma.

Brachial valves: all internal moulds, fig. 8 SGL 3341 (1 of), 100m west of "Fonte de Cassemes", fig. 9 SGL 3049 (1 of), Leira Ma, fig. 10 SGL 3040, Leira Ma, fig. 11 SGL 3049 (1 of), Leira Ma, fig. 12 SGL 3049 (1 of), Leira Ma, fig. 13 SGL 3052 (1 of), Leira Ma, fig. 14 SGL 3334, 100m west of "Fonte de Cassemes", fig. 15 SGL 3341 (1 of), 100m west of "Fonte de Cassemes", fig. 10 BM.B83007 Bucaco locality unknown.

All x2.0.

This fauna is from a horizon just above the base of the Porto de Santa Anna Formation, within the Leira Ma Member (Zone 8).

#### Genus Eorhipidomella

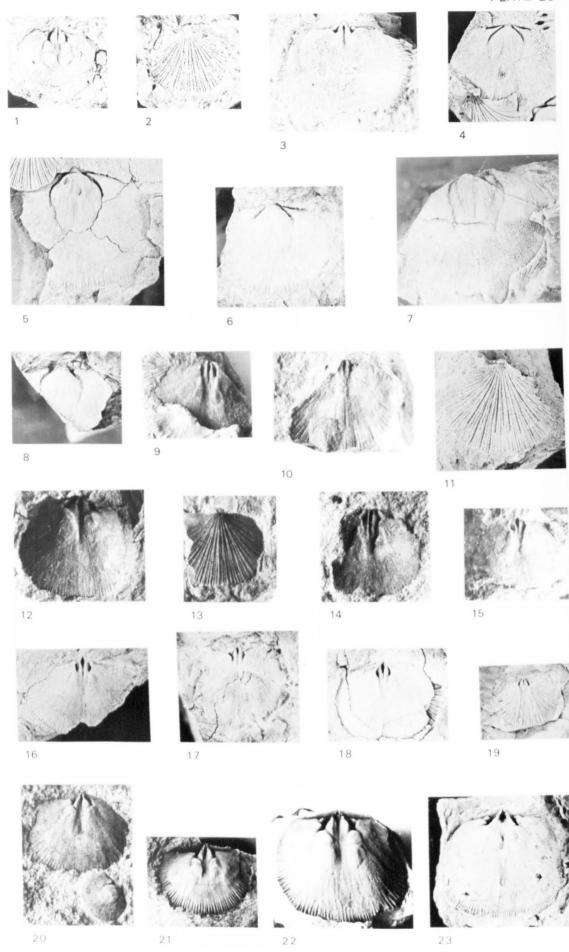
### Eorhipidomella musculosa (Melou, 1976) (Plate 19, figs. 4-16)

- 1970 <u>Strophomena</u> sp.: Drot, in Chauvel et al. p. 618; pl. XIII, fig. 15
- 1976 <u>Crozonorthis musculosa</u> nov. gen. nov. sp.: Melou p. 700-705; pl. 4, figs. 1-14; pl. 5, figs. 1-10.
- 1983 <u>Eorhipidomella musculosa</u> (Melou): Villas pl. 2 figs. 8,12

MATERIAL. About 20 valves of this species have been recovered from the lower part of the Fonte da Horta Formation in Buçaco, several from the same horizon at Dornes, and several nundred moulds from Penha Garcia.

DESCRIPTION. The description given by Melou (1976) needs little addition. One feature which is prominent in some immature pedicle valves was not mentioned in that description; that is the prescence of a strong concentric ridge on the inside of the valve corresponding to a position just outside the maximum extent of the diductor muscle-scars in gerontic specimens.

DISTRIBUTION. Abundant material of this species has been



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recovered from the lower levels of the Fonte da Horta of the Buçaco (CACWELL2), Dornes (SDP5) and Penha Garcia areas (PG 6,7). At Penha Garcia it also occurs in the upper ferruginous beds of the Monte da Sombadeira Formation. In the Penha Garcia syncline the species thus has a considerable vertical range (at least 15m). Its range in the Dornes/Amendoa/ Mação syncline has not been measured, but at Buçaco it occurs through less than 10m of strata, and coexists with  $\underline{\text{Heterorthina morgatensis}}$  for at least part of its range. This is contrast with its occurrence in Crozon where, in the Postolonnec section, it only occurs through less than a metre, and coexists with  $\underline{\text{H}} \cdot \underline{\text{kerfornei}}$  (the biozone of  $\underline{\text{H}} \cdot \underline{\text{morgatensis}}$  is some 15m lower down the succession).

DISCUSSION. This species seems to be indicative of a palaeogeographical belt between the areas yielding the <u>Praeleda</u> and <u>Placoparia</u> associations. It coexists with <u>Aegiromena mariana</u> at Penha Garcia, and in its type locality in Spain. Its occurrence in such a limited way in Crozon close to the bed

Plate 23.

Svobodaina sp.

Figs. 1,2 internal and external moulds of a brachial valve, Louredo, x2.0, fig. 3 internal mould of a brachial valve, QXP1, x2.0.

Svobodaina armoricana Babin and Melou, 1972
Figs. 4,5,6,7,8 internal moulds of pedicle valves, VS2,
figs. 16-18 internal moulds of brachial valves, VS2, figs.
9,10,12,14,15,20 internal moulds of brachial valves, 14,15 from
bed 16 of Val San Jorge section, others bed 15, fig. 11 external
mould of brachial valve, VS2, fig. 13 external mould of brachial
valve, bed 15 VSG, fig. 19 internal mould of brachial valve
FAV1, fig. 21 internal mould of brachial valve BM.B 82887, fig.
22 internal mould of brachial valve BM.B 83017, fig. 23 internal
mould of brachial valve, ZUV 12. All x2.0.

yielding <u>Gymnograptus</u> <u>linnarssoni</u> suggests that its usual environment was not that of the <u>Praeleda</u> community, but short lived movements of facies belts moved its range into areas normally occupied by that association.

Genus <u>Svobodaina</u> Havlicek, 1950

Type species: <u>Orthis inclyta</u> Barrande, 1879.

### Svobodaina sp. (Plate 23, figs. 1-3)

Material probably referable to <u>Svobodaina</u> Havlicek has been recovered from Zone 5 deposits in Buçaco, Dornes?, and Mação. This material is distinct from <u>S. armoricana</u>, although the available material does not enable full description of this form.

Svobodaina armoricana Babin and Melou, 1972 (Plate 23, figs. 4-23, Plate 24, figs. 1-3)

- v 1853 Orthis Berthoisi Rouault: Sharpe p. 141 (non pp. 154-155; pl. VIII, fig. 4).
- v 1900 Orthis Berthoisi Rou.: Delgado pp. 39(partim), 40, b1(partim); (non pp. 31).
- ? 1968 Drabovia? sp.: Pillet and Robardet p. 72; figs. 1,1a.
- \* 1972 Svobodaina armoricana nov. sp.: Babin and Melou pp. 87-90; textfigs. 6,7; pl. IX, figs. 1-5; pl. X, figs. 1-8.

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v 1980 <u>Svobodaina armoricana</u> Babin and Melou, 1972: Cooper pp. 349-353; pl. 20, figs. 8-13; pl. 31, figs. 1-6.

MATERIAL. A few well-preserved moulds have been recovered from the mudstone members of the Louredo Formation, this has been supplemented by museum specimens and the examination of topotype material. The sandier facies of the Louredo and Cabeço do Peão Formations also yield this species, and about 100 specimens were available for study altogether.

DESCRIPTION. The material from the mudstones (e.g. plate 23 figs. 21-24) correspond well to the full description given by Babin and Melou (1972). The material from the coarser sediments, while including some material similar to the mudstone specimens, includes also a large proportion of a different form. second form agrees closely with the description of Orthis Berthoisi Rouault var. erratica Davidson, 1869, as redescribed by Cocks and Lockley (1981) as Corineorthis erratica (e.g. plate 23 figs. 5-18). These two forms are present together, and indeed seem to form a continuous series within a sample (e.g. the material figured by Cooper). the differences between the two forms are two: firstly, and most importantly the brachiophore bases of the "erratica form" extend anteriorly between the muscle scars as far as the anterior adductors, the brachiophore plates are narrow, with sub-parallel bases, as opposed to the thicker, more splayed bases of the "armoricana form", which enclose a wider notothyrial chamber, and have secondary shell material lying lateral to the posterior adductor scars.

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second difference lies in the characteristic shape of the ventral muscle field (e.g. plate 23, figs. 5,7) which coincides exactly with that exhibited by erratica.

While the end members of this variation would give adequate grounds for the erection of two species, the continuum present in some Portuguese samples suggests that a single species exhibiting ecophenotypic variation may be present.

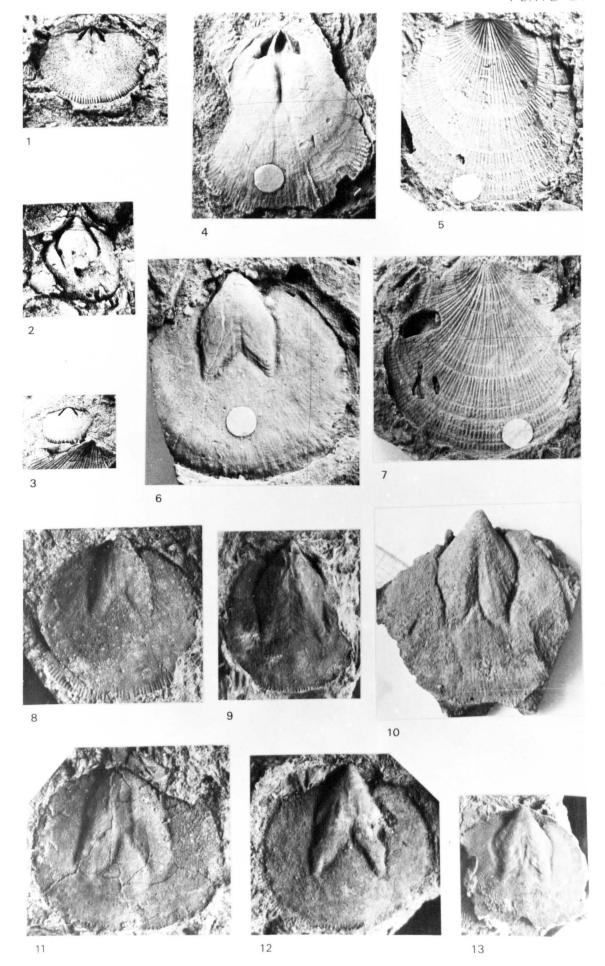
DISTRIBUTION. This species occurs very widely in the Ibero-Armorican arc. Melou records it in Normandy and Brittany. In Portugal it occurs in the mudstone intercalations of the Louredo Formation (Zuvinhal and Vale Saido Members) as well as the bioturbated sandstones and siltstones of the upper half of the Cabeço do Peão Formation. If erratica is conspecific then the known range is extended to include the sandstones of the St.-Germain-sur-Ille Formation of Brittany.

DISCUSSION. The name <u>armoricana</u> is retained here until further

Plate 24.

Svobodaina armoricana Babin and Melou, 1972
Fig. 1 internal mould of brachial valve, Plage de Raguenez, figs. 2,3 internal moulds of pedicle valves, Plage de Raguenez, x2.0.

Fig. 4 internal mould of brachial valve, BM.B 82999, fig'd Sharpe pl. VIII fig 4d, fig. 5 external mould of brachial valve, BM.B 82997, fig'd Sharpe pl. VIII, fig 4a, fig. 6 internal mould of pedicle valve, BM.B 82997, fig'd Sharpe pl. VIII fig. 4b, fig. 7 external mould of brachial valve, BM.B 82998, fig'd Sharpe, pl. VIII, fig 4c, figs. 8,13 internal moulds of pedicle valves from "100m O. de Fonte de Cassemes", figs. 9,11,12 internal moulds of pedicle valves from Delgado's Zuvinhal section bed 4, fig. 10 internal mould of pedicle valve from Leira Ma. All x2.0.





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study of <u>erratica</u> and populations from coarse clastic sediments referred at present to <u>armoricana</u> has been completed.

#### Svobodaina sp. A

(Pl. 24 figs. 4-13, S. cf. sp. A: Pl. 25 figs. 1-18)

- v 1853 Orthis Berthoisi Rouault: Sharpe pp. 142,154,155 (non p. 141); pl. VIII, fig. 4a-d.
- v 1908 Orthis Berthoisi Rou.: Delgado pp. 31,39(partim),61 (partim).
- ? 1969 Svobodaina cf. inclyta (Barrande, 1879): Drot in Chauvel et al. p. 622, pl. XIII, figs. 17, 18.
- ? 1983 <u>Svobodaina ellipsoides</u> (Barrande): Villas pl. 2 figs. 5, 6, 7.

MATERIAL. Abundant material of this species has been collected from the Leira Ma Member of the northern part of the Bucaco syncline. A limited amount of material was collected from the same level in the Rio Ceira inlier. Dr. P.J. Brenchley kindly made a collection from Corral de Calatrava available for study. This material include upwards of 100 valves. All the material is preserved as moulds.

Plate 25.

Svobodaina cf. sp. A

All material from Corral de Calatrava. All x2.0.

Figs. 1, 2, 3, 4, 5, 6, 7, 8, 10, 11 internal moulds of pedicle valves, figs. 12, 13, 14, 15, 16, 17, 18 internal moulds

of brachial valves.

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DESCRIPTION. Biconvex becoming strongly dorsi-biconvex in large specimens; valves about 90% as long as wide, rounded outline, hingeline short (about 40% max. width), ornament finely costellate, brachial valve gently sulcate, becoming less so with age.

Ventral interior with stout teeth supported by short dental plates, these often become secondarily thickened in gerontic specimens, strongly impressed ventral muscle field, average of 60% of valve length, outline of field highly variable, diductors enclose adductor scars anteriorly on majority of specimens, pedicle callist large, triangular, and strongly ridged.

Dorsal interior with stout, fairly long divergent brachiophores, cardinal process differentiated with bulbous cardinal process divided longitudinally by 1 or 3 fissures, strongly crenellates laterally, fulcral plates absent, muscle field well impressed, often very strongly impressed posteriorly, posterior scars crescentic, irregularly oval anterior scars, mantle canal system poorly known.

DISTRIBUTION. This species occurs at the base of the Porto de Santa Anna Formation in the Buçaco syncline. It appears first in the oolitic ironstone bed at the base of the Leira Ma Member. It also occurs in the upper siltier parts of the member, frequently reaching a larger size than in the oolite. It has not been recorded from any higher level in the formation. The basal beds of the Rosan Formation also yield this species, but not abundantly. The Serra do Cadaveira Member of the Dornes and Amendoa areas yields a Svobodaina, but it is not known at present

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if it should be referred to this species. The material described by Cooper from the "Serra do Cadaveira Member" came mainly from a slightly lower horizon, and clearly belongs in <u>S. armoricana</u> (although is largely of the <u>erratica</u> morph - see above). The "Bancos Mixtos" of the Sierra Morena contain an abundant fauna of brachiopods dominated smaller than the material from the Porto de Santa Anna Formation, but seem otherwise identical.

DISCUSSION. The material from the Bancos Mixtos (plate 25) differs from the Porto de Santa Anna Formation material in several aspects. firstly the ventral diductor scars generally (but not always) have divergent medial margins, leaving the adductor field open anteriorly. Secondly the material is much smaller than the portuguese specimens, and lastly there seems to be a tendancy towards more divergent brachiophores. These differences are not held to represent specific differences, for there is considerable variation within any population, however it may be possible to erect subspecies based on such variation.

Family SAUKRODICTYIDAE Wright, 1964

Genus Saukrodictya Wright, 1964

Type species: Saukrodictya hibernica Wright, 1964

Saukrodictya sp. A (Plate 26, figs. 1-3)

MATERIAL. This species is represented by relatively abundant material from the Queixopeira Member of the Mação area. Most of

the material is however fragmentary, and only half a dozen reasonably complete moulds are available.

DESCRIPTION. Saukrodictya with ventri-biconvex shell, cardinal angles slightly alate, hingeline probably maximum width, pedicle valve carinate, brachial valve with very low convexity and broad shallow sulcus. Ventral interarea apsacline, low, dorsal interarea anacline, low.

Ventral interior poorly known, dental plates thin, short, muscle field probably confined to delthyrial cavity, dorsal interior with delicate cardinalia, details uncertain, muscle field poorly impressed, ornament strongly impressed on interior of both valves.

DISTRIBUTION. This species is found in the Queixopeira Member of the Cabeço do Peão Formation. It has been recovered from the Macao area (QXP2), but not so far from the Dornes region.

# Saukrodictya sp. B (Plate 26 figs 4-11)

MATERIAL. The illustrated specimens (Plate 26, figs 4-11) form the only relatively complete material available. As with the other members of this genus found in central Portugal the nature of the ornament seems to make the shells particularly vunerable to breakage.

DESCRIPTION. The pedicle valves seem close to the material of

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sp. A described above, but cardinal angles appear to be obtuse rather than alate. The brachial valves are more strongly convex and more markedly sulcate than those of sp. A, and exhibit a longer median ridge. The cardinalia appear to be relatively larger than those of the earlier species, while the muscle field is more strongly marked, and the internal expression of the ornament less pronounced.

DISTRIBUTION. This species of <u>Saukrodictya</u> is known from the base of the Venda Nova Group (Leira Ma Member) and of the Rosan Formation (Zone 8).

#### Saukrodictya spp. indet.

Deposits of Zone 9, 10, and 11 have yielded fragmentary material of this genus. Although recognisable at generic level even from small fragments, no detail study of this material is yet possible.

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Plate 26.

Saukrodictya sp. A

Figs. 1,2 internal moulds of brachial valves, QXP2, fig. 3 internal mould of pedicle valve, QXP2, all x2.0.

Saukrodictya sp. B

Fig. 4 internal mould of pedicle valve, Leira Ma, fig. 5 external mould of pedicle valve, BM.B 83031, figs. 6-9 internal moulds of pedicle valves; fig. 6 SGL 3377 (1 of) 100m 0. Fonte de Cassemes, fig. 7 SGL 3377 (1 of) locality as 6, fig. 8 SGL 3377 (1 of) locality as 6, fig. 8 SGL 3377 (1 of) locality as 6, figs. 8 SGL 3377 (1 of) locality as 6, figs. 10,11 external and internal moulds of a brachial valve, RAG1. All x2.0.

Figs. 12-15 internal moulds of pedicle valves, fig. 12 SGL 3020, others SGL 3019. All from Leira Ma, all x2.0.

Family TYRONELLIDAE Mitchell, 1977

Genus Tyronella Mitchell, 1977

Type species: Tyronella killeyensis Mitchell, 1977

Tyronella? sp. A (Plate 18 figs. 15-22)

MATERIAL. Large numbers of mediocrely preserved vavles from coquinoid nodular layers at Dornes, a few isolated well preserved moulds from Buçaco, and a few well preserved moulds from nodules from the Schistes de Veryac'h, Crozon.

DESCRIPTION. Ventri-biconvex shell of transverse outline, abot 60% as long as wide, both interareas low, ventral apsacline flat, dorsal anacline, very low; dorsal valve sulcate; widest point about 20-25% of vavle length anterior of hingeline, hingeline about 80% of maximum width. Shell punctate. Ornament costellate.

Ventral interior with small teeth supported by recessive, almost obsolescent divergent dental plates, muscle field impressed on valve floor, cordate, extending anteriorly for 30% of valve length, delthyrium probably open, but possibly constricted apically.

Dorsal interior with small triangular myophore, passing anteriorly into prominent median septum, extending anteriorly for 80% of valve length, septum almost reaches floor of pedicle valve, septum widest immediately anterior to cardinal process and narrowing anteriorly, brachiophores thin, low, widely divergent, almost parallel to hingeline, sockets narrow, long, parallel to

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hingeline.

DISTRIBUTION. This species occurs in the topmost part of Zone 4, in the Buçaco, Dornes, Mação and Crozon areas. At Buçaco and Mação its total range does not seem to exceed 2m. It disappears abruptly at the top of the Carregueira Formation.

4 **4** 4

DISCUSSION. The stratigraphical importance of this species is great, since its range is so restricted. The generic assignation of the species, and hence any hint of its origin, is more problematical. The genus Tyronella Mitchell from the Ashgill of Ireland agrees with the present material in the general shell form, ornament, and the internal arrangement of the brachial valve, it does however differ strongly in the prescence of a spondylium in the ventral valve. An alternative taxonomic position for this species would be within the Kayserellidae Wright, but in this family the Kayserellinae have a septalium in the brachial valve, and the Prokopiinae have a ridge demarking the dorsal muscle field.

Enteletacean indet.
(Plate 26, figs. 12-15)

The material of this species includes four internal moulds of pedicle valves (all illustrated). The material all comes from Leira Ma (Zone 8), and consists of a pedicle valve with a low interarea, recessive dental plates, a slight pedicle callist, and a cordate muscle field extending anteriorly for 35% of

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valve length. Shell outline subcircular, length about 90% of maximum width, maximum width about midlength, hingeline 70% of maximum width. Pedicle valve striking for its low convexity apart from umbonal region, and for its broad sulcus.

Suborder Triplesiidina Moore, 1952

Superfamily Tripleciacea Schuchert, 1913

Family TRIPLECIIDAE Schuchert, 1913

Genus Triplesia Hall, 1859

Type species: Triplesia extans (Emmons, 1842)

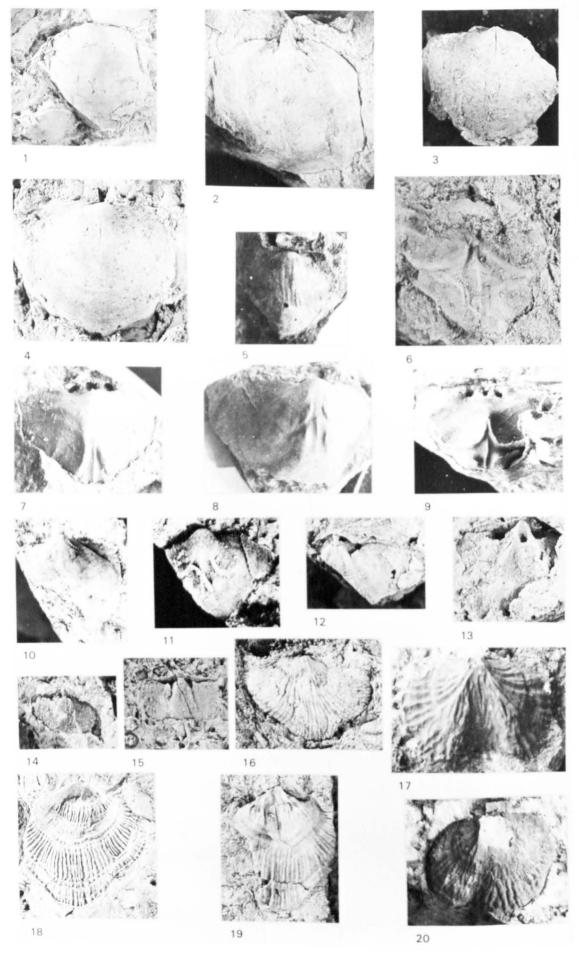
<u>Triplesia</u> sp. A (Plate 27, figs. 1-4)

MATERIAL. This species is represented by a large number of valves from Zone 5 of the Dornes/Mação area, as well as a smaller amount from the same horizon at Buçaco.

DESCRIPTION. Dorsi-biconvex shell of transversely sub-circular outline, very slightly marked fold and sulcus, external surface of shell almost smooth, with occasional faint growth lines.

Ventral interior with short, slightly divergent dental plates extending anteriorly for 12% of valve length, defining small umbonal cavity. Dorsal interior with only very faintly impressed structures, but with a short low median septum, cardinal process long, forked.

DISTRIBUTION. This species is found in the Favaçal Bed of the



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Buçaco, Dornes and Mação areas. It also occurs as one of the less-important members of the fauna of the Queixopeira Member in the Macao area.

DISCUSSION. This species closely resembles Triplesia simplex Havlicek, 1971 from the lower part of the Lower Ktaoua Formation of Morocco. Havlicek's material seems to exhibit a more more marked fold and sulcus. Other fauna from this same level in Morocco is close to elements of the Zone 5 fauna (e.g. Colpocoryphe grandis).

Triplesia sp.

(Plate 27, fig. 5)

A single brachial valve of a Triplesia from Zone 8 of the

Plate 27.

Figs. 1,3 internal  $\frac{\text{Triplesia}}{\text{moulds of brachial valves, SDP1, x2.0,}}$ fig. 2 internal mould of pedicle valve, SDP1, x2.0, fig. 4 internal mould of brachial valve, Louredo, x3.0.

Triplesia sp.

Fig. 5 internal mould of brachial valve, SGL 3325, 100m 0. Fonte de Cassemes, x2.0.

Triplesia sp. B

Figs. 6-9 internal moulds of brachial valves, fig. 6 from Cabeco do Pedrogao, figs. 7-9 from bed 2 of Delgado's Val San Jorge section. All x2.0.

Triplesia cf. sp. B

Figs 10,11 internal moulds of brachial valves from B135, x2.0.

Bicuspina sp.

Figs. 12-15 internal moulds of pedicle valves, POR11, x2.0. Oxoplecia sp.

Fig. 16 internal mould of brachial valve, ABER3, fig. 17 internal mould of pedicle valve, SGL 3350, 100m 0. de Fonte de Cassemes, figs. 18,19 external and internal moulds of a pedicle valve, ABER3, fig. 20 internal mould of a pedicle valve, SGL 3361, 100m O. de Fonte de Cassemes. All x2.0.

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Buçaco syncline, is in the museum of the Servicos Geológicos. It shows less strongly impressed scars than the later sp. B.

323.

Triplesia sp. B
(Plate 27, figs.b-9)

The material of this species (from the Zone 9/10 interregnum and from ?Zone 10 of the Buçaco syncline) is fragmentary, so a full description cannot be given. Only the brachial valve is known. The muscle field is very strongly impressed.

<u>Triplesia</u> cf. sp. B (Plate 27, figs. 10,11)

The Zone 11 deposits of the northern part of the Buçaco syncline yield a <u>Triplesia</u>, which is commonly the largest and most frequent brachiopod in the assemblage. It shows the degree of impression of the muscle scars increasing with size, but the size range does not overlap with the large sp. B of the earlier deposits; it is thus difficult to determine whether this material is conspecific. Again the material is all rather fragmentary.

Genus <u>Bicuspina</u> Havlicek, 1950

Type species: Bicuspina cava (Barrande, 1848)

Bicuspina sp.
(Plate 27 figs. 12-15)

At present this species has been recovered from only a single locality within the upper part of the Poiares Member (samples POR10, POR11, POR12). This is of top zone 9 or Zone 9/10 interegnum age. Only fragmentary pedicle valves have been recovered.

Genus Oxoplecia Wilson, 1913

Type species: Oxoplecia calhouni Wilson, 1913

Oxoplecia sp.
(Plate 27, figs. 17-20)

Only a few fragments of material referrable to this genus have been recovered from Zone 9 during this study, and there is further material in the collections of the "Services Geológices" from the lower part (Zone 8) of the Porto de Santa Anna Formation of the Buçaco syncline. The material frequently shows strong imbrications, with regions where the ornament becomes totally obscured. The internal details of this material are unknown.

Order Strophomenida Opik, 1934

Suborder Strophomenidina Opik, 1934

Superfamily Plectambonitacea Jones, 1928

Family LEPTELLINIDAE Ulrich and Cooper, 1936

Subfamily Leptestiininae Havlicek, 1951

Genus Leptestiina Havlicek, 1952

Type species: Benignites (Leptestiina) prantli Havlicek, 1952.

### Leptestiina aonensis Melou, 1971 (Plate 28, figs. 1-5)

1976 <u>Leptestiina aonensis</u> nov. sp.: Melou pp. 95-98; pl. 1, figs. 1-6; pl. 2, figs. 1-3.

? 1983 Leptestiina aonensis Melou: Villas pl. 3 figs. 13-16.

MATERIAL. About 10 valves (in the form of moulds) have been found in the Zone 10 deposits of the Poiares Member, at Ferradosa and Poiares. In addition another 10 valves were collected at locality GAR1 (Coat Garrec), the type locality for the species.

DESCRIPTION. This species was fully described by Melou (1971), so redescription is unnecessary here.

DISTRIBUTION. Within the present study this species has been found in the Poiares Member of the Ferradosa Formation, in the southern part of the Buçaco syncline. It has also been found during this study in the lower part of the Rosan Formation, at La

Pointe de Raguenez, Crozon, Finistère. The original description of this species was of material from Coat Garrec, Finistère, which is also interpreted in this study as being from the lower part of the Rosan Formation. It has also been recorded by Villas (1980,1983) from the lower part of the Calizas de Cistideos Formation, of the Eastern Celtiberian chain.

DISCUSSION. Leptestiina aonensis Melou has been considered as indicating an Ashgill age for the fauna from Coat Garrec, Finistère (Melou 1971), and has further been used to indicate a Rawtheyan age for an upper Ordovician fauna from Celtiberia (Vilas 1980). In fact there is little direct dating for this species, and its supposed position in a hyopothetical evolutionary sequence between Leptestiina prantli and Tufoleptina is of dubious value in this context.

## Leptestiina? sp. (Plate 28, figs. 6.7)

MATERIAL. External and internal moulds of an incomplete brachial valve.

DESCRIPTION. The internal mould of thebrachial valve exhibits a muscle field very similar to that of <u>Leptestiina</u>, the external mould however, shows little sign of radial ornament. This might be due to the poor preservation.

DISTRIBUTION. The single specimen described here is from the

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upper part of the Rosan Formation, Rosan quarry (tuffaceous beds above the pillow lava).

Genus Leangella Opik, 1933

Type species: <u>Plectambonites scissa</u> (Salter) var. <u>triangularis</u>
Holtedahl, 1916

Leangella cf. anaclyta Havlicek, 1981
(Plate 28, figs. 8-10)

cf1981 <u>Leangella anaclyta</u> sp. n.: Havlicek pp. 21,22, plate 7 figs. 19-27; textfig. 2b.

1983 Leangella anaclyta Havlicek: Villas pl 3 figs 10-12.

This species is represented by the internal moulds of two pedicle valves in the museum of the Serviços geológicos from the Leira Ma Member (Zone 8). In addition a single internal mould of a pedicle valve was found in the lower part (base of Zone 9) of the Rosan Formation.

Leangella? sp. indet.
(Plate 28, figs. 11,12)

This material consists of an internal and an external mould of pedicle valves from Zone 11 beds in the Rio Ceira inlier. The detailed morphology of the valves is poorly known, and until further material is recovered even its assignation to <u>Leangella</u> must remain tentative.

Subfamily Aegiromeninae Havlicek, 1961

Genus Aegiromena Havlicek, 1961

Type species: Leptaena aquila Barrande, 1848.

Aegiromena cf. aquila praecursor (Havlicek, 1952)

(Plate 28, figs. 21-27, Plate 29, figs 1-5)

MATERIAL. 20-30 poorly preserved valves from the Favaçal Bed, and 10 from the Queixopeira Member, the measurements are based on 14 of the better specimens.

DESCRIPTION. Shell gently concavo-convex, semicircular in outline, brachial valve 48% as long as wide; cardinal angles

Plate 28.

Leptestiina aonensis Melou, 1976

Figs. 1,2 internal and external moulds of a pedicle valve, POR2, fig. 3 internal mould of a brachial valve, GAR1, figs 4,5 internal moulds of pedicle valves, GAR1. All x3.0.

Leptestiina? sp.

Figs. 6,7 internal and external moulds of a brachial valve, ROS1, x3.0.

Leangella cf. anaclyta Havlicek, 1981

Fig. 8 internal mould of pedicle valve, SGL 3054, Leira Ma, fig. 9 internal mould of pedicle valve, SGL 3058, Leira Ma, both x3.0, fig. 10 internal mould of a pedicle valve, RAG1, x2.0.

Leangella? sp. indet.

Fig. 11 external mould of pedicle valve, fig. 12 internal mould of pedicle valve, both x3.0, RC11.

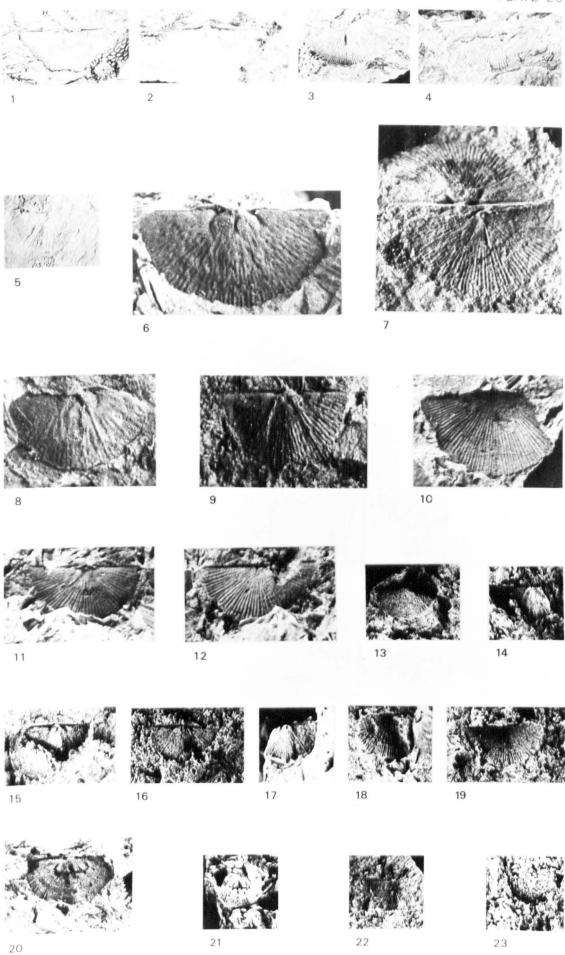
Aegiromena mariana Drot, 1972

Fig. 13 internal mould of brachial valve, fig. 14 internal mould of brachial valve, with external moulds of conjoined pair, fig. 15 latex cast of specimen in 14, figs. 10,17 internal mould of pedicle valve and external mould of brachial valve, with latex cast, figs 18,19 internal mould of pedicle valve and external mould of brachial valve, with latex cast, all PGb, all x3.0

Aegiromena? sp. A

Fig. 20 external mould of brachial valve, CAC1, x3.0. Aegiromena cf. aquila praecursor (Havlicek, 1952)

Fig. 21 external mould of brachial valve, fig. 22 latex cast of specimen in 21, fig. 22 external mould of pedicle valve (conjoined with specimen in 21), fig. 23 latex cast of specimen in fig. 22, all LOR1, x3.0. Fig. 25 internal mould of brachial valve, fig. 26 internal moulds of pedicle valves, fig. 27 latex cast of specimen in fig. 26, all Louredo, x3.0.



acute or very slightly alate; width of valves upto 11mm; ventral interarea apsacline, dorsal hypercline, forming angle of 180 between interareas; pseudodeltidium small, convex; ornament costellate, fine, with 12-20 ribs/2mm at anterior margin of shell; fine concentric growth-lines present.

Ventral interior with prominent teeth supported by strong dental plates; small adductor field, divided by thin longitudinal septum, is placed umbonally, and is surrounded by the bilobed diductor field; diductor scars separated by median ridge; broad vascula media diverge anteriorly from anterior of diductor scars; interior of valve covered by fine, small, radially arranged papillae.

Dorsal interior with trilobate cardinal process fused to widely divergent socket-ridges; dorsal muscle platform weakly defined, extending anteriorly for 45% of valve length, often with radial ridges laterally, and concentric striations antero-medially; median septum very strong, extending anteriorly for 65% of valve length, although it may be dicontinuous at strong lateral are arranged papillae.

DISTRIBUTION. This species has been recovered from the Favaçal Bed of the Buçaco and Dornes areas, and from the Queixopeira Member of the Dornes and Mação areas. Aegiromena aquila praecursor (Havlicek, 1952) occurs in the Letná Formation of Bohemia, while a closely similar form occurs in the underlying Libeň Formation (Havlicek, 1967).

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Havlicek's subspecies in overall shape, ornament, and general internal organisation. It differs however in the septal arrangement in the brachial valve, with the Portuguese material possessing strong lateral septae alongside the median septum.

Aegiromena sp. aff. descendens (Havlicek, 1952)

(Plate 29, figs. 6-12)

v 1906 <u>Leptaena tenuissime-striata</u> McCoy? : Delgado pp. 31, 60.

1973 Aegiromena cf. descendens (Havlicek, 1952) : Melou pp.

260-261; pl. XXXVI, figs. 4, 5, 6.

MATERIAL. This species is relatively common in some beds within the Leira Ma Member, it is also common in some beds at the base

Plate 29.

Aegiromena cf. aquila praecursor (Havlicek, 1952)

Fig. 1 external mould of brachial valve, fig. 2 internal mould of pedicle valve, fig. 3 internal mould of brachial valve, fig. 4 external mould of brachial valve, fig. 5 external mould of pedicle valve, all QXP2, all x3.0.

Aegiromena cf. descendens (Havlicek, 1952)

Fig. 6 internal mould of pedicle valve, SGL 2502 (1 of), bed 4 of Delgado's Zuvinhal section, fig. 7 internal moulds of conjoined valves, SGL 3003 (1 of), Leira Ma, fig. 6 internal mould of pedicle valve, SGL 2552 (1 of), locality as 6, fig. 9 internal mould of pedicle valve, SGL 3053 (1 of), Leira Ma, fig. 10 external mould of pedicle valve, SGL 2559 (1 of), locality as 6, fig. 11,12 internal and external mould of brachial valve, SGL 2552 (2 of), locality as 6. All x3.0.

Aegironetes tristis Havlicek, 1967

Figs. 13-17 internal moulds of pedicle valves, figs. 18,19 external moulds of pedicle valves, figs. 20-22 internal moulds of brachial valves, fig. 23 external mould of brachial valve, fig. 16 from B135, all others RC11, all x4.0.

of the Rosan Formation. Most of the material is fragmentary, but the specimens in the Servicos Geológicos museum show the features of this species well.

DESCRIPTION. Shell highly variable in external appearance between finely ribbed, gently cncavo-convex and more coarsely ribbed, strongly concavo-convex or geniculate end members; shape semicircular (mean length: width ratio is 0.52); ornament costellate, with 8-14 ribs/2mm; maximum width recorded 9mm; ventral interarea apsacline, dorsal hypercline.

Ventral interior with teeth supported by strong dental plates; small adductor field halved by septum; diductor field divided by ridge, bilobate; vascula media impressed as broad furrows extending antero-laterally from diductor scars; interior of valve covered in small fine papillae.

Dorsal interior with trilobed cardinal process fused with widely divergent socket ridges; dorsal muscle field poorly impressed; prominent median septum divides muscle field, but does not extend anteriorly to it; small septae or enlarged papillae may lie at the limit of the muscle field on either side of the median septum.

DISTRIBUTION. This species has been found in the lower part of the Porto de Santa Anna Formation (the Leira Ma Member) of the Buçaco syncline. It has also been recorded in this study from the "Lumachelles terminales" of the Bancos Mixtos of the Sierra Morena (Corral de Calatrava), where it occurs with elements identical or close to those of the Leira Ma Bed, and also from

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the lower part of the Rosan Formation of the Crozon Peninsula (Pointe de Raguenez, Plage de Raguenez).

DISCUSSION. The species described here shows strong similarities with A. descendens from the Bohdalee Formation of Bohemia (Havlicek 1967) in terms of general shape, size, and internal arrangement. It differs in lacking the four fields of prominent papillae in the pedicle valve seen in the Bohemian species. The more finely ornamented material (such as that from the Leira Ma Bed) seems identical to that described as A.cf. descendens by Melou (Melou 1973) from an oblitic ironstone in the Coevrons syncline (Normandy). The coarse ribbed material is here referred to the same species because a wide spectrum of forms is present in the material from the Rosan Formation. Some of the specimens with coarse ornamentation approach the morphology of A.meneghiniana (Vinassa, 1927) recently redescribed by Havlicek (Havlicek 1981) from the Montagne Noire and Sardinia, of probable upper Caradoc age.

# Aegiromena mariana Drot, 1972 (Plate 28, figs. 14-19)

- 1970 <u>Viruella</u> aff. <u>antiqua</u> (Jones, 1928): Drot, in Chauvel et al. p. 616.
- 1970 Aegiromena (?) mariana nov. sp.: Drot, in Chauvel et al. pp. 617-618.
- 1973 Aegiromena mariana Drot, 1970: Melou pp. 254-259; pls. XXXIII, XXXIV, XXXV, and XXXVI, figs. 1-3;

textfig. 1.

MATERIAL. The species is represented by abundant material from Penha Garcia, but the preservation of this material is often somewhat indifferent.

DESCRIPTION. This material agrees in all respects with that described by Melou (Melou 1973) from Spain and Brittany, so a full description will not be given here.

DISTRIBUTION. This species occurs in Portugal in the Penha Garcia syncline, in the lower part of the Fonte da Horta Formation.

DISCUSSION. The occurrence of this species in the Penha Garcia syncline is interesting, for in the basal part of the Fonte da Horta Formation it occurs with Eorhipidomella musculosa, exactly as it does in its type material (see Melou 1973 pl.XXXIII fig. 6) from El Centenillo. The upper part of the range of this species at Penha Garcia is as yet poorly defined, but it does seem to occur through ?30m of strata above the beds with E. musculosa.

### Aegiromena? sp. A

MATERIAL. External mould of brachial (?) valve, and fragment of internal mould, on a single slab; CAC1.

DESCRIPTION. The single complete specimen is the external mould of a brachial valve, with a hingeline of 19mm and length of 9mm.

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The ornament is finely and unequally parvicostellate, with typically 2 ribs between each pair of accentuated ribs, rib density 16/2mm at anterior margin, fine growth lines present, with sporadic imbrication (roughly at 4,5,6,7 mm lengths), cardinal angles perpendicular, possibly acute in early growth stages, protegular node 0.2 mm long.

DISTRIBUTION. The single slab bearing this material is from the upper part of the Fonte da Horta Formation, of the Buçaco syncline (Zone 2).

DISCUSSION. The size of this specimen is nearly twice that of the only other plectambonitacean so far recognised from the Llandeilo of Central Portugal (Aegiromena mariana), and that species has not yet been found in the Buçaco syncline. The ornament alone is not sufficient to suggest a possible genus, and further material must be recovered before this interesting occurrence can be interpreted fully. However it is interesting to note the occurrence of a large plectambonitacean, probably an Aegiromena, in the Llandeilo of the Valongo syncline in northern Portugal. This species has the same length/width ratio and similar overall dimensions to the complete valve described here. If the specimen here is conspecific with the as yet undescribed material from Valongo and Arouca, then it may provide a useful means of correlation between the two facies.

Genus Aegironetes Havlicek, 1967

Type species: Aegironetes tristis Barrande, 1879.

# Aegironetes tristis Barrande, 1879 (Plate 29, figs. 13-23)

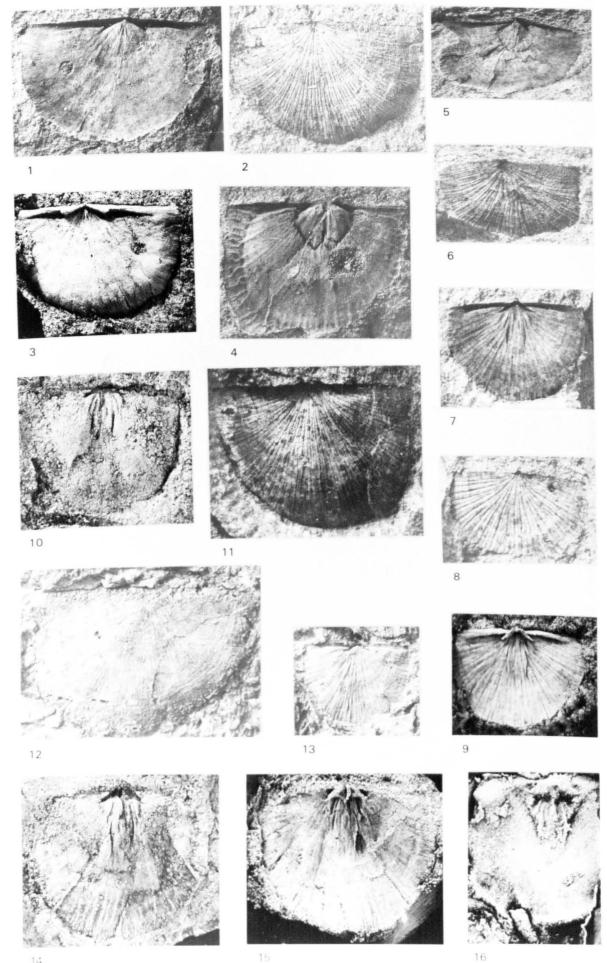
- \* 1879 Strophomena tristis Barr.: Barrande pl. 70, fig. VI-1
  - 1879 Orthis humillima Barr.: Barrande pl. 69, fig. V-2.
  - 1952 Sowerbyella tristis (Barrande, 1879): Havlicek p. 408.
  - 1967 Aegironetes tristis (Barrande, 1879): Havlicek pp. 47,48, plate IV figs. 17-23; textfig. 20.
  - 1982 Aegironetes tristis (Barrande, 1879): Havlicek and Mergl, p. 39, plate 3, figs. 6-8.

MATERIAL. This species is represented by about 20 moulds.

Plate 30.

Strophomena? cf. sardoa Vinassa, 1927

Figs. 1,2 internal and external moulds of a pedicle valve, fig. 3 latex cast of specimen in fig. 1, figs. 4,11 internal and external moulds of pedicle valve, figs. 5,6,7,8 internal and external moulds of associated pedicle and brachial valves, fig. 9 latex cast of internal mould of brachial valve in fig. 7, fig. 10 internal mould of brachial valve, fig. 12 external mould of brachial valve, figs. 13 internal mould of brachial valve, figs. 14,15 internal mould of brachial valve and latex cast, fig. 18 latex cast of internal mould of brachial valve. Fig. 12 from POR3, fig. 13 from ABER5, all others from ABER4, all x2.0.



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DESCRIPTION. The material agrees in all aspects with that described by Havlicek, from the upper Kraluv Dvur Formation of Bohemia. The material will not therefore be described here.

DISTRIBUTION. This species has only been recovered from two localities in Portugal, the top (sample RC 11) of the thin representative of the Venda Nova Group in the section to the west of Vila Nova do Ceira (southern part of the Buçaco syncline), and the topmost part of the Porto de Santa Anna Formation in the northern part of the syncline.

DISCUSSION. The Portuguese material appears identical to that described by Havlicek (Havlicek, 1967), from close to the top of the Králův Dvůr Formation, Czechoslovakia. This material can be tentatively dated as Rawtheyan from its geometrical position just 40cm below the Kosov Formation of Hirnatian age. It occurs in a relatively deep-water association with Chonetoidea radiatula, Foliomena folium and species of Tretaspis. The species occurs in Portugal immediately below mudstones with a fauna including Bracteoleptaena sp. A, Horderleyella sp. B, and Plectothyrella? sp. A. The conglomeratic sandstones of the Ribeira do Bracal Formation occur only 14m above the locality yielding this species, and like the sandstones of the Kosov Formation, these are interpreted as being of Hirnantian age.

Superfamily Strophomenacea King, 1846

Family STROPHOMENIDAE King, 1846

Subfamily Strophomeninae King, 1846

Genus Strophomena Rafinesque in De Blainville, 1825.

Type species: Strophomena rugosa Rafinesque in De Blainville, 1825.

## Strophomena? cf. sardoa Vinassa, 1927 (Plate 30, figs. 1-16)

- \* 1927 Strophomena sardoa; Vinassa p. 481, pl. 4, figs 7-9,?10
  - ?1927 Strophomena expansa; Vinassa, pl. 4 figs. 3,3a
  - 1948 <u>Rafinesquina (Playfairia) deltoidea;</u> Dreyfuss, p. 38, pl. 7, fig. 12
  - 1981 <u>Strophomena sardoa</u> Vinassa 1927; Havlicek pp.24-25, pl. 8, figs. 1-9.
  - 1983 <u>Katastrophomena sardoa</u> (Vinassa); Villas pl. 3, figs. 3,4.

MATERIAL. This species is represented by about 20 moulds from the lower part of the Rosan Formation, principally sample ABER4. There is some further material from Portugal, including many rather fragmentary specimens from samples POR2/3.

DESCRIPTION. Concavo-convex to roundedly ventrally geniculate; dorsal valve resupinate, being slightly convex near umbo; outline semicircular with length about 70% of maximum width, which occurs on hingeline, disc typically 14mm long and 20mm wide; cardinal

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angles perpendicular or slightly mucronate; ventral interarea apsacline, low and sometimes horizontally striated, dorsal interarea very low, anacline, notothyrium covered by prominent convex chilidium; ornament unequally parvicostellate, with about 9 major ribs reaching the umbo on the brachial valve, rib density about 10/5mm on trail and 14/5mm 7mm anterior of umbo, major ribs separated by 1-3 minor ribs; surface covered with fine growth lines, which are occassionally disruptive, particularly near geniculation.

Ventral interior with strong teeth supported by recessive dental plates, which are continuous with ridge bounding anterior sides of muscle field; muscle field sub-pentagonal, 30% as long as valve, low median ridge; on both valves the accentuated ribs are visible on the interior of young specimens, but in adults the accentuated ribs are only visible on the trail, and the interior disc becomes in fine dense surface the covered ofpseudopunctation; vascular system strongly impressed on trail, lemniscate.

Dorsal interior with widely divergent socket ridges fused to cardinal process lobes; cardinal process slightly bilobed transverse ridge in young specimens, becoming low massive slightly bilobed pad in gerontic specimens, with corrugated postero-ventral surface; slightly thickened notothyrial platform, with 3 pairs of trans-muscle septae of which the inner pair extend anteriorly for 50% of disc length. In large specimens the muscle-field develops a strong platform, whose lateral bounding ridges merge anteriorly with the inner pair of trans-muscle septae.

DISTRIBUTION. This species has been recorded from the lower part of the Venda Nova Group (Poiares Member, Ferradosa Formation) of the Buçaco syncline, and from the equivalent deposits in the lower part of the Rosan Formation in the Crozon Peninsula. It forms the index species for Zone 9.

DISCUSSION. The species described here is very close to Strophomena sardoa Vinassa from the upper Caradoc (?) of the Montagne Noire and Sardinia recently redescribed by Havlicek (1981). The Sardinian species differs from the material described here by a less-marked geniculation. The attribution of these forms to Strophomena Rafinesque, is tentative; the marked geniculation is not general for this genus, Strophomena usually displays a median septum when it posseses trans-muscle septae, and also usually posseses a much longer, bilobed cardinal process than seems to be the case for this material. The earlier species Blyskavomena blyskavensis (see below) has internal structures closely resembling this species, but has its geniculation (if indeed the single specimen showing geniculation is conspecific with the other material) dorsally as opposed to ventrally in sardoa.

Genus Blyskavomena Havlicek

Blyskavomena cf. blyskavensis Havlicek
(Plate 31, figs. 1-13)

Appendix C. 340.

Vanek, pl. X figs. 3,4 (nom. nud.)

cf. 1967 <u>Dactylogonia</u> <u>blyskavensis</u> sp. n.: Havlicek p. 85, pl. X figs. 1-5

MATERIAL. This species is represented by moulds of about 20 valves from the Queixopeira Member, and a single specimen in the museum of the Servicos Geológicos from Bucaco. Some further material from the Favacal Bed may be referable to this species.

DESCRIPTION. Semicircular outline, length 85% maximum width, which occurs at hingeline, cardinal angles perpendicular, pedicle valve gently convex (one specimen from the Favacal Bed which may belong with this species is geniculate, but none of the more numerous younger material is), brachial valve almost flat. Ornament unequally parvicostellate, cancellated by strong growth lines.

Pedicle valve with open delthyrium, dental plates short, divergent, muscle scar becoming increasingly well impressed with shell size, diductor scars with ridge running laterally and anteriorly form anterior tip of dental plates, ridge does not pass anterior to the median ridge between the diductor scars, which is itself strongly differentiated from the diductor scars. Interior surface showing ornament in small specimens, smooth in more adult material, and finely papillate in gerontic material.

Brachial valve interior with large paired cardinal process lobes, each fused to a strong divergent socket ridge, typically three pairs of trans-muscle septae plus a weaker long median septum are developed, a muscle platform such as that figured by

Havlicek (and such as that which occurs in  $\underline{S}$ ? cf.  $\underline{sardoa}$ ) has not been observed.

DISTRIBUTION. This species occurs in the Queixopeira Member of the Cabeço do Peão Formation, in the Dornes and Mação regions. A single valve referable to this species from the lower part of the Louredo Formation of the Buçaco syncline, is in the museum of the Serviços Geológicos in Lisboa. Fragmentary strophomenacean material from the Favaçal Bed of the Bucaco and Dornes/Amendoa/Mação synclines may also be referable to this species. All these occurrences are lower Caradoc in age.

DISCUSSION. This material is similar to that described by Havlicek (1967) as <u>Dactylogonia</u> <u>blyskavensis</u> from the upper part of the Letna Formation of Bohemia, but the strong geniculation of that species has not been observed in the Portuguese material.

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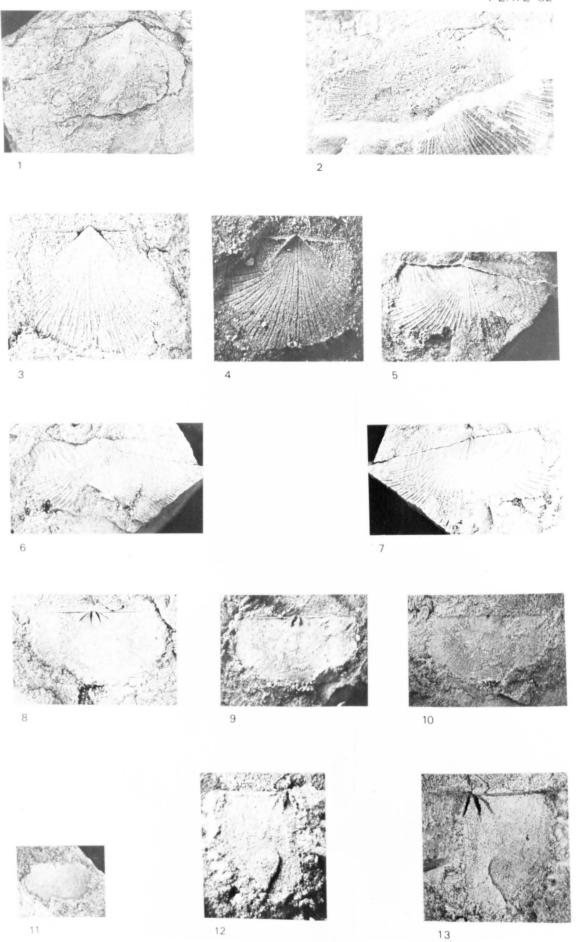
Plate 31.

Blyskavomena cf. blyskavensis (Havlicek, 1967)

Fig. 1 internal mould of pedicle valve, MDC5, fig. 2 external mould of ?pedicle valve, Louredo, figs. 3,4,5 internal moulds of pedicle valves, QXP2, fig. b internal mould of pedicle valve, bed 15 of Delgado's Val San Jorge section, figs. 7,8 internal mould of brachial valve with latex cast, QXP2, figs. 9,11,12 external casts of brachial valves, QXP2, figs. 10,13 internal moulds of brachial valves QXP2. All x2.0.

Bracteoleptaena sp. A

Figs. 14,15 external and internal moulds of brachial valve, figs. 16,17 internal moulds of brachial valves, fig. 17 internal mould of pedicle valve, all x4.0, all from RC12.



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The trans-muscle septae are not as strong in the Portuguese material as in Havlicek's figured material, nor does his material display a median septum.

Subfamily Rafinesquininae Schuchert, 1893

Genus <u>Hedstroemina</u> Bancroft, 1929

Type species: Hedstroemina fragilis Bancroft, 1929.

### Hedstroemina sp. A

(Plate 32, figs. 1-13)

MATERIAL. Moulds of several dozen valves preserved in a sandstone.

DESCRIPTION. A Hedstroemina of low convexity, plano-convex, probably about 60% as long as wide, cardinal angles perpendicular to slightly obtuse, maximum width at or near hingeline, ventral interarea apsacline, dorsal anacline, ornament unequaly costellate, growth lines may be prominent, some specimens show impersistant rugae postero-laterally, always exhibits a prominant median rib.

Plate 32.

Hedstroemina sp. A

Figs. 1,2 internal moulds of pedicle valves, figs. 3,4 internal mould of pedicle valve with latex cast, figs. 6,7,5 internal and external moulds of pedicle valve, with latex cast of external mould respectively, figs. 8,9,10 internal mould, latex cast of internal mould, and external mould of a brachial valve, fig. 11 external mould of brachial valve, figs. 12,13 latex cast and internal mould of brachial valve, all x2.0, all from VACA1.

Ventral interior with widely divergent dental plates supporting small teeth, external ornament impressed on interior of valve, muscle scars generally not impressed.

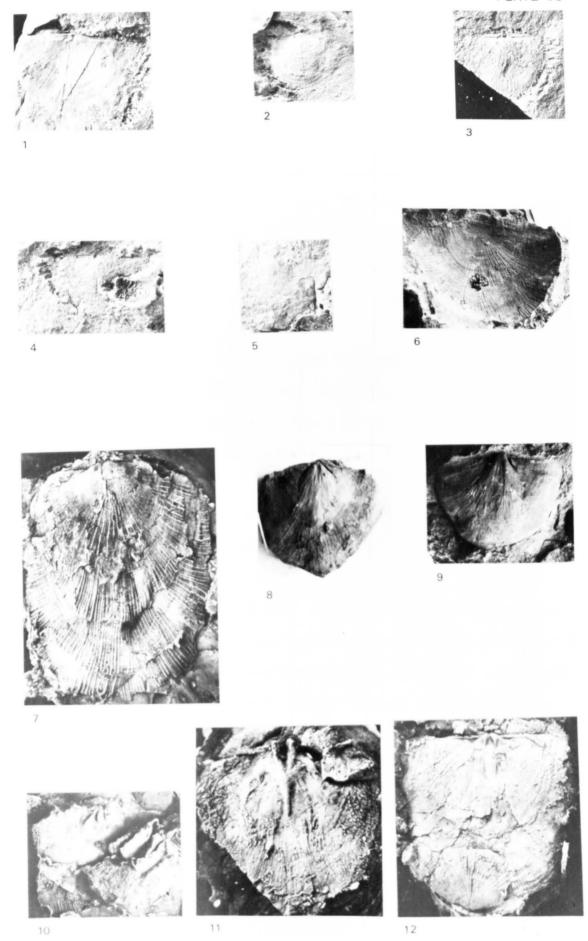
Dorsal interior with slightly divergent cardinal process lobes which extend slightly more anteriorly than the widely divergent socket ridges (about 12 and 10% of valve length respectively), muscle scars gently impressed posteriorly by very weakly developed notothyrial platform, not impressed anteriorly.

DISTRIBUTION. The material on which this species is based is from the upper part of the Louredo Formation of the Penha Garcia synclines. At Penha Garcia it occurs in the sandstones underlying the mudstones of the Vaca Member.

Hedstroemina cf. sp. aff. mundae (Sharpe, 1853)
(Plate 33, figs. 1-5)

The material referred here derives from the Galhano Member in the northern part of the Buçaco syncline. Like H. sp. A it appears to have been very thin-shelled, displays a prominent median rib, and is very finely ribbed umbonally. Larger specimens do however show greater convexity than the Penha Garcia material, and the young specimnes are alate, both features more associated with sp. aff. mundae.

Hedstroemina sp. aff. mundae (Sharpe, 1853)
(Plate 33, figs. 6-12)



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MATERIAL. This species is represented by large numbers of well preserved moulds from coquinoid layers within the oolitic ironstone of the Leira Ma Member.

DESCRIPTION. This species is very close to <a href="Hedstroemina">Hedstroemina</a> mundae (Sharpe, 1853), but differs mainly in details of ornament; Sharpe's species has a coarser ornament near the umbo. In internal morphology this material is very close to Sharpe's species, although some specimens possess a much more strongly developed notothyrial platform, and median ridge in the brachial valve than is usual in <a href="Hedstroemina">Hedstroemina</a> mundae. Some specimens of this species have been found which exhibit a much more highly concavo-convex shell than has been observed in material of Sharpe's species. The material is distinguished from the earlier forms (<a href="Hedstroemina">H. sp. A and H. cf. sp. aff. mundae</a>) by its thicker shell, greater convexity, greater degree of impression of muscle scars, and lack of a strong median rib on the pedicle valve. It still retains the fine umbonal ribbing of the earlier forms.

Plate 33.

Hedstroemina cf. sp. aff. mundae (Sharpe, 1853)

Fig. 1 external mould of pedicle valve, fig. 2 internal mould of pedicle valve, figs. 3,4 external moulds of brachial valve, fig. 5 internal mould of brachial valve. Fig. 2 from ZUV16 others PSA3, all x2.0.

Hedstroemina sp. aff. mundae (Sharpe, 1853)
Figs. 6,9 external and internal moulds of pedicle valve, SGL 2547, bed 4 of Delgado's Zuvinhal section, x2.0, fig. 7 latex cast of external mould of pedicle valve, Louredo, x1.3, fig. 8 internal mould of pedicle valve, SGL 2946 (1 of), locality as 6, figs. 10-12 latex casts of internal moulds of brachial valves, Louredo, x2.0, note external of pedicle valve in fig. 12.

DISTRIBUTION. This species is particularly abundant within the colitic bed at the base of the Leira Ma Member (Porto de Santa Anna Formation) in the Louredo area, in the Buçaco syncline. Here it often totally dominates the assemblages, although it is accompanied by Svobodaina sp. A, Rostricellula sp. A, and Dolerorthis sp..

DISCUSSION. See discussion under H. mundae.

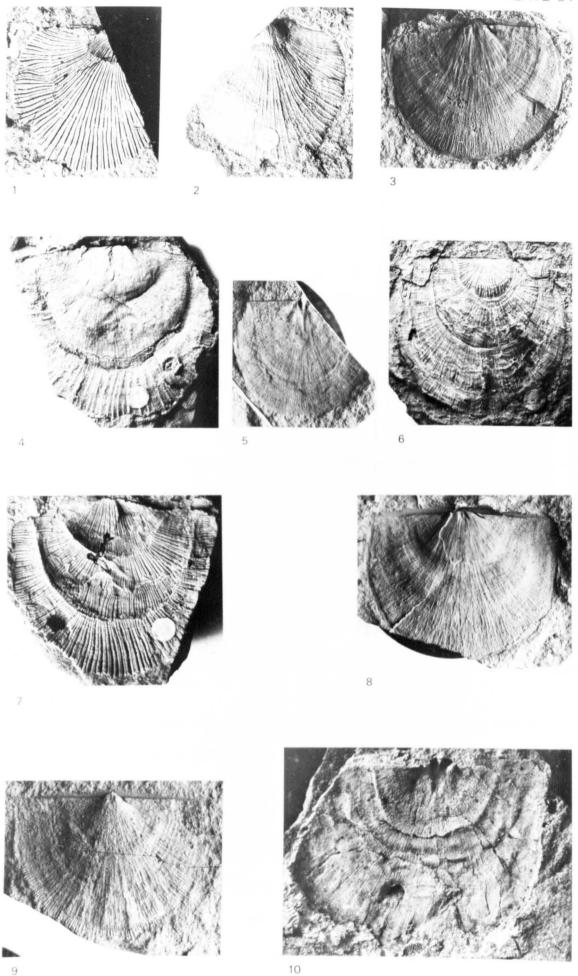
### Hedstroemina mundae (Sharpe, 1853)

(Plate 34, figs. 1-10)

- v 1853 Orthis Mundae n.s.: Sharpe p. 154; pl. VIII, fig. 5.
- v 1853 <u>Leptaena Beirensis</u> n.s.: Sharpe p. 156-157; pl. VIII, fig. 8.
- v 1853 Leptaena ignava n.s.: Sharpe p. 157; pl. VIII, fig. 9.
- v 1908 Leptaena Beirensis Sharpe: Delgado pp. 31,60.
- v 1908 Strophomena cf. Phillipsi Barrande: Delgado p. 60.
  - 1974 Rafinesquina beirensis (Sharpe): Mitchell p. 389.

MATERIAL. This material is abundant within the Leira Ma Member, and paricularly well preserved material is housed in the museum of the Servicos Geológicos (several dozen specimens).

DESCRIPTION. Strongly concavo-convex, 75% as long as wide, early growth stages may be alate, later stages have obtuse cardinal angles; ventral interarea anacline, dorsal interarea apsacline; ornament unequally parvicostellate, with high narrow ribs



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seperated by wide flat interspaces on the ventral valve, ornament on dorsal valve less marked, with costellae more equal, ornament often irregular, with frequent patterns of ribbing suggesting repair to damaged shell margin, pedicle valve rib density 5-6/mm upto 10 mm from umbo, 4-5/mm over other areas, 2-4 ribs between accentuated costellae; fine concentric growth-lines; occasional disruptive growth-lines which may totally obscure radial ornament (e.g see Pl. fig. ); width of shell upto 45mm.

Ventral interior with squat teeth supported by short dental plates diverging at about 70, extending forward for about 8% of valve length, and further continued as low ridges laterally bounding ventral muscle-field for 18% of valve length; muscle field with large flabellate diductor scars, often reaching 45% of valve length, with less well impressed lanceolate adductor scars, which are sometimes anteriorly enclosed by diductors; interior of valve covered in fine, dense, pseudopunctation, with pseudopunctae arranged radially in interspaces between internal expression of the costellae; apical foramen not observed.

Dorsal interior with twin blade-like cardinal process lobes,

Plate 34.

Hedstroemina mundae (Sharpe, 1653)

Figs. 1,2 external and internal moulds of pedicle valve, holotype, BM.B 83001 (=Sharpe pl. VIII figs. 5a,b), x1.5, fig. 3 internal mould of pedicle valve, SGL 2927, Leira Ma, x1.0, figs. 4,7 internal and external moulds of pedicle valve, BM.B 82959 (=Sharpe pl. VIII figs. 8a,b), x1.5, fig. 5 internal mould of brachial valve, SGL 2941, Leira Ma, x1.0, fig. 6 external mould of brachial valve, BM.B 82960 (=Sharpe pl. VIII fig. 9), x1.5, fig. 8 internal mould of pedicle valve, SGL 2919, Leira Ma, x1.0, fig. 9 internal mould of pedicle valve, SGL 2923, Leira Ma, x1.0, fig. 9 internal mould of brachial valve, ABER5, x2.0.

with sub-parallel bases, divergent ventrally, anterior ends of bases are convergent onto prominent anchor-shaped notothyrial platform, cardinal processes extend anteriorly for 10% of valve length; postero-lateral margins of notoythyrial platform bear fine socket ridges running posteriorly to join with cardinal process lobes, median ridge between adductor scars variably developed, low to prominent; dorsal muscle field lightly impressed, extending anteriorly for 50% of valve length; in neanic valves the space between the cardinal process lobes is exaggerated by a local high convexity of the shell near the umbo, but in larger specimens this becomes filled by the secondary material of the notothyrial platform, although the external expression, a node, is retained.

DISTRIBUTION. Hedstroemina mundae (Sharpe) has been found in the Bucaco syncline at the base of the Venda Nova Group, in the upper part of the Leira Ma Member in the beds immediately overlying the oolitic horizon. It also occurs in the lower part of the Rosan Formation in the Crozon peninsula.

DISCUSSION. Sharpe described material here allocated to this species as Orthis Mundae n.s., Leptaena Beirensis n.s. and Leptaena ignava n.s., and of these O. Mundae has priority. The type material for this species (BM.B 83001, Pl. 34, figs. 1,2) consists of internal and external moulds of a fragmentary pedicle valve. It is therefore suggested here that the type material for Hedstroemina mundae (Sharpe, 1853) should include not only this specimen, but also the material figured by Sharpe as L. Beirensis

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and L. ignava.

The species described here as <u>H</u>. sp. A, <u>H</u>. cf. sp. aff. <u>mundae</u>, <u>H</u>. sp. aff. <u>mundae</u> and <u>H</u>. <u>mundae</u> form an almost continuous range of morphology from the earliest thin-shelled, low convexity form with fine umbonal ribbing and accentuated median ventral rib, to a high-convexity, thick shelled form, with coarse umbonal ribbing and no accentuated median ventral rib. it may be that the species described here owe their disjunct characters more to the nature of the fossil record than to morphologically discrete species. Only more detailed collecting will allow further analysis of this interesting lineage, with important biostratigraphic potential.

# Hedstroemina sp. B (Plate 35, figs. 1-14)

- v 1906 Strophomena rhomboidalis Wilkens: Delgado pp. 31, 60.
- v 1906 Strophomena deltoidea Conrad: Delgado p. 60.

MATERIAL. This species has yielded abundant material (about 20 specimens) from the Leira Ma Member. In addition there is a large collection of this species in the museum of the Serviços Geológicos.

DESCRIPTION. Concavo-convex with brachial valve concave, pedicle valve roundedly geniculate, shell 80% as long as wide, disc semicircular; before formation of trail cardinal angles acute, with maximum width of valve at hingeline, in geniculate valves

the maximum width lies anterior to the hingeline; ventral interarea flat, anacline, dorsal interarea flat, apsacline; ornament parvicostellate, about 4 costellae per mm at 5 and 12mm anterior of umbo, not strongly differentiated except for prominent median rib, which is particularly well developed on pedicle valve; disc and posterior part of trail with concentric rugae, those on the disc have a wavelength of 0.8 to 1.0mm, meet the hingeline concentrically, and number about 5-8, those on the trail are not so well developed but are of similar dimensions and generally number 1-3; also concentric fine growth lines.

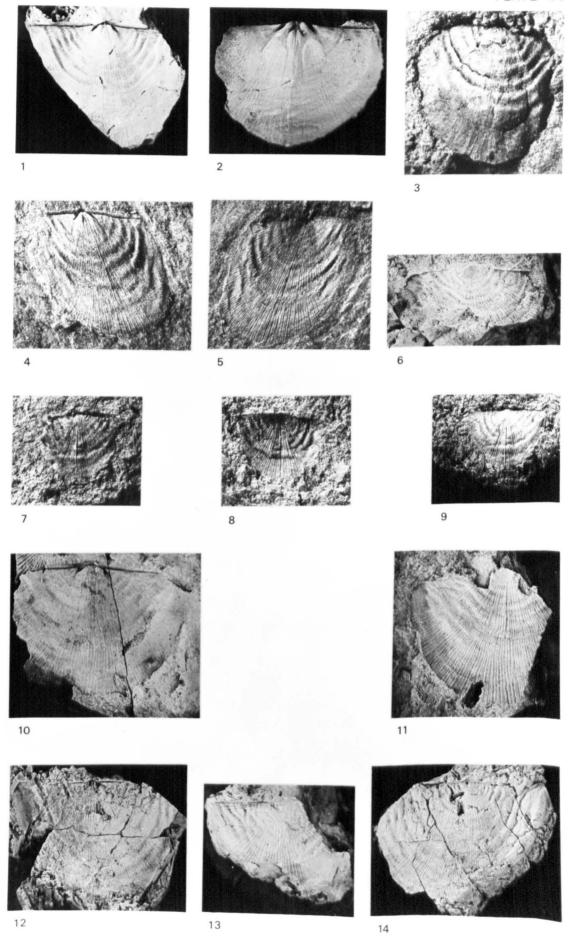
Ventral interior with stubby teeth, supported by short widely divergent dental plates extending anteriorly for 10% of valve length; ventral muscle field consisting of lanceolate adductor scars, often overhung by shell-material posteriorly, with sub-triangular diductor scars laterally, which do not enclose adductors anteriorly, diductor scars extend to 30% of valve length; small apical foramen; valve interior covered in very small pseudopunctae.

Dorsal interior with delicate, small cardinalia; cardinal process lobes blade-like, parallel, extending anteriorly for 6%

Plate 35.

### Hedstroemina sp. B

Figs. 1,2 internal moulds of pedicle valves, RC31, fig. 3 internal mould of pedicle valve, ABER4, figs. 4,5 internal and external moulds of pedicle valve, RAG1, fig. 6 external mould of pedicle valve, RC31, figs. 7-9 internal and external moulds of pedicle valve with latex casr of external, ABER4, figs. 10,11 internal and external moulds of pedicle valve, PSA9, figs. 12,14 internal and external moulds of brachial valve, RC31, fig. 13 external mould of brachial valve, RC31, all x2.0.



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of valve length, seperated by thin ridge which supports convex, medianly grooved chilidium; notothyrial platform weakly developed, muscle scars not observed; socket ridges extend forward for 10% of valve length, and enclose 20% of valve width between their anterior tips, posteriorly fused to cardinal process lobes.

DISTRIBUTION. This species occurs in the lower parts of the Venda Nova Group (in the Leira Ma Member, zone 8, of the Porto de Santa Anna Formation, but not in the basal colitic bed) of the Buçaco syncline, and in the lower part (?Zone 9) of the Rosan Formation, Crozon.

DISCUSSION. This species falls within the embrace of the genus Hedstroemina, but is clearly far removed from the lineage of species described above. The large group of species described above seem closer to Rafinesquina pseudoloricata (Barrande) of the "upper Caradoc" of Bohemia and Morocco, than to many of the Hedstroemina species of northern Europe.

Hedstroemina sp. C

(Pl. 36, figs. 1-10)

MATERIAL. All specimens from the Rosan Formation, Rosan, ROS1.

DESCRIPTION. Plano-convex, dorsally geniculate <u>Hedstroemina</u>, semicircular in outline, 80% as long as wide, disc semicircular, cardinal angles slightly alate; shell surface covered with

concentric wrinkles, radial ornament unequally parvicostellate, with typically 16 ribs/5mm near anterior margin of disc; ventral interarea apsacline, with large apical foramen, dorsal interarea anacline with convex chilidium.

Ventral interior with short teeth supported by receeding dental plates extending forward for 10% of valve length; ventral muscle field poorly defined, roughly triangular, extending forward for 30% of valve length, maximum width 35% of valve maximum width occurring 15% of valve length anterior of umbo, muscle field traversed by fine ridges.

Dorsal interior with stout bilobed cardinal process, with narrow median ridge, lobes anteriorly divergent, extending forward for 8% of valve length, ankylosed posteriorly to socket ridges which extend forward for 10% of valve length, notothyrial platform anchor shaped, median ridge low, muscle field poorly impressed.

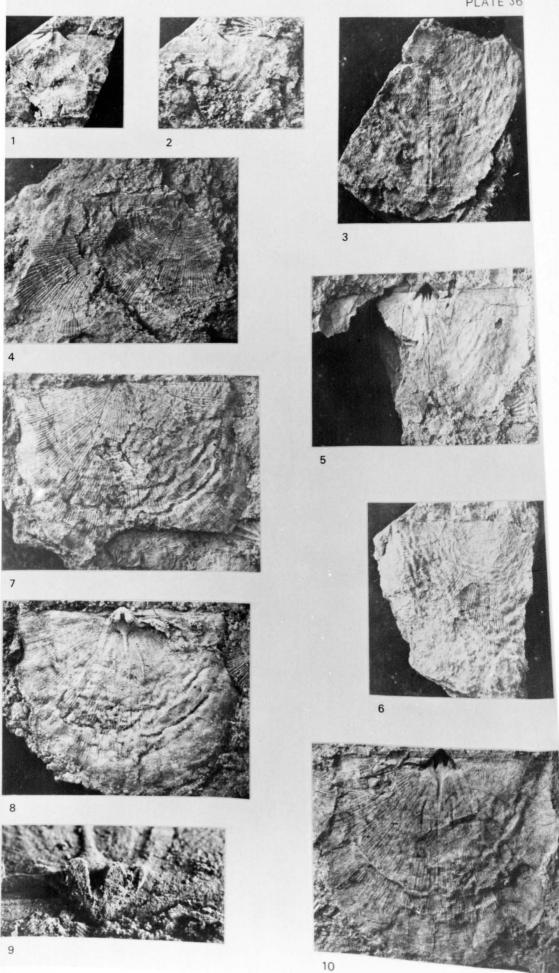
DISTRIBUTION. This species has only been recorded from the upper part of the Rosan Formation in the Rosan quarry (tuffaceous beds above the pillow lava). This is of Zone 10 age.

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Plate 36.

Hedstroemina sp. C

All material from ROS1. Pedicle valves: figs. 1, 2 internal moulds, figs. 3, 4 external moulds, all x1.3. Brachial valves: figs. 5 and 6 internal and external moulds of a valve, x1.3, figs. 10 and 7 internal and external moulds of a valve, x1.3, with fig. 8 latex cast from internal mould, x1.3, and fig. 9 detail of latex cast, posterior oblique view of dorsal cardinalia, x5.0.



DISCUSSION. This species does not appear to be closely related to any of the other <a href="Hedstroemina">Hedstroemina</a> recorded here.

Family LEPTAENIDAE Hall and Clarke, 1894

Genus <u>Leptaena</u> Dalman, 1828

Type species: <u>Leptaena rugosa</u> Dalman, 1828.

### Leptaena sp.

(Plate 37, figs. 1,2)

This material consists of an internal and external mould of a brachial valve from Zone 11 depostis in the northern part of the Bucaco syncline (B135). The material is not sufficient for specific identification, although it does appear similar to the material figured by Havlicek and Mergl (1982) as <u>Leptaena</u> cf. rugosa Dalman.

Leptaenid? indet.

(Plate 37, figs. 3-5)

These three specimens in the museum of the Servicos Geológicos are tentatively assigned to the Leptaenidae. They bear some resemblance to the specimen figured by Villas (1983 pl. 3, fig. 1) as <a href="Hedstroemina">Hedstroemina</a> sp. from the Calizas de Cistideos Formation of Celtiberia.

Leptaenid indet.

(Plate 37, fig. 6)

This is represented by the internal and external moulds of a single specimen, a pedicle valve from the lower part of the Rosan Formation (ABER4). The specimen appears to be a leptaenid, but generic identification is not possible.

Genus Bracteoleptaena Havlicek, 1963

Type species: Bracteoleptaena bracteola (Barrande, 1879)

Bracteoleptaena sp. A

(Plate 31, figs. 14-18)

MATERIAL. There are several tens of specimens from the Ribeiro do Braçal Formation (Zone 12) of the Rio Ceira inlier; as with other material from this horizon, much of it is poorly preserved, and many of the moulds suffer from being composite. Further material is known from a similar horizon further north near Riba de Baixo (PEN2), in coquinoid beds, but this material is very fragmentary, although individual fragments may preserve details (such as the papillate interior) well.

DESCRIPTION. Ventri-biconvex shell of semicircular outline, about 60% as long as wide, hingeline maximum width, both valves convex near umbo, while the brachial valve particularly becomes planar anteriorly; ornament poorly known but costellate, with ribs derived by branching, ornament stronger on pedicle valve,

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which also bears faint rugae. The prominent protegular node of the brachial valve is devoid of ornament.

The internal structure of the pedicle valve is poorly known (the specimen in fig. 17 is the best-preserved), but does include divergent, short dental plates. The internal features of the brachial valve include divergent socket ridges which become parallel to hingeline distally; the pit anterior to the cardinal processes is very deep, and the cardinal process are separated by a deep groove. The interior of the valve is covered with fine papillae, except for a field in front of the pit, the edges of this field are marked by a zone of much larger papillae.

DISTRIBUTION. This species has only so far been recorded from two localites (see above), both of which are in the Ribeiro do Bracal Formation of the Buçaco syncline, and are of Zone 12 age.

DISCUSSION. This material is close to <u>B. polonica</u> as described by Temple; however, the illustrations given by Temple (e.g. Pl. XV fig. 2) do not indicate the prescence of the distribution of papillae to be the same as described above for the Portuguese material, for the papillae seem to decrease in size away from the dorsal umbo, and do not show a smooth zone in front of the pit, with a ring of coarser papillae around it.

# Genus <u>Kiaeromena</u> Spjeldnaes, 1957 <u>Kiaeromena</u>? sp.

The interstitial limestone of the Lostmarc'h pillow lava

(Zone 10) has yielded 6 specimens of this species, none complete. The interior of the brachial valve is not yet known. The pedicle valve has a convex disc, bearing 6-8 rugae. These rugae meet the hingeline acutely. The angle between the disc and trail is obtuse, and without a peripheral rim. The radial ornament is not well seen in this material. Ventral muscle field is subcircular, and about half the length of the disc. The internal sides of the diductor scars curve gently inwards towards the midline. The material seems to resemble closely that described as <a href="Kiaeromena chouberti">Kiaeromena chouberti</a> by Havlicek (1971) from the upper Caradoc of Morocco, but differs in the acute angle of the rugae with the hingeline.

Plate 37.

Leptaena sp.

Figs. 1,2 external and internal moulds of brachial valve, B135, x4.0.

Leptaenid? indet.

Figs. 3,4 internal moulds of pedicle valves, fig. 5 external mould of ?pedicle valve, SGL 3219 (3 of), 900m S.8 E. Sazes church, all x2.0.

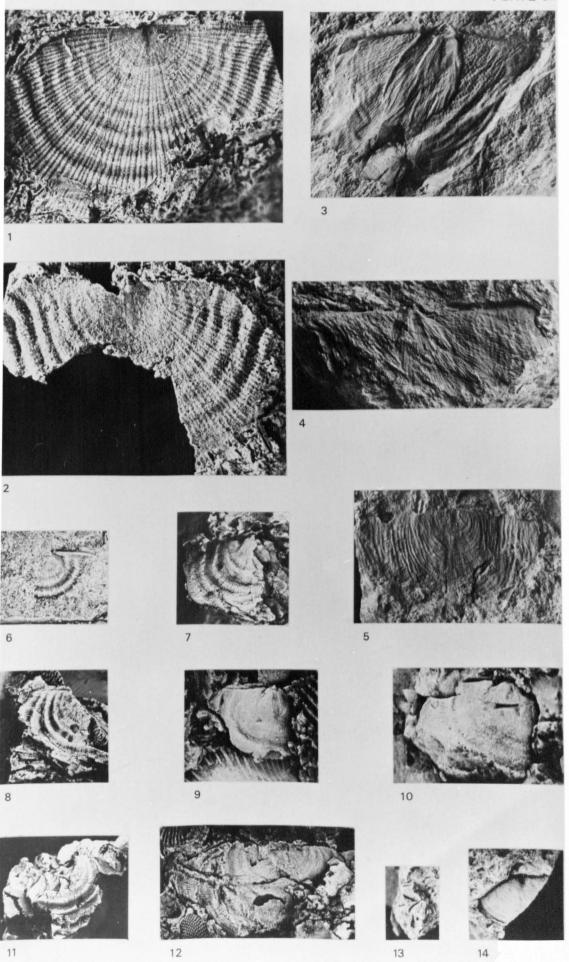
Leptaenid indet.

Fig. 6 internal mould of pedicle valve, ABER4, x4.0.

Kiaeromena? sp.

Figs. 7-11 internal moulds of pedicle valves, fig. 12 external mould of brachial valve, all from LM10, all x2.0.

Figs. 13,14 fragment of internal and external mould of brachial valve, RC11. x4.0.



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Order Pentamerida Schuchert and Cooper, 1931

Suborder Syntrophiidina Ulrich and Cooper, 1936

Superfamily Porambonitacea Davidson, 1853

Family PORAMBONITIDAE Davidson, 1853

Genus Porambonites Pander, 1830

Type species: Porambonites intermedia Hall and Clarke, 1895.

Porambonites (Porambonites) riberoi Sharpe, 1853
(Plate 16, figs. 1-16)

- v 1853 <u>Porambonites Riberoi</u> n.s.: Sharpe p. 156; pl. VIII, fig 7.
- v 1853 Porambonites lima n.s.: Sharpe p. 156; pl. VIII, fig. 6.
- v 1908 Porambonites Riberoi Sharpe: Delgado pp. 31,60.
- v 1908 Porambonites lima Sharpe: Delgado p. 60.
  - 1974 Porambonites riberoi Sharpe: Mitchell p. 389.

MATERIAL. About 20 valves in the form of moulds were recovered from the Leira Ma Member during this study. In addition the type material, and other specimens from Sharpe's collection in the British Museum (Natural History) (5 specimens), and a large collection (10 specimens) in the museum of the Servicos Geologicos, are available. Of this material only one specimen, from sample RC31, maintains its true convexity (see pl. 38 figs. 12,13); the other material is all flattened to some degree, perhaps indicating the original thinness of the shell.

DESCRIPTION. Strongly biconvex shells of rhomboidal outline,

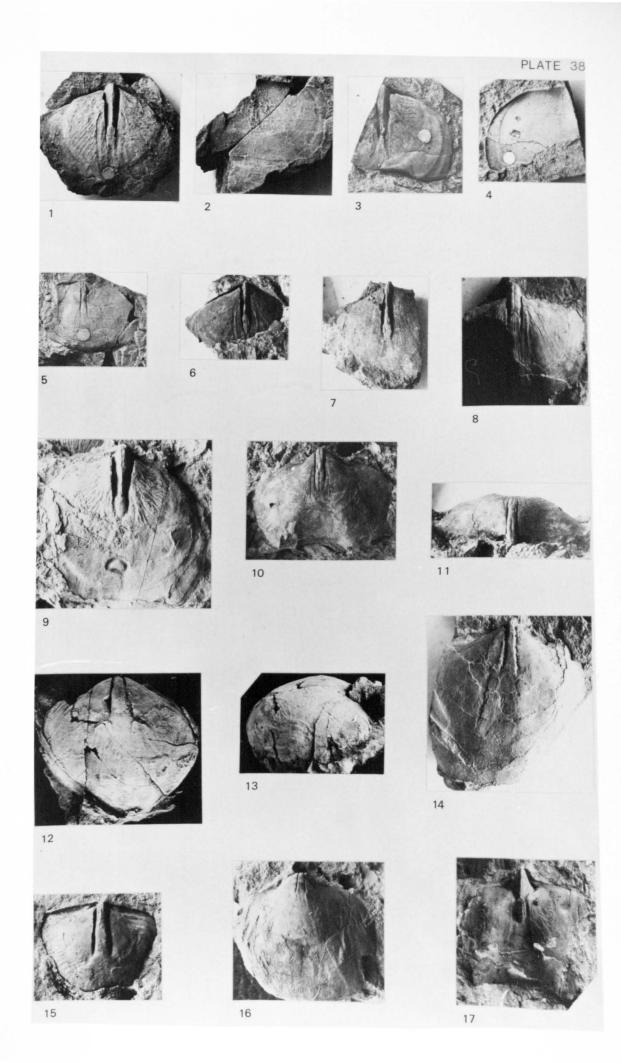
about 85% as long as wide. Hingeline probably about 50% of maximum width, which occurs at about midlength. very shallow fold and sulcus, forming about 25% of width at point of maximum width, increasing to 45% of maximum width at anterior margin. Ornament of ribs which arise by division, rib density 4-5/mm, sculpture of pits in radial rows between ribs, 2-5/mm, arranged in concentric zones of different density.

Interior of pedicle valve with dorsally divergent dental plates with parallel bases, bases often immediately adjacent, so plates "V" shaped in cross section (in contrast to brachial plates, which have discrete sub-parallel bases). Delthyrium open. Vascula genitalia occupy a large subcircular field, and consist of canals radially directed away from dental plates, extending anteriorly well beyond anterior ends of dental plates. At midlength of muscle field the dental plates curve slightly

Plate 38.

Porambonites (Porambonites) ribeiroi Sharpe, 1853
Pedicle valves: fig. 1 internal mould, BM.B 82957 (= Sharpe
Pl. VIII fig. 7b), fig. 2 external mould, BM.B 82961 (=Sharpe Pl.
VIII fig. 7a), figs. 3 and 4, internal and external moulds of
specimen respectively, BM.B 82983 (=Sharpe Pl. VIII figs. 6b and
6a respectively), fig. 5 internal mould, BM.B 82958 (=Sharpe Pl.
VIII fig. 7c), fig. 6 internal mould, SGL 3089, 100m west of
"Fonte de Cassemes", fig. 7 internal mould, SGL 3281, Leira Ma,
100m west of "Fonte de Cassemes", fig. 8 internal mould, SGL
3030, Leira Ma, fig. 9 internal mould, SGL 3029, Leira Ma, fig.
10 internal mould, SGL 3285, 100m west of "Fonte de Cassemes",
fig. 11 specimen as fig. 10, posterior view. Brachial valves:
fig. 12 internal mould, RC31.001, fig. 13 as fig. 12 lateral
view, fig. 14 internal mould, SGL 3023, Leira Ma, fig. 15
internal mould, SGL 3088, 100m west of "Fonte de Cassemes", fig.
16 internal mould, SGL 3024, Leira Ma. All x1.0.

Porambonites (Porambonites) cf. dreyfussi Havlicek, 1981 Fig. 17 internal mould of pedicle valve, SGL 3214, 900m S8E of Sazes church. x1.0.



Appendix C. 358.

towards midline. Midline marked through muscle field by low, narrow median ridge.

Interior of brachial valve with long brachial plates with parallel bases, extending anteriorly for 25-30% of valve length; at distal ends of plates lie well impresses sub-circular adductor scars. Mantle canal system of radial canals poorly known.

DISTRIBUTION. This species is known from the Leira Ma Member at the base of the Porto de Santa Anna Formation of Buçaco. Some fragments from the equivalent stratigraphic level in the Crozon Peninsula may also belong here.

DISCUSSION. Sharpe erected two species <u>ribeiroi</u> and <u>lima</u>, which are considered here to be conspecific. The species <u>ribeiroi</u> has priority. The species shows some similarity with the species <u>P</u>. (P.) <u>magnus</u> (Meneghini, 1880) from strata of comparable age in the Montagne Noire, and Sardinia recently redescribed by Havlicek (1981). Havlicek's illustrations permit little detailed comparison of the forms, and his assertion that <u>ribeiroi</u> does not possess a fold and sulcus is erroneous, although that of magnus may be more marked.

Porambonites (Porambonites) cf. dreyfussi Havlicek, 1981
(Plate 38, fig. 17)

cf 1948 Meristella sp: Dreyfuss p. 36, pl. 8, fig. 10. cf 1981 Porambonites (Porambonites) dreyfussi sp. n.:

Havlicek pp. 27,28, pl. 9, figs. 14-17

MATERIAL. This species is represented by some very fragmentary material from Cabeço Pedrogão (Zone 9/10 interregnum), and by two internal moulds from the same locality in the museum of the Serviços Geológicos.

DESCRIPTION. The material is too sparse to present a full description, but the following distinctions from  $\underline{P}$ .  $(\underline{P})$  ribeiroi can be made: the sulcus is much more pronounced, the dental plates are are shorter and more strongly medially bowed at their midlength, and the field of vascula genitalia is much more restricted. These factors all agree with the description of  $\underline{P}$ .  $(\underline{P})$  dreyfussi given by Havlicek.

DISTRIBUTION. Material compared with P. dreyfussi has only been recovered so far from the silicified beds in the Porto de Santa Anna Formation at Cabeço Pedrogão, south of Sazes (Zone 9/10 interregnum).

DISCUSSION. The distribution of this species stratigraphically higher than <u>ribeiroi</u> reflects the stratigraphic distribution of the species described by Havlicek, with the range of <u>dreyfussi</u> above that of magnus (a species close to <u>ribeiroi</u>).

Porambonites (Porambonites) sp. A

(Plate 39, figs. 1-4)

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MATERIAL. This species is represented by a single complete internal mould of a pedicle valve, together with a few more fragmentary specimens.

DESCRIPTION. This species is incompletely known, but differs markedly from the earlier two species in prescence of a strong angular sulcus. The hingeline is long. The ventral cardinalia resemble those of <u>ribeiroi</u>. The ornament is again very close to that of <u>ribeiroi</u>.

DISTRIBUTION. The description is based on material from the limestone in the pillow lava at Pointe de Lostmarc'h. In addition fragmentary porambonitid material has been recovered from the Rosan quarries and road cutting (also upper part of the Rosan Formation), but this is insufficient to establish whether it is conspecific with the Lostmarc'h species.

Family PARASTROPHINIDAE Ulrich and Cooper, 1938

Genus <u>Parastrophinella</u> Schuchert and Cooper, 1931

Type species: <u>Parastrophinella</u> reversa (Billings, 1857)

Parastrophinella? sp. A
(Plate 39, figs. 5-15)

MATERIAL. The material of this species is principally the several dozen specimens housed in the museum of the Serviços geológicos.

DESCRIPTION. No full description of this form can be given for

it has not been possible to study the internal structure of the material housed in Lisboa. The spondylium and septalium arrangement seems close to that of the later species here tentatively described to <a href="Ecoanastrophia">Ecoanastrophia</a> (see below), and it is possible that this is a precursor of that species. This is also suggested by the strongly impressed dorsal muscle field, which is more prominent than usual for <a href="Parastrophinella">Parastrophinella</a>, and strongly suggests the prominent, strongly marked muscle field on a raised platform of the later species.

DISTRIBUTION. This species figures very strongly in the collections in the Serviços Geológicos from Leira Ma, and from "100m west of the spring of Cacemes". In the present study further material has been recovered from the upper part of the Leira Ma Member at Leira Ma itself, and a lesser amount from the same horizon at Porto de Santa Anna. Further probably conspecific material has been found in the lower part of the Rosan Formation (Pointe de Raguenez, Plage de Raguenez, and Coat Garrec).

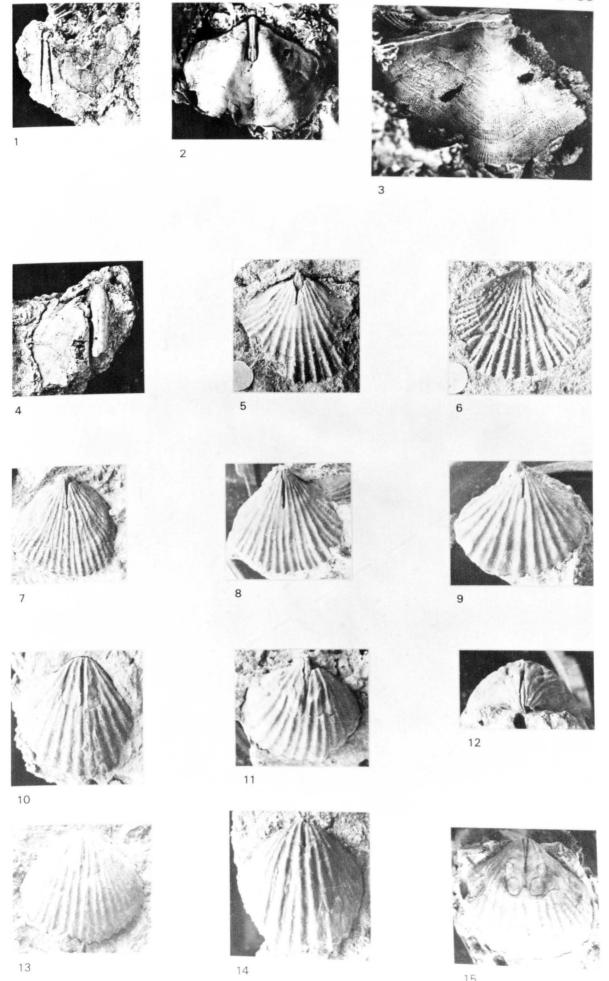
Plate 39.

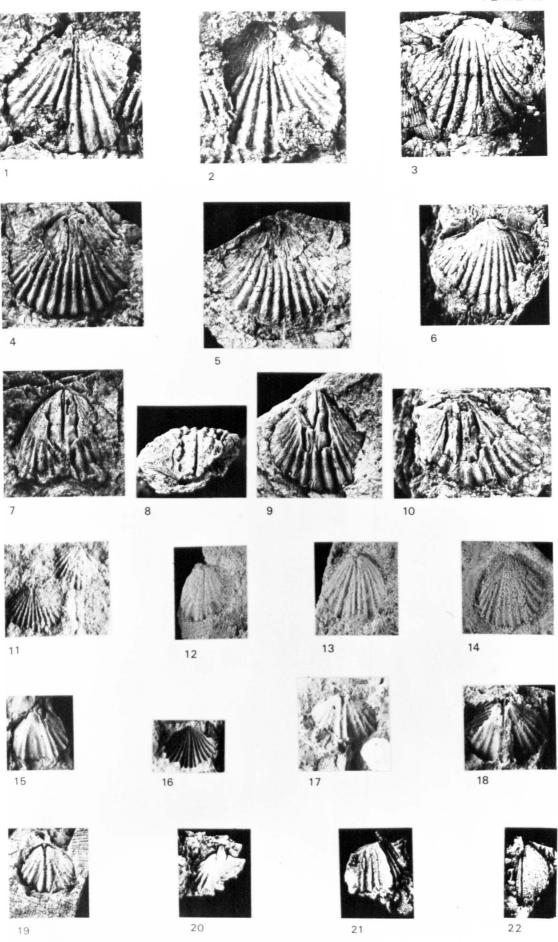
Porambonites (Porambonites) sp. A

Pedicle valves: fig. 1 internal mould, ROS1, x2.0, fig. 2 internal mould, LM10, x1.0, fig. 3 external mould, LM10, x2.0, fig. 4 internal mould, ROS1, x2.0.

Parastrophinella? sp. A.

Pedicle valves: figs. 5 and 6 internal and external moulds of a valve, BM.B 83029 and BM.B 83030 respectively, fig. 7 internal mould, SGL 3309, 100m west of "Fonte de Cassemes", fig. 8 internal mould, SGL 3307, locality as 7, fig. 9 internal mould, SGL 3308, locality as 7. Brachial valves: fig. 10 internal mould, SGL 3308, locality as 7, fig. 11 internal mould, SGL 3295 (1 of), locality as 7, fig. 12 internal mould, posterior view, SGL 3295 (1 of), locality as 7, fig. 13 internal mould, SGL 3295 (1 of), locality as 7, fig. 14 internal mould, SGL 3295 (1 of), locality as 7, fig. 14 internal mould, SGL 3295 (1 of), locality as 7, fig. 15 specimen as fig. 12, dorsal view. All x2.0.





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Genus <u>Eoanastrophia</u> Nikiforova and Sapelnikov, 1960

Type species: <u>Eoanastrophia</u> <u>antiquata</u> Nikiforova and Sapelnikov,

1960

### Eoanastrophia? sp. A

(Plate 40, figs. 1-10)

MATERIAL. All from the Rosan Formation, Rosan quarry, ROS1.

DESCRIPTION. Shell biconvex, roundedly triangular in outline, brachial valve 85% as long as wide, and 30% as deep as long. Maximum width occurs anterior to midpoint. Convexity of both valves increases towards anterior and antero-lateral margins. Ornament of costae appearing about 3mm anterior to umbo, and usually with median rib on pedicle valve, generally about seven ribs on each flank, growth lines present.

Ventral interior with spondylium supported anteriorly by low

Plate 40.

#### Eoanastrophia? sp. A

Figs. 1,2 internal mould of pedicle valve with its latex cast, fig. 3 latex cast of external mould of pedicle valve, figs. 4,5 internal mould of pedicle valve and its latex cast, fig. 6 latex casr of external mould of ?pedicle valve, figs. 7-10 internal moulds of brachial valves. All from ROS1, x2.0.

#### Rostricellula sp. A

Fig. 11 internal mould of brachial valve, bed 16 of Delgado's Val San Jorge section, figs 12,13 internal moulds of brachial valves, VACA1, internal mould of pedicle valve, VACA1, all  $x \ge 0$ .

Rostricellula sp. B
Fig. 15 internal mould of pedicle valve, SGL 2544 (1 of), bed
4 of Delgado's Zuvinhal section, fig. 16 external mould of
brachial valve, specimen no. and locality as 15, figs. 17,18
internal moulds of brachial valves specimen nos. and locality as
15, fig. 19 internal mould of brachial valve, Louredo, all x2.0.

Rostricellula sp. C Figs. 20,21 internal moulds of pedicle valves, fig. 22 internal mould of brachial valve, all LM10, x2.0.

septum extending to 35% of valve length; details of muscle scars unknown. Dorsal interior with deep septalium, supported anteriorly by septum extending to 30% of valve length, alate plates absent; well developed muscle platform standing well above valve floor, extending forward for 55% of valve length.

DISTRIBUTION. The tuffaceous beds above the pillow lava in the Rosan quarries (upper part of the Rosan Formation) provide the only locality to have so far yielded this species.

Order Rhynchonellida Kuhn, 1949

Superfamily Rhynchonellacea Gray, 1848

Family TRIGONIRHYNCHIIDAE McLaren, 1965

Genus Rostricellula Ulrich and Cooper, 1942

Rostricellula sp. A (Plate 40, figs. 11-14)

Type species: Rostricellula rostrata Ulrich and Cooper, 1942.

This material is known from Zones ?6 and 7 from the Louredo Formation. The ribbing is finer than that of sp. B, and tends to develop more ribs in the sulcus (5 rather than 3).

Rostricellula sp. B
(Plate 40, figs. 15-19)

- v 1906 Rhynchonella cf. ambigena Barr. : Delgado pp. 31,60.
- ? 1974 Rostricellula sp.: Mitchell p. 389.

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This species is a common element of the fauna in the colitic ironstone at the base of the Porto de Santa Anna Formation. It seems to be absent in the higher levels of the Leira Ma Member. The material seems close to the species ambigena and termieri from Bohemia and Morocco respectively, but the small amount of material available has not permitted the statistical analysis of shape. The fold generally has four ribs, and the sulcus two.

Rostricellula sp. C (Plate 40, figs. 20-22)

This form is known only from the interstitial limestone of the pillow lava at Pointe de Lostmarc'h (upper part of the Rosan Formation). It is tentatively ascribed to <u>Rostricellula</u> although its internal morphology is not fully known. the ribs are more angular than the previuos species, and the outline a little less transverse.

Order Spiriferida Waagen, 1883

Suborder Atrypidina Moore, 1952

Superfamily Atrypacea Gill, 1871

Family ATRYPIDAE Gill, 1871

Subfamily Zygospirinae Waagen, 1883

Genus Protozyga Hall and Clarke, 1893

Type species: Protozyga exigua Hall, 1847

Protzyga? sp. indet.
(Plate 41, figs. 10-12)

This species is only very poorly known at present. The available material consists only of the three illustrated valves, and even with these it is not certain that the pedicle and brachial valves belong together.

A ventri-biconvex shell of slightly elongate outline, pattern of folds and sulci unknown. Ventral interior with thin dental plates. Dorsal interior with strong median septum. Dorsal cardinalia unknown.

Suborder Athyrididina Boucot, Johnson and Staton, 1964
Superfamily Athyridacea Gill, 1871
Family MERISTELLIDAE Waagen, 1883
Subfamily Meristellinae Waagen, 1883
Genus Plectothyrella Temple, 1965

Type species Plectothyrella platystrophoides Temple, 1965.

Plectothyrella? sp. A (Plate 41, figs. 1-9)

MATERIAL. This species is represented by two internal moulds of pedicle valves from the Ribeira do Braçal Formation of the Rio Ceira Inlier (one with a fragment of the corresponding external). There is also an internal and external mould from the same horizon near Riba de Baixo (PEN2), in a similar preservation to the Ceira material. The Riba de Baixo locality has also yielded

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a coquinoid layer with several tens of valves (as moulds) of this species, but these specimens, although preserving detail well, are generally rather fragmentary.

DESCRIPTION. A ventri-biconvex shell of sub-circular outline; distal parts of shell rarely preserved, presumably because they were thin-shelled. Pedicle valve sulcate, external of brachial valve unknown, presumably with fold; ribbing strong, well rounded, 3 ribs in sulcus, about 7 ribs each side laterally; ribbing impressed on interior of valve; surface of valve with strong growth-lines, become imbricate distally (Fig. 4).

Pedicle interior with long dental plates, becoming secondarily thickened in large specimens (compare figs. 2,5). Umbonal region poorly preserved in available material but delthyrium probably open. Pedicle chamber poorly known (fig. 5), ventral platform between pedicle chamber and marked geniculation bears a median ridge (fig. 7).

Brachial interior with open notothyrium; hinge plate divided, with narrow notothyrial chamber, widely divergent, small sockets, crural bases stout, more distal parts of brachial valve unknown.

DISTRIBUTION. This species has been recovered from only two localites, both in Zone 12, from the Ribeira do Braçal Formation of the Buçaco syncline.

DISCUSSION. The close resemblance of this material to  $\underline{P}$ .

Platystrophoides Temple is striking. Indeed it is possible that

the two species are synonomous. However, in the lack of information on the brachial valve, and the lack of knowledge of the ornament, it is preferable to keep the two species distinct. The close resemblance does however add weight to the tentative assignation of the Ribeira do Braçal Formation, and indeed therefore Zone 12, to the Hirnantian. A position close to the Hirnantian/Rawtheyan boundary for these deposits would agree with the sedimentological evidence for the deposition of the Rio Ceira Group during the onset of the upper Ordovician glaciation.

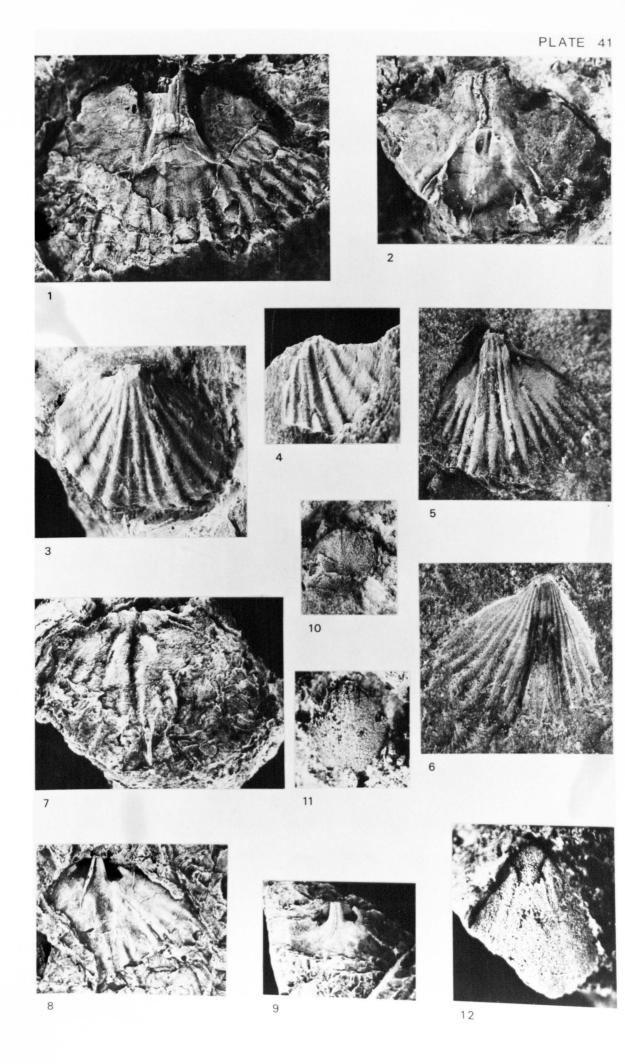
Plate 41.

Plectothyrella sp. A

Figs. 1,2,7 internal moulds of pedicle valves, PEN2, figs.
3,4 internal and part of external mould of a pedicle valve, RC12,
figs. 5,6 internal and external moulds of a pedicle valve, PEN2,
figs. 6,9 intrnal moulds of brachial valves, PEN2, all x4.0.

Protozyga? sp.

Fig. 10 internal mould of brachial valve, RC11, figs. 11,12 internal moulds of pedicle valves, B135, all x4.0.



Phylum Mollusca Cuvier, 1797

Class Rostroconchia Pojeta, Runnegar, Morris and Newell, 1972

Order Ribeirioida Kobayashi, 1933

Family RIBERIIDAE Kobayashi, 1933

Type species: Ribeiria pholadiformis Sharpe, 1853

Genus Ribeiria Sharpe, 1853

Ribeiria pholadiformis Sharpe, 1853
(Plate 42, figs. 1-4)

- 1853 <u>Ribeiria pholadiformis</u> n. s.: Sharpe p. 158: pl. IX, fig. 17.
- 1976 <u>Ribeiria pholadiformis</u> Sharpe: Pojeta and Runnegar p. 50 pl. 7, figs. 3-12.

MATERIAL. A dozen internal moulds, and several fragmentary external moulds.

DESCRIPTION. The preservation of the available material is not sufficiently good to enable the identification of the "side muscle scars". Little can be added to the description in Pojeta and Runnegar (1976).

DISTRIBUTION. This species is a persistent member of the fauna of the Fonte da Horta Formation, and the equivalent parts of the Postolonnec Formation. It has been recorded so far from the Buçaco and Dornes areas of central Portugal. It occurs in Zones 1 to 3. This species has not been recorded above the lowest parts

(0)

0

of Zone 3.

DISCUSSION. Pojeta and Runnegar (<u>ibid</u>. p. 33) suggest that ribeiriids were infaunal deposit or suspension feeders, and it is not inconceivable that <u>Ribeiria</u> had a similar mode of life to the nuculoid bivalves which are so common in the same sediments.

Rostroconch indet.

(Plate 42, figs. 5-7)

The upper part of the Favaçal Bed of the Dornes area has yielded several incomplete shells of a large rostroconch. These have the general form of <u>Bransonia</u> Pojeta and Runnegar, but the shells are incomplete and the ornament is poorly known. Until further material is recovered this form must remain in open nomenclature.

Plate 42.

Ribeiria pholadiformis Sharpe, 1853

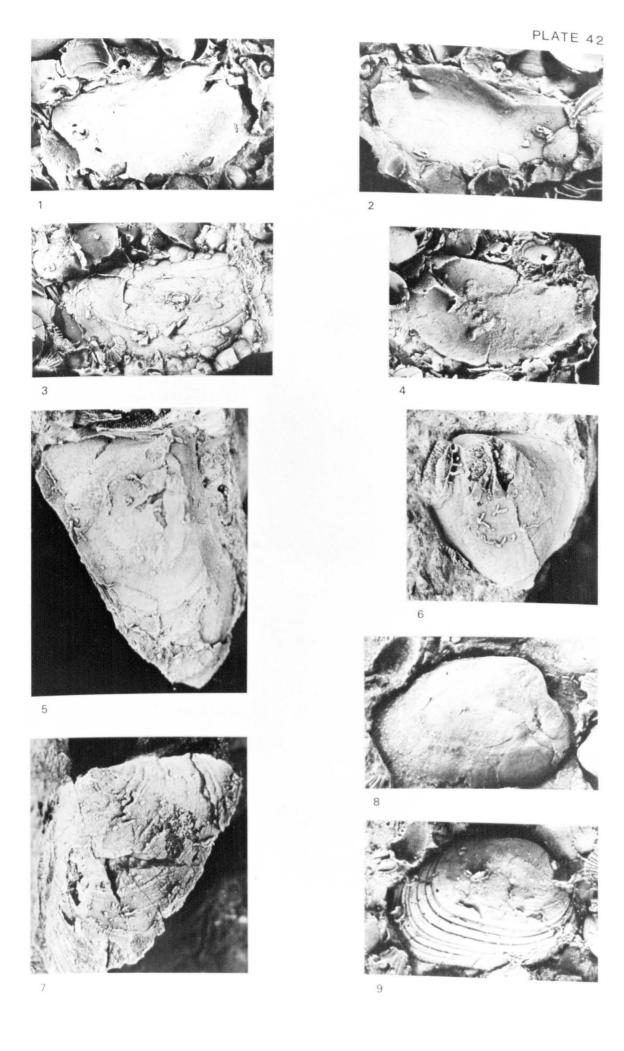
Figs. 1,2,3 internal mould of right side, with latex cast and latex cast of external mould of same specimen respectively, CACWELL1, fig. 4 latex cast of internal mould of right side, CACWELL1. All x2.0

Rostroconch indet.

Figs. 5,7 internal mould of right side and part of corresponding external mould, fig. b internal mould of left side, all MDC5, all x2.0.

Glyptarca lusitanica (Sharpe, 1853)

Figs. 6,9 internal mould of right valve, with latex cast of corresponding external mould, x3.0, CACWELL1



Class Bivalvia Linnaeus, 1767

Subclass Heteroconchia Hertwig, 1895

Order Actinodontoida Douville, 1912

Superfamily Cycloconchacea Ulrich, 1884

Family CYCLOCONCHIDAE Ulrich, 1884

Genus Glyptarca Hicks, 1873

Type species: Glyptarca primaeva Hicks, 1873

Glyptarca lusitanica (Sharpe, 1853)
(Plate 42, figs. 8,9, Plate 43, figs 1-4)

- v\*1853 <u>Dolabra? lusitanica</u> n.s.: Sharpe pp. 141,151; pl.IX, fig. 3.
- v 1853 <u>Cypricardia? beirensis</u> n.s.: Sharpe pp. 141, 152; pl. IX, fig. 16.
  - 1855 Arca naranjoana n.s.: de Verneuil and Barrande p. 989; pl. 26, fig. 12.
  - 1891 Arca? naranjoana? Verneuil and Barrande: Barrois p. 198;pl. 3, fig. 2.
  - 1901 Arca? naranjoana Verneuil and Barrande: Kerforne p. 194.
  - 1901 <u>Dolabra lusitanica</u> Sharpe: Kerforne p. 194.
  - 1908 <u>Dolabra? lusitanica</u> Sharpe: Delgado pp. 33, 34, 41,42, 51, 59, 81, 92.
  - 1908 <u>Cypricardia? beirensis</u> Sharpe: Delgado pp. 33, 34, 41, 42, 51, 59, 81, 92.
  - 1910 Arca? naranjoana Verneuil and Barrande: Marsille pp. 29,32

371.

0

0

- 1923 Arca? naranjoana Verneuil and Barrande: Kerforne p. 180.
- 1966 Actinodonta naranjoana (de Verneuil and Barrande) 1855:
- 1970 <u>Actinodonta naranjoana</u> (de Verneuil and Barrande) 1855:

  Bradshaw pp. 636-638; textfigs. 13-16.

MATERIAL. Several dozen valves from the Fonte da Horta Formation, principally from the Buçaco syncline, together with several from the Cabril Formation. A few valves were also collected from the upper part of the Postollonec Formation from horizons equivalent to both the Fonte da Horta and Cabril Formations.

DESCRIPTION. A full description of this species was given by Bradshaw (1970).

DISTRIBUTION. The recorded range of Arca naranjoana de Verneuil and Barrande includes the supposed Llandeilo sediments of the Sierra Morena (type material), Brittany and Normandy. The current species is probably conspecific with Verneuil and

Plate 43.

Glyptarca lusitanica (Sharpe, 1853)

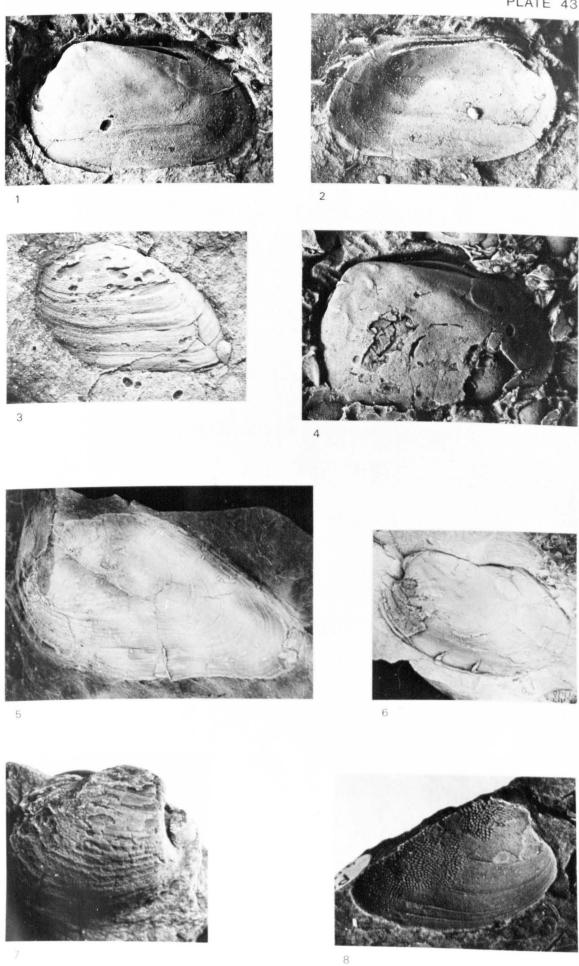
Fig. 1 internal mould of left valve, fig. 2 latex cast of specimen in fig. 1, fig, 3 latex cast of external mould of specimen on fig. 1, fig. 4 internal mould of left valve, all from CACWELL1, all x3.0.

Glyptarca? sp. A

Fig. 5 external mould of right valve, ABOb, fig.b internal mould of left valve, ABO5, both x2.0.

Redonia deshayesiana Rouault, 1851

Fig. 7 internal mould of right valve, BM.PL 4097 (?=Sharpe pl IX fig 2a), fig. 8 external mould of left valve, BM.PL 4179 (?= Sharpe pl. IX fig. 1a), both x3.0.



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Barrande's material, but this material has not been redescribed. The records from the Armorican Massif include the description of A. naranjoana by Babin (1966), and this tallies well with the Portuguese material. Within central Portugal the species is recorded from Buçaco, Dornes and Mação, in occurrences of zone 1 to zone 3.

DISCUSSION. The material of the species <u>Dolabra? lusitanica</u> and <u>Cypricardia beirensis</u> Sharpe in the Sharpe material of the British Museum have been examined, and there seems little ground for separating them. They are accordingly synonomised here. Sharpe's species have priority over <u>Arca naranjoana</u> de Verneuil and Barrande, although they have not appeared so frequently in the literature. The species <u>lusitanica</u> has priority over beirensis.

# Glyptarca sp. A (Plate 43, figs. 5,6)

MATERIAL. Several composite moulds from the Carregueira Formation of the Macao area.

DESCRIPTION. The material of this species is rather poorly preserved, being composite moulds, which have suffered from compression. The attribution of this material to <u>Glyptarca</u> is based largely on the similarity of the valve outline to the earlier species  $\underline{G}$ . <u>lusitanica</u>. The dentition of this form is unknown.

DISTRIBUTION. This large species of <u>Glyptarca</u> is found in the Carregueira Formation and in the corresponding "Schistes de Veryac'h" of Crozon. Both these occurrences are Zone 4 in age.

DISCUSSION. This material shows some similarity in valve shape to Modiomorpha dollfussi (De Tromelin, 1876) and Modiolopsis morierei De Tromelin, 1876 from the Caradoc of Normandy.

Family REDONIIDAE Babin, 1966

Genus <u>Redonia</u> Rouault, 1851

Type species: Redonia deshayesiana Rouault, 1851

Redonia deshayesiana Rouault, 1851
(Plate 43, figs. 7,8, Plate 44, figs. 1-3)

- \* 1851 Redonia deshayesiana Marie Rouault : Rouault p. 364; figs. 1,2
  - 1851 Redonia duvaliana Marie Rouault : Rouault p. 365; figs.

    1,2
- v 1853 Redonia deshayesiana Rouault: Sharpe pp. 141, 148; pl.

  IX, fig. 1.
- v 1853 Redonia duvaliana Rouault: Sharpe pp. 141,148; pl.IX, fig. 2.
  - 1855 Redonia deshayesiana Rouault : de Verneuil and Barrande pl. 16, fig. 10.
  - 1855 Redonia duvaliana Rouault : de Verneuil and Barrande pl.
    16, fig. 11.

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1876 <u>Redonia deshayesiana</u> Rouault : de Tromelin and Lebesconte p. 641.

- 1876 Redonia duvaliana Rouault : de Tromelin and Lebesconte p. 641.
- 1901 Redonia deshayesiana Rouault : Kerforne p. 198.
- 1901 Redonia duvaliana Rouault: Kerforne p. 198.
- 1908 <u>Redonia Duvaliana</u> Rouault : Delgado pp. 34, 41, 42, 51, 59, 81.
- 1910 Redonia deshayesiana Rouault : Marsille p. 32.
- 1910 Redonia duvaliana Rouault: Marsille p. 32.
- 1934 Redonia deshayesi Rouault: Gouzien p. 179.
- 1934 Redonia duvali Rouault: Gouzien p. 179.
- 1966 Redonia deshayesi Rouault, 1851: Babin p. 246; textfig. 67; pl. X, figs. 13-16.
- 1970 Redonia deshayesi Rouault, 1851, emend. Gouzien, 1934:
  Bradshaw pp. 638-642; textfigs. 16-21.
- 1971 Redonia deshayesiana duvaliana Rouault :Pojeta pl. 7, fig. 7.

MATERIAL. About 20 valves as external and internal moulds.

DESCRIPTION. Bradshaw (1970) gave a full description of this species so it will not be repeated here.

DISTRIBUTION. Within the strata studied in this project  $\underline{R}$ .

deshayesiana has been found in the lower levels of the Fonte da

Horta Formation (zone 1) of the Buçaco and Dornes areas. Babin

(1966) quotes a wide distribution in the Llandeilo of Armorica.

The species has also been recorded from Spain (Sierra Morena; Born, 1918, Tamames; Gutierrez-Marco and Rabano, in press).

Subclass Palaeotaxodonta Korobkov, 1954

Order Nuculoida Dall, 1889

Superfamily Nuculacea Gray, 1824

Family PRAENUCULIDAE McAlester, 1969

Genus Praeleda Pfab, 1934

Praeleda costae (Sharpe, 1853)
(Plate 44, figs. 10-12)

- v\*1853 <u>Nucula Costae</u> n.s.: Sharpe pp. 141,148-149; pl. IX, fig. 4.
- v 1853 Nucula Ciae n.s.: Sharpe pp. 141,149; pl. IX, fig. 5.
  - 1855 Nucula Costae Sharpe: de Verneuil and Barrande p. 989.
  - 1876 <u>Ctenodonta Costae</u>? (Sharpe) : de Tromelin and Lebesconte p. 641.
  - 1876 <u>Ctenodonta Ciae</u> Sharpe : de Tromelin and Lebesconte p. 641.
  - 1886 Ctenodonta Costae (Sharpe): Barrois p. 680.
  - 1886 Redonia Ciae Sharpe: Barrois p. 680.
  - 1891 <u>Ctenodonta Costae</u> (Sharpe): Barrois p. 189; pl. 1, fig. 6.
  - 1901 Ctenodonta Ciae Sharpe: Kerforne p. 195.
  - 1901 Ctenodonta Costae (Sharpe): Kerforne p. 196.
  - 1908 <u>Ctenodonta Ciae</u> Sh.: Delgado pp.34,41,51,59(<u>partim</u>), 82,89,92; (non pp. 32,39).

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1908 <u>Ctenodonta Costae</u> Sh.: Delgado pp. 34,41,51,59(<u>partim</u>), 82,89,92; (non pp. 32,29).

- 1923 Ctenodonta Ciae Sharpe: Kerforne p. 180.
- 1934 Ctenodonta Costae Sharpe: Gouzien p. 179.
- 1966 <u>Ctenodonta ciae</u> (Sharpe) 1853: Babin p. 49; textfigs.
  10-12; pl. 1, fig. 9.
- 1966 <u>Palaeoneilo ctenodontoides</u> n.s.: Babin p. 76; textfigs. 26-28; pl. 1, figs. 9-10; pl. 11, figs. 6, 12, 13.
- 1970 <u>Praeleda costae</u> (Sharpe) 1853 : Bradshaw pp. 630-633; textfigs. 7-10.
- 1970 <u>Praeleda ciae</u> (Sharpe) 1853 : Bradshaw pp. 633-636; textfigs. 11,12.

MATERIAL. Several dozen valves from the Fonte da Horta Formation, preserved as moulds, together with a few valves from the Cabril Formation. Several of the Fonte da Horta Formation specimens are conjoined valves.

DESCRIPTION. Bradshaw (1970) described in detail <u>Praeleda costae</u> and <u>P. ciae</u> Sharpe. After examination of the type material of these species (<u>Nucula costae</u> Sharpe, 1853: BM.PL 4100, <u>Nucula ciae</u> Sharpe, 1853 BM.PL 4101, 4102) the view is taken in the present work that the two species are synonymous. This species shows great variation in dentition, and in curvature of the umbo, and these factors are often further confused by preservational effects. The species will not be redescribed here since the descriptions by Bradshaw (<u>ibid</u>.) suffice to show the morphology, and the variability, of this species.

DISTRIBUTION. This species is abundant throughout the Fonte da Horta Formation of Buçaco and Dornes (Zones 1 and 2). It is also present at most of the fossiliferrous localities in the Cabril Formation (Zone 3) of the Buçaco, Dornes and Mação regions. The species is also common in the equivalent parts of the Postolonnec Formation (Crozon).

Praeleda association in central Portugal. A similar species occurs in phase 2 of this association, but at present sufficiently well preserved material is not available for its specific determination.

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Plate 44.

Redonia deshayesiana Rouault, 1051

Fig. 1 internal mould of left valve, BM.PL 4179 (=Sharpe pl. IX fig 1c), fig. 2 internal mould of left valve, BM.PL 4098 (= Sharpe pl. IX fig. 2b), fig. 3 internal mould of right valve (= Sharpe pl. IX fig. 1b), all x3.0.

Praeleda costae (Sharpe, 1853)

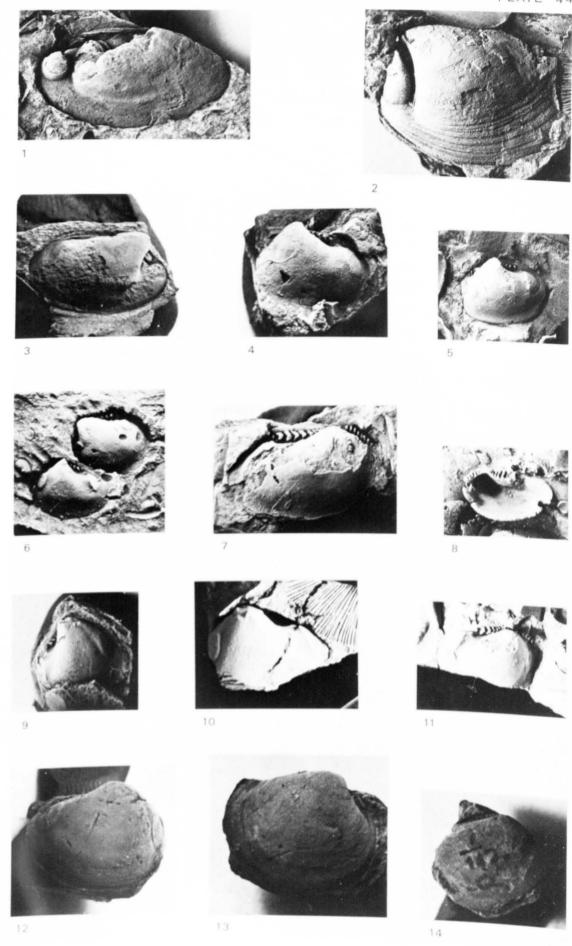
Fig. 4 internal mould of right valve, BM.PL 4102, fig. 5 internal mould of right valve, BM.PL 4100, (=Sharpe pl. IX fig. 4b), fig. 6 internal mould of right valve (with internal mould of left valve of Tancrediopsis ezquerrae above), CACWELL1, fig. 7 internal mould of left valve, BM.B 4101 (=Sharpe pl IX fig. 5c?), fig. 8 latex cast of internal mould of left valve, CACWELL1, all x3.0.

Praeleda ribeiroi (Sharpe, 1853)

Fig. 9, holotype, internal mould of left valve, BM.PL 4103, (=Sharpe pl. IX fig. 6b), figs. 10,11 internal moulds of right and left valves respectively, ZUV12, fig. 12 internal mould of left valve, one of BM.PL 4129-4132, all x3.0.

Myoplusia eschwegii (Sharpe, 1853)

Fig. 13 internal mould of right valve, no. as fig. 12, fig. 14 internal mould of right valve, no. as above, all x3.0.



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# <u>Praeleda ribeiroi</u> (Sharpe, 1853) (Plate 44, figs. 4-8)

- v\*1853 <u>Nucula Ribeiro</u> n.s.: Sharpe pp. 141,149; pl. IX, fig. 6.
  - 1908 <u>Ctenodonta Riberoi</u> Sh.: Delgado pp. 32,40,59(<u>partim</u>),

    (non pp. 34,42,43.).
- ? 1908 <u>Ctenodonta Costae</u> Sh.: Delgado pp. 32,39,59(<u>partim</u>),
  (non pp. 34,41,51,59,82,89,92.).
- ? 1908 <u>Ctenodonta Ciae</u> Sh.: Delgado pp. 32,39,59(<u>partim</u>), (non pp. 34,41,51,59,82,89,92).
  - 1972 <u>Deceptrix</u> cf. <u>ciae</u> (Sharpe), 1853: Babin and Robardet pp. 35-37; pl. III, figs. 2-6.
  - 1972 <u>Deceptrix pulchra</u> (Pfab) <u>armoricana</u> n.subsp.: Babin and Melou pp. 81-82; textfig. 4; pl. VIII, figs. 4-7.

MATERIAL. This species is represented by a dozen specimens, chiefly from a nodular bed in the Zuvinhal Member (ZUV12) which yields undeformed material, including several conjoined pairs of valves.

DESCRIPTION. This species has been described by Babin and Robardet (1972) and by Babin and Melou (1972). The paper by Babin and Robardet in particular discusses the differences between this species and the Llandeilo <u>Praeleda</u>.

DISTRIBUTION. This species is common in the mudstone intercalations within the upper part of the Louredo Formation

(Vale Saido, Zuvinhal and Galhano Members) of the Buçaco syncline. It is recorded (as <u>Deceptrix</u> <u>pulchra armoricana</u> Babin and Melou) by Babin and Melou from the Caradoc of Crozon, and Normandy.

DISCUSSION. Babin describes (1966, pp. 47-49, textfigs. 7-9)
Ctenodonta ribeiroi (Sharpe) 1853), attributes a Llandeilo age to the type material, and refers material (on which his description is based) to the species from the Llandeilo of the Crozon peninsula. In fact however, the type locality for Nucula ribeiroi Sharpe, 1853 (Portela de Loredo, in the Buçaco syncline) is of Caradoc age (Zone 7), and yields Svobodaina armoricana (e.g Sharpe p. 141). The material referred to the species by Babin is probably referrable to Praeleda costae (Sharpe). The type material for Nucula ribeiroi does agree with the description of Deceptrix pulchra armoricana Babin and Melou, 1972 from the Caradoc of Crozon (Schistes de Raguenez, Kermeur Formation).

Genus <u>Concavodonta</u> Babin and Melou, 1972

Type species: <u>Concavodonta ponderata</u> (Barrande, 1881)

### Concavodonta cf. ponderata (Barrande, 1881)

- \* 1881 <u>Nucula ponderata</u> : Barrande pl. 271, case IV, figs.
  - 1881 <u>Nucula dispar</u> : Barrande pl. 273, case VIII, figs. 9-12.

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1934 Ctenodonta ponderata : Pfab p. 224; pl. II, fig. 7.

- 1972 <u>Ctenodonta? ponderata</u> (Barrande), 1881 : Babin and Robardet pp. 29-31; pl. I, fig. 7.
- 1972 <u>Concavodonta ponderata</u> (Barrande) ? , 1881 : Babin and Melou p. 83; pl. VII, figs. 5-7.

MATERIAL. A single valve of this species has been recovered in sample ZUV12.

DESCRIPTION. For a description of this species see Babin and Melou (1972).

DISTRIBUTION. The sole occurrence of this species amongst the material recovered from central Portugal is of Zone 7 age. The occurrences of this species in Brittany and Normandy are likewise of Zone 7 age.

1,1

Superfamily Nucalanacea Adams and Adams, 1858

Family MALLETIDAE Adams and Adams, 1858

Genus Myoplusia Neumayr, 1884

Myoplusia eschwegii (Sharpe, 1853)
(Plate 44 figs. 13,14, Plate 45, figs. 1-7)

- \*v1853 Nucula Eschwegii n.s.: Sharpe pp. 141,150 pl. IX figs. 10a,b.
- v 1853 <u>Nucula Maestri</u> n.s.: Sharpe pp. 141, 150 pl. IX, figs. 9a,b.

1881 <u>Nucula contrastans</u>: Barrande p. 271; pl. II, figs. 1-16.

- ? 1884 Myoplusia contractans: Neumayr p. 416.
- ? 1934 <u>Praeleda contrastans</u>: Pfab p. 233; pl. III,figs. 4,7-9.
  - 1972 Myoplusia contrastans (Barrande), 1881?: Babin and Melou pp. 83-85; pl. VII, figs. 8-10; pl. VIII, figs. 1-3.

MATERIAL. A dozen well preserved moulds from ZUV12, together with several other specimens in a poorer state of preservation from other samples.

DESCRIPTION. This species was fully described by Babin and Melou, 1972. The type material of Sharpe's species agrees with their description closely. The use of Sharpe's name is preferred to that of Barrande's species for that has not been revised since Pfab, and Babin and Melou were only tentative in their assignation of the material to contrastans.

DISTRIBUTION. This species occurs in the mudstones of the Vale Saido and Zuvinhal Members (Zone 7), of the Bucaco syncline.

DISCUSSION. Myoplusia eschwegii is probably the commonest bivalve in the zone 7 deposits at Bucaco. Its dominance in the fauna was similarly noted for the Schistes de Raguenez by Babin and Melou.



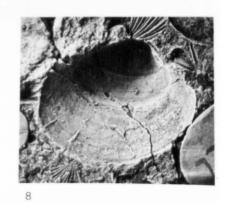
















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### Myoplusia cf. bilunata perdentata (Barrande, 1881)

- cf1881 <u>Leda</u> <u>bilunata</u>: Barrande pl. 270, case I, figs. 13-24 (non 1-12), after Pfab.
  - 1881 Leda perdentata: Barrande pl. 270, case II, figs. 1-9.
  - 1881 Nucula faba: Barrande, case IV, figs. 8-9.
  - 1934 <u>Ctenodonta bilunata perdentata</u>: Pfab p. 227; pl. II, figs. 12,13.
  - 1972 <u>Ctenodonta cf. bilunata perdentata</u> (Barrande), 1861:

    Babin and Robardet pp. 31-33; textfig. 2; pl. II,
    figs. 1-6.
  - 1972 Myoplusia cf. bilunata perdentata (Barrande), 1881:

    Babin and Melou pp. 85-86; pl. VII, figs. 1,2.

MATERIAL. A single well-preserved valve from sample ZUV12, as well as several other poorly preserved valves from other samples.

Plate 45.

Myoplusia eschwegii (Sharpe, 1853)

Fig. 1 internal mould of right valve, one of BM.PL 4129-4132, fig.2 internal mould of left valve, holotype, BM.PL 4108, fig'd Sharpe pl IX figs 10a,b, figs. 3,4,5 internal moulds of left, right and right valves respectively, ZUV12, fig. 6 internal mould of right valve, BM.PL 4134, fig. 7 internal mould of right valve of conjoined pair, BM.PL 4133. All x3.0.

Sluha? beirensis (Sharpe, 1853)
Fig. 8 external mould of left valve, BM.PL 4112, fig. 9 internal mould of right valve, BM.PL 4110 (=Sharpe pl. IX fig. 12), fig 10 internal mould of left valve, BM.PL 4112 (?=Sharpe pl. IX fig. 13). All x3.0.

DESCRIPTION. The present material adds nothing to the description of Babin and Melou, 1972).

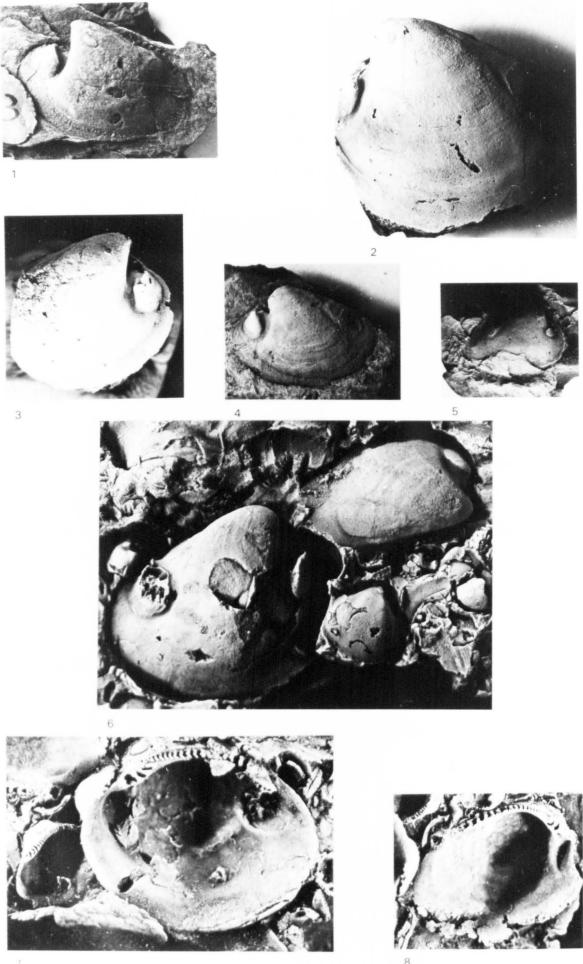
DISTRIBUTION. This species has been recorded from the Vale Saido and Zuvinhal Members of the Louredo Formation (Zone 7) of the Buçaco syncline.

Genus Sluha Barrande

Type species: Sluha expansa Barrande

Sluha? beirensis (Sharpe, 1853)
(Plate 45, figs. 8-10, Plate 46, figs. 1-8)

- v\*1853 <u>Nucula beirensis</u> n.s.: Sharpe p. 150; pl. 19, figs.
- v 1853 <u>Nucula bussacensis</u> n.s.: Sharpe p. 151; pl. 19, figs. 13-14.
  - Nucula hopensacki n.s.: de Verneuil and Barrande p.989; pl. 28, fig. 8.
  - 1876 <u>Ctenodonta beirensis</u>: de Tromelin and Lebesconte p. 654.
  - 1876 <u>Ctenodonta bussacensis</u>: de Tromelin and Lebesconte p. 683.
  - 1886 Ctenodonta beirensis: Barrois p. 680.
  - 1886 <u>Ctenodonta bussacensis</u>: Kerforne p. 195.
  - 1901 Ctenodonta beirensis: Kerforne p. 195.
  - 1901 Ctenodonta hopensacki: Kerforne p. 196.
  - 1908 Ctenodonta beirensis Sh.: Delgado pp. 34,41,42,51,59,



82,89,92.

- 1912 Palaeoneilo hopensacki : Douville p. 493; fig. b.
- 1934 Ctenodonta bussacensis: Gouzien p. 179.
- 1966 <u>Ctenodonta bussacensis</u> (Sharpe), 1853 : Babin p. 73; textfigs. 23,24; pl. 11, figs. 10,11.
- 1966 <u>Palaeoneilo hopensacki</u> (De Verneuil and Barrande), 1855:
  Babin p. 74; textfig. 25; pl. 11, fig. 9.
- 1966 Palaeoneilo beirensis (Sharpe), 1853: Babin p. 74; textfig. 25; pl. 11, fig. 9.
- 1970 <u>Cardiolaria</u> <u>beirensis</u> (Sharpe) 1853 : Bradshaw pp. 624-628; textfigs. 1-4.

MATERIAL. This species is represented by abundant material from the Fonte da Horta Formation of Buçaco and Dornes, and also by a smaller amount of material from the Cabril Formation of Buçaco, Dornes, and Mação.

DESCRIPTION. A full description was given by Bradshaw (1970), and therefore one will not be provided here.

Plate 46.

Sluha? beirensis (Sharpe, 1853)

Fig. 1 internal mould of left valve, BM.PL 4111 (=Sharpe pl. IX fig. 14b), fig. 2 internal mould of left valve, BM.PL 4150, fig. 3 internal mould of right valve, CACWELL1, fig. 4 internal mould of left valve, BM.PL 4143, fig. 5 internal mould of right valve, BM.PL 4361, fig. 6 internal moulds of a left and right valve, CACWELL1 (note also internal mould of left valve of Tancrediopsis ezquerrae), figs. 7,8 latex casts of specimens in fig. 6. All x3.0.

DISTRIBUTION. The species is known from deposits of Zones 1-3 throughout the Fonte da Horta and Cabril Formations of the Buçaco and Dornes areas. It also occurs in the equivalent deposits in Armorica; the Postolonnec and Andouillé Formations.

DISCUSSION. The role of this species in the palaeocommunity of the Fonte da Horta Formation (the <u>Praeleda</u> association phase 1) was probably one of importance, for it is one of the commonest, and largest species present. It presumably did not have the same active burrowing mode of life as <u>Praeleda</u> (one of the other common elements of this association), for the dentition is much reduced. It was however still probably a deposit-feeder.

### Genus Tancrediopsis

Type species: Tancrediopsis contracta (Salter)

# <u>Tancrediopsis</u> ezquerrae (Sharpe, 1853) (Plate 47, figs. 1-5)

- v\*1853 Nucula ezquerrae n.s.: Sharpe p. 149; pl. IX, fig. 3.
  - 1876 <u>Ctenodonta ezquerrae</u>: de Tromelin and Lebesconte p. 624.
  - 1886 Ctenodonta ezquerrae: Barrois p. 680.
- ? 1908 Ctenodonta ezquerrae (Sharpe): Delgado pp. 34,42,59,82, 89,92.
  - 1901 Ctenodonta ezquerrae: Kerforne p. 196.
  - 1966 <u>Ctenodonta costae</u>: Babin p. 52; textfigs. 13-15; pl. 1, figs. 6,7.

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1970 <u>Tancrediopsis ezquerrae</u> (Sharpe) 1853: Bradshaw pp. 628

-630; figs. 5-6.

MATERIAL. Several tens of specimens, as moulds, from the Fonte da Horta and Cabril Formations.

DESCRIPTION. This species was fully described by Bradshaw (1970).

DISTRIBUTION. Abundant in Zones 1-3 of the Fonte da Horta and Cabril Formations.

Genus uncertain

"Leda" escosurae Sharpe, 1853
(Plate 47, fig. 6)

Only a few fragments of this species have been recovered during this project. It seems desirable however to illustrate Sharpe's type-material for the name escosurae has recently been used for Llandeilian material by Babin and Melou (1972) (after Kerforne) and by Gutierrez-Marco et al. (1984) (as Myoplusia escosurae). The type material of Sharpe is however from Zone 7 deposits of the Louredo Formation. The species is not placed here in Myoplusia Neumayr for the overall shape, the dentition and the ornament are all markedly different form those of members of this genus. The ornament contains radial as well as concentric elements to give a very fine reticulate appearance.

Phylum Hemichordata

Class Graptolithina Born, 1846

Order Graptoloidea Lapworth, 1875

Genus Climacograptus Hall, 1865

Climacograptus? bekkeri (Opik, 1927)
(Plate 47, figs. 7,8; fig. 13a)

- 1924 <u>Climacograptus kuckersianus</u> Holm; Elles, 17, pl. 1, figs. 1-7, textfigs. 3-5.
- 1924 Mesograptus modestus E & W; Bekker, 18, pl. 1, figs. 8-9, textfigs. 6a,6b.
- 1927 Diplograptus bekkeri sp. nov.; Opik, 28-33, pl. 6.
- 1932 <u>Climacograptus haljalensis</u> n. sp.; Holm MS; Bulman 10-13, pl. 2, textfigs. 4-6.

Plate 47.

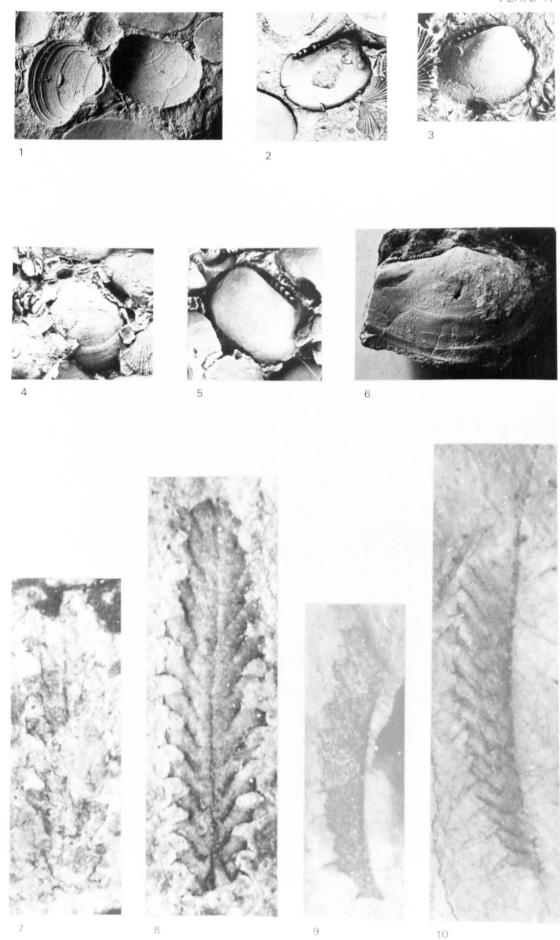
Tancrediopsis ezquerrae (Sharpe, 1853)

Fig. 1 external mould of left valve (to right), with external mould of right valve of <a href="Praeleda costae">Praeleda costae</a> to left), BM.PL 4104 (=Sharpe pl. IX fig 7a), fig. 2 internal mould of right valve, BM.PL 4105 (=Sharpe pl. IX fig. 7b), fig. 3 internal mould of right valve, CACWELL1, fig 4,5 latex cast of external mould and internal mould respectively of left valve, CACWELL1, all x3.0.

"Leda" escosurae Sharpe, 1853
Fig. b internal mould of right valve, BM.PL 4138, (=Sharpe pl. IX fig. 8a), x3.0.

Climacograptus? bekkeri (Opik, 1927)
Fig. 7 Louredo, fig. 8 FAV1, both x10.

Monograptus cf. fritschi Perner, 1899
Figs. 9,10 Carvoieira, both x10.



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MATERIAL. Numerous specimens from several localities, mostly with some relief but often twisted and contorted in a dark but bleached shale or silty micaceous shale.

DESCRIPTION. Judging from the distal fragments available the rhabdosome probably has a total length of about 20mm, and a distal dorso-ventral width (monderate three dimensions) of 2.5mm excluding genicular processes. Including the latter the dorso-ventral width reaches 3.3mm at the level of about th8. Thereafter the genicular processes reduce in size so that the total dorso-ventral width reduces to 2.5mm maximum. At the level of th1 the dorso-ventral width is upto 1.4mm excluding genicular spines (1.9mm including) but by th2 and th2 has already reached 1.8mm (2.2mm) so that the rhabdosome as a whole has a parallel-sided appearance.

In obverse view the sicula is exposed for 0.8mm of its length but the near-transparent periderm shows it to have a length of 1.7-2.0mm with its apex at the level of the aperture of th3. Th1 originates 0.6mm above the sicular aperture, grows downwards to just below the latter position and then turns outwards at about 45 (rather than upwards as in many diplographids) so that its apertural region is quite strongly everted. It possesses a stout sub-apertural spine.

The origin of th1 is about 0.4mm above the aperture of the sicula, and it grows across and then has a more upward disposition than 1 so that its aperture is less everted. The sub-apertural is present but it is a little more proximal than that on th1. It is equally robust and often slightly curved

downwards.

Whilst the sicula has a short robust virgella it is not certain whether there is an anti-virgellar spine since none of the specimens shows this region adequately. Bacause of the odd disposition to thi there is no true geniculum on the ventral wall of thi but thereafter all the thecae have a marked geniculum above a climacograptid thecal excavation, and until about the speciment has a conspicuous spine or process. After this level the geniculum process reduces rapidly so that more distal thecae have no more than a flange.

The distal thecae have also a a more flowing geniculum so that the thecal profile as a whole bacomes less climacograptid and begins to trend towards orthograptid. In part, however, this is a result of preservational views in the material to hand.

The median septum may be complete, and it is more or less straight. The proximal thecae are spaced at about 13 in 10mm, have a length (th1 -3) of about 1mm, and the thecal excavations are semi-circular occupying upto 50% of each stipe's width. more distally the thecae are spaced at as low as 10 in 10mm, have a length of 1.5-1.8mm, and the excavations, although still 0.3-0.5mm wide, now occupy less than 50% of each stipe's width.

The ventral thecal wall and interthecal septum are quite clear on much of the material and show the thecal overlap to be 50% proximally an rather more than 50% distally.

DISTRIBUTION. This species is restricted to the Zone 4 deposits of the Carregueira Formation. It has been found in the Buçaco, Dornes, Amendoa and Mação regions. In the Carregueira Formation

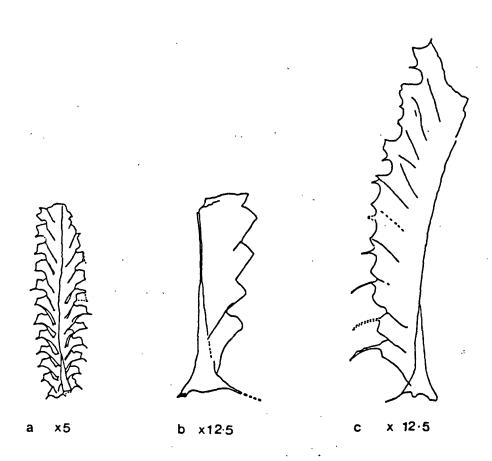


Figure. 13. a. Climacograptus? bekkeri Opik, 1927, Louredo

b. Monograptus cf. deubeli Jaeger, 1959, Zuvinhal

c. Monograptus cf. frischi Perner, 1899, Carvoiera

type section near Mação it has been recovered from several levels within the formation, but at Dornes, Amendoa and Buçaco finds are almost entirely restricted to a single horizon 1.00- 1.20m below the base of the Favaçal Bed.

DISCUSSION. On the preservation it is difficult to detect differences of dimension from locality to locality, but it is clear that they are much the same. The thecal spacing on Opik's original material is a little higher proximally, but about the same distally; and the genicular spines seemingly reduce more quickly to flanges (by about th6) but otherwise general dimensions and details of development are the same. The apertural thecal lips show, on Opik's specimens, low, paired lappets. There is certainly a suggestion of this on the present material but the the thecal apertural rims are not all that well preserved: in general they resemble Opik's pl. &, fig. 12 specimen rather than some of the others, except that the supragenicular wall in the Portuguese material does not slope inwards on any thecae.

Bullman's <u>C. haljalensis</u> is very close to indeed to the Portuguese material on almost all counts. The narrow dorso-ventral width may simply reflect the full three dimensional nature of the Holm material. Whether any of this material should be referred to the genus <u>Climacograptus</u> is doubtful: the thecae show a "<u>Diplograptus</u>" profile change along the rhabdosome, and there is an incipient "<u>Amplexograptus</u>" aspect to the thecal apertural regions. Opik himself referred the species to <u>Diplograptus</u>, but this genus does not display the kind of genicular process development exhibited by <u>C? bekkeri</u>.

Genus Monograptus Geinitz, 1852

Monograptus cf. deubeli Jaeger, 1959
(fig. 13b)

- cf. 1959 Monograptus deubeli n. sp.; Jaeger, 126-127, pl. 10, figs. 4-8.
- cf. 1959 Monograptus deubeli Jaeger 1959; Holland et al. 672-3, pl. 130, fig. 3.

MATERIAL. A monotypic assemblage (locality ZUV28) of more than fifty specimens.

DISCUSSION. In its measurents and dimensions the Portuguese material is very close to the above descriptions, but is remarkable for the exquisite preservation of the sicula. All the siculae show the wide trumpet-shaped aperture (fig. 13c) which is typified by a robust virgella directed almost ventrally, a low flange, and a pronounced dorsal lip (in some instances growth lines are depicted). The material described by Holland et al. showed the trumpet-shaped sicula very clearly, with a suggestion of a lateral flange, but the dorsal process was not so clearly marked (or possibly, so clearly seen). In Jaeger's originals the width of the aperture may be slightly less than in this material but there the dorsal process seems quite well marked. We are, in short, fairly confident that the Portuguese specimens are unusually well preserved specimens of M. deubeli.

Monograptus cf. fritschi Perner, 1899
(Plate 47, figs. 9,10; fig. 13c)

cf. 1899 Monograptus fritschi n. sp.; Perner, pl. 17, fig. 15.

cf. 1942 <u>Pristiograptus</u> (<u>Saetograptus</u>) <u>fritschi</u> <u>fritschi</u> (Perner, 1899); Pribyl, 18-19, pl. 3, figs. 14-16.

MATERIAL. A monotype assemblage of four well preserved specimens from locality "Carvoeira".

DISCUSSION. The specimens are closely comparable to previous descriptions but seem to be better preserved in showing details of spines and siculae more clearly. The distal dorso-ventral width is about 1.5mm where the thecal spacing is of the order of 11 in 10mm; more proximally the thecal spacing may be as high as 16 in 10mm. The thecal spines become shorter distally so that the total dorso-ventral width remains about the same. Two features in particular are seen more clearly than in previously described material. Firstly, the base of the thecal spines (probably paired) is in the middle part of the thecal apertures on th1 and th2 and they gradually migrate dorsally so that by th6 they appear almost as a genicular flange. Secondly, the sicula, whilst having the same size and disposition as in Pribyl's material, displays a very broad trumpet-shaped aperture not unlike that of the stratigraphically earlier M cf. deubeli. This is not illustrated in previous papers but its apparent absence may simply be a function of poorer preservation. The virgella is directed almost fully ventrally, and the mesial part of the Appendix C. 394.

sicular aperture has pronounced lappets, whilst the dorsal process is conspicuous and robust.

Phylum Arthropoda Siebold and Stannius, 1845

?Subphylum Trilobitomorpha Stormer, 1944

Class Trilobita Walch, 1771

Order Ptychopariida Swinnerton, 1915

Suborder Asaphina Salter, 1864

Superfamily Asaphacea Burmeister, 1843

Family ASAPHIDAE Burmeister, 1843

Subfamily Nobiliasaphinae Balashova, 1971

Genus Nobiliasaphus Pribyl and Vanek, 1965

Type species: Asaphus nobilis Barrande, 1846.

Nobiliasaphus sp. A (Plate 48, figs. 1.2)

1908 Asaphus nobilis Barr.: Delgado pp. 33,41,42,50, 57(partim.),

MATERIAL. The only material of this species recovered in the present study was a single pygidium, and a hyperstome which possibly belongs with this species (Plate 48, fig. 9).

DISTRIBUTION. This species has been found in the Fonte da Horta Formation of the Buçaco syncline, in deposits of Zones 1 and 2.

DISCUSSION. The available material of this species does not permit comparison with other known members of the genus. The pygidium of this species shows a relatively wider axis than in the later species (see below). The same difference has been

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observed (Kriz and Pek, 1974) for Llandeilo representatives of the genus in Bohemia, compared with the type species from the Bohdalec Formation.

## Nobiliasaphus sp. B (Plate 48, figs. 3-6)

- v 1908 Asaphus nobilis Barr. : Delgado p. 57 (partim.).
- v 1947 <u>Asaphus nobilis</u> Barrande: Thadeu p. 220; pl. 1, figs. 6-7.
- ? 1976 Nobiliasaphus sp. indet. : Hammann pp. 60-61; pl. 5, figs. 59-61.

MATERIAL. During the present study a pygidium here referred to this species was found in the Poiares Member at Poiares, and fragments recovered from both the Poiares and Leira Ma Members. Two cranidia and three pygidia from the Leira Ma Member are in the museum of the "Serviços Geológicos", and form the basis of Thadeu's (1947) description.

DESCRIPTION. The available material is rather incomplete, but does seem to resemble the type species for the genus,  $\underline{N}$ . nobilis Barrande, fairly closely, in possessing a relatively narrow pygidial axis, which tapers from the anterior of the pygidium. The earlier sp. A (above) has a wider axis, in which the first few axial rings show little decrease in width.

DISTRIBUTION. This species is best known (Thadeu, 1947) from the

base of the Porto de Santa Anna Formation (Leira Ma Member: Zone 8) of the Louredo area (Buçaco syncline). In addition a pygidium is described here from the base of the Ferradosa Formation (Poiares Member: Zone 9) at Poiares, further south in the Buçaco syncline. Hammann (1976) records material of Nobiliasaphus from the Sierra Morena in the upper part of the "Bancos Mixtos", which yields other trilobites and brachiopods in common with the Leira Ma Member.

### Subfamily Uncertain

"Ogygia" glabrata Salter, 1853
(Plate 48, figs. 7,8)

- 1853 Ogygia glabrata Salter, n.s.: Sharpe p. 141
- \* 1853 Ogygia? glabrata n.s.: Salter, in Sharpe p. 160; pl. VII, fig. 4.
  - 1908 Asaphus glabratus Sh.: Delgado p. 33.
  - 1908 Ogygia glabrata Sh.: Delgado pp. 42,57.

MATERIAL. Four pygidia of this species were recovered during this study, all from the Fonte da Horta Formation (Zones 1 and 2) of the Buçaco syncline.

DISCUSSION. As no cephalic material is known at present, this species will not be described further here.

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Superfamily Illaenacea Hawle and Corda, 1847

Family ILLAENIDAE Hawle and Corda, 1847

Subfamily Ectillaeninae Jaanusson, 1959

Genus Ectillaenus Salter, 1867

Type species: Ectillaenus perovalis (Murchison, 1839).

# Ectillaenus sp. A (Plate 48, figs. 10-12)

- ? 1853 <u>Illaenus giganteus</u>, Burm. : Salter, in Sharpe pp.141, 158-159; pl. VII, fig. 1.
  - 1908 <u>Illaenus Hispanicus</u> Vern. et Barr. : Delgado pp. 33, 41,42,50,57.
  - 1908 Illaenus Lusitanicus Sh.: Delgado pp. 42,57.

MATERIAL. Material recovered during this project includes an internal mould of an articulated carapace (fig. 11), a thorax and pygidium (internal and external moulds) (fig. 12), a partly articulated but disturbed carapace (fig. 10), as well as various smaller fragments.

DESCRIPTION. Cephalon with fairly small eyes, set at a distance from the axial furrows equivalent to 80% of the minimum distance apart of the furrows. Axial furrows adaxially bent between the eyes. Pygidial axial furrows short, pygidium 70% as long as broad. Axis of thorax broad. 10 thoracic segments.

DISTRIBUTION. This species is found in the Fonte da Horta Formation (Zones 1 and 2), and probably occurs throughout central Portugal.

## Ectillaenus? <u>loredensis</u> (Thadeu, 1947) (Plate 48, figs. 16,17)

v 1908 <u>Illaenus Loredensis</u> sp. n.: Delgado, p. 57. (<u>nom. nud.</u>)
v 1947 <u>Illaenus loredensis</u> Delgado: Thadeu, p. 221, pl. II,
figs. 1-3.

This species was described in some detail by Thadeu, so a description will not be given here. The species is close to sp. A above, but differs in the following respects: the eyes are larger, set further backwards, and lie 70% of the distance apart of the axial furrows, from the furrows, the axial furrows of the pygidium continue further back, and finally the pygidium is about 80% as long as broad.

Subfamily Bumastinae Raymond, 1916

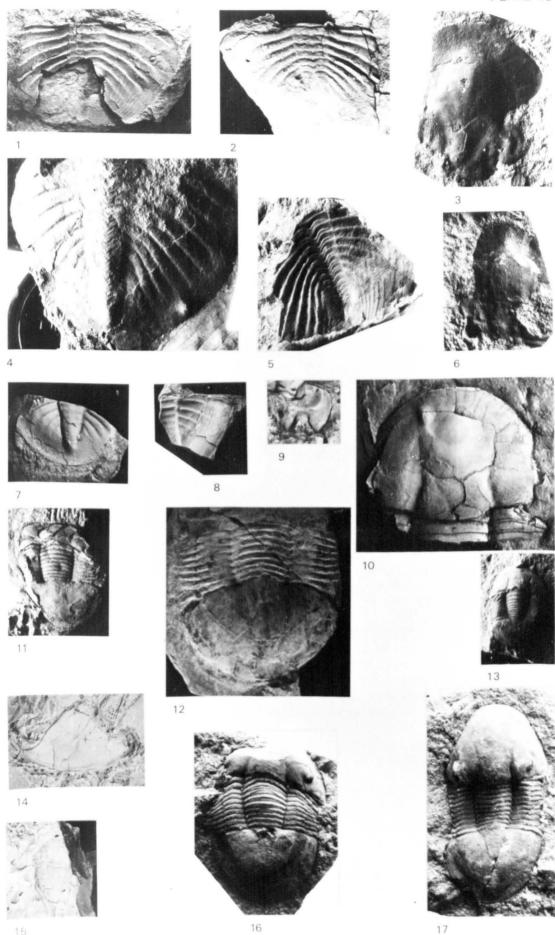
Genus <u>Dysplanus</u> Burmeister, 1843

Type species: Asaphus (Illaenus) centrodus Dalman, 1827

Subgenus <u>Zetillaenus</u> Snadjr, 1957

Type species: <u>Illaenus</u> wahlenbergianus Barrande, 1852

(Plate 48, fig. 15)



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v 1980 <u>Dysplanus</u> sp. indet.: Cooper pp. 227-230, pl. 21, fig. 1

MATERIAL. This species is represented by several rather fragmentary pygidia and a poorly preserved articulated specimen (fig. 15).

DESCRIPTION. The material found adds little to the observations of Cooper, based on cranidial material.

DISTRIBUTION. <u>Dysplanus</u> is a relatively common element of the Zone 6 trilobite fauna of the Queixopeira Member.

Plate 48.

## Nobiliasaphus sp. A

Fig. 1,2 external and internal moulds of pygidium, CACWELL2, x1.0.

#### Nobiliasaphus sp. B

Figs. 3,6 internal moulds of cranidia, figs. 4,5 internal moulds of pygidia, all x1.0, Leira Ma.
"Ogygia" galabrata Salter, 1853

Figs. 7,8 internal and part of external mould of pygidia, CACWELL2, x1.0.

Asaphid indet.

Fig. 9 Hyperstome, CACWELL1, x1.0.

### Ectillaenus sp. A

Fig. 10 internal mould of cranidium, CACWELL1, fig. 11 internal mould of complete exoskeleton, CACWELL1, fig. 12 internal mould of pygidium and thorax, CAC1, all x1.0 except 12 which is x0.6..

## Dysplanus sp. A

Fig. 15 external mould of articulated specimen, QXP2, x1.0.

#### Dysplanus sp. B

Figs. 13,10,17 internal moulds, Leira Ma, x1.0.

Colpocoryphe grandis (Snajdr, 1956)

Fig. 14 internal mould of free-cheek, QXP2, x1.0.

<u>Dysplanus</u> (<u>Zetillaenus</u>) <u>ibericus</u> Hammann, 1976 (Plate 48, fig. 13)

- v 1908 <u>Illaenus</u> cf. panderi Barr. : Delgado p. 57.
  - 1947 <u>Illaenus Wahlenbergianus</u> Barrande : Thadeu p. 222;pl. 2, fig. 4.
- \* 1976 <u>Dysplanus</u> (<u>Zetillaenus</u>) <u>ibericus</u> n.sp.: Hammann pp. 51-53; pl. 2, figs. 23-25; pl. 3, figs. 26-37; textfig. 5.

MATERIAL. The portuguese material of this species is restricted to a single articulated specimen.

DESCRIPTION. This specimen agrees with the description of Hammann (1976).

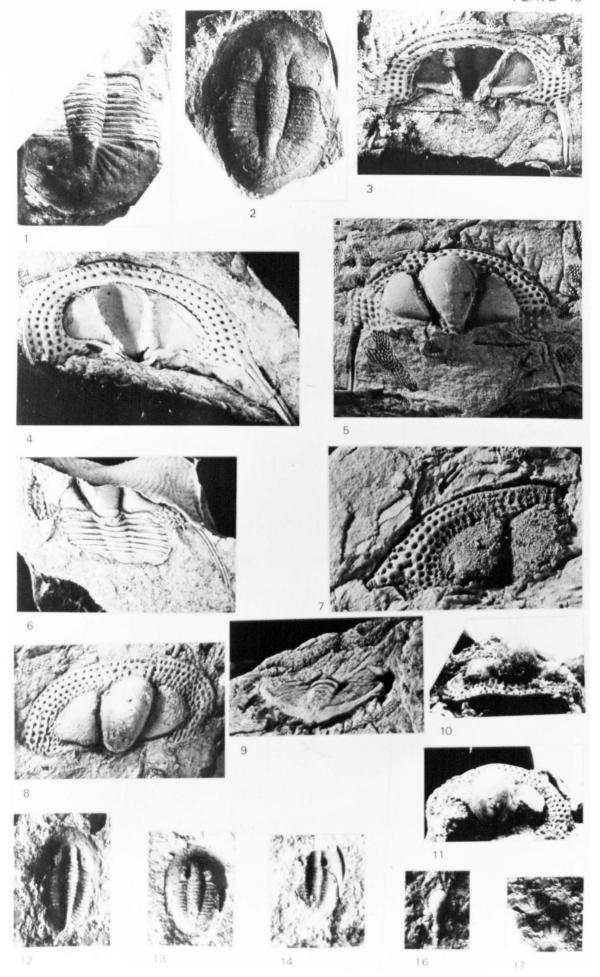
DISTRIBUTION. The specimen is from Leira Ma, form the Zone 8 deposits of the Leira Ma Member.

DISCUSSION. The prescence of this species at Leira Ma is yet another tie between the fauna of the Leira Ma Member and that of the upper part of the Bancos Mixtos of the Sierra Morena.

Genus <u>Delgadoa</u> Thadeu, 1947

Type species: <u>Delgadoa</u> loredensis (Thadeu, 1947).

Delgadoa loredensis (Thadeu, 1947)
(Plate 49, figs. 1,2)



v Choffatia loredensis gen. et sp. n.: Delgado p. 57 (nom. nud.)
v Delgadoa loredensis (Delgado) nov. comb.: Thadeu pp. 223,224,

Pl. 1, figs. 8-12.

This species was described by Thadeu, 1947, and will not be redescribed here. Some comment on the genus <u>Delgadoa</u> Thadeu is, however, necessary. The initial designation of this species (Delgado, 1908) was without either a specific or generic definition, but merely a mention in a faunal list. Thadeu subsequently accepted Delgado as author of the species, but pointed out that the generic name used by Delgado (<u>Choffatia</u>) was already occupied by a plant, and hence he erected a new generic name, <u>Delgadoa</u>. In fact the occupation of the name by a plant would not prevent its use under the ICZN for an animal as well. However, as Delgado did not supply a definition it seems

Plate 49.

Delgadoa loredensis (Thadeu, 1947)

Figs. 1,2 internal moulds of articulated specimens, Leira Ma, x1.0.

Deanaspis seunesi (Kerforne, 1900)

Figs. 3,4 latex casts of internal moulds of cephala, QXP2, fig. 5 internal mould of cephalon, QXP2, fig. 6 latex cast of external mould of articulated specimen, QXP2, fig. 7 internal mould of cephalon, VACA2, fig. 8 latex cast of external mould of cephalon, QXP2, fig. 9 internal mould of pygidium, QXP2, all x2.8.

Onnia? sp.

Figs. 10,11 two views of internal mould of cephalon, bed 4 of Delgado's Zuvinhal section, in SGL. x1.0.

"Proetus" loredensis Thadeu, 1947

Figs. 12-14 internal moulds of three articulated carapaces, Leira Ma, in SGL, all x1.0.

Phillipsinella sp. indet.

Fig. 16 internal mould of cranidium, fig. 17 internal moulds of two pygidia, both from bed 2 of Delgado's Val San Jorge section, specimens in SGL, x2.0.

desirable to leave both his names invalid, and to adopt Thadeu's generic name, and to accept Thadeu as author of the species.

The occurrence of all the material is within the Zone 8 deposits of the Leira Ma Member, at Leira Ma itself.

Suborder Harpina Whittington, 1959

Family HARPIDAE Hawle and Corda, 1847

Genus <u>Eoharpes</u> Raymond, 1905

Type species: Harpes primus Barrande, 1856.

Echarpes macacensis Romano and Henry, 1982

- ? 1908 Harpes of. Flanaganni Portlock: Delgado p. 80.
- ? 1908 Harpes cf. Doranni Portlock : Delgado p. 80.
- v 1982 Echarpes macacensis sp. nov.: Romano and Henry pp. 626-629; pl. 63, figs. 1-6.

MATERIAL. Two cephala of this species were recovered in this study. Both of these were from the Queixopeira Member of the Mação area (sample QXP2).

DESCRIPTION. The new material adds nothing to the description given by Romano and Henry (1982).

DISTRIBUTION. This species is only known from the lower part of the Queixopeira Member (Zone 6) of the Mação area.

DISCUSSION. This species is one of several which belong to

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genera unknown in central Portugal before Zone 6, but whose representatives do occur in earlier deposits in northern Portugal.

Suborder Trinucleina Swinnerton, 1915

Family TRINUCLEIDAE Hawle and Corda, 1847

Subfamily Marrolithinae Hughes, 1971

Genus <u>Deanaspis</u> Hughes, Ingham and Addison, 1975

Type species: <u>Deanaspis</u> bedinanensis Dean, 1967

## <u>Deanaspis</u> <u>seunesi</u>? (Kerforne 1900)

- 1853 Trinucleus Pongerardi Rouault: Ribeiro p. 141.
- 1853 <u>Trinucleus Pongerardi</u> Rouault: Salter, in Ribeiro, pp. 159-160.
- 1900 Trinucleus seunesi: Kerforne
- 1908 <u>Trinucleus Bureaui</u> Oehlert: Delgado pp. 32,40,58 (partim). 80, 88.
- 1908 <u>Trinucleus Goldfussi</u> Barr. Delgado p. 58 (partim)
  - 1908 Trinucleus Seunesi Kerforne: Delgado p. 80
  - 1974 Onnia sp.: Mitchell p. 388
  - 1974 Onnia cf. seunesi p. 389
  - 1975 Onnia seunesi (Kerforne, 1900): Hughes et al. pp. 575,
    596

MATERIAL. This species is represented by fragmentary material from the Zone 5 Favaçal Bed, by abundant (several tens) specimens from the Zone 6 Queixopeira Member (on which material this

description is largely based), and several, generally less well-preserved material from Zone 7 of the Louredo Formation of Buçaco and Penha Garcia.

DESCRIPTION. Cephalic outline rounded to subangular in front, and rounded laterally. Lateral margins straight, or slightly concave anterior of base of genal spine. "Ears" moderately large, with posterior border to fringe slightly sigmoidal, with greatest curvature just medial to outside of cheek lobes; greatest breadth is across genal angles, and is about twice median length of cephalon; glabella and cheek lobes smooth; glabella pear-shaped, 60% as wide as long, swollen anteriorly where it overhangs the fringe, its maximim width just posterior to hyperstomal pits; axial furrows straight, with small hyperstomal pit towards anterior end; in front of the hyperstomal pit and posterior to the fringe pits there is a small area (1.5x0.5mm on a large specimen) bearing at least 20 small tubercles on the underside of the carapace.

Occiptial furrow well-marked, especially laterally where there are a pair of occipital pits; occipital ring narrow, and does not bear a spine; pleuroccipital fuurow narrow, fulchral pits situated about 30% of the distance from the axial furrow to the lateral margin. Genal spines about 1.7 times the length of cephalon in length, and are continuous with lateral margin of fringe; marginal suture of usual trinucleid type, there may be a raised marginal rim.

The pits of I1 and I2 are larger than those of I3 and E1 which are of a comparable size to each other, I1 may be raises

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above E1, but there is often no true girder list anteriorly, although it may be developed laterally, E1 contains several auxiliary pits; F, In and I3 pits may lie in radial sulci antero-laterally; the number of pits is as follows:

E1+e1 = 24

I1 = 20 · · · ·

I2 = 19

I3 = 12

 $\mathbf{n}_{\mathbf{p}}$  In = 13  $\mathbf{n}_{\mathbf{p}}$ 

F = 15

and typically have the following distribution: .

E1 0-17, e1 I, III, IX, XIV, XV, I1 0-18, 11 XIX, I2 0-18, I3 6-18, In 2-15.

There are usually 7 pits on the posterior margin if the fringe.

The ventral surface of the fringe has a poorly developed girder, usually only distinct laterally; anteriorly the first internal pseudogirder is very prominent, while the second is also noticeable laterally; the declined margin of the fringe and each of the interarc gaps bears clearly marked terrace-lines; those of the girder appear continuous with the line of the ridge on the lower face of the genal spine, while each of the internal sets swings inwards along the posterior margin, and along the posterior interradial.

The thorax is poorly known (specimen in fig. 6 only), and the pygidium is known only from three specimens; pygidium about 3 times as wide as long, with a steeply declined margin, outline is roundedly triangular, about 1 clear, and four indistinct axial

rings.

DISTRIBUTION. Material of this species has been recovered from the Favacal Bed of Buçaco and Mação (Zone 5), from the lower part of the Louredo Formation of Penha Garcia (Zone 6?), from the Queixopeira Member of the Mação area (Zone 6), from the Vale Saido and Zuvinhal Members of the Buçaco area (Zone 7), and from the Vaca Member of the Louredo Formation in the Penha Garcia syncline (Zone 7). Outside Portugal the species has its type material from the upper part of the Kermeur Formation of Crozon.

DISCUSSION. No significant differences have been found between the different populations of this species recovered. None of the material shows development of an occipital spine.

The generic assignation of this species requires some justification. The species was placed in Onnia by Hughes et al. (1975), and indeed it does tend to show the development of the first internal pseudogirder that characterises that genus. However, the strong development of that pseudogirder is restricted to the anterior regions of the fringe, and in these same areas the girder is much more strongly developed than is usual for Onnia. A weak girder list and an internal list are shown in some specimens. The degree of differentiation in size of I1 and I2 pits is not that great; in some specimens (e.g. that in fig. 8) these pits are barely larger than the other arcs.

The overall impression given by this species is that it is not a typical <u>Onnia</u>. However, it is close in many respects to that genus. It may be that this species represents a stock

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intermediate between the typical Llandeilo to lower Caradoc Deanaspis, and the typical upper Caradoc Onnia. It is decided on balance to place this species in the genus Deanaspis.

Genus Onnia Bancroft, 1933

Type species: Onnia superba (Bancroft, 1929)

\* \*\*

Onnia? sp. A
(Plate 49, figs. 10,11)

- 1908 Trinucleus Bureaui Oehlert: Delgado p. 31,58 (partim)
- 1908 Trinucleus Goldfussi Barr.: Delgado p. 58 (partim)
- 1947 Trinucleus Bureaui Oehlert: Thadeu p. 219, pl. 1, fig. 1
- 1947 <u>Trinucleus Seunesi</u> Kerforne: Thadeu p. 219,220 pl. 1 figs. 2-5

The lower part of the Porto de Santa Anna Formation has yielded several specimens in the past, and these are to be found in the collections of the Serviços Geológicos. None was found during the present study. However, several specimens were recovered during the current project from the lower part (Zone 9) of the Rosan Formation.

This material has not yet been fully studied, but several differences from the earlier species <u>seunesi</u> are discernable. These include a more convex fringe, a more angular anterior margin, and a less elongate glabella. The single specimen showing the lower lamella of the fringe hints that this material material might be best placed in <u>Onnia</u>, for it seems to show a

very strong first internal pseudogirder antero-laterally.

Order Proetida Salter, 1864

Family PROETIDAE Salter, 1864

Genus uncertain

"Proetus" loredensis Thadeu, 1947
(Plate 49, figs. 12-14)

v 1908 <u>Proetus Loredensis</u> sp. n.: Delgado p. 57 (<u>nom. nud.</u>)
v\*1947 <u>Proetus loredensis</u> Delgado: Thadeu pp. 226,227; pl. 2
figs. 11-13

This species is represented by several articulated specimens in the museum of the Serviços Geológicos, from the Zone 8 deposits of the Leira Ma Member. It will not be described here.

Family PHILLIPSINELLIDAE Whittington, 1950

Genus Phillipsinella Novak, 1885

Type species: Phacops parabola Barrande, 1846.

Phillipsinella sp. indet.

v 1908 Phillipsia parabola Barr. : Delgado pp. 38,57.

This material derives from a level yielding a Zone 10 fauna, but must be very close stratigraphically to the level yielding a Zone 11 fauna. The future study of this species is therefore of

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some importance. The material is not very well preserved, and comprises some 20 pygidia and cephala. There is at least one articulated specimen. All the material is from bed 2 of Delgado's Val San Jorge section, in the upper part of the Porto de Santa Anna Formation.

Order Phacopida Salter, 1864

Suborder Cheirurina Harrington and Leanza, 1957

Family CHEIRURIDAE Salter, 1864

Subfamily Eccoptochilinae Lane, 1971

Genus Eccoptochile Hawle and Corda, 1847

Type species: Cheirurus claviger Beyrich, 1845.

Eccoptochile (Eccoptochile) cf. clavigera (Beyrich, 1845)
(Plate 50, figs. 1-5).

cf1845 <u>Cheirurus claviger</u>: Beyrich, p. 13, figs. 2,3
cf1852 <u>Cheirurus claviger</u> Beyrich; Barrande, pl. 40, figs. 1-12,
pl. 42, fig. 1

1908 Cheirurus claviger Beyr.: Delgado p. 80, 92
cf1947 Eccoptochile (Eccoptochile) clavigera clavigera
(Beyrich), 1845: Prantl and Pribyl, p. 26, pl. VI,
figs. 1,2

cf1956 Eccoptochile (Eccoptochile) clavigera (Beyrich, 1845):

Snajdr, pp. 507-508, pl. III, fig.10; pl. V, fig. 8
cf1966 Eccoptochile (Eccoptochile) clavigera (Beyrich): Havlicek
and Vanek, pp. 53,55,57,58,66; pl. X, fig. 5
v 1980 Eccoptochile (Eccoptochile) clavigera (Beyrich, 1845):

Cooper pp. 242-246; pl. 22, fig. 9

1980 Eccoptochile (Eccoptochile) cf. clavigera (Beyrich,

1845): Romano p. 614; pl. 79, fig. 9.

MATERIAL. This material includes about a dozen cranidia, several partly articulated specimens and several isolated pygidia and hyperstomes.

DESCRIPTION. This species will not be described here. The material described by Romano and Cooper is conspecific with the present material. The material now available is considerably more than either of these previous authors had, and a revision of this species is required.

DISTRIBUTION. This species is found in the lower part of the Queixopeira Member (Zone 6) of the Dornes and Mação areas.

Eccoptochile claviger is known from the Libeň to Bohdaleč Formations of Bohemia.

DISCUSSION. The prescence of <u>Eccoptochile</u> within the <u>Drabovia</u> cf. <u>redux</u> association of Zone 6 is another example of the migration into central Portugal during Zones 5 and 6 of genera previously known from northern Portugal, but not from the central areas.

Eccoptochile (Eccoptochile) sp. aff. clavigera (Beyrich, 1845)

(Plate 50, figs. 6-8)

v 1908 Cheirurus claviger Beyr.: Delgado p. 57 (partim)

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v 1947 <u>Cheirurus claviger</u> Beyrich: Thadeu pp. 228,229; pl. III, figs. 2-3

v 1947 Cheirurus (?) Venceslasi Delgado: Thadeu pp. 229,230; pl. III, fig. 5.

This species closely resembles Beyrich's species. it is also somewhat similar to <u>Eccoptochile? impedita</u> Hammann 1972, but this species appears (from Hammann's illustrations) to have longer 2p and 3p furrows, and a 1p fuurow with a more posteriorly inclined medial termination. As with the previous species, it must be remarked that a revision of the upper Ordovician cheirurids in Portugal would be desirable. All the available material of this species is from the Zone 8 Leira Ma Member.

Genus <u>Pseudosphaerexochus</u> Schmidt, 1881

Type species: <u>Pseudosphaerexochus</u> hemicranium (Kutorga, 1854)

# Pseudosphaerexochus? sp. A (Plate 50, figs. 9-14)

- v 1908 Cheirurus Bocagei sp. n.: Delgado p. 57.
- v 1908 Cheirurus Venceslasi sp. n.: Delgado p. 57.
- v 1908 Cheirurus cf. tumescens Barr.: Delgado p. 57.
- v 1908 Cheirurus aff. verrucosus Brogger: Delgado p. 57.
- v 1947 Cheirurus(?) Bocagei Delgado: Thadeu p. 228; pl. III, fig. 1.
- v 1947 Cheirurus aff. completus Barrande: Thadeu pp. 230,231;

pl. III, figs. 6-7.

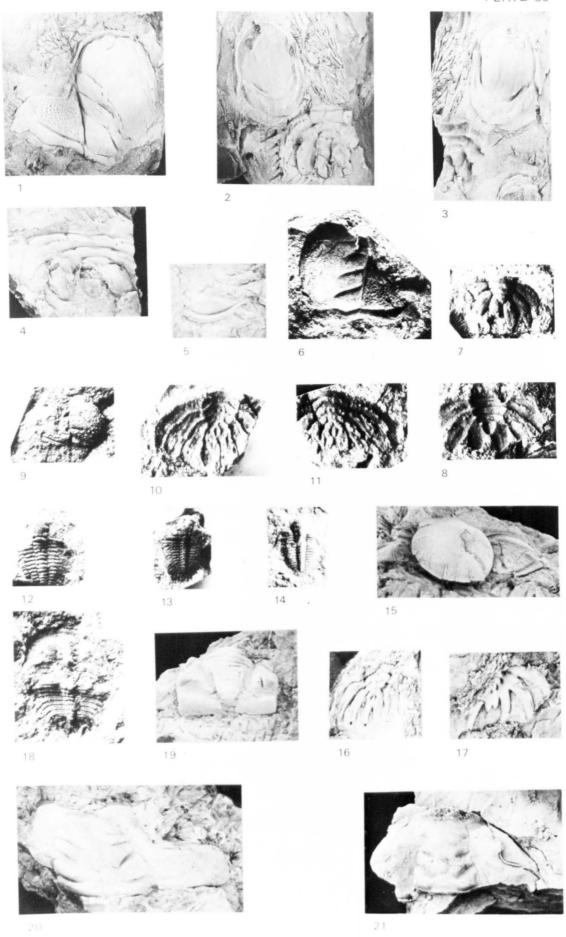
v 1947 Cheirurus aff. verrucosus Brogger: Thadeu p. 231; pl.

III, fig. 8.

MATERIAL. This species is represented in the collections of the Servicos Geológicos by ther material illustrated here, and by another pygidium.

DESCRIPTION. The material grouped into this species in this study was subdivided greatly by Delgado and Thadeu. However, all the material shows a similar tuberculate ornament, and possesses a more inflated glabella than E sp. aff. clavigera. The generic assignation of this form is somewhat doubtful, particularly because of the inflated glabella, and the pygidium which bears four pairs of pleural spines. The thorax includes 11 segments. The thorax and pygidium are compatible with Actinopeltis, but the glabella is not sufficiently inflated. None of the subgenera of Eccoptochile possess 11 thoracic segments, so an assignation to Pseudosphaerexochus is possible. The pygidial spines of this genus are, however, usually pointed, rather than the rounded Eccoptochile-like spines present in this material. This species appears close to Actinopeltis vercingetorix Pribyl and Vanek, 1969, but for the reasons given above the generic assignation of this species should perhaps also be reconsidered.

DISTRIBUTION. All this material is from the Zone 8 Leira Ma Member of the Leira Ma locality, Louredo, in the Buçaco syncline.



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Genus Actinopeltis Hawle and Corda, 1847

Type species: Cheirurus globosus Barrande, 1846

### Actinopeltis tejoensis Romano (in prep.)

(Plate 50, figs. 15-17)

v 1908 Cheirurus sp. n. aff. gryphus Barr.: Delgado p. 80

This species will be described in the near future by Romano. The species is restricted to the Zone 6 deposits of the Queixopeira Member, which have yielded two cephala, a thorax, and two isolated pygidia.

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Plate 50.

Eccoptochile cf. clavigera (Beyrich, 1845)

Fig. 1 internal mould of cranidium, figs. 2,3 internal and external moulds of pygidium and hyperstome, fig. 4 internal mould of pygidium, fig. 5 internal mould of free cheek, all from QXP2, all x1.0.

Eccoptochile sp. aff. clavigera (Beyrich, 1845)

Fig. b internal mould of cranidium, figs. 7,8 internal moulds of pygidia, all from Leira Ma, x1.0.

Pseudosphaerexochus? sp. A

Fig. 9 internal mould of cranidium, figs. 10,11 external and internal moulds of a pygidium, figs. 12-14 internal moulds of articulated carapaces, all from Leira Ma, all x1.0.

Actinopeltis tejoensis Romano (in prep.)

Fig. 15 internal mould of cephalon, figs. 16,17 latex casts of external moulds of pygidia, all from QXP2, all x2.0.

Areia? sp.

Fig. 18 internal mould of carapace, Leira Ma, x1.0.

Colpocoryphe grandis (Snajdr, 1956)

Fig. 19 internal mould of pygidium, fig. 20 internal mould of cranidium, both QXP2, x1.0.

Neseuretus (Neseuretus) tristani (Brongniart, 1822) Fig. 21 internal mould of cephalon, CACWELL1, x1.0.

Subfamily Areiinae Prantl and Pribyl, 1947

Genus <u>Areia</u> Barrande, 1872

Type species: <u>Areia bohemica</u> Barrande, 1872

Areia? sp.

(Plate 50, fig. 18)

- v 1908 Areia Bussacensis sp. n.: Delgado p. 57 (nom. nud.)
- v 1947 Cheirurus gelasinosus Portlock: Thadeu p. 229; pl. III, fig. 3

The single specimen of this species is the internal mould, partly damaged, of an articulated carapace. The overall resemblance of the specimen to Areia bohemica Barrande seems to justify its inclusion in that genus. Thadeu, however, points out that the pygidium has two axial rings and pairs of spines in bohemica, whereas this specimen, he claimed, has three. Examination of the specimen does not bear out Thadeu's claim, and the pygidium does seem to have two pairs of spines. Delgado's assignation of the species to Areia is therefore tentatively upheld, pending full description of the portuguese material.

The specific name also provides problems, for Delgado did not describe the species, and his name of <u>bussacensis</u> must be regarded <u>nomen nudum</u>. The material is therefore left here in open nomenclature. The name <u>bussacensis</u> would still be available if on full examination the species does appear to be distinct.

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Suborder Calymenina Swinnerton, 1915

Family COLPOCORYPHINAE Hupe, 1955

Genus Colpocoryphe Novak in Perner, 1918

Type species: Calymene arago Rouault, 1849.

Colpocoryphe grandis (Snadjr, 1956)

(PLate 48, fig. 14; Plate 50, figs. 19,20)

- 1901 Calymene aragoi Rouault: Kerforne pp. 176-177.
- ? 1908 Calymene Aragoi Rou. : Delgado pp. 41,57(partim.).
  - 1926 <u>Calymene</u> (<u>Synhomalonotus</u>) <u>tristani</u> (Brongniart): Born p. 202.
  - 1950 <u>Colpocoryphe aragoi</u> (Rouult 1848): Termier and Termier pl. 194, figs. 1-3; pl. 199, fig. 1.
- \* 1956 <u>Calymene (Colpocoryphe) grandis</u> nov. sp.: Snajdr pp. 529-530; pl. 3, figs. 1-9.

....

- 1965 <u>Plaesiacomia grandis</u> (Snajdr, 1956): Vanek p. 29;pl. 2, figs. 7-8.
- 1965 <u>Colpocoryphe of grandis</u> Snajdr: Babin and Plusquellec; pl. 1, fig. 1.
- 1966 Colpocoryphe grandis (Snajdr 1956): Destombes pp. 35-36 pl. 2, figs. 1-7.
  - 1966 Colpocoryphe grandis Snajdr: Havlicek and Vanek pl. 8, fig. 5.
- 1968 <u>Colpocoryphe lennieri</u> (Bergeron 1894): Babin et al. p. 268.
  - 1969 Colpocoryphe lennieri (Bergeron): Henry p. 17.
    - 1970 Colpocoryphe grandis Snajdr, 1956 : Gil Cid p. 285;pl.

- 1, fig. 6.
- 1973 <u>Colpocoryphe lennieri</u> (Bergeron 1894): Clarkson and Henry p. 118.
- 1974 <u>Colpocoryphe lennieri</u> (Bergeron): Lindstrom,
  Racheboeuf and Henry fig. 3
- 1974 <u>Colpocoryphe lennieri</u> (Bergeron 1894) : Henry <u>et al</u>.: p. 333.
- 1980 Colpocoryphe cf. lennieri (Bergeron, 1893): Cooper pp. 272-277; pl.24, fig. 7.
- 1980 <u>Colpocoryphe grandis</u> (Snajdr 1956): Henry pp. 64-66; textfig. 21; pl. 8, figs. 1-3,5,7-8; pl. 45, fig. 3.
- 1983 <u>Colpocoryphe grandis</u> (Snajdr 1956): Hammann pp. 85-87; textfig. 34; pl. 14, figs 131-133.

This species will shortly be redescribed by Romano, so no description will be given here. Some comment on its distribution is however desirable. The first appearance of the species is within the upper part of Zone 4, in the Carregueira Formation. It is abundant in the Favaçal Bed, being represented by numerous articulated specimens, and is also numerous at Queixopeira in Zone 6. The species has not yet been recorded in Zone 6 outside the Mação area, but at its other horizons it occurs more widely. No material of this species has been recorded from Zone 7 deposits in Portugal, but Henry (1980) records it from the Schistes de Raguenez (Zone 7) of Crozon. It is just possible however that this is a product of the historical confusion of the Schistes de Veryac'h and the Schistes de Raguenez (discussed by Babin and Melou, 1972), for the species is abundant in the

Schistes de Veryac'h (Zone 4).

Subfamily Reedocalymeninae Hupe, 1955

Genus <u>Neseuretus</u> Hicks, 1873

Type species: <u>Neseuretus ramseyensis</u> Hicks, 1873

Subgenus <u>Neseuretus</u> Hicks, 1873

Neseuretus (Neseuretus) tristani (Brongniart, 1822)
(Plate 50, fig. 21; plate 51, fig. 1)

For a full synonomy see Hammann (1983).

This species is ubiquitous in the mudstones of the Fonte da Horta and Cabril Formations (Zones 1 to 3). Its last appearance seems to be within the <u>Marrolithus bureaui</u> Biozone. It has not been possible, on the basis of the available material, to attempt to subdivide the species into subspecies as has been done by Hammann (1983). The descriptions by Henry (1980) and Hammann (1983) serve to illustrate this well-known species adequately, so no description will be attempted here.

Genus <u>Calymenella</u> Bergeron, 1890

Type species: <u>Calymenella boisseli</u> Bergeron, 1890

Calymenella boisseli Bergeron, 1890

\* 1890 <u>Calymenella boisseli</u> n.g. n.sp.: Bergeron pp. 365-371; pl. 5, figs. 1-7.

1948 <u>Calymenella boisseli</u> Bergeron 1890 : Dreyfuss p. 55; pl. 11, figs. 4,5.

- 1950 <u>Eohomalonotus</u> (<u>Calymenella</u>) <u>boisseli</u> (Bergeron 1890):

  Prantl and Pribyl p. 124.
- 1957 <u>Calymenella</u> (<u>Calymenella</u>) <u>boisseli</u> Bergeron 1890: Sdzuy p. 288.
- ? 1959 <u>Calymenella (Eohomalonotus) boisseli</u> Bergeron 1890 : Cavet p. 141.
  - 1961 Calymenella boisseli Bergeron 1890: Whittard p. 163
  - 1978 <u>Calymenella boisseli</u> Bergeron 1890: Hammann and Henry pp. 405-407; textfig. 1; pl. 1, figs. 1-5.
  - 1980 <u>Calymenella</u> (<u>Calymenella</u>) <u>boisseli</u> Bergeron, 1890:

    Cooper pp. 246-251, pl. 22 fig. 10; pl. 23 figs. 1-2.
  - 1980 <u>Calymenella boisseli</u> Bergeron 1890: Henry pp. 74-76; textfigs. 28,30; pl. 12, figs. 6-10.
  - 1983 <u>Calymenella boisseli</u> Bergeron 1890 : Hammann pp. 72,73; pl. 15, fig. 137.

Cooper recorded this species from the upper part of the Cabeco do Peao Formation. Some very poor material was found at the same horizon, in the present study, but was not specifically identifiable. Material of this genus was also found in the present study at Penha Garcia in Zone 7 sediments, and although poor, this material suggested <u>C. alcantarae</u> Hammann and Henry, 1978.

Cooper's material of <u>C. boisseli</u> does not appear to have been found in the Serra do Cadaveira Member as now defined (see chapter 1), but from a slightly lower horizon within the

formation.

Subfamily Pharastomatinae Hupe, 1953

Genus <u>Prionocheilus</u> Rouault, 1847

Type species: <u>Prionocheilus</u> verneuili Rouault, 1847.

the state of

#### Prionocheilus mendax (Vanek, 1963)

1900 Calymene pulchra Barrande: Kerforne p. 173.

- 3.

- 1900 Calymene pulchra Barrande: Bureau p. 165, fig. 23.
  - 1907 <u>Prionocheilus verneuili</u> Rouault, 1847: Bezier figs. P.1-
- \* 1965 Pharostoma pulchrum mendax subsp. n.: Vanek pp. 30-32, fig. 6; pl. 2, fig. 10; pl. 3, figs. 6,7; pl. 4, figs. 2-5.
  - 1966 <u>Pharostoma pulchrum mendax</u> Vanek: Havlicek and Vanek pl.

    10, fig. 6.
- 1969 <u>Prionocheilus pulcher</u> subsp. indet.: Racheboeuf p. 74; pl. 3, figs. 1a-c.
  - 1974 <u>Prionocheilus pulcher mendax</u> (Vanek): Lindstrom et al. p. 21.
  - 1976 <u>Prionocheilus mendax</u> (Vanek, 1965): Pribyl and Vanek p. 38, pl. 4, fig. 1.
  - 1980 <u>Prionocheilus mendax</u> (Vanek 1965): Henry pp. 80-82; figs. 31,82; pl. 13, figs. 5,6; pl. 14, figs. 1-7.

Material of this species has been recovered from the lower part of the Fonte da Horta Formation in the Penha Garcia

syncline. The species is also known from the Valongo Formation of the Valongo syncline, northern Portugal.

## Prionocheilus cf. pulcher (Barrande, 1846) (Plate 51, figs. 2-4)

- 1846 Calymene pulchra: Barrande p. 27.
- 1847 Pharostoma pulchrum: Hawle and Corda, p.88 pl. 5 fig. 49.
- 1852 Calymene pulchra Barrande: Barrande p. 575, pl. 19.
- 1872 Calymene pulchra Barrande: Barrande p. 36, pl., 16.
- 1908 Calymene pulchra Barr.: Delgado p. 80.
- 1917 Calymene (Pharastoma) pulchra: Novak in Perner, p. 12
- 1953 Pharostoma pulchrum (Barrande): Pribyl p. 25.
- 1955 Pharastoma pulchrum pulchrum (Barrande, 1846): Snajdr, pp. 504-505.

This species is known in central Portugal from the lower part of the Queixopeira Member in the Mação area (samples QXP2 and ABO10). In Bohemia  $\underline{P}$ .  $\underline{pulcher}$  occurs in the Zahořany Formation.

# Prionocheilus costai (Thadeu, 1947) (Plate 51 figs. 5-7)

- v 1908 <u>Calymene costai</u> n. sp.: Delgado p. 57 (nom. nudum).
- v\*1947 <u>Pharastoma costai</u> (Delgado 1908): Thadeu pp. 218, 224-226; pl. 2, figs. 5-10.
- v 1949 Pharastoma costai (Delgado 1908): Thadeu p. 129.
  - 1960 Pharastoma costai (Delgado 1908): Whittard p. 138.

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1976 <u>Prionocheilus costai</u> (Delgado 1908) : Hammann pp. 57-59; textfig. 7; pl. 4, figs 46-51; pl. 5, figs. 52-58.

1983 <u>Prionocheilus costai</u> (Delgado 1908): Hammann p. 55; pl. 3, figs. 34-36.

This species is known from the Leira Ma Member (Leira Ma locality: zone 8) of the Buçaco syncline. Hammann (1976) also records this species from the Sierra Morena in the top part of the "Bancos Mixtos". In addition, during this study a cranidium was recovered from the lower part of the Rosan Formation (Zone 8 or 9).

As with the other members of this genus, this species will not be described here for it is at present under revision by Romano.

Subfamily Kerfornellinae Henry, 1980° Genus Kerfornella Henry, 1976

Type species: Asaphus brevicaudatus Deslongchamps, 1825.

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# Kerfornella miloni Henry, 1976 (Plate 51, fig. 8)

- 1969 <u>Plaesiacomia? brevicaudata</u> (Deslongchamps): Henry p. 16; fig. 2 (partim).
- 1973 <u>Plaesiacomia? brevicaudata</u> (Deslongchamps): Robardet et al.; fig. 4D.
- ? 1976 Plaesiacomia? brevicaudata (Deslongchamps): Henry et al.
  p. 332; pl. 10, figs. 8,9.

\* 1976 Kerfornella miloni nov. sp.: Henry pp. 667-668; pl.1, figs. 2,5-7.

1980 <u>Kerfornella miloni</u> Henry 1976: Henry pp. 107-108; textfigs. 47,48; pl. 22, figs. 1,4,6,9.

This species is rare in the Fonte da Horta Formation of the Buçaco syncline. It is represented by a single cranidium, and fragments of a second, both from the same sample (CACWELL1) from Zone 2.

Genus <u>Plaesiacomia</u> Hawle and Corda, 1847

Type species: <u>Plaesiacomia rara</u> Hawle and Corda, 1847

### Plaesiacomia oehlerti (Kerforne, 1900) (Plate 51, fig. 9)

- \* 1900 <u>Homalonotus</u> (<u>Plaesiacomia</u>) <u>oehlerti</u> n. sp.: Kerforne pp. 784-786; pl. 13, figs. 1-2.
  - 1901 <u>Homalonotus</u> (<u>Plaesiacomia</u>) <u>oehlerti</u> Kerforne : Kerforne pp.177-178.
  - 1908 <u>Homalonotus</u> (<u>Plaesiacomia</u>) <u>oehlerti</u> Kerforne : Delgado pp. 27,33,41,42,57,80,89,92.
  - 1942 <u>Plaesiacomia oehlerti</u> (Kerforne): Costa pp. 93-94; figs. 1,2.
  - 1955 <u>Homalonotus rarus</u> (Corda): Redlin p. 57; pl. 1, figs. 11-12.
  - 1966 Plaesiacomia oehlerti Kerforne: Vanek p. 25.
  - 1966 Plaesiacomia oehlerti (kerforne 1900): Dean pp. 135-140;

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- pl. 1, fig. 5; pl. 2, figs. 2-5,7-8; pl. 3, figs.1-5.
- 1966 <u>Plaesiacomia oehlerti</u> (Kerforne): Henry pp. 884,885; fig. 1.
- 1967 <u>Plaesiacomia oehlerti</u> (Kerforne): Pillet and Robardet p. 25; fig. 1c.
- 1967 Plaesiacomia oehlerti (Kerforne): Henry p. 120.
  - 1968 <u>Plaesiacomia oehlerti</u> (Kerforne): Henry and Morzadec pp. 158,159; figs. A,B.
  - 1969 Plaesiacomia oehlerti (Kerforne): Henry fig. 2.
  - 1969 <u>Plaesiacomia oehlerti</u> (Kerforne, 1900) :Racheboeuf p.75;
    pl. 3, figs. 4a-4b.
  - 1971 <u>Plaesiacomia oehlerti</u> (Kerforne 1900): Henry, <u>in</u> Carre et al. pp. 779,780; pl. 25, figs. 5,8a-8c.
  - 1973 <u>Plaesiacomia oehlerti</u> (Kerforne): Robardet <u>et al.</u>
    p. 122; figs. 4E-F; pl. 18, fig. 11.
  - 1973 <u>Plaesiacomia oehlerti</u> (Kerforne 1900) : Robardet pp. 107,117,145,150.
  - 1976 <u>Plaesiacomia oehlerti</u> (Kerforne): Henry <u>et al</u>. p. 332; pl. 9, fig. 5; pl. 10, figs. 6-7.
  - 1980 <u>Plaesiacomia oehlerti</u> (Kerforne 1900): Henry p.109; textfigs. 50C-D, 51A, 82; pl. 23, figs. 4-5,7-9; pl. 24, figs. 1-4,12; pl. 45, figs. 6,8.
  - 1980 <u>Plaesiacomia oehlerti</u> (Kerforne 1900): Henry pl. 1, figs. 1,4,7,?9.
  - 1980 <u>Plaesiacomia oehlerti</u> (Kerforne, 1900): Cooper pp.
    283-295; pl. 24, figs. 10-12; pl. 25, figs. 1-8; pl.
    27, fig. 1; pl. 30, figs. 3-5,7.
    - 1983 Plaesiacomia oehlerti (Kerforne 1900): Hammann pp.

105-108; textfigs. 16, 18, 43, 44; pl. 18, figs. 168-175; pl. 23, fig. 221; pl. 24, fig. 225.

This species is one of the most characteristic trilobites of the central portuguese region during Zones 1 and 2. It is an important member of the <u>Praeleda</u> Association (phase 1), and does not occur to the north (Valongo/Arouca), in the areas dominated by the <u>Placoparia</u> Association. The species is well-known and requires no further description here.

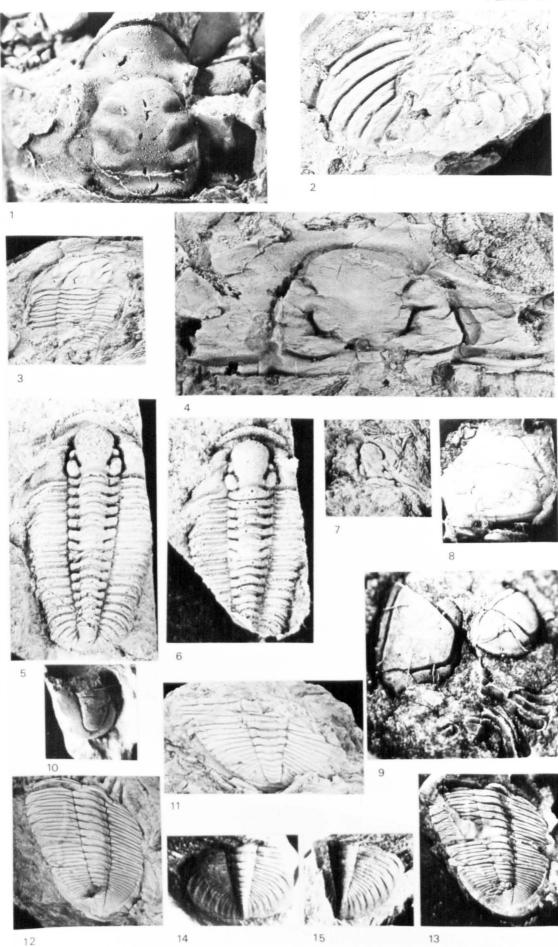
One interesting aspect of this species is that it does not occur above the very basal part of Zone 3 in Buçaco, while in Brittany it is recorded (Henry, 1980) from as high as the Marrolithus bureaui biozone at La Touche.

## Plaesiacomia n. sp. aff. rara Hawle and Corda, 1847 (Plate 51, fig. 10)

- 1901 <u>Homalonotus (Plaesiacomia) oehlerti</u> Kerforne: Kerforne pp. 177-178 (partim).
- 1968 <u>Plaesiacomia</u> <u>brevicaudata</u> (Deslongchamps): Pillet and Robardet pp. 24-25; textfig. 1b; pl. 2, figs. 1a-
  - 1972 Plaesiacomia cf. rara: Carre et al. p. 780.
  - 1972 <u>Plaesiacomia</u> n. sp. aff. <u>rara</u> Hawle and Corda:

    Robardet <u>et al</u>. pp. 120-122; textfigs. 4a,4b; pl. 18,

    figs. 1-6,12-13.
  - 1973 <u>Plaesiacomia</u> nov. sp. aff. <u>rara</u>: Robardet pp. 69, 72,101,102,122,123,155; textfig. 16.



- 1974 Plaesiacomia aff. rara: Lindstrom et al. p. 20.
- 1980 <u>Plaesiacomia</u> nov. sp. aff. <u>rara</u> Hawle and Corda 1847 : Henry pl. 1, figs. 5,6,8.
- 1980 <u>Plaesiacomia</u> n. sp. aff. <u>rara</u> Hawle and Corda 1847:

  Henry pp. 111-113; textfigs. 50A-B, 51B; pl. 23,

  figs. 6,10; pl. 24, figs. 5-11; pl. 45, fig. 5.
- 1983 <u>Plaesiacomia</u> n. sp. aff. <u>rara</u> Hawle and Corda 1847:

  Hammann pp. 103,104; pl. 18, figs. 179-180.

This species is rare in the mudstone members of the Louredo Formation (Zone 7) in the Buçaco syncline. The illustrated pygidium is the only "three-dimensional" specimen of this species found; other specimens include a cranidium and a cephalon, both flattened.

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Plate 51.

Neseuretus (Neseuretus) tristani (Brongniart, 1822)
Fig. 1 internal mould of cranidium, CACWELL1, x3.5.

Prionocheilus cf. pulcher (Barrande)

Fig.2 internal mould of pygidium, fig.3 internal mould of articulated carapace, fig.4 internal mould of cranidium, all QXP2, all x2.0.

Prionocheilus costai (Thadeu, 1947)

Fig. 5 internal mould of articulated carapace, fig. 6 latex cast of external mould of same specimen, Leira Ma, fig. 7 internal mould of cranidium, RAG1, all x2.0.

Kerfornella miloni Henry, 1976

Fig. 8 latex cast of external mould of cranidium, CACWELL1, x1.0.

Plaesiacomia oehlerti (Kerforne, 1900)

Fig. 9 internal moulds of a cephalon and a cranidium, with fragmentary external mould of thorax, CACWELL2, x3.5.

Plaesiacomia n. sp. aff. rara Hawle and Corda, 1847 Fig. 10 internal mould of pygidium, ZUV12, x3.0.

Eudolatites sp. A

Fig. 11 internal mould of pygidium, figs. 12,13 internal mould of pygidium and thorax, with latex cast of corresponding external mould respectively, all QXP2, x1.0.

Eudolatites sp. B

Figs. 14,15 internal and part of external mould respectively of pygidium, Leira Ma, x1.0.

Suborder Phacopina Struve, 1959

Family DALMANITIDAE Vogdes, 1890

Genus <u>Eudolatites</u> Delo, 1935

Type species: Dalmanites angelini Barrande, 1852

Eudolatites sp. A (Plate 51, figs. 11-13)

This material is all from the lower part of the Queixopeira Member (Zone 6) in the Mação area (sample QXP2). The available material includes four pygidia, and one articulated thorax and pygidium. Two internal moulds of cranidia with large anterior glabellar lobes might possibly belong here, but have been tentatively placed in <u>Dalmanitina</u>. The pygidial axis narrows less rapidly than in the later sp. B, while the pleurae of the pygidium are less posteriorly deflected than in the later species. There appear to be 11 or 12 axial rings on the pygidium, in contrast to 10 on the later species. All this material is from the Queixopeira Member, Zone 6.

### Eudolatites sp. B

(Plate 51, figs. 14,15)

- v 1908 <u>Dalmanites</u> cf. <u>Angelini</u> Barr. : Delgado p. 57.
- v 1947 <u>Dalmanites Angelini</u> Barrande: Thadeu p. 232; pl. 3, fig. 13.
- ? 1976 <u>Eudolatites</u> (<u>Banilatites</u>) sp. indet. : Hammann p. 62; pl. 6, fig. 93.

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The material of this species comprises a single pygidium, as internal and external moulds. The species appears distinct from the earlier Zone 6 material as described above. This specimen is from the Leira Ma Member, Zone 8.

#### Subfamily uncertain

Genus Phacopidina Bancroft, 1949

Type species: Phacopidina harnagensis Bancroft, 1949.

#### Phacopidina micheli (Tromelin, 1877)

- 1877 <u>Dalmanites micheli</u>: Tromelin and Lebesconte p. 599.

  (Nomen nudum).
- \* 1877 <u>Dalmanites micheli</u>: Tromelin p. 12.
  - 1886 <u>Dalmanites micheli</u> Tromelin and Lebesconte:

    Lapparent and Fritel pl. 2, figs. 11-14.
  - 1900 <u>Dalmanites phillipsi</u> (Barrande) var. <u>micheli</u> Tromelin: Bureau p. 168; figs. 27b-27c (non fig. 27a).
  - 1963 <u>Kloucekia micheli</u> (Tromelin, 1876): Henry p. 261; figs.
  - 1965 <u>Kloucekia micheli</u> (Tromelin, 1876): Henry pp. 199-210; figs. 1-2; pl. 1, figs 1-4,6-9 (<u>non</u> fig. 5); pl. 2, figs. 1-7 (<u>non</u> fig. 8).
  - 1969 <u>Kloucekia micheli</u> (Tromelin, 1876): Racheboeuf p. 79; pl. 4, figs 3a-3c.
  - 1970 Kloucekia micheli (Tromelin): Henry and Nion fig.7a (non fig. 7b).

1971 Kloucekia micheli (Tromelin 1877): Hammann pp. 267, 270.

- 1972 <u>Kloucekia</u> (<u>Kloucekia</u>) <u>micheli</u> (Tromelin 1877):

  Destombes p. 56.
- 1972 Kloucekia? micheli (Tromelin 1877): Hammann and Schmidt p. 298; pl. 2, figs. 13-18.
- 1973 <u>Kloucekia micheli</u> (Tromelin, 1877): Clarkson and Henry pp. 106-107; figs 1 C-D (non figs. 1 A-B)
- 1976 <u>Phacopidina micheli</u> (Tromelin): Henry <u>et al</u>. p. 332; pl. 10, figs 1-4.

MATERIAL. This species is represented by abundant material from the Fonte da Horta Formation (several tens of specimens).

DESCRIPTION. A full description of this species is given in Henry (1980), and Hammann (1974).

DISTRIBUTION. This species is known from the Fonte da Horta Formation in Portugal (Zones 1-3). In addition the species occurs in the Armorican Massif where several subspecies have been recognised; P. micheli micheli from Domfront, Traveusot en Guichen and La Touche, P. micheli couyerensis from the Andouille Formation of Bas Couyer and la Cultais, and P. micheli subsp. indet. from the Postolonnec Formation of the Crozon peninsula.

Phacopidina? sp. A (Plate 52, figs. 1-4)

Appendix C. 430.

This species is represented by internal and external moulds of three pygidia and three cephala, all from the Queixopeira Member (Zone 6). All the material is from the Queixopeira locality in the Mação area. This interesting material is in need of detailed study.

Phacopidina sp. B?
(Plate 52, figs. 5-7)

v 1947 <u>Dalmanites socialis</u> Barr. var. <u>proaeva</u> Emmrich: Thadeu p. 233; pl. 3, figs. 14-16.

MATERIAL. Thadeu describes seven specimens of this species (3 complete, 3 cephalons/thoraxes, and a pygidium. This material is housed in the museum of the "Servicos geológicos" in Lisboa. No further material was recovered during the present study.

DESCRIPTION. The material has not been revised in this study, so no description will be given here. It differs from the species P? sp. A in having a more inflated glabella, with more strongly marked glabellar furrows. The pygidial pleural fields show both inter- and intra- pleural furrows in contrast to the weak development of intra-pleural furrows alone in the earlier species.

DISTRIBUTION. Known from the Leira Ma Member (Zone 8) of the Bucaco syncline (Leira Ma locality).

Genus Scotiella Delo, 1935.

Scotiella? taouzensis (Destombes, 1972)

Type species : Dalmania logani Hall, 1860.

- \* 1972 <u>Kloucekia</u> (<u>Kloucekia</u>) <u>taouzensis</u> n.sp.: Destombes pp. 58-60; textfig. 21; pl.15, fig. 4-8.
  - 1974 Scotiella? taouzensis (Destombes 1972): Hammann pp. 89-91; textfig. 33; pl. 9, figs 133-139.
- v 1980 Scotiella taouzensis (Destombes, 1972): Cooper

Material of this species has been found in the upper part of the Cabeco do Peao Formation of the Dornes, Macao and Penha Garcia areas (all these occurrences are zone 7). This species occurs in rather coarse-grained sediments, often in association with <u>Calymenella boisseli</u> Bergeron, and this sediment type has lead to most of the available material being rather poorly preserved.

Subfamily Dalmanitininae Destombes, 1972

Genus <u>Eodalmanitina</u> Henry, 1965

Type species: Calymene macrophtalma Brongniart, 1822

Eodalmanitina destombesi (Henry, 1966)

Eodalmanitina destombesi destombesi (Henry, 1966)

\* 1966 <u>Dalmanitina</u> (<u>Eodalmanitina</u>) <u>destombesi</u> nov. sp. :Henry

, 190g .

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pp.558-561 (<u>partim</u>); pl. 16, figs. 1-3,6-7 (<u>non</u> figs. 4-5).

- 1970 Eodalmanitina destombesi (Henry 1966): Henry and Nion pp. 215-217; figs. 2A-2B, 3G-3H.
- 1971 Eodalmanitina destombesi: Hammann p. 270.
- 1974 <u>Mucronaspis destombesi destombesi</u> (Henry 1966):

  Hammann pp. 46-49; figs, 15, 17-18; pl. 5, fig.

  77-82.
- 1980 <u>Eodalmanitina destombesi destombesi</u> (Henry 1966): ...
  Henry p. 136; figs. 63, 65; pl. 34, figs. 4-5, 9.

This species is fairly common in the sediments of Zones 2 and 3 in the Fonte da Horta and Cabril Formations. It has been well described before (e.g. Henry, 1980) and so will not be described here.

Genus <u>Dalmanitina</u> Reed, 1905

Type species: Phacops socialis Barrande, 1846.

Subgenus Dalmanitina Reed, 1905

Dalmanitina (Dalmanitina) philippoti Henry, 1980

- 1901 <u>Dalmanités socialis</u> (Barrande) : Kerforne pp. 179-180 (partim).
- ? 1908 <u>Dalmanites socialis</u> Barr. : Delgado pp. 39, 57(partim).
- \* 1980 <u>Dalmanitina</u> (<u>Dalmanitina</u>) <u>philippoti</u> n. sp.: Henry pp.

  142-144; textfig. 66C; pl. 36, figs. 2, 4, 7.

DESCRIPTION. The material of this species is rather poorly preserved, and small in amount. This species was described fully by Henry (1980), and nothing further can be added here.

DISTRIBUTION. This species has been found in the Vale Saido and Zuvinhal Members of the Buçaco syncline. Fragments of a <a href="Dalmanitina">Dalmanitina</a> have also been found in the Galhano Member, but specific identification has not been possible. All the material recovered in Portugal is of Zone 7. The species is known in Brittany from the Schistes de Raguenez in the upper part of the Kermeur Formation (Plage de Raguenez, Crozon).

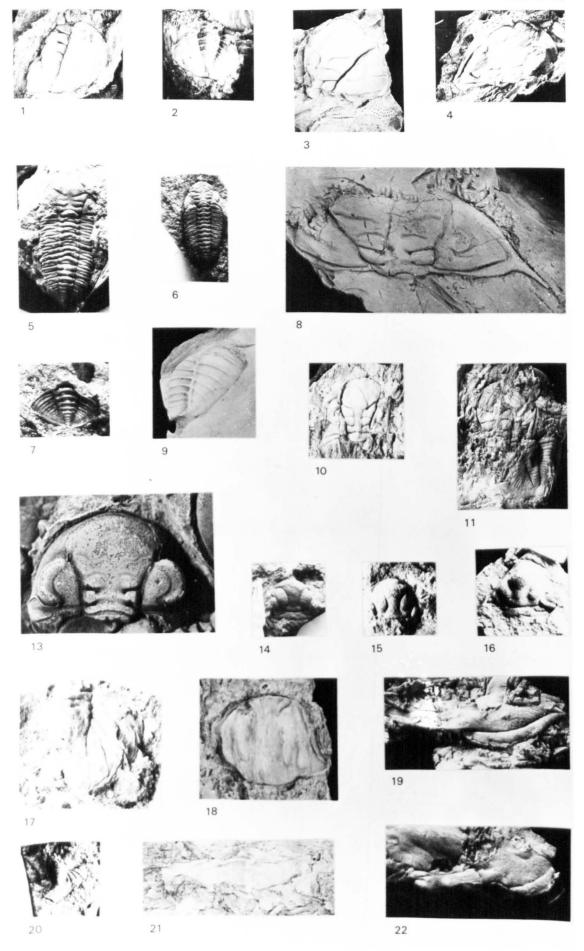
<u>Dalmanitina</u> (<u>Dalmanitina</u>) n.sp. aff. <u>acuta</u> Hammann, 1971 (Plate 52, figs. 8,9)

1901 <u>Dalmanites socialis</u> (Barrande): Kerforne pp. 179-180 (partim).

MATERIAL. this species is represented by abundant material from the Carregueira Formation, particularly from its type section.

DESCRIPTION. The material from the Carregueira Formation agrees with the description given by Henry (1980), so will not be further described here.

DISTRIBUTION. This species is known from the Carregueira Formation (Zone 4) in central Portugal. It occurs through the whole thickness of the formation, and has been found in the



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Bucaco, Dornes and Macao areas. In Armorica Henry records the species from the Schistes de Veryac'h (the Armorican homologue of the Carregueira Formation) of the Postolonnec and Veryac'h sections, Crozon, at which localities material was also collected during this study.

#### <u>Dalmanitina</u> (<u>Dalmanitina</u>) ? sp.

(Plate 52, figs. 10,11)

The Queixopeira Member of the Macao district (QXP2) has yielded a pygidium referrable to <u>Dalmanitina</u>, but which is not specifically identifiable. The same locality (Zone 6 in age) yielded two cranidia (illustrated here). These cranidia resemble some specimens of <u>Dalmanitina</u>, but are rather poorly preserved.

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Plate 52.

Phacopidina? sp. A

Fig. 1 latex cast of of cephalon, fig. 4 latex cast of external mould of cephalon, all from QXP2, all x1.0.

Phacopidina? sp. B

Figs. 5,6 internal moulds of articulated carapaces, fig. 7 internal mould of pygidium, all from Leira Ma, x1.0.

Dalmanitina (Dalmanitina) n. sp. aff. acuta Hammann, 1971

Fig. 8 internal mould of cephalon, fig. 9 external mould of pygidium, ABO, x1.0.

Dalmanitina (Dalmanitina)? sp.

Figs. 10,11 latex casts of external moulds of cranidia, note also pygidia of <u>Eudolatites</u> sp. A in fig. 11, QXP2, x1.0.

Morgatia hupei (Nion and Henry 1967)

Fig. 13 internal mould of cephalon, CACWELL1, x3.5.

Lichids indet.

Figs. mould of a cranidium, figs. 17,20 internal moulds of pygidia, all from Leira Ma, x1.0.

Selenopeltis buchi (Barrande, 1846)

Fig. 18 internal mould of cranidium, figs. 19,22 latex casts of external moulds of free cheeks, fig. 21 external mould of pygidium, all from QXP2, all x1.0.

The anterior lobes of the glabella of these specimens do seem a little more inflated than usual for <u>Dalmanitina</u>, and it is possible that these specimens should istead be placed with the material of <u>Eudolatites</u> sp. A, for which no cephalon has yet been recognised.

Genus <u>Crozonaspis</u> Henry, 1968

Type species: Crozonaspis struvei Henry, 1968.

#### Crozonaspis struvei Henry, 1968

- 1967 Phacopidella (Prephacopidella) hupei nov. sp.: Nion and Henry p. 887; pl. 24, fig. 4 (non figs. 1-3, 5-9).
- \* 1968 <u>Crozonaspis struvei</u> n. sp.: Henry pp. 370-374; figs.

  1-2, 4; pl.1, figs. 1-5; pl. 2, figs. 7-12 (?non fig. 6).
  - 1968 <u>Crozonaspis struvei</u> Henry 1968: Clarkson pp. 384-388; figs. 1a-1e; pl. 1, figs. 1-3.
  - 1969 <u>Crozonaspis struvei</u> Henry, 1968 : Racheboeuf p. 84;pl. 5, figs. 1a-1b.
  - 1970 <u>Crozonaspis struvei</u> Henry, 1968: Clarkson and Henry fig. 2b; pl. 1, figs. 2-4.
  - 1971 Crozonaspis struvei Henry: Henry and Thadeu p. 1345.
  - 1972 <u>Crozonaspis struvei</u> Henry, 1968: Destombes pp. 37,38,
  - 1973 <u>Crozonaspis struvei</u> Henry, 1968: Clarkson and Henry pp. 109-110; figs. 5A-5C.

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- 1974 Crozonaspis struvei Henry, 1968 : Sadler pp. 88,90.
- 1974 <u>Crozonaspis struvei</u> Henry, 1968: Hammann pp. 54,57-60; figs. 20-21; table 1; pl. 2, figs. 28-30.
- 1976 <u>Crozonaspis struvei</u> Henry: Henry <u>et al</u>. pp. 332; pl. 9, figs. 1-4, 5(partim), 6.
- 1980 <u>Crozonaspis struvei</u> Henry 1968: Henry pp. 148-150; figs. 69, 82, 87B, 88; pl. 39, fig. 1; pl. 48, figs. 1-6.
- 1980 <u>Crozonaspis armata</u>: Cooper

Previous accounts (Henry 1968, Clarkson 1968, Hammann 1974 and Henry 1980) provide a detailed account of the morphology of this species. It is one of the most common trilobites of the Praeleda association (phase 1), in Zone 2 and the lower part of Zone 3.

#### Crozonaspis chauveli? Henry, 1980

- 1901 <u>Dalmanites incertus</u> (Deslongchamps): Kerforne pp. 182-183 (partim).
- 1969 Kloucekia incerta: Henry p. 92.
- 1969 Kloucekia dujardini (Rouault): Henry p. 17.
- 1974 <u>Crozonaspis?</u> n. sp. aff. <u>dujardini</u>: Lindstrom,

  Racheboeuf and Henry fig. 3.
- \* 1980 <u>Crozonaspis chauveli</u> n. sp.: Henry pp. 15b-157; figs.

  74, 87C, 88; pl. 40, figs. 3-4, 7, 9-10; pl.42, figs.

  1-2; pl. 46, figs. 7.

This species is the commonest trilobite in the lower part of

the Carregueira Formation in its type locality, but seems to be replaced to some extent in the upper parts by  $\underline{D} \cdot (\underline{D} \cdot)$  n. sp. aff. acuta. All the material is of Zone 4 age. The available material, although fairly numerous, is rather poorly preserved and adds little to the published descriptions (henry 1980).

#### Crozonaspis dujardini (Rouault, 1847)

- \* 1847 Phacops dujardini n. sp.: Rouault p. 320; pl. 3, fig. 5
  - 1856 <u>Dalmanites dujardini</u> Rouault: Verneuil and Barrande p. 977; pl. 26, fig. 6.
  - 1894 <u>Calymene aff. tristani</u> Brongniart: Bergeron pp. 42-43; pl. 6, figs. 1-2.
  - 1901 <u>Dalmanites incertus</u> Deslongchamps : Kerforne pp. 182-183 (partim).
  - 1967 <u>Kloucekia (Phacopidina) dujardini</u> (Rouault 1847): Coates pp. 88-90; figs. 5f-5h, 6a-6d.
  - 1968 Kloucekia incerta (Deslongchamps): Henry and Morzadec p. 159.
  - 1968 <u>Kloucekia</u> (<u>Denckmannites</u>) <u>praecursor</u> n. sp. :Pillet and Robardet pp. 26-27 (<u>partim</u>); pl. 2, figs. 2a-2b (<u>non</u> 2c).
  - 1969 Kloucekia incerta: Henry p. 96.
  - 1969 Kloucekia (Phacopidina) dujardini (Rouault, 1847):

    Pillet and Robardet pp. 70-71; fig. 3; pl. 2, figs.1,
  - 1969 Kloucekia dujardini: Henry pp. 15,17.
  - 1970 Kloucekia (Phacopidina) dujardini (Rouault, 1847)

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- : Pillet and Robardet p. 17; pl. 1, figs. 6-9.
- 1972 <u>Kloucekia? dujardini</u> (Rouault): Robardet, Henry, Nion,
  Paris and Pillet p. 139 (partim).
- 1973 <u>Kloucekia dujardini</u> (Rouault 1847): Clarkson and Henry pp. 113-117; figs. 7-9.
- 1973 Kloucekia? dujardini (Rouault, 1847): Robardet, Henry,
  Nion, Paris and Pillet p. 122 (partim); pl.18, figs.
  7-8, 14.
- 1974 <u>Crozonaspis? dujardini</u> (Rouault 1847): Hammann pp. 68-70, figs. 20, 26; pl. 4, figs. 60-66.
- 1980 <u>Crozonaspis dujardini</u> (Rouault 1847): Henry pp. 157-160 figs. 75-76, 87D-88; pl. 40, figs. 2, 6, 11;pl. 42, figs. 3-7; pl. 46, figs. 3-4, 8-9.

Henry (1980) provides a summary of the most important aspects of the morphology of this species, and provides references to earlier descriptions. This species is abundant in the Vale Saido and Zuvinhal Members of the Buçaco syncline. These deposits are placed in Zone 7 of the scheme erected here, and this species with its wide distribution (Crozon; "Schistes de Raguenez", Riadan; "Schistes ardoisiers" of the Riadan Formation; Sainte-Sauveur-Le-Vicomte; Sangsurière Formation, Saint-Germain-sur-Ay; Sangsurière Formation, Tanville, le Ferrière-Bechet and Domfront; Pont-de-Caen Formation) in Armorica should be, and indeed already is, valuable in correlation.

This species is the numerically most important trilobite of phase 3 of the <u>Praeleda</u> association.

Family PHACOPIDAE Hawle and Corda, 1847

Genus Morgatia Hammann, 1972

Type species: Phacopidella (Prephacopidella) hupei Nion and Henry, 1967.

Morgatia hupei (Nion and Henry, 1967)
(Plate 52, fig. 13)

1980 Morgatia hupei (Nion and Henry 1967): Henry pp. 167-171 textfigs. 80, 82, 89; pl. 43, figs. 1-7,9;pl. 44, figs. 1-4,7,9.

For a full synonomy see the description by Hammann (1974).

This species is known from Zone 2 of the Bucaco syncline (upper part of the Fonte da Horta Formation). Henry (1980) describes its distribution in Armorica as the upper part of the Postolonnec (Crozon peninsula) and Andouillé (synclinorium of Menez Bélair and Laval syncline) Formations (below the Marrolithus bureaui zone), and the top of the Pissot Formation of Domfront. At some localities (e.g. CACWELL1) this species is very important numerically within the trilobites of the Praeleda Association (phase 1).

Order Lichida Moore 1959

Lichids indet.

(Plate 52, figs. 14-17,20)

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- v 1908 Lichas cf. incola Barr.: Delgado p. 57.
- v 1908 Lichas aff. convexus Angelin: Delgado p. 57.
- v 1947 Lichas aff. convexus Angelin: Thadeu pp. 231-232, pl. 3 fig. 9.
- v 1947 Lichas aff. incola Barrande: Thadeu p. 232, pl. 3, figs. 6-7.

The lichid material from the Leira Ma Bed includes two types of cephala (those in figs. 14,15 (="incola") and that in fig. 16 (="convexus")). There are also two types of pygidia (one of each in figs. 17,20). However, which belongs with which is not certain, nor is the generic identity of either type. Until this material is fully revised the question must be left open.

Order Odontopleurida Whittington, 1959

Family ODONTOPLEURIDAE Burmeister, 1843

Subfamily Selenopeltinae Hawle and Corda, 1847

Genus Selenopeltis Hawle and Corda, 1847

Type species: Odontopleura Buchii Barrande, 1846.

#### Selenopeltis sp. indet.

The Fonte da Horta Formation (Zones 1 to 3) has yielded several incomplete thoracic segments of Selenopeltis, but the species is unknown.

## Selenopeltis buchi (Barrande, 1846) (Plate 52, figs. 18,19,21,22)

- 1908 Acidaspis Buchi : Delgado p. 80.
- 1966 <u>Selenopeltis buchi</u> <u>buchi</u> : Havlicek and Vanek pp. 54, 55, 57, 58; pl. XI, fig. 11.
- 1973 <u>Selenopeltis buchi</u> <u>buchi</u>, <u>S. buchi inermis</u>: Pribyl and Vanek pp. 65-68.
- 1975 <u>Selenopeltis buchi</u> <u>buchi</u>, <u>S. buchi inermis</u>: Pribyl and Vanek p. 59; pl. IV, figs. 8, 7 respectively.
- 1976 Selenopeltis buchi: Pribyl and Vanek p. 14.
- 1978 Selenopeltis buchi : Bruton in Bruton and Henry p. 895.
- 1982 <u>Selenopeltis buchi</u> (Barrande, 1846): Romano pp.215,216; pl. 1, figs. 1-14; pl. 2, figs. 6, 7.

The Zone 6 deposits of the Queixopeira Member have yielded, in sample QXP2 from near Macao, several specimens of  $\underline{S}$ .  $\underline{buchi}$ . These include external and internal moulds of three cranidia, four free cheeks, two pygidia, one articulated thorax, and numerous isolated thoracic segments.

The current material adds little to the description and comments of Romano.

