THE NATURE AND DISTRIBUTION OF LOESS IN BRITAIN

by

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ABSTRACT

The previous literature concerning the distribution of loess in Britain has been noted with the general location of the deposits being concentrated in southern and eastern England. Other deposits have been recorded from the south west of England, Wales, north west England and Scotland. The field studies of these deposits have been limited to those occurring in eastern and south eastern England. A brief account of the loess which occurs as a band across northern Europe from the eastern part of Russia to the north of France is given, which along with the British deposits suggests that a single mechanism has controlled their transportation and deposition. ' Hobbsean ' anticyclonic conditions are proposed as the dominant factor in forming this distribution pattern. The geotechnical and mineralogical properties of the samples obtained have been studied along with those supplied from a New Zealand site, for comparison. The mineralogical studies using x-ray diffractometry, x-ray fluoresence and thermogravimetry suggest that much of the ' clay fraction ' consists of primary mineral particles.

Study of the calcareous concretions found in the Essex brickearths along with those from an East German site and a Hungarian Brickworks has been undertaken. A highly alkaline environment is proposed for their formation, this is supported by the etching of the quartz particles by the calcium carbonate.

The nature of the individual grains was observed and recorded by scanning electron microscopy; optical microscopy was used to study the soil fabric.

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INTRODUCTION

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INTRODUCTION

The definition of loess as a material and its mode of formation have been controversial topics of discussion for over one hundred years. The specific properties that any deposit must present in order to be considered as a loess vary with the individual investigator and as a result of this so does the theory of formation. It is possible that loess will always remain a controversial subject, particularly between western and east European workers. The aim of this study is to show the deposits which occur in Britain that may be considered as loess in terms of deposits in central and western Europe. The British deposits that have been investigated in the field are confined to the eastern part of England but those found in Wales and Scotland have not been investigated but are referred to in conjunction with a review of other deposits in Chapter 2.

In order to be able to proceed with an analysis of the deposits that are found in eastern England, a clear understanding of the numerous theories of deposition is required along with a knowledge of the nature and appearance of a ' typical loess '. In this introductory chapter the significance of the composition of loess is discussed along with the production mechanisms of loess sized particles and the various theories of formation and origin of the deposits.

As a basis to any initial understanding it is necessary to ascertain the nature of a definition; should it be a purely physical description of the material or should it include a genetic clause as to both the origin of the particles and to their means of transport and deposition into a loess deposit.

Most of the workers in the west were content to accept the aeolian method of deposition as outlined by Richthofen when describing the Chinese deposits (1882), until Russell (1944), revived the theory of loessification, a method of loess formation that was given a great deal of prominence by Berg working in Russia in the early part of the twentieth century. The aeolian versus the insitu theorists created the most controversy up to the early 1950s with much of the discussion since then being concentrated on desert and or glacial origin for loess material.

Charlesworth (1957), describes loess as ' by far the most important periglacial accumulation ' and lists a total of more than 700 references in his bibliography of the subject. Flint (1971), considers the loess as ' one of the most remarkable Pleistocene sediments ' and goes on to describe it as being commonly nonstratified and nonconsolidated, composed dominantly of silt size particles with accessory clay and sand and deposited primarily by the wind. In this description Flint recognises the wind as a means of transport with the loess becoming thinner in a direction downwind of the source of the material.

The Rhine valley loess was the original deposit and it is from the German language describing its loose nature, that it takes its name. Lyell (1834), who when describing this particular deposit realised that it had been brought down the river having being derived from the glacial sediments of the Alps. The presence of similar material being carried in the river in suspension led Lyell to this conclusion and a later study of the Mississippi Delta during a visit in 1845 - 46 (Lyell 1847), led him to concluding a similar means of deposition for these deposits.

In 1882, after several years work in China, Richthofen published his views, in the Geological Magazine, on the origin of loess.

This appeared as a letter to the editor giving an account of his work and also as part of his dispute with H. H. Howarth, who in various notes to the same publication, (1882, p.9 - 18 & 69 - 80) applied the theory of flood to the account for the origin of the Chinese loess. Richthofen regarded any theory on the origin of loess would have to take into account twelve major characteristic peculiarities. These included the loess above 8,000 feet in China and 5,000 feet in the Carpathians of Europe, the presence of a large number of land shells, the angular quartz grains and the mammal fauna which indicates a close relation to that found on the steppes and grassland. Accordingly Richthofen reached the conclusion that the only means by which all his criteria could be satisfied was of a subaerial nature and that it was only by the action of the wind that the fine material had been sorted and lifted from the dry desert areas of China and carried into the valley of the Yellow River. Throughout the latter part of the nineteenth century the main controversy centred around the fluvial and the aeolian theories, this later gave way to insitu versus aeolian discussions with the occasional remarks that received little attention such as Keilhack (1920), who concluded that ' .. the entire loess in all the world is a homogenous mixture and must have originated from a common source which caused its deposition, it is only one step to the question of whether this completely precludes the possibility of an extraterrestrial or cosmic origin of loess '.

The Russian soil scientists were not in agreement with the aeolian theory and as Smalley (1976, p.58) points out Berg was the most persistant proponent of the insitu theory; loess being formed in the position that it is found; and contending on several grounds the aeolian theory to be invalid. Berg (1932), considered the

loess of China to be a result of mans activity on similar beds of Upper Tertiary age and that the loose unconsolidated Chinese loess overlying more consolidated deposits was a cultivated soil. A further objection to the aeolian theory raised by Berg concerned the texture of the deposit. He could not reconcile that the wind should only sort out a 10 - 15µ fraction when it was capable of lifting both finer and coarser particles. As a counter-claim to the aeolian protagonists Berg quotes a theory he first reported in 1916 whereby loess and loess-like sediments are formed in situ from various fine grained rocks, rich in lime carbonate, through the agency of weathering and soil formation in the conditions of a dry climate.
Russell's paper (1944 op cit), on the Lower Mississippi Valley loess, sparked a great deal of discussion when he stated his belief in the loessification theory. He considered that Berg's theory was the closest of the existing approaches that had been made to account for the origin of the loess material but found Berg's insistance of arid climatic conditions untenable. Russells main criticism of the fluival or lacustrine approach was based on the lack of stratification of loess in-situ whilst he argued in the case of the aeolian theory that no actual or hypothetical directions of wind could account for its distribution.

The process of loessification begins with the parent material which in the case of the Mississippi was deposited as alluvium on flood plains during the Pleistocene. This affects the finer parts of such deposits, particularly those having accumulated in backswamps and are present only in minor amounts along Pleistocene meander belts. Weathering and differentiation of soil profiles form the initial stage of the process whilst the original calcareous content is lost to the ground water. This results in a brown loam that thickens on flat areas where it eventually accumulates in considerable thickness in deeply dissected areas as it creeps into the valleys.

The presence of calcium carbonate is important to Russell's loessification process,as in the area of the Mississippi Valley the carbonates are derived from terrace materials and brown loams of the surface upslope from the colluvial deposit. The stress on the lime content is also given in Russells definition of loess which he considered should include the following essential characteristics:- ' Loess is unstratified, homogeneous, porous, calcareous silt, it is characteristicthat it is yellowish or buff,tends to split along vertical joints, maintains steep faces, and ordinarily contains concretions and snail shells. From the quantitative standpoint at least 50% by wieght must fall within the grain size fraction 0.01 - 0.05 mm and it must effervesce freely with dilute hydrochloric acid.'

This unfortunately ignores one important factor consiered central to most definitions of loess; the presence of a high percentage of quartz;and as Smalley (1971), points out loessification is irrelevent if loess is defined in terms of fine quartz material but may be meaningful in terms of calcium carbonate. Although quartz is the most abundant mineral in the majority of those deposits regarded as loess, its presence in such large quantities in a silt grade fraction has only in recent years given rise to any discussion as to its origin.

Smalley (1966), attempted to show the processess that take place in order to produce silt size grains that may be deposited to form loess. On the basis of the crushing of quartz grains in an automatic pestle and mortar, Smalley was able to show that a uniformly graded sample could be divided into a sample of bimodal distribution, one part less than 200µ and the other greater than 500u. From this it was concluded that by a process of glacial grinding on granitic rocks, particles of sand size and fine silt size may be produced.

The history of a loess deposit was shown to be separable into six events:- i) formation of quartz grains by glacial action, ii) crushing of quartz and other rock materials by the glacier, iii) transport of detritus by the glacier, iv) deposition of mixed detritus as the glacier melts, v) transport by wind, vi) and deposition again.

Kuenen (1969), in a discussion of the Smalley and Vita-Finzi (1968), paper refers to his own earlier work on the nature of formation of loess size particles during wind transport. Spalling of quartz particles Kuenen believed to result in the production of some chips smaller than 40µ but in most cases he found the dust that resulted from this abraision to be smaller than 2u.

Vita-Finzi and Smalley (1970), in reply pointed out that their main aim was to show that the widely accepted dual classification of loess, into cold and hot (or glacial and desert) categories, could not be upheld, (see Table 1.1. below), and had suggested a wind abraision in order to account for the silt sized spalls found in the desert.

The finer material is of a size most efficiently raised by the wind, the most efficiently transported in suspension in air and the one in which the cohesive forces become dominant in an aggregate, it is these particles that form the loess deposits.

The derivation of loess particles appears from the literature to be either from periglacial or desert sources. Smalley and Vita-Finzi (1968 op cit), give a list (Table 1.1.) of the authors who indicated their preferences for similar alternatives.

TABLE 1.1.

Author	Loess Types	
Bryan (1945)	glacial	desert
Butler (1956) p.147	cold	hot
Butzer (1965) p.194	periglacial	desert or continental
Charlesworth (1957) p.511	periglacial	continental
Flint (1957) p.183	glacial	desert
Grahmann (1932)	glacial	continental
Holmes (1965) p.766	glacial	desert
King (1966) p.172	cold	hot
Obruchev (1945) p.259	cold	warm
Scheidegger (1961) p.34	glacial	desert
Scheidig (1934) p.5	glacial	continental
Thornbury (1954) p.313	glacial outwash.	desert

Bryan (1945), believed the main source of loess in Nebraska to be the outwash of glacial rivers pulverised by frost action with deposition taking place on the margins of the glaciated areas where anticyclonic winds combined with prevailing westerlies. Bryan also makes the suggestion that although desert conditions may be associated with the formation of loess deposits, glacial or periglacial processes are likely to be involved.

The association of loess deposits with a glacial source is not totally accepted, several workers, particularly those working in Mediterranean areas giving a great deal of credence to the hypothesis of desert loess. If such a sediment is shown to exist it can hardly owe its origin to the Pleistocene glaciers for a source of material or as a means of producing the silt grade fraction required. Smalley and Vita-Finzi (1968 op cit) considered the mechanical processes of the desert particle impact unable to produce sufficient particles to result in a major loess deposit and that the large loess deposits, such as those of China - which had been regarded as derived from the Gobie and Ordos deserts since Richthofen's account - to owe their origin to Pleistocene glaciation.

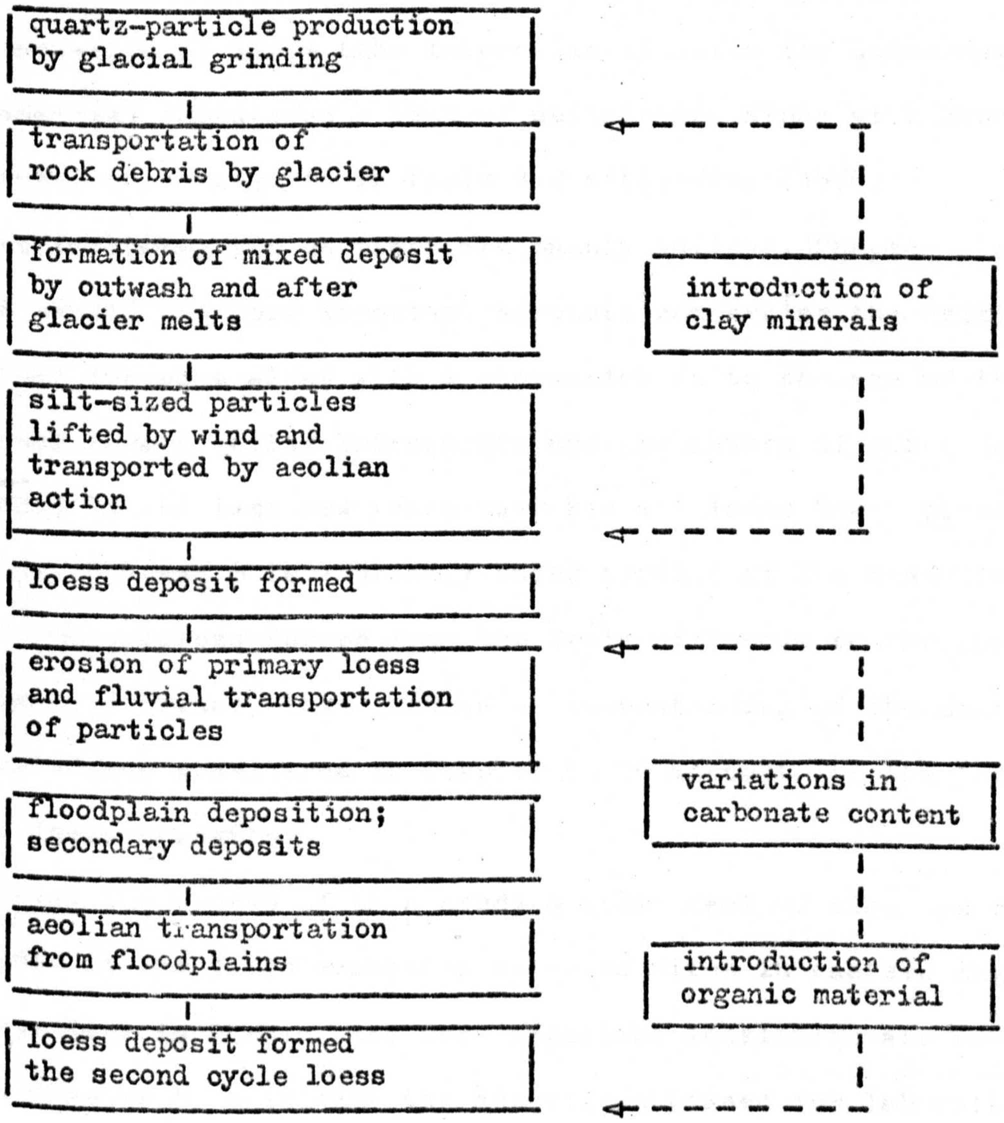
The glaciation of Southern China has been well accounted for by Sun and Yang (1961) and Ching (1965) which allows the processes of glacial grinding to have taken place in the formation of the material for Chinese Loess.

Yaalon (1969), proposes that Pleistocene and Holocene loess of desertic origin is found in the Be'er Sheva basin of the Northern Negas. The aeolian material is considered to be derived mainly from the Sinai desert with additional dust being brought from the North African desert. Silt and clay size material is obtained in the desert by the disintegration and weathering of pre-existing rock with infrequent floods washing the loose material into wadis and onto fans and plains. From these it is picked up by the wind and deposited on the desert margins. An earlier account of the Be'er Sheva loess (Ginzborg & Yaalon 1963) describes the deposit as being of various thickness with exposed section up to 12m thick and covering an area of 1,600 Km^2.

Having briefly discussed the problems of loess, referring to the literature concerning the formation of silt sized quartz particles and the means of transporting them, it is possible to attempt to understand the complexities confronting the loess investigator. Smalley (1976 p.7) shows an outline of a possible sequence of important events in the formation of a loess deposit, Fig.1.1. The processes which are envisaged with primary loess undergoing alteration and secondary deposition are discussed in Chapter 4.

FIG.1.1.

EVENTS IN THE FORMATION OF LOESS DEPOSITS.



Events in the right hand column cannot be assigned a definite place in the left sequence.

after Smalley (1976).

Because of the lack of agreement of terminology and the confusion that had arisen as a result the various definitions the Loess Commission of INQUA (the International Union for Quaternary Research) formulated a list of definitions along with synonymous terms, this is given in Table 1.2 after Fink (1974).

The following two chapters are mainly reviews. Chapter 2 attempts to record the more important accounts concerning the British Loess deposits along with a discussion as to the age of the Lower Thames Valley Brickearths and the nature of other deposits which in the last few years have had a ' loess tag ' placed upon them. Chapter 3 is a broadly based account of the distribution of loess across Europe from the Urals of Russia to the Channel coast of France. This enables an understanding of the distribution mechanisms considered in Chapter 4, to account for the location of loess deposits.

During the course of this study a great deal of time has been spent in the field examining numerous sites in eastern England from Kent to Durham, the more important localities are described in Chapter 5, outlining the deposits obtained for laboratory investigations. The Engineering significance of loess in many parts of the world is considered of prime importance. In Britain it does not present the same foundation problems as those encountered in eastern and central Europe, this is mainly due to its lack of thickness. However, the engineering properties are reviewed in Chapter 6 along with the mechanical analysis and shear strength parameter of some of the deposits investigated.

Chapters 7 - 9 are concerned with the mineralogical content of the deposits. X-Ray analyses are covered in Chapter 7 with Chapters 8 and 9 discussing thermogravimetric techniques and the results obtained from the Stanton-Redcroft thermobalance. The

TABLE 1.2.

INQUA Loess Commission definitions

Name	Definition/description and synonyms
Loess	German synonyms:Löss, typischer Löss ("typical loess"). Characteristics:the definitely dominant fraction of the sediment is within 60 - 20 µm(coarse silt,very fine sand), unstratified,primarily calcareous, quite porous capillary network;on the whole,dry material is yellow,buff,brownish yellow.
Sandy loess	German synonyms:Sandlöss,Flottsand,lössiger Sand sandiger Löss. Characteristics:mixture of grains sized 60 - 20µm & 500 - 200µm (fine sand,medium sand);often the distribution of particle sizes show a major peak within the silt range and a lesser peak within the medium sand range; sometimes there is an equal distribution amoung silt,(very)find sand, and medium sand fractions;very often they are unstratified or in thin beds, usually noncalcareous, not so porous as loess, colour similar to loess.
Clay-loess, clayey loess, argillaceous loess	German synonyms:Tonlöss,toniger Löss,tonreicher Löss. Characteristics:peak particle size of the sediment is within the range from 60 - 20µm with 25 - 30% of particles being smaller than 2µm (clay size);unstratified, low porosity;similar carbonate content and colour to loess.
Loess-like sediments	German synonyms:Lossderivate.lossartige Sediments. General characteristics: the term covers primarily aeolian material that has been moved or redeposited in various (secondary) processes (allochthonous loess-like sediments) and/or modified insitu (autochthonous loess-like sediments); relevant processes are : "Deluvial" (colluvial) processes and soliflustion: hill-washed loess, solifluction loess, solifluxion loess (German terms:Solifluktionslöss,Fliesslöss, Berglöss,Hanglöss). Fluvial (proluvial) processes: brickearth, brickearth (German:Schwemmlöss,subaquatischer Löss). Modification caused by cryoturbation: cryoturbation loess (German:Kryoturbationlöss). Eluvial and pedogenic processes: loess loam (German:Lösslehm,Gleylöss,Staublehm ("dust loam"),Decklehm ("covering loam"). Thorough, intense pedogenic modification and transformation (redeveloping): "semi-pedoliths" and"pedoliths"(these terms are proposed by M. Pecsi for lithified soils formed from loess material). Loess-like sediments may have originated from either loess, sandy loess, or clay loess; in any case their porosity is less than that of the original material; great variation of carbonate content, some may be essentially noncalcareous; colours may differ considerably in particular cases.

after Fink (1974).

presence of concretions in loess deposits throughout the world has always been noted with little investigation. The record of actual loess concretion studies is thin, in comparison to the loess literature as a whole, with only a handful of detailed accounts. Chapter 10 discusses the loess concretions along with photomicrographs of thin sections of British, East German and Hungarian concretions.

Chapter 11 is a description of several photomicrographs of undisturbed soil samples and of scanning electron micrographs of quartz and dolomite silt grade particles.

The discussion and conclusions of this work in Chapters 12 and 13 are followed by an Appendix which includes several of the derivative thermogravimetric histograms not included in Chapter 9.

At the beginning of this introduction mention was given to Charlesworth's large bibliography of 700 references concerning loess. The total literature must be in the order of several thousand accounts especially as twenty years have passed since Charlesworth published.

CHAPTER TWO

LOESS IN BRITAIN : A SURVEY OF THE RECORD

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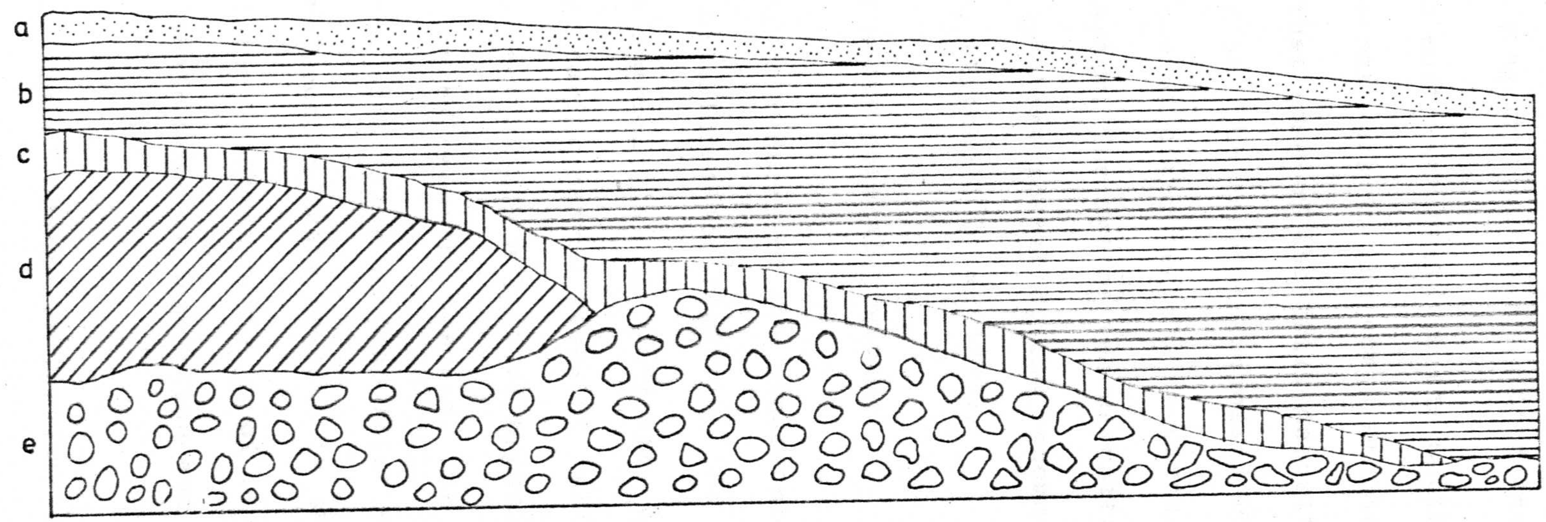
The widespread occurrence of the brickearths, later referred to as loess, in south east England has long been recognised, with the first record of the term being used in 1667 (Arkell and Tomkieff 1953 p.40*). This was first used to describe a material used for the purpose of making bricks. During the nineteenth century many localities have been described containing brickearths, mainly by the Victorian collectors whose primary interest was not in the material as such, but in the fauna and implements present within it. The brickearths and associated deposits, usually sands and gravels, yield a vast amount of information, not only of the nature of the molluscan fauna of the late Pleistocene, but also of the mammalia including the existance of human cultures within this area of Britain.

The rapid expansion of London during the latter half of the last century resulted in the opening of numerous brick pits to enable the provision of material required by this building demand, and it was the availability of these pits with their working faces permanently exposed that attracted the geologists and natural historians of the time. Unfortunately for the present day geologist many of these pits which helped the creation of a greater London one hundred years ago have been infilled to provide land for the development of the last twenty five to thirty years.

* Arkell & Tomkieff quote Evelyn, Mem.ii,24, Oxford English Dictionary, ' We went to search for brickearth.' as the original source of the term.

FIG 2·1

SECTION OF THE BRICKEARTH AT LONDON STREET, FOLKESTONE



a: Alluvium b: Brickearth c: Angular flint drift d: Gault in situ
e: Lower Greensand in situ

After Mackie 1851

This chapter provides a record of the sections that are not exposed today, along with the sections and field sketches from the main workers during the last one hundred and fifty years.

Loess appears to be most widespread in the south east of England although recent work in the north and the west has attempted to show that some of the drift deposits of these areas do contain loess. The southern deposits will be considered primarily, with those of other regions receiving attention at the end of this chapter. The age of the deposits in each region is considered, using where possible, the recommended time scale for the Quaternary, (Mitchell et al 1973).

Brickearths of the south coastal regions:

The large number of collectors of the nineteenth century have provided a wealth of information regarding the brickearths which would otherwise be unavailable today. Mackie, one such collector, describes deposits bearing mammal bones at Folkestone, Kent (1851), which, although mainly a list of organic remains, shows several sections with brickearths present. The relationship between this and the underlying angular flint with the Gault Clay and the Lower Greensand beds beneath is shown in Fig.2.1. This banking up of the brickearth may be of significance in the interpretation of their mode of deposition and will be discussed in Chapter 4.

Godwin-Austen's account of the Newer Tertiary deposits of the Sussex coast (1857), as Quaternary deposits were known at the time, shows sections with brickearths which in all cases appear as the youngest beds and in places contain ferrous nodules, in contrast to the calcareous variety as described later from the brickearths of the Thames estuary region. The deposits of

FIG 2·2a

SECTION OF THE BRICK PIT NEAR PORTSLADE STATION

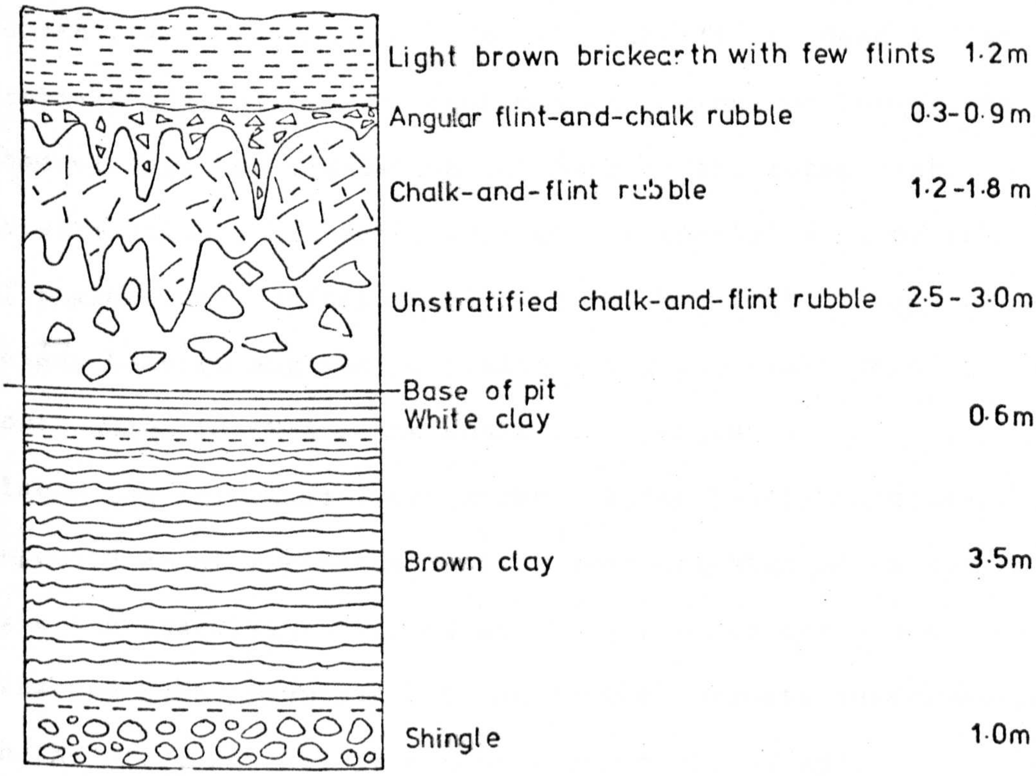
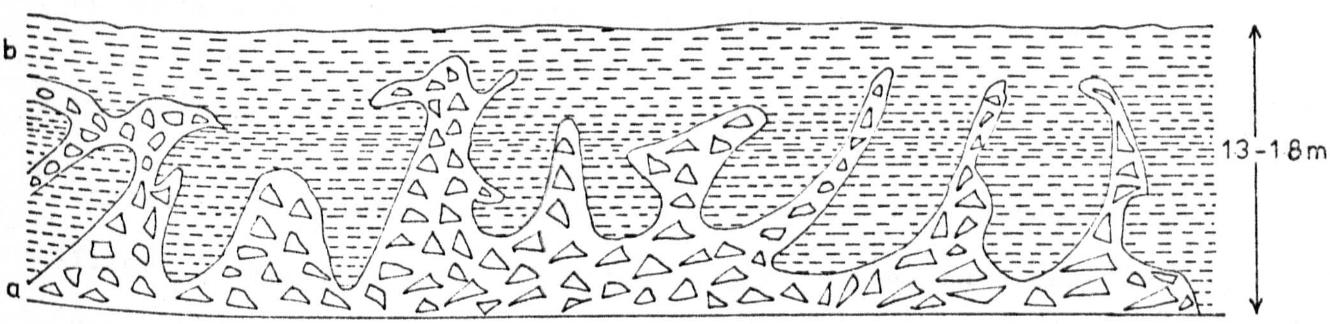


FIG 2·2b

SECTION IN THE CLIFF NEAR PAGHAM



a: Irregular seams of flint-gravel b: Brickearth

After Prestwich 1892

brickearth studied by Godwin-Austen were observed to be of sub-aerial origin as a result of the terrestrial fauna contained within them.

One of the most prominent geologists of the last century was Joseph Prestwich whose work on the superficial deposits of southern England and the continental regions bordering the Channel laid the foundation for much of the subsequent investigations. His major work on the coastal area of the south of England was, unfortunately, one of his last, recording the raised beaches and head deposits along the coast from Kent to south Wales including the south west peninsula (1892). In several places the brickearths are shown, either overlying disturbed deposits as at Portslade Station near Brighton or contorted with the underlying beds as at Pagham. These are shown in Figs: 2.2a and 2.2b. Prestwich, in an earlier report, describes loess in the cliff at Chesilton near Portsmouth, (1875).

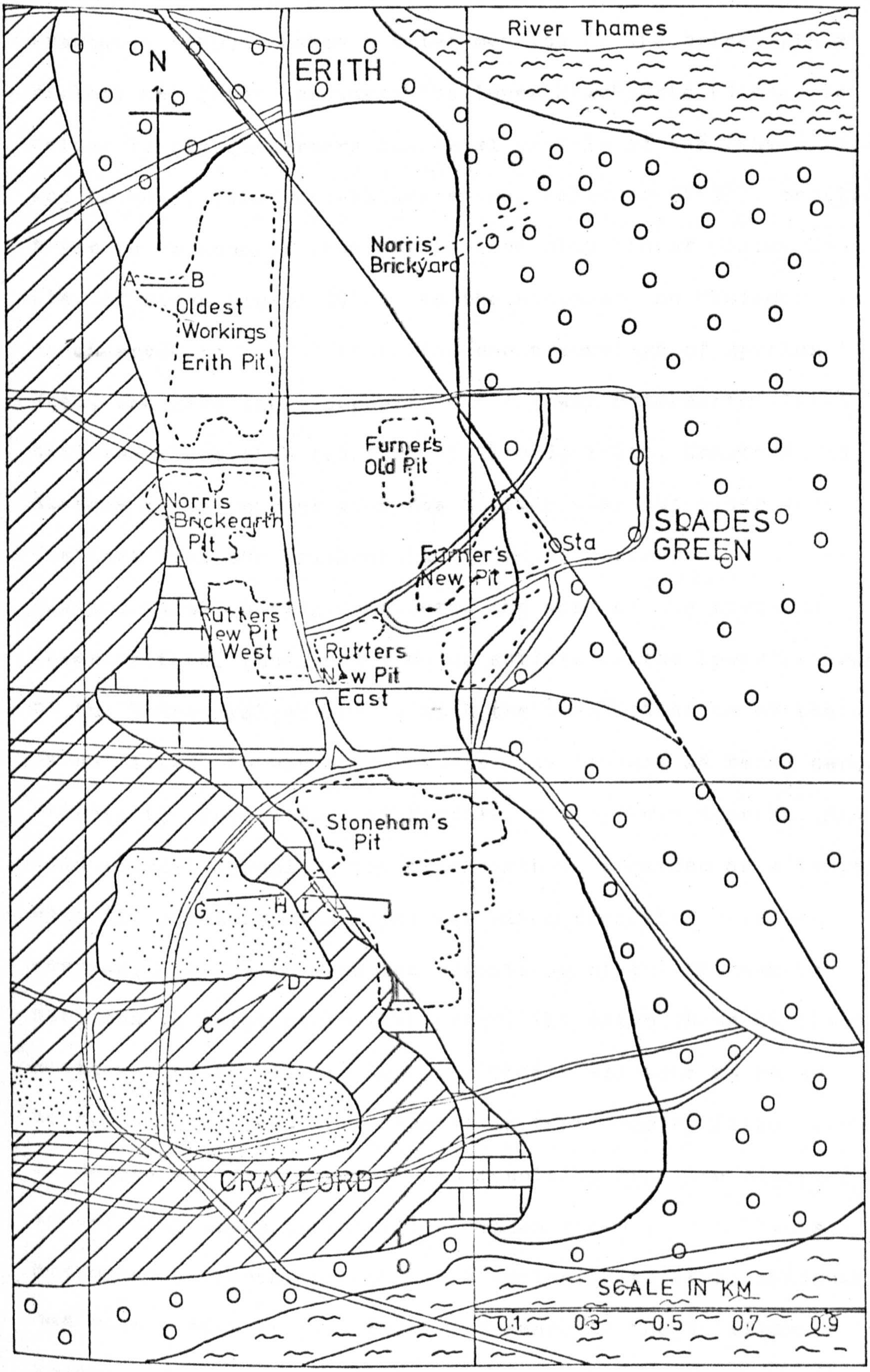
Thames Valley Brickearths:

Although the south coast brickearths appear widespread the deposits that have received greatest attention are those of the Lower Thames Valley, and the deposits of the Thames estuary region in south east Essex and north east Kent.

Lower Thames Valley and associated Valley deposits:

The numerous brickworkings north and south of the Thames in the Ilford, Grays Thurrock, Erith and Crayford areas have been well documented since Morris's account of the region in 1836, and 1838. Kennard (1944), in his account of the Crayford Brickearths records the extent of these deposits as shown in Fig.2.3. The original and later names by which the pits were known, usually

FIG 2·3
MAP OF THE CRAYFORD DEPOSITS



MAP AFTER KENNARD 1944
SECTION LINES AFTER TYLOR 1869

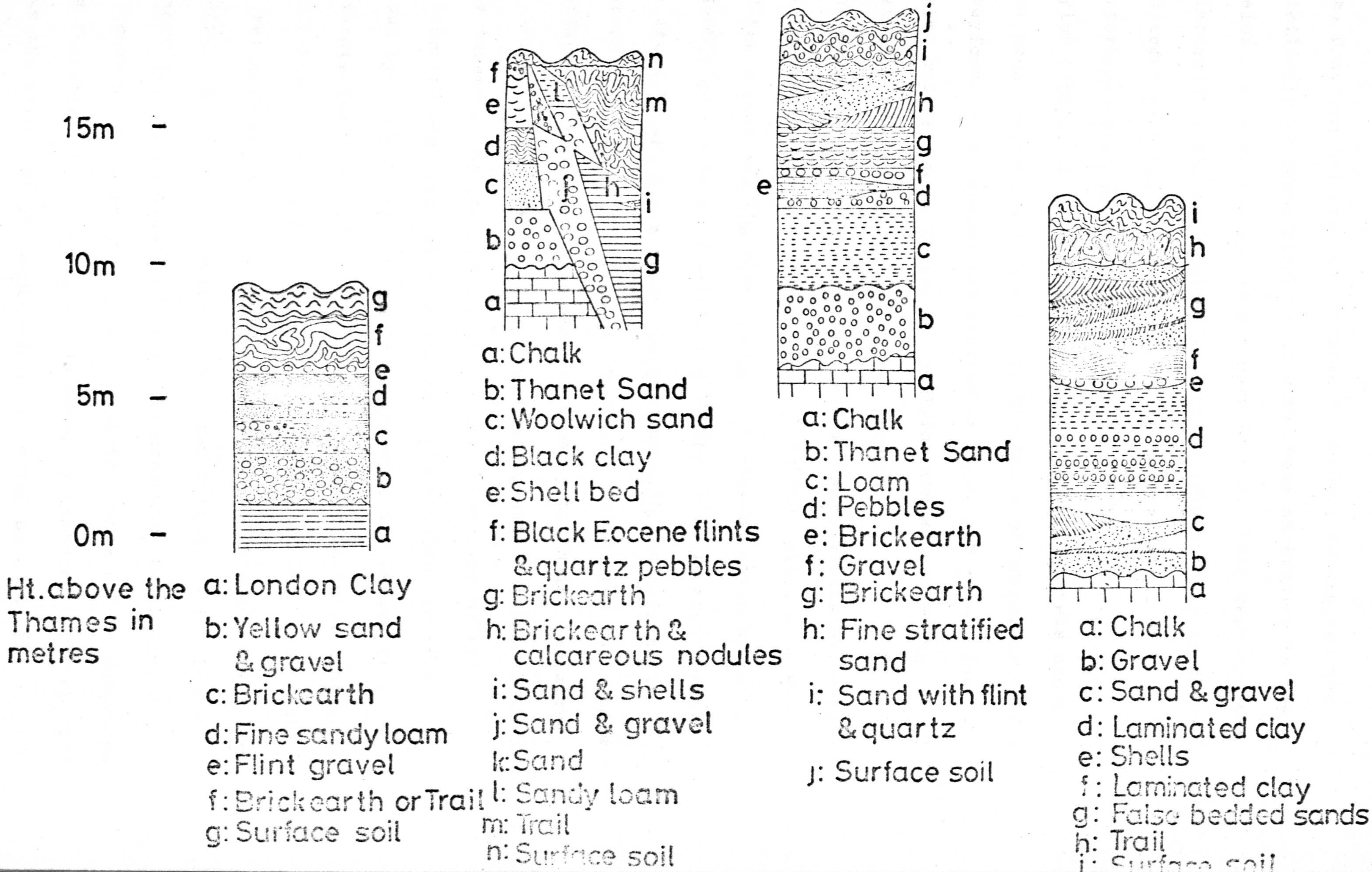
after their owners, are indicated and are of valuable assistance in the location of deposits described earlier by several other workers, including Spurrell and Tylor.

Prestwich (1855a) makes a brief mention of the brickearth at Hackney and later considers the Lower Brickearth (1864a) to belong to the Quaternary low level gravels of the Thames Valley and to be of late post-Pliocene age. Falconer (1858), concluded these to be younger than the boulder clay (Lower Chalky Boulder Clay of Baden Powell 1948), as the Elephant and Mastodon remains he observed to be a ' true Pliocene assemblage of species '. Wood, who gave these deposits the ' Lower Brickearth' label, believed those that occurred at Ilford, Erith, Crayford and Wickham to be younger than the boulder clay but older and distinct from the brickearths at Grays Thurrock.

Dawkins (1867), having considered the work of the previous investigators, published a major article on the Lower Brickearths of the Thames Valley which, with the identification of the vast fauna listed, he was able to determine its age as being deposited between the Forest Beds of Norfolk, a temperate deposit, and the cold glacial deposits. The brickearth is regarded as a temperate deposit. Sections at four of the sites described have been redrawn, Fig.2.4 to show the elevations of the brickearth horizons in relation to each other. The datum shown on these sections is the height above the Thames alluvium as referred to by Dawkins. The term ' trail' is that used by Fisher (1866), to denote any festooned gravels resulting from the slumping of superficial deposits under the frozen sub-soil conditions which accompany a glacial climate in a peri-glacial area; although it has been used with particular reference to the solifluxion product of the glacial phase which succeeded the deposition of

FIG 2·4

SECTIONS AT FOUR LOWER THAMES VALLEY BRICK PITS [AFTER DAWKINS 1867]



the Crayford Brickearths. Prestwich (1864b), recognised the similarity of these brickearths with those he studied in the Seine and Somme valleys of northern France. These deposits are discussed in Chapter 3 along with their relationship to the adjacent gravels, a factor, according to Prestwich, of importance when considering the origin of the loess.

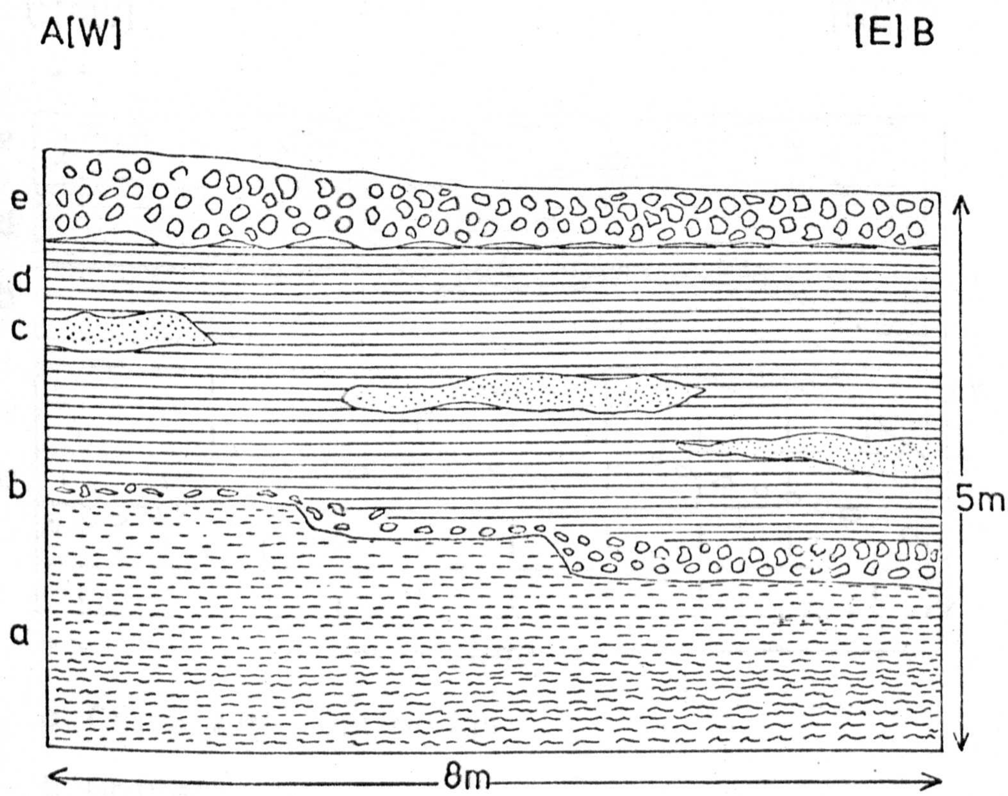
Tylor (1869), in his account of the Quaternary gravels shows numerous sections and maps of the brickpits of Grays, Erith and Crayford, with several illustrated in Figs. 2.5 - 2.8. The Upper Brickearth at Stonehams pit Tylor states as having resulted from sludging from higher ground.

The Crayford and Erith deposits received many visits by members of the Geologists Association. Spurrel (1880), gives a record of the mammal remains found whilst the account given by Leach (1906), of visits to Norris's and Rutters pits is accompanied by sections which are again shown along with photographs by Chandler and Leach (1912). The brickearth rests upon the eroded surface of the Thanet Sand and the underlying Chalk, the slope of which, as seen in Norris's pit, was suggested as representing the foreshore of the river prior to the deposition of the brickearth and associated sands, and is equivalent to that shown by Spurrel (op cit) in Stonehams pit, who showed it to indicate the site of a palaeolithic implement factory. Hinton and Kennard (1906), discuss the significance of the brickearth in relation to the stone implements found in the area. They give a broad outline of the recent geological history of the Lower Thames Valley, an account of which is presented below with a discussion of the chronology of the Lower Thames Valley deposits.

The formation of the trail is discussed by Chandler (1914 op cit) with the view that it formed during a period of cold with

FIG 2·5

SECTION A-B IN THE ERITH PIT



a: Thanet Sand

b: Gravel laid in water cut steps in Thanet Sand

c: Gravel lens

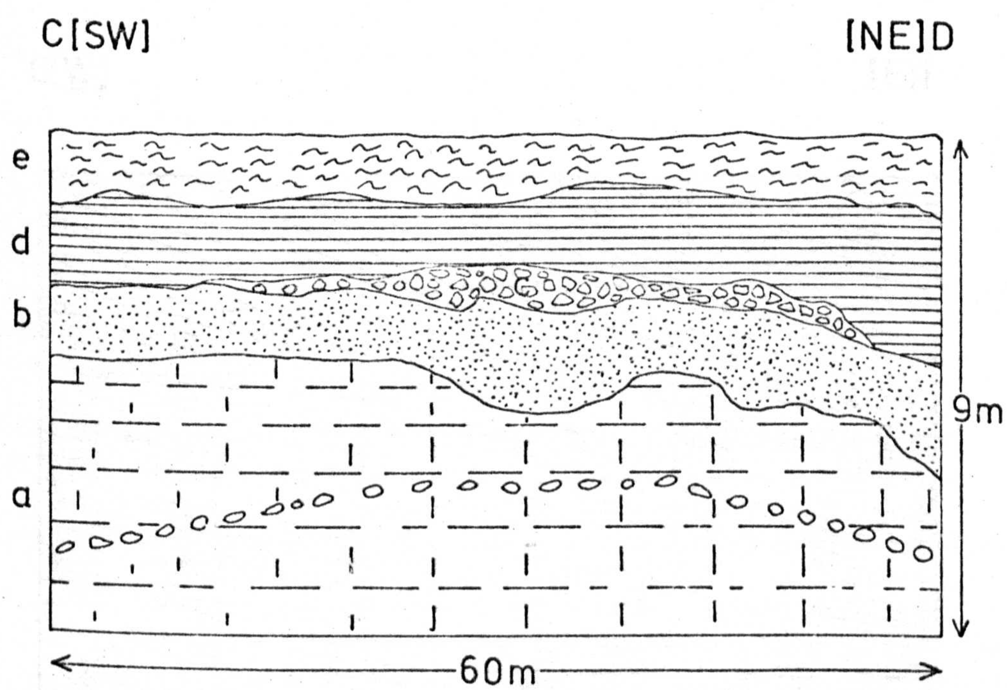
d: Brickearth

e: Gravel

After Tylor 1869

FIG 2·6

SECTION C-D IN THE CRAYFORD PIT [STONEHAM'S]



a: Chalk with flint bands

b: Gravel

c: Coarse flint gravel

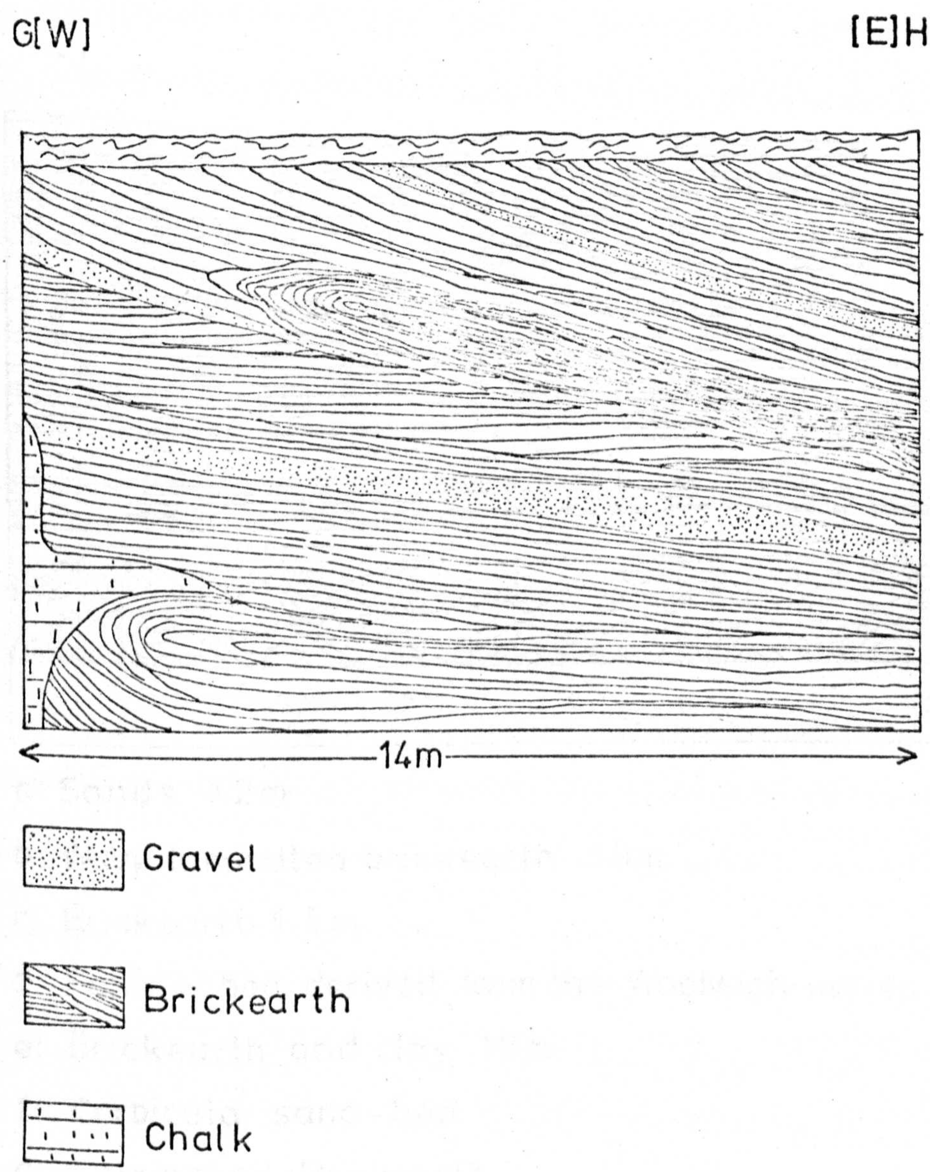
d: Brickearth

e: Gravel

After Tylor 1869

FIG 2·7

SECTION G-H IN THE CRAYFORD PIT [STONEHAM'S]

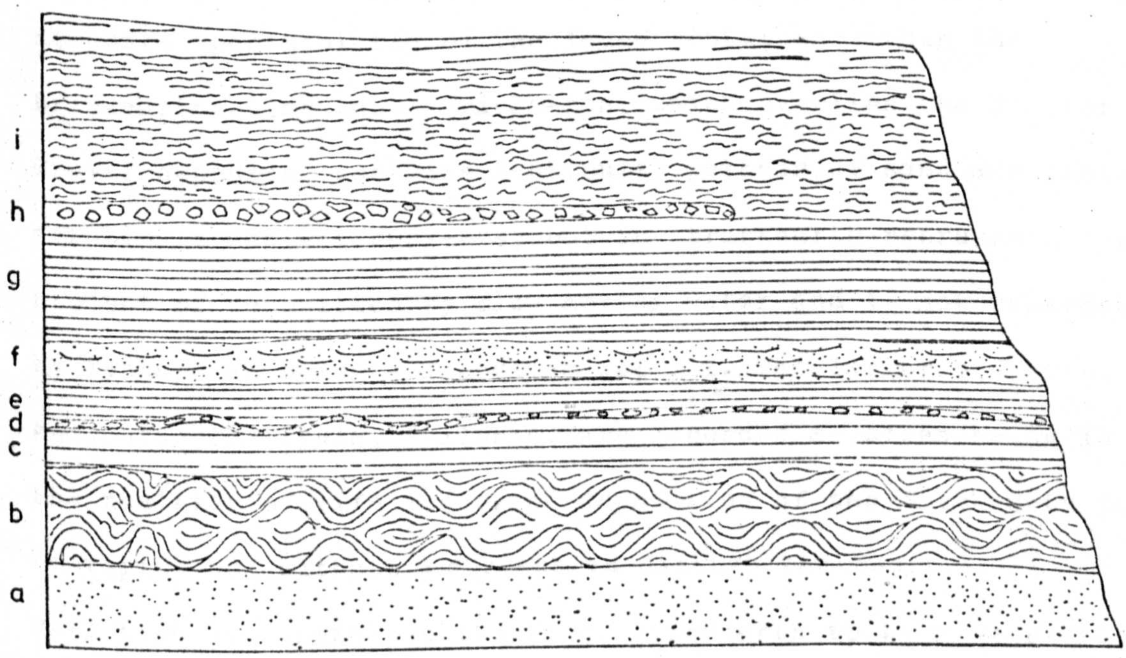


After Tylor 1869

FIG 2·8

SECTION I-J IN THE CRAYFORD PIT [STONEHAM'S]

I [W] [E] J



a: Sands 1·2m

b: Wavy laminated brickearth 1·9m

c: Brickearth 1·5m

d: Pebble bed derived from the Woolwich series

e: Brickearth and clay 1·9m

f: Corbicula sand-bed

g: Laminated Brickearth
h: Gravel
i: Loam

} 7·6m (g–i)

After Tylor 1869

abundant snowfall. The soliflucted nature of the deposit being contorted as a result of the creep of a semi-fluid slush flowing down a slope on a partially thawed sub-soil was recorded as evidence of such conditions. The trail also contained vertically orientated stones suggesting a frozen soil where the ice would be able to form a shell around the pebbles, which on thawing would leave a space allowing the pebbles to fall downwards; this process being constantly repeated and in time cause the pebbles to assume a vertical position.

Kennard (1944 op cit) gives a detailed account of the Crayford deposits, particularly of the fauna contained within the brickearths. The Lower Brickearth, which overlies the Crayford Gravel deposits, contains lenticular patches of sand and pebbles denoting transient currents, but the brickearth represents the product of deposition by slow moving water and is not regarded by Kennard as being a floodloam deposit. The larger bivalves, Anodonta, Corbicula, Psilunio, are recorded as often being in the position of life inferring deposition of the Brickearth to be rapid, but without a current to disturb the bed.

Bull (1942), considered the Upper Brickearth to be a weathered and decalcified loess, a theory not supported by Kennard who supported Tylor's view of it having resulted by sludging from higher ground. Its highly contorted nature as mentioned by Chandler (1914 op cit) along with the other periglacial features it displays suggests Tylor to be correct in his interpretation. Prestwich implied that loess was a floodloam deposit but as the term gradually came to indicate deposition by aeolian means Kennard was not in favour of its use to describe the Crayford deposits.

Dating of the Lower Thames Valley Brickearths:

The age of these deposits is still the subject of a great deal of discussion regarding the validity of the evidence, evidence that has not allowed this problem to be resolved after nearly a century and a half.

The stratigraphical, fossil and archaeological recordings, that have allowed the correlation with other deposits, have been questioned by more recent workers who have established conflicting evidence based on pollen studies.

The earlier workers; Prestwick, Falconer, Wood, Dawkins, as already mentioned, attempted with the available data to relate these deposits to the boulder clay, found north of the valley, and the glacial period from which it resulted. Later workers realised, as did Wood, that the brickearths post-dated the boulder clay and attempted to place them in the sequence that took place since this glaciation, (Anglian of present terminology).

The short time period that is represented by the Pleistocene is too short for the fauna and flora to have established any evolutionary trends that may be detectable and used for zonation as in the case of earlier geological periods. Much of the evidence rests upon assemblages, the whole collection of species present, along with their relative abundance or the appearance or disappearance of a particular species.

This whole problem of fossil and archaeological evidence is further complicated by mis-identification in the past and also by the redeposition of artifacts and organic remains, some of the latter of Pliocene age, into younger deposits as a result glacial and periglacial mixing.

Where molluscs and mammals have been shown to be the autochthonous component of the sediment the only conclusions that can be drawn are ones of climate and environment as Kennard (1944 op cit) suggests in his interpretation of the depositional environment of the Lower Brickearths of Crayford.

Several views on the age of the brickearths are recorded here, mainly those of workers of the last forty years when the terrace systems of the Thames Valley had become firmly established. An account of the work of King and Oakley (1936) is given, and the controversy that has arisen since this paper, with the publication of data from other workers.

The glacial and interglacial stages used in all but the most recent reports are not usually of the present accepted convention as given by Mitchell et al (1973). Where such cases arise both the authors stage name and its present name (if possible) are indicated.

Hinton and Kennard (1906 op cit), divided the history of the Lower Thames Valley into eight stages as shown in Table 2.1. The basis of the subdivisions are the series of base levels that represent pauses in the elevation of the Weald and which have resulted in the deposition of gravels and their associated deposits, in some cases these are the brickearths. The Crayford Brickearths are representative of Hinton and Kennard's fifth stage which are the third terrace group. The stone implements that are found in the deposits of each of these stages are fully recorded indicating their relative ages and enabling correlation with other deposits containing similar implements.

TABLE 2.1.

The History of the Lower Thames Valley (Hinton & Kennard)

1st stage	Plateau Gravel
2nd stage	Hill Gravel
3rd stage	Dartford Gravel
4th stage	100 ft. Terrace
5th stage	Crayford Brickearths
6th stage	Fourth Terrace
7th stage	Buried Channel
8th stage	Modern Alluvium

The series of terraces that have developed in the Thames Valley as a result of the successive lowering of the base levels and their associated deposits resulting from the intermediate periods of aggradation, assumed for many years a chronological significance. King and Oakley (1936), pointed out the draw back to the absolute use of this method when a raising of the base level allowed aggradation to take place at higher levels than previously formed terraces, this results in the older deposits being observed at a lower topographic level than the younger deposits. This occurred at Swanscombe where, as outlined below, the older Lower Gravel and Loam deposits of Stage V underlie the younger Late Boyn Hill Stage deposits of Stage VIII, which stratigraphically, according to the law of superposition is correct.

The sequence of events that have been recorded in the Lower Thames Valley are complicated. Many authors have attempted to unravel and interpret the information to enable the chronological order of events to be established. An account of the stages as given

by King and Oakley is presented below, from this it is possible to establish the relative positions of the various brickearth deposits as they appear in the scheme of events that took place in this region during the Pleistocene. In establishing these stages these authors have drawn upon the work of many previous investigators who have recorded the sections along with the contained fossils and flint implements, these are mentioned in parenthesis where appropriate in the relevant sections.
King and Oakley included a diagram of sections corresponding to the text, this has been reproduced as Fig.2.9.

SECTION I Plateau Gravels:

Deposition of gravels of which the relics are seen on high ground varying from 400 - 300 feet O.D.

SECTION II Early stages of valley cutting, etc.:

A period when the main lines of the present Lower Thames drainage system was established.

SECTION III Great Eastern Glacier Stage:

Deposition of the Chalky - Jurassic Boulder Clay north of the Thames.

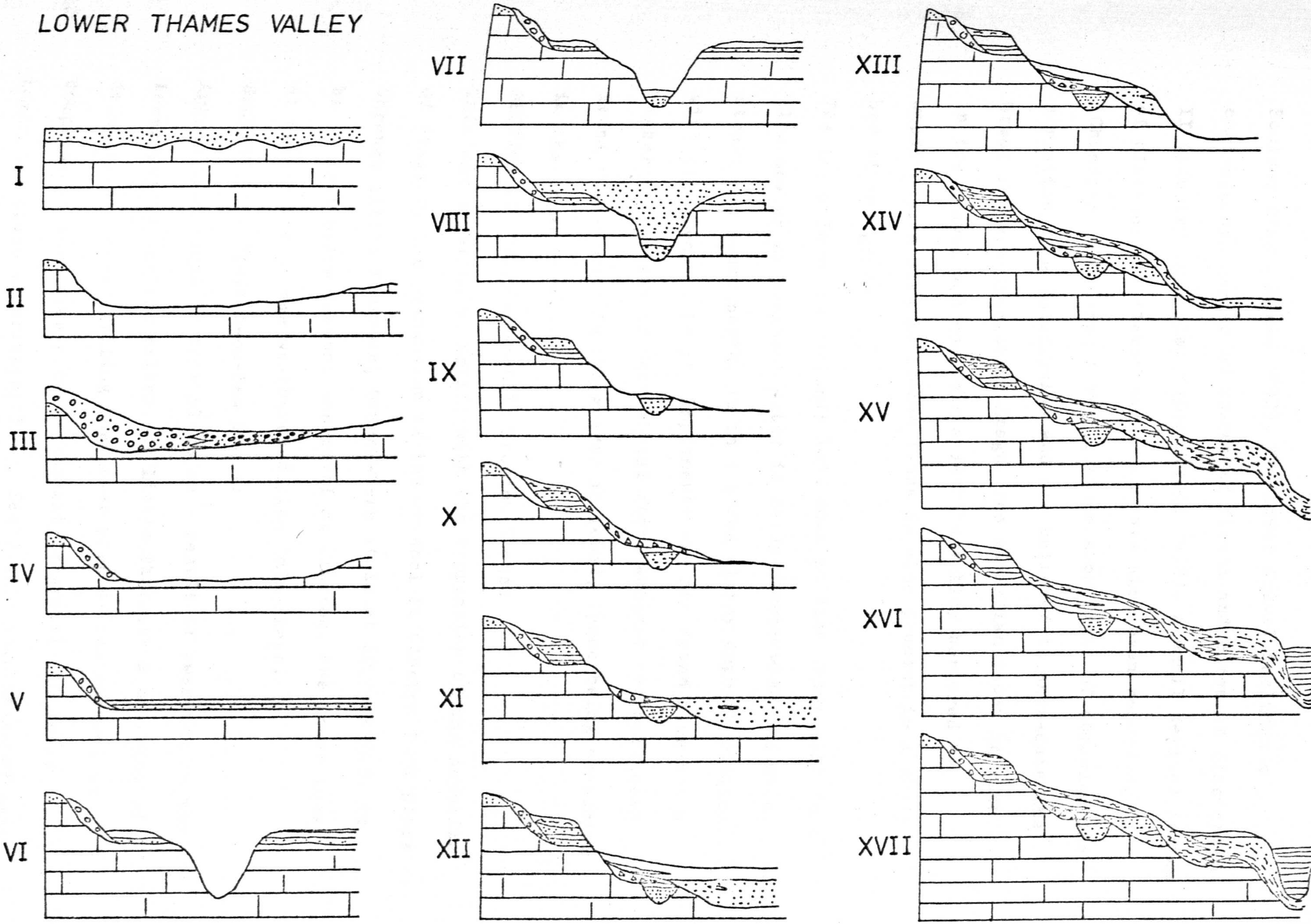
SECTION IV Pre-Boyn Hill Erosion Stage:

Erosion of the Chalky - Jurassic Boulder Clay associated outwash gravels. Eratic blocks remained on the surface to be incorporated in later deposits.

SECTION V Lower Barnfield (or Early Boyn Hill Stage):

Deposition of the lower gravel and the lower loam took place and is preserved at Swanscombe as the 100 foot or High Terrace in Barnfield and Rickson's pits. The Lower Gravel contains erratics believed to have been derived from the Chalky - Jurassic Boulder Clay. At Hornchurch the gravels of the 100 foot terrace are recorded as resting on the eroded surface of the Chalky - Jurassic

FIG 2.9 DIAGRAMMATIC SECTIONS ILLUSTRATING STAGES [I-XVII] OF THE PLEISTOCENE SUCCESSION IN THE LOWER THAMES VALLEY



After King and Oakley 1936

Boulder Clay (Holmes 1892). The Lower Gravel includes a contemporary series of unbraided flakes and cores of Clactonian II industry (Chandler 1930; Breuil 1932). A small derived series of Clactonian I flakes and cores have also been rocorded, (Chandler 1930; Breuil 1932), these show signs of abrasion and striation from solifluxion and are believed to ante-date the Great Eastern Glaciation Stage. The mammalian fauna is rich in the gravel and suggests a fertile valley bordered by woodlands. A rich molluscan fauna is also present in a shell bed in the gravel.

The Lower Loam was probably laid down as fine muddy silt from slow moving or stagnant water in reedy swamps when the main stream had swung north. It is a brown clayey deposit riddled with calcareous tubules. Implements are not found here but a higher proportion of terrestrial forms amongst the molluscan fauna than occurs in the gravel is found, these being exclusive in the upper part.

SECTION VI Inter-Boyn Hill Erosion Stage:

This was a period of uplift with the truncation of the deposits of Stage V. The excavation of the channel to Clacton took place through Little Thurrock, Grays. where it is at 20 feet O.D. to be 14 feet below present sea level at Clacton. The Lower Loam at Swanscombe became weathered during this stage.

SECTION VII Clacton-on-Sea Stage:

Aggradation began to take place as a result of swamping in the lower reaches of the valley. At Little Thurrock a sequence of deposits are found filling the lower part of the channel and comprise in ascending order:- fluviatile gravel (10 feet) laminated clays or brickearth (15 feet) with thin seams of sand and gravel with mammalian remains and freshwater molluscs (see

Fig.2.4 after Dawkins 1867), followed by current bedded sands. The flint implements at Little Thurrock are of Clactonian II culture. The land flora indicates warmer and drier summers than at present.

SECTION VII (continued) Ilford Stage:

The brickearths of the Uphall and Ilford brickpits are slightly later in the aggradation stage than those of Little Thurrock with some of the fauna that is present in the Clacton Stage being shown to be absent in this stage. The fineness in grade of the deposit points to a temporary ponding of the river, perhaps through the unusally rapid rise of base level. The comparative coarseness of the Late Boyn Hill deposits is accounted for by the aggradation being counterbalanced by an increase in the volume of water and therefore the resulting increase in the transporting power of the river.

The interstratified sands and fine gravels of Stoke Newington Common appear to mark the transition from the Ilford to the Middle Barnfield Stage.

SECTION VIII Middle Barnfield or Late Boyn Hill Stage:

This is the final stage of the period of aggradation during which the flood-plain was raised to a higher level than during the Early Boyn Hill Stage. Most of the gravels on the Boyn Hill terrace in the Lower Thames Valley are believed to have been deposited during this phase of maximum aggradation. In many places the earlier deposits were swept away or resorted, at Swanscombe they partially escaped and now underlie this later aggradation, with the weathered surface of the Lower Loam overlain by current bedded sands and gravels in Barnfield pit, these are termed the Middle Gravels. The fauna indicates a temperate climate and the implements are those of Middle

Acheulian and Clactonian III industries which are found in the earlier part of this stage in the Stoke Newington deposits.

SECTION IX Pre-Coombe Rock Erosion Stage:

Erosion and cliff formation took place during this stage. Late Acheulian implements are found on the banks of the Wansunt channel beneath the brickearth whilst the brickearths in the Globe pit at Greenhithe and the Upper Loam of the 100 foot terrace at Swanscombe yield a similar industry, accompanied in the case of the latter by Early Levalloisian flakes and cores (Burchell 1931).

Knapping floors of Early Levalloisian Man were established on the 30 foot erosional shelf at Baker's Hole, Northfleet.

SECTION X Baker's Hole or Main Coombe Rock Stage:

Coombe rock covers the Levalloisian I - II workshop floor at Baker's Hole (Smith 1911; Burchell 1933) and this marks a definite glacial period which can be correlated with the Little Eastern Glaciation of East Anglia. Periglacial activity predominated with frozen sub-soil conditions and solifluxion leading to formations of thick accumulations of coombe rock in the steep sided lateral valleys of the chalk areas and contorted taele gravels in other places such as the contorted gravel which channels the surface of the Ilford Brickearths as described by Hinton (1900). At the end of this stage melting snow gave rise to melt water erosion.

SECTION XI Taplow Stage:

The aggradation of gravels followed the melt water erosion of the previous stage. The fauna of this stage indicates cold conditions whilst the molluscan fauna is practically unknown. Early Levalloisian type implements are present but abraided and striated (Burchell 1934). Burchell (1935), described a floor of early Middle Levalloisian implements (Levalloisian III) at the base of the gravel underlying the Crayford Brickearths at Northfleet, and thus give a clue to the date of this stage.

SECTION XII Crayford Stage:

Thick and widespread deposits of brickearth accumulated in the main valley overlying the Taplow Gravels and consisiting of sandy flood loams and laminated loesslike deposits which are believed to represent wind-blown material accumulated in sheets of slack water. These sub-aqueous brickearths interdigitate with structureless brickearths indistinguishable from loess and which were almost certainly accumulated sub-aerially. This latter type are mainly preserved in lateral valleys such as near Greenhithe where the Geological Survey classified them as ' Coombe Deposits', (Dartford Memoir, p. 106).

The brickearths are typically developed in the neighbourhood of Crayford where they attain a maximum thickness of 35 feet and show a tripartite division.

The lower brickearth is 20 feet thick, a well bedded yellow calcareous loam locally containing loess püpchen, the fauna is mainly of the cold steppe type.

The equivalent sub-aerial brickearths in the Ebbsfleet Valley contains shells of Pupa muscorum to the exclusion of other species indicating bleak conditions. A minor coombe rock is seen near the top of this division, pointing to the return of frozen sub-soil conditions. At Crayford and Erith the brickearths are succeeded by fluviatile sands interbedded with silty brickearth with a large fauna, this being indicative of temperate conditions.

The upper brickearth at Crayford is mainly reddish-brown clayey loam, probably representing a loessic deposit which has been subject to loamy weathering and decalcification with calcareous nodules. This has revealed a cold mammalian fauna suggesting tundra conditions conflicting with the molluscan evidence of the underlying shell bed which indicates temperate conditions.

SECTION XIII ' Flood-Plain ' Erosion Stage:

A period of falling base level occurred during which the river cut down to about its present level or below.

SECTIONS XIV - XVI Upper-Flood Plain Terrace, Buried Channel and ' Trail ' Stage:

The formation of the Upper Flood Plain Terrace and the cutting of the Deep or Buried Channel of the Lower Thames appear to fall within a period of predominantly cold conditions marked by intermittent solifluxion giving rise to ' trail '.

SECTION XIV Ponders End Stage Upper Flood Plain Terrace Stage No.1

Tundra conditions prevailed at the beginning with probably a diminution of the river with springs freezing for most of the year. The flora contains arctic species whilst the molluscs are generally dwarf varieties. Solifluxion has taken place and it is possible that the lower trail at Ebbsfleet is of the early part of this stage.

Amelioration of the climate occurred at the end of this stage with the river being augmented, as a result of the seasonal thawing, and also having to carry partially frozen sludge which prevented downcutting and helping aggradation.

SECTION XV Buried Channel Erosion Stage:

Lowering of the base level gradually outbalanced the effect of overloading the river and let to marked downcutting. A deep narrow gorge eroded to a maximum depth of 100 feet below O.D. in the Lower Thames Valley extending up the main valley as far as Brentford.

SECTION XV (continued) Slades Green Trail Stage Upper Flood Plain Terrace Stage No.2:

A return to periglacial conditions resulted in marked solifluxion in the Thames Valley, the terrace slopes being enveloped in trail. Trail is well seen in the gravel pit close to Slades Green Station (now filled in), where it consists of unstratified clayey gravel up to 10 feet thick, overlying and festooned into the Crayford Brickearths.

This trail is reported to be the equivalent of the Hunstanton Brown Boulder Clay of the fourth glaciation of East Anglia.

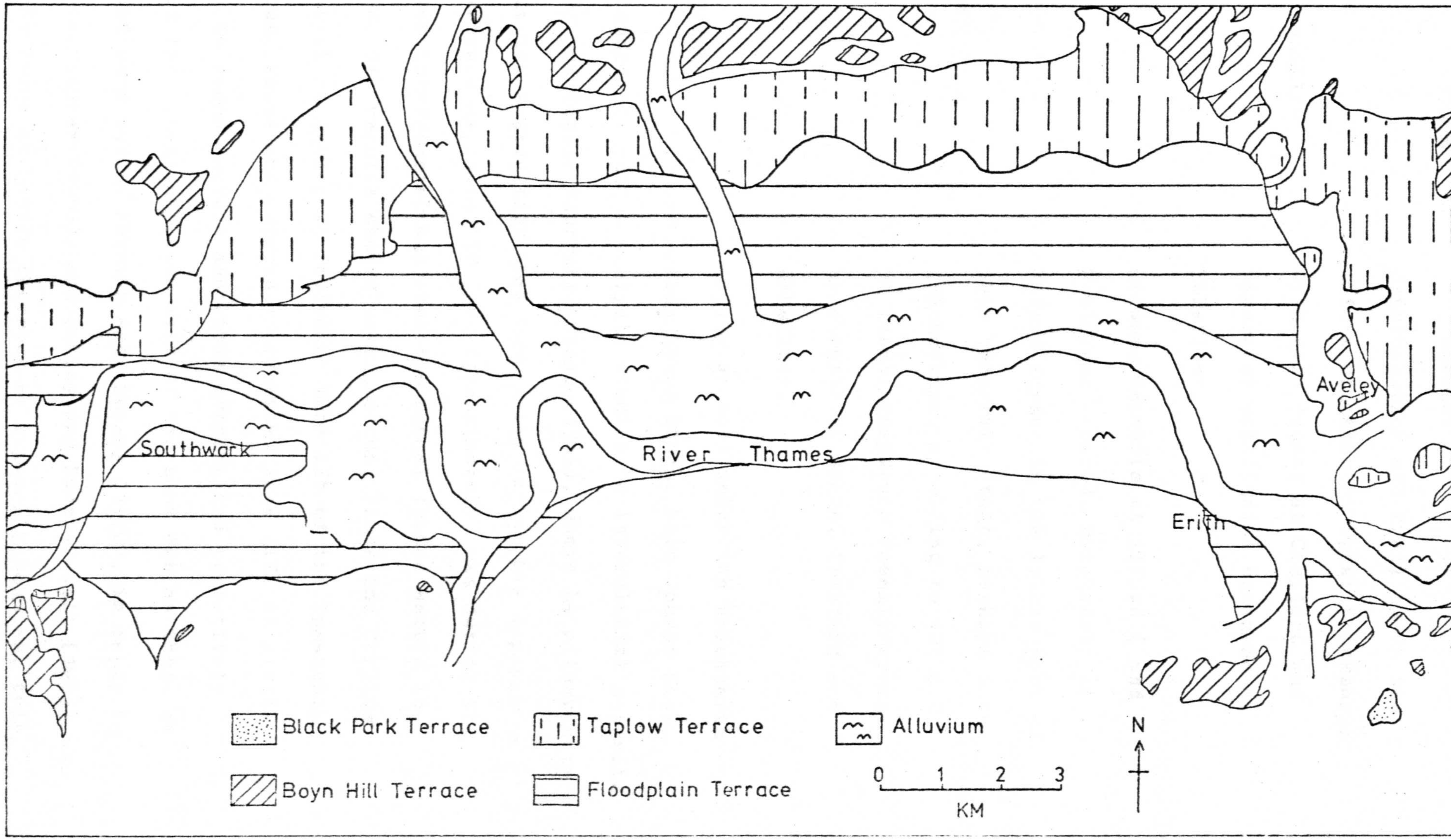
SECTIONS XVI - XVII Buried Channel Filling Stages etc.:

The remaining sections are those representing the channel filling as a result of an amelioration of the periglacial climate and the erosion that has taken place prior to the deposition of the present alluvium.

The lower terraces that are prominent in the Lower Thames Valley are shown by Wooldridge and Linton (1955), this map is reproduced as Fig.2.10 with the full succession of the terraces being well displayed on the north bank of the river in Essex.

The brickearths of Ilford were considered by West et al (1964), on the basis of pollen analysis, to be formed after the middle of the Ipswichian interglacial (later than King and Oakley), and state that the mammal faunas require to be restudied in the light of the environmental changes which were known to have taken place in the interglacials. A correlation given by these workers as a result of the dating of the Ilford deposits is shown below:

FIG 2·10 THE TERRACES OF THE LOWER THAMES VALLEY



After Wooldridge & Linton 1955

STAGE	DEPOSIT
WEICHSELIAN	Cryoturbation and trail above the Ilford Brickearth. Upper Brickearth with cold faunas at Crayford and uppermost solifluxion horizons at Ebbsfleet.
IPSWICHIAN	Organic deposits at Ilford (and Trafalger Square). Brickearth at Ilford formed in the latter part of this temperate stage, perhaps into Weichselian, aggrading to 42' O.D. at least. Temperate fossiliferous brickearth at Grays, Crayford and Ebbsfleet.
GIPPING	Taplow gravels under the brickearth near Seven Kings. Main Coombe Rock.

West extended his pollen analysis studies to interglacial deposits at Aveley and Little Thurrock, Grays (1969), where he attempts to show that the aggradation that took place during the deposition of the Middle Terrace deposits (50 feet approximately) was during the Ipswichian interglacial and that the mammal faunas should be restudied. His results showed that Quercus, Pinus and Corylus were present at Aveley to represent zone IIb of the Ipswichian and Corpus, Pinus and Quercus represented zone III. At Little Thurrock he found Quercus and Pinus present and tentatively concluded that these deposits were of the same age as those at Aveley and were not of Hoxnian age. Conway (1970), in reply to West quotes Zeuner (1959), and Oakley and Baden-Powell (1963) who regard the fauna at Little Thurrock as typically Hoxnian, this being the pre-Wolstonian interglacial. The non-marine molluscan fauna also agrees with King and Oakley (1936 op cit) and Kerney (1959), that the Little Thurrock Brickearth falls within a gap in the sequence at Barnfield pit, Swanscombe. This gap is represented by King and Oakley as Stages VI and VII who as recorded above place these deposits in the Ilford Stage (VII). Conway also cites the archaeological evidence for a Hoxnian age for these brickearths as they contain remains of Clactonian II industry, in the lower part of the deposit at least, these industries cannot be shown to be younger than Hoxnian.

Wymer (1957), in his study of gravels at 49 feet O.D. in the Globe Quarry of Little Thurrock supports King and Oakley when he found them to precede the brickearth and from the fauna contained within the gravel to be of Great Interglacial Age (Hoxnian). It was also found to be a little more recent than Lower Gravel at Swanscombe and to contain similar Clactonian flint implements.

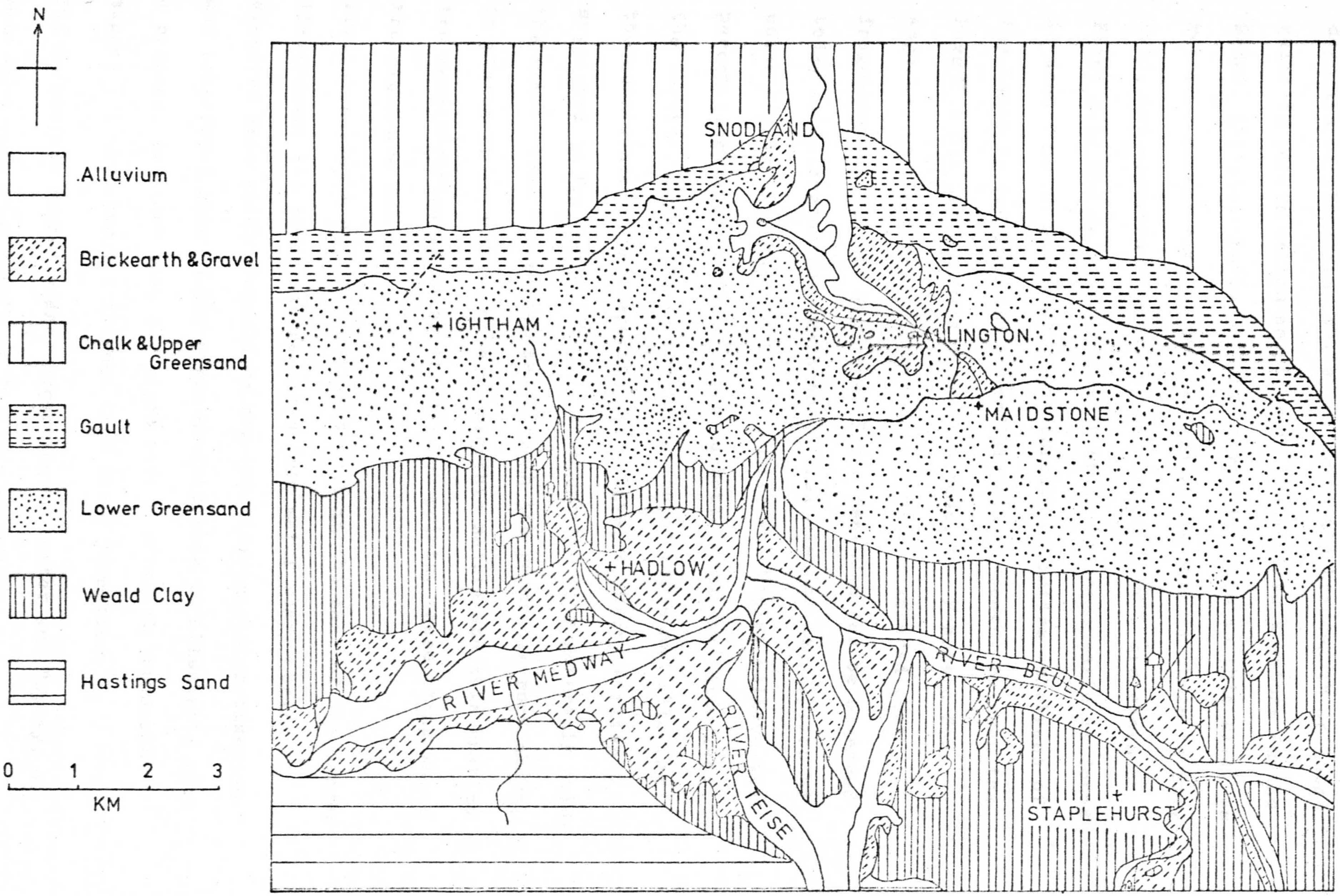
Wymer (1968), appeared to contradict this evidence when he regarded the flint implements of the middle and lower Thames valley as not providing any certain means of distinguishing between the Hoxnian and Ipswichian interglacials.

The exact dating of these deposits is still undecided with Kelloway et al (in Mitchell et al 1973), placing all the lower Thames valley brickearth deposits in the Ipswichian but accepting that the evidence of Hoxnian age for some of the deposits still exists.

Brickearths in the tributaries of the Lower Thames Valley:

The fact that the brickearths were not totally confined to the main valley of the Thames was recognised as early as 1838 by Morris.

FIG 2·11 GEOLOGICAL SKETCH MAP OF THE MEDWAY VALLEY AND THE ADJACENT DISTRICT



After Foster & Topley 1865

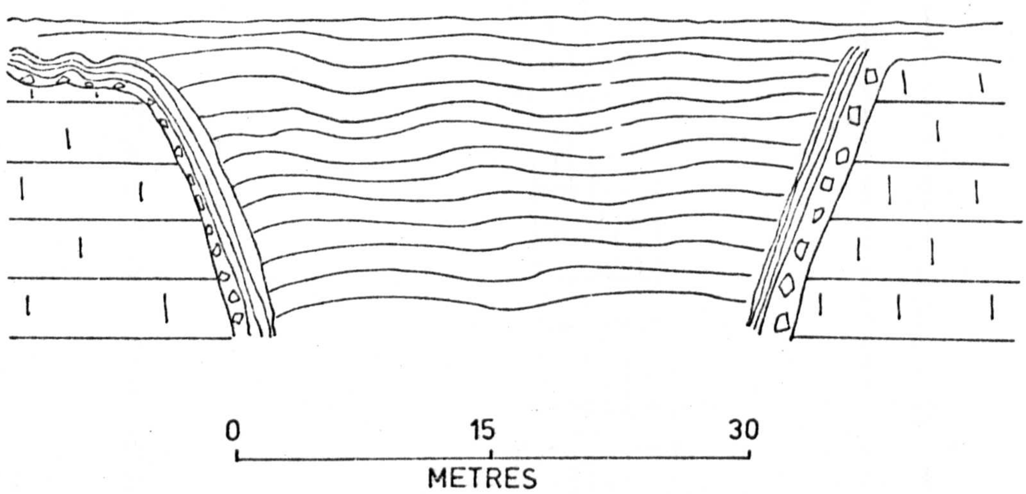
Foster and Topley (1865), in their study of the superficial deposits of the Medway valley refer to the brickearth as loess which in places occurs as pipes in the Kentish Ragstone (Hythe Beds). The distribution of brickearth deposits in this area, as recorded at the time by the Geological Survey, is shown in Fig. 2.11, and sections from Foster and Topley's work are shown in Figs: 2.12 and 2.13. The pipes in which the brickearth is found is described in places as going through an entire thickness of the Ragstone and into the Atherfield Clay beneath. Between the Ragstone and the Brickearth are two beds, the Sandgate Beds adjacent to the brickearth and a clay with weathered rock fragments next to the Ragstone. These features can be observed today at Allington near Maidstone, analysis and description of which appears in Chapters 5 - 9. Foster and Topley believe that percolating water, enriched with carbonic acid, had dissolved the Ragstone resulting in the formation of pipes and allowing the subsidence of the deposits from above, a theory earlier suggested by Prestwich (1855b). Although the clay generally holds the water that has percolated through the permeable rock above, in places it appears to have a permeable nature and this enables the concentration of water at selected points, these being where the pipes are found.

Prestwich (1855b op cit) indicated that in the case of the harder limestones, the pipes had resulted from water wear " being directed into given channels by pre-existing cracks or fissures " and considered some of the pipes at Maidstone to illustrate such a process. The fact that the pipes have a parallel trend also suggests a structural influence upon their formation.

The brickearth deposits are, according to Foster and Topley, a loam laid down as a result of flooding caused by water that could

FIG 2·12

SECTION ACROSS A BRICKEARTH PIT, MAIDSTONE



Brickearth distinctly stratified, contorted in the lower part of the pit

Sandgate Beds: fuller's earth interstratified with beds of sand

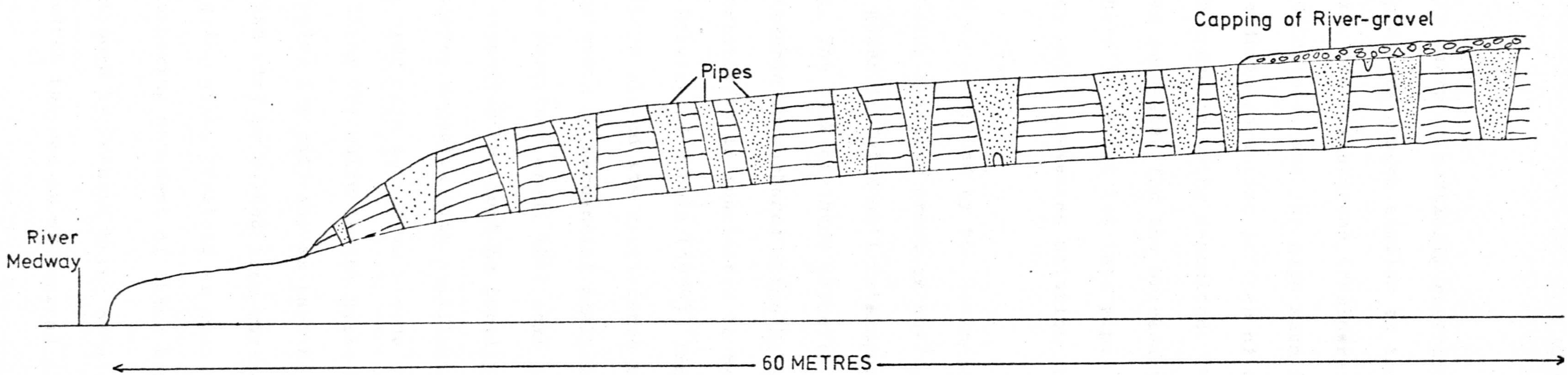
Clay with angular and weathered lumps of Rag

Kentish Rag

After Foster & Topley 1865

FIG 2·13

SECTION OF BRICKEARTH PIPES AND KENTISH RAG, HALF A MILE SOUTH OF ALLINGTON CHURCH



After Foster & Topley 1865

only escape through the Chalk scarp at partially restricted points, these being the deep narrow gorges similar to that at Snodland. The scarp was, during the Pleistocene, considered to be much further south, nearer Maidstone, and the gaps much narrower and therefore able to impede drainage during periods of excess rainfall, resulting in the brickearth being deposited. This method of deposition has been suggested for the brickearths at Hadlow, west of Maidstone, here it is not let into pipes as it rests upon an impervious clay which prevented solution from taking place.

Head Brickearth in this area is described by the Geological Survey Memoir (Worssam, 1963), as being a yellow brown or buff coloured structureless loam or silt, generally with well developed vertical jointing but without bedding. The bulk of these deposits were found in gulls or widened fissures in cambered Hythe Beds of the Medway and Len valleys:the brickearth is considered to be similar to that described by Dines, Holmes and Robbie (1954), from the Chatham area where these authors showed its resemblence to the loess of North Germany on the basis of mechancial analysis. Worssam suggests, that in the Maidstone area, that some of the material may have been wind deposited but most is locally derived from pre-existing silty or clayey deposits with solifluxion or sheet flooding predominating over wind action as a mode of transport. The brickearth filling the gulls in the Hythe Beds, as described by Foster and Topley (op cit) may in part have originated as silt borne by the wind or washed from surface spreads on high ground into gulls which remained as open fissures after the cessation of the cambering movement of these beds.

River Brickearth is also mentioned by Worssam being of a similar appearance to the Head Brickearth but not as widespread and occurring as level or gently sloping cover, 5' - 10' thick bordering on modern alluvium.

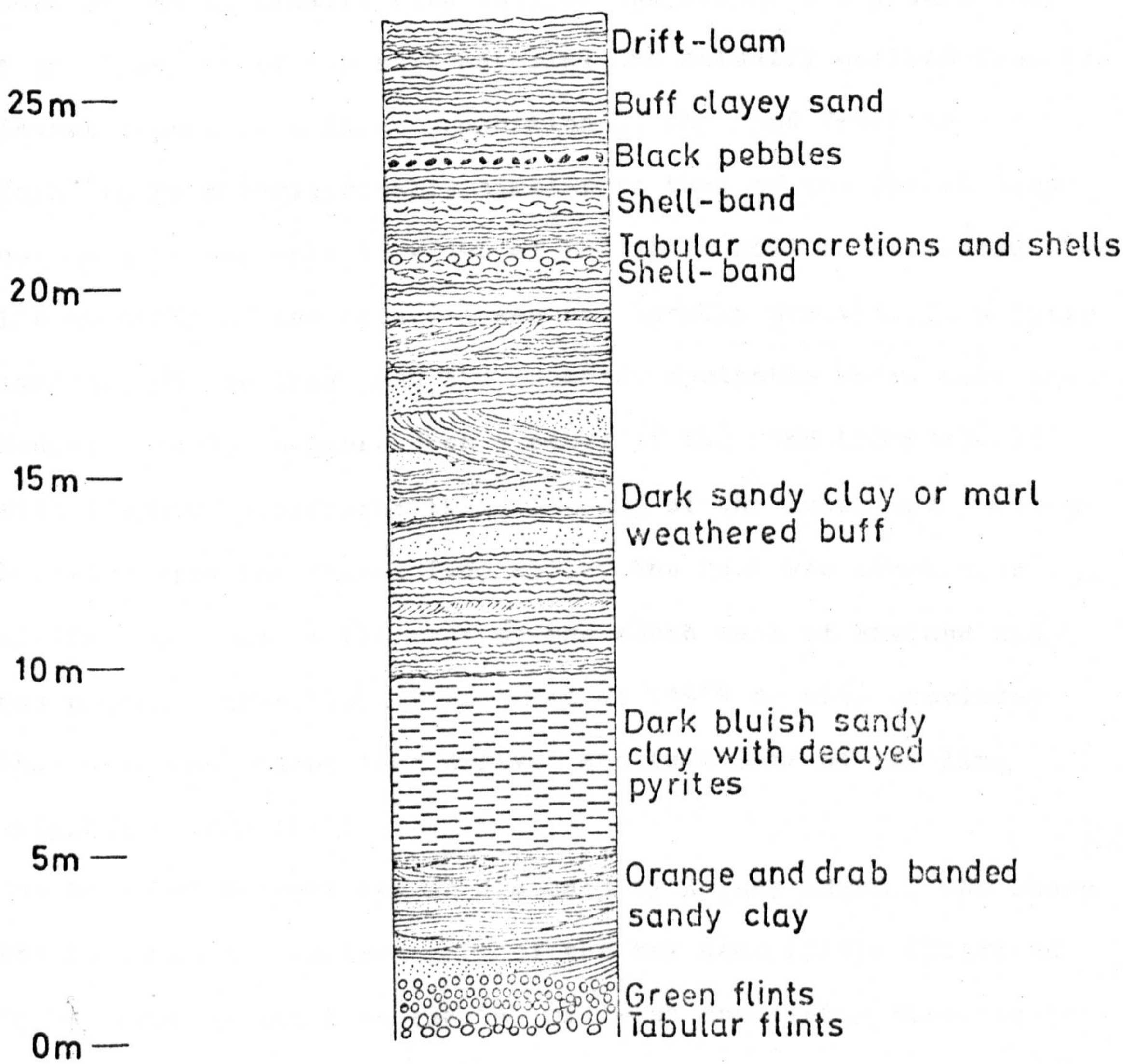
Dines, Holmes and Robbie (1954 op cit), described several brickearth sites from the Lower Medway Valley, the section at Hallin being later described by Kerney (1971). Here the brickearth is well graded, coarse to medium silt, not a pure loess but a wind blown dust intermixed with the chalky detritus washed in from the valley sides. The age of this deposit Kerney suggested to be Middle Weichselian, it appears stratigraphically earlier than the Late Weichselian but the fauna does not indicate it to have been deposited during the cold period of 28,000 - 13,000 B.P. An interstadial within the period 55,000 - 28,000 B.P. was proposed, this would probably be equivalent to the Upton Warren interstadial complex. The brickearths of the Darent valley to the west of the Medway do not appear as extensive as in the latter, as Prestwich discovered when describing the drift stages within the valley (1891). The most important occurrence is that on the south side of Limpfield Common.

Loess of the Isle of Thanet:

Loam and drift deposits have been described from the now famous Pegwell Bay section for over one hundred years with Prestwich showing this as drift in his sections when describing older Tertiary deposits, (1852). Gardener (1883), who was also describing the Teriary deposits, shows the upper part of this section as drift-loam overlying buff clayey sand containing black pebbles, (Fig.2.14), this being the deposit described by Pitcher, Shearman and Pugh (1954), as loess. The recognition of this material as loess was based on the criteria as laid down by Russell (1944), when describing the lower Mississippi valley loess. The deposit

FIG 2·14

VERTICAL SECTION AT PEGWELL BAY



[after Gardner,1883]

was composed of highly angular quartz grains with a small proportion of exceedingly thin flakes of mica with a suite of heavy minerals similar to those found in the underlying Thanet Beds.

Weir and Catt (1969), showed by a mineralogical comparison of the different size fractions greater than 2um from the lower part of the brickearth with that of the Thanet Beds, that only a small amount of the soil material was actually derived from the Thanet deposits. A large proportion of the sand fraction was found to be mineralogically similar to that of the Thanet Sand but as this was only 10 - 14% of the total soil it indicated that the majority of the material was not locally derived. In a later analysis of the loess and the adjacent sediments Weir, Catt and Madgett (1971), suggest from a study of the sand (50um >) and silt (2-50um) fractions that 10 - 20% of the loess was derived locally from the Thanet Beds whilst the rest was considered similar to loess in the rest of the south east of England and had probably travelled. Pitcher et al (1954 op cit) concluded that some was Thanet Sand derived and that some of the lime originated from the Chalk.

The loess at Pegwell Bay is dicussed by Kerney (1965), who shows the loess in the eastern part of the bay near Little Cliffsend to be covered with Post-glacial hillwash containing firecrackled stones and flint flakes of Neolithic and Bronze Age. Also shown by Kerney is evidence for more than one phase of cryoturbation action having taken place with later involutions being shown to cut across earlier ones. From C^{14} dating an age of 30,000 - 14,000 B.P. is given, this is pre-Bølling Pleniglacial Stadial B of the Middle Weichselian, (Devensian). This would suggest that the Pegwell Bay loess is equivalent in age to the upper part of the brickearth at Cherry Orchard Lane to the north in south east Essex as described below.

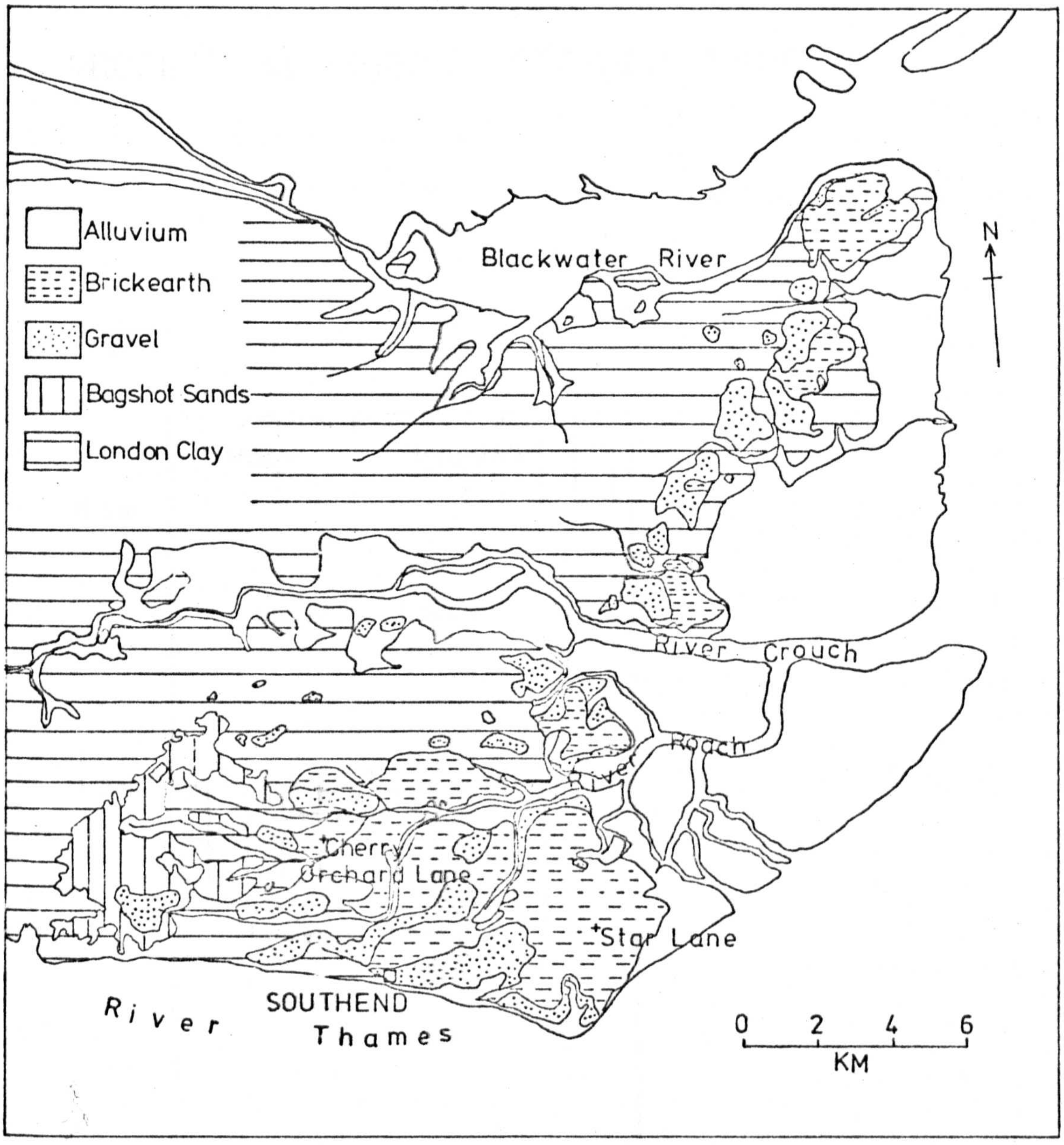
Fookes and Best (1969) confirmed the Pegwell Bay deposits as loess on the basis of their geotechnical properties, their silty nature, their moderately high density and their displaying metastable characteristics, these being soils that have the ability to collapse and subside under load upon wetting. They postulated that the silt sized quartz material which much of the deposit is comprised was derived from retreating Wurm glaciers to the north and east.

Essex Brickearths:

The north bank of the Thames in the estuary region has various superficial deposits including brickearths which Gruhn, Bryan and Moss (1973), have recently shown to occur mainly south of the river Crouch (Fig.2.15). Mechanical analysis has indicated that these brickearths are of a loess nature having a silt content in the 50% - 80% range. In the majority of the sites studied it was regarded as being in a primary position, deposited by wind during a phase of periglacial climate, whilst at Eastwood fine horizontal bedding was observed suggesting deposition by fluvial means. At Cherry Orchard Lane a sequence of two distinct loess horizons were noted (Fig.2.16), these being separated by a weathered layer of parabraunerde soil, this being an indication of warm temperate conditions. The events that took place in the formation of these deposits are described as representing the Devensian period with the lower loess being of Early Devensian age (pre 50,000 B.P.), and the upper loess being of Late Devensian age (26,000 - 10,000 B.P.). The warm temperate soil was suggested as either belonging to the Chelford interstadial of the Early

FIG 2·15

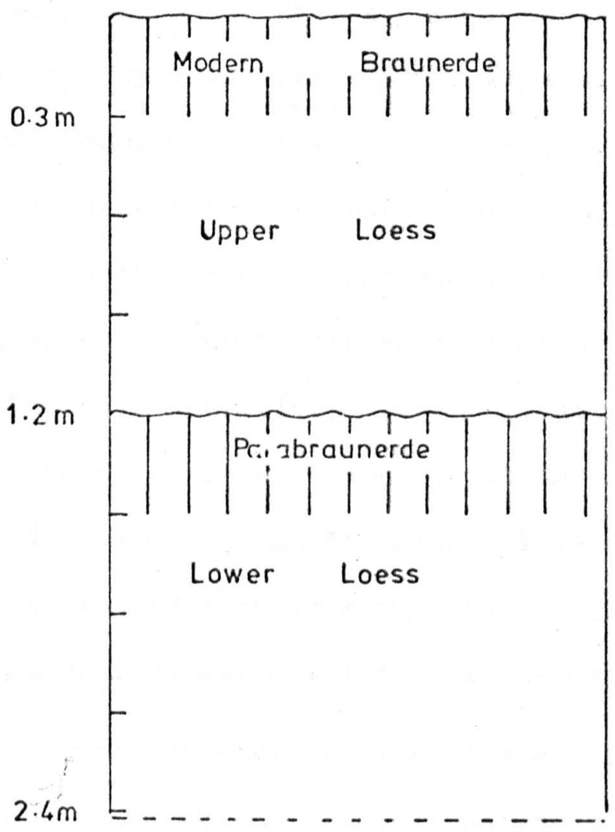
GEOLOGICAL MAP OF SOUTHEAST ESSEX



After Gruhn, Bryan & Moss 1974

FIG 2·16

PROFILE AT CHERRY ORCHARD LANE



BURIED PARABRAUNERDE SOIL FORMED ON THE LOWER LOESS

After Gruhn, Bryan & Moss 1973

Devensian (60,000 B.P.) or the Upton Warren interstadial complex of the Middle Devensian (50,000 - 26,000 B.P.). Calcareous concretions or ' race ' were also found by these authors at Cherry Orchard Lane and these along with their associated deposits, as well as the deposits at Star Lane Brickworks, are described in Chapters 5 and 10. These two sites are at present the only ones that are commercially worked for brickmaking with the Eastwood site, as mentioned by Gruhn et al, no longer open.

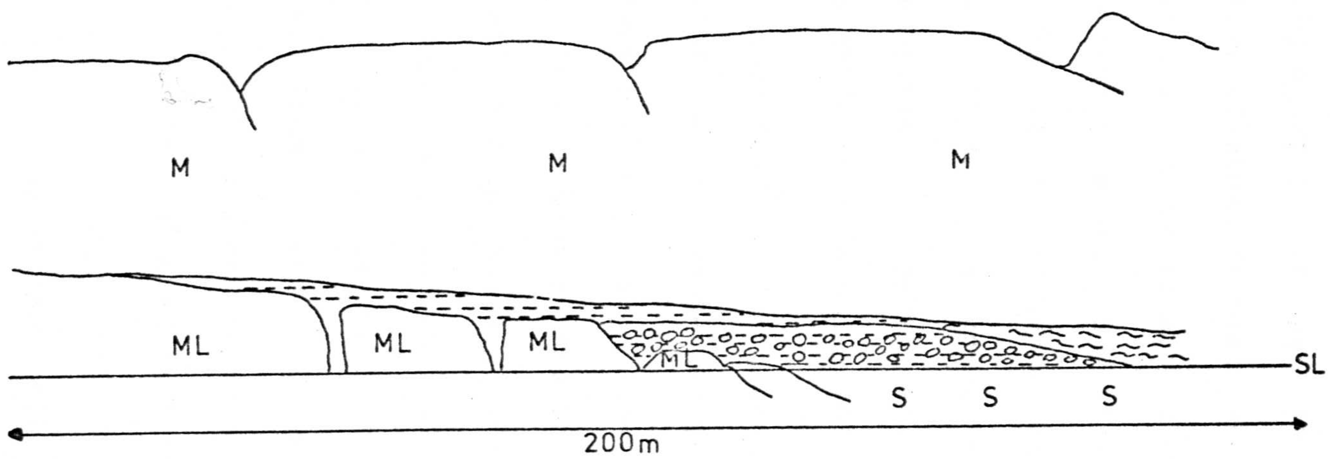
Loess in Durham:

The only known deposit of loess in this area of England is that described by Trechmann (1919), at a site on the Durham coast at Warren House Gill. The deposit, a pale brown material containing calcareous concretions and found between the older Scandinavian Drift and the younger Cheviot Drift (Fig.2.17), appeared to Trechmann similar to the loess he had observed in New Zealand and to the descriptions previously attributed to continental loess in Europe. The thickness at this site is 1' to 12', being banked against the north facing slope as though by aeolian action of what is now seen as a post-glacial valley superimposed upon a pre-glacial valley cut into the Magnesian Limestone.

The genuine undisturbed loess has a thickness of approximately 6 feet and is absent from the northern slope of the valley. It passes upwards into a loess that has been redeposited by water and which shows evidence of horizontal bedding having seams of sand and fine gravel within it. The undisturbed loess does not show signs of stratification but indicates a tendency to break in a vertical direction rather than along a horizontal plane.

The concretions which occur throughout the undisturbed bed although more numerous towards the base will be described in

FIG 2·17 THE DURHAM COAST AT WARREN HOUSE GILL SHOWING THE POSITION OF THE LOESS



True loess with concretions

Loess, gravel, and sand with occasional boulders, redeposited by water

Contorted drift consisting of Scandinavian drift mixed with loess

S Scandinavian drift

M Main local drift

ML Magnesian Limestone

After Trechmann 1919

Chapter 10 . The upper disturbed sediment is devoid of concretions, this suggesting that the concretions are as much an interglacial form as the loess and have been washed out during the time of fluvial redeposition.

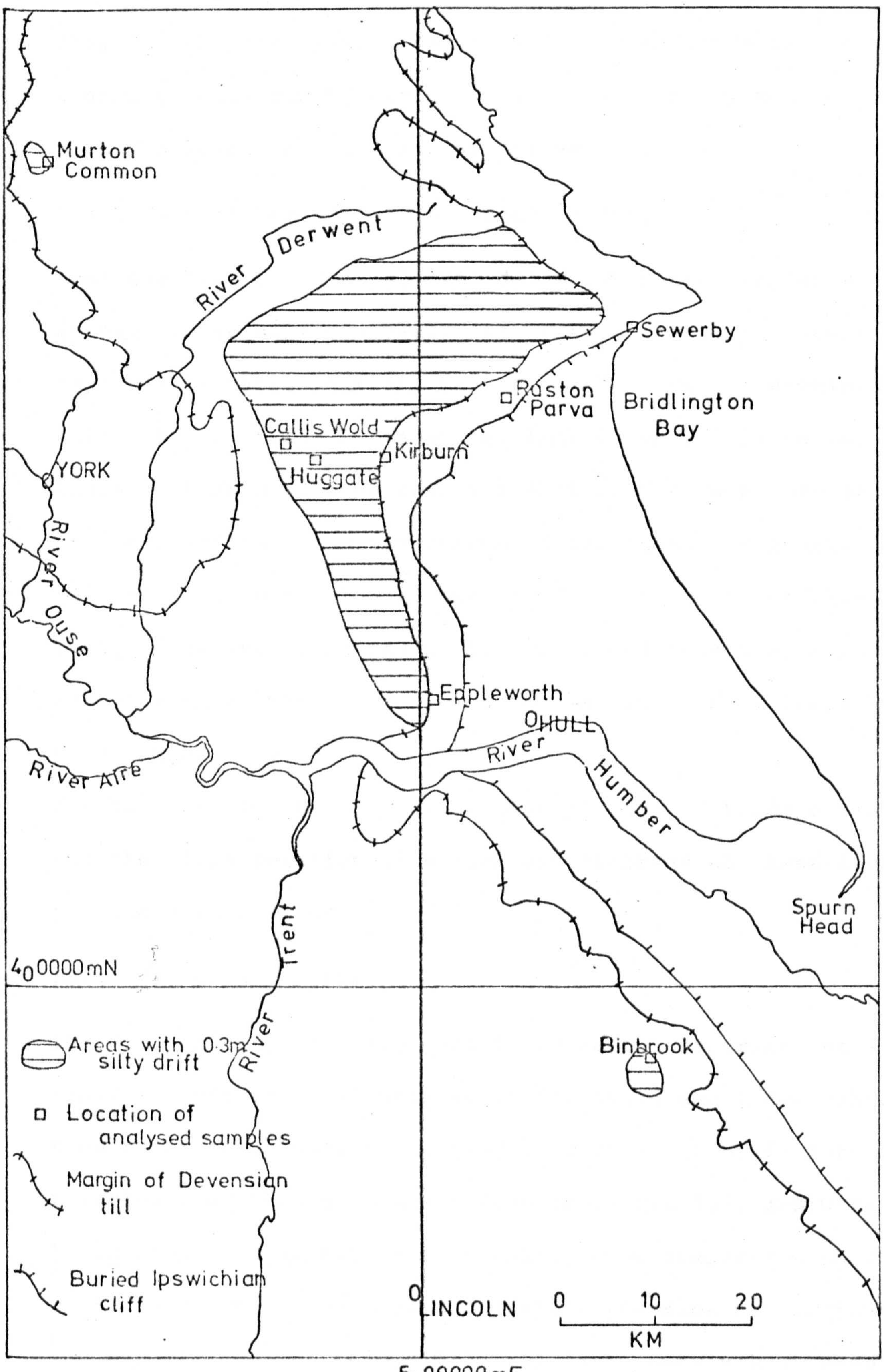
Mineralogically, Trechmann found the loess to be similar to that occurring in Bonn, the results obtained are compared with those of other British deposits and loess from a site in New Zealand. In comparison to water deposited glacial clays the Durham loess had a low alumina content but a high silica and carbonate of lime percentage. The low plasticity and high porocity and light colour were also noticable differences. The industrial development along the north east coast has resulted in this exposure being totally covered by the spoil of a colliery.

Thin drifty soils that occur on the Chalk have been given a great deal of prominence in the last twenty years. In many cases these soils have been shown to be derived from other areas, and not to have been formed insitu by the residual weathering of the Chalk. Perrin (1956), describes Chalk Heath soils from the South Downs of England and compares their mechanical property of grain size with that of a Brickearth from Wye in Kent and a Loess from Herford in Germany. The two British deposits appeared comparable and an analysis of the heavy mineral fraction of the sand grade indicated that those minerals present in the Chalk Heath soil were too rich to be considered as the residual portion of weathering of the Chalk. The presence of blue amphibole suggested to Perrin that these soils had been derived from Pleistocene deposits and were therefore of Pleistocene or post-Pleistocene age.

A later work by Perrin, Davies and Fysh (1974), discussed aeolian deposits in eastern and southern England, of Late Pleistocene age,

FIG 2·18

DISTRIBUTION OF LOESS-CONTAINING SUPERFICIAL DEPOSITS IN EASTERN YORKSHIRE AND LINCOLNSHIRE



After Catt, Weir, & Madgett 1974

with five main geographical provinces distinguished. Typical mechanical composition curves are given for each area along with heavy mineral analysis of the soils and the underlying Boulder Clay for eastern areas. The silts of the southern province are stated to shcw continuity, on the basis of heavy mineral counts, with the loess on the Chalk of northern France.

Loess in east Yorkshire and Lincolnshire:

From the literature on glacial deposits in this region there appears to be only one record of loess, this being recently reported by Catt, Weir and Madgett (1974). Having examined the thin silty superficial deposits, that occur mainly on the Wolds, these authors concluded that the silt content was composed chiefly of loess derived from the debris of the Devensian glaciation. Several sites were studied west of the margin of the Devensian Till, these are indicated in Fig.2.18, and from the grain size and mineral content a basis ıor the recognition of loess was established.

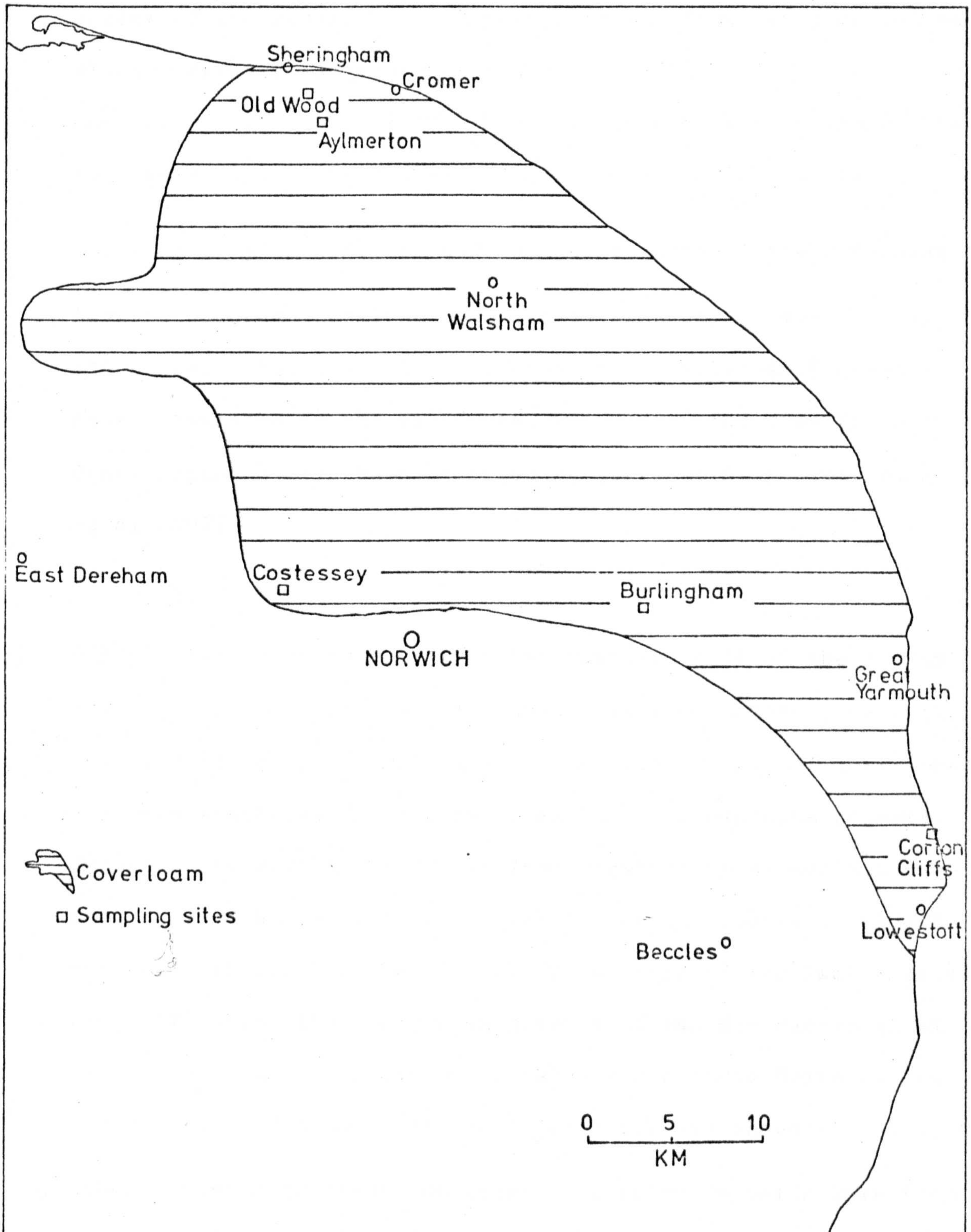
Further descriptions and discussion of some of these deposits and the field relationships that are observed at these localities are found in Chapters 5 - 9.

Loess in north Norfolk:

The distribution of loess containing soils, described on a similar basis to that outlined in Yorkshire and Lincolnshire, has been recorded by Catt et al (1971), working in north Norfolk. The coverloams of this area are extensive (Fig.2.19), and were found to be comprised mainly of silt which, when compared with the silt in the loess of Pegwell Bay indicated mineralogical similarities. The significance of this similarity is to some extent questionable with the silt comprising 75% quartz and 20% feldspars. The silt

FIG 2·19

DISTRIBUTION OF COVERLOAM IN NORTH NORFOLK



After Catt, Corbett, Hodge, Madgett, Tatler & Weir 1971

fraction was also found to be comparable with that of the Hunstanton Till of north Norfolk, this was considered to be the source of the coverloam silt being derived from the Weichselian glacial outwash sediments by deflation.
Samples of deposits at three of the sites described by these authors in this area have been examined and are described in Chapter 5.

Loess in Clay with Flints and Coombe deposits in the Chilterns:

Several records containing loess have been noted, Avery et al (1959) described loess in the brown earth series at Hampden, Buckinghamshire in the Batcoombe, Winchester and Charity soils. Other deposits have been recorded by Avery et al (1969) and Avery et al (1972).

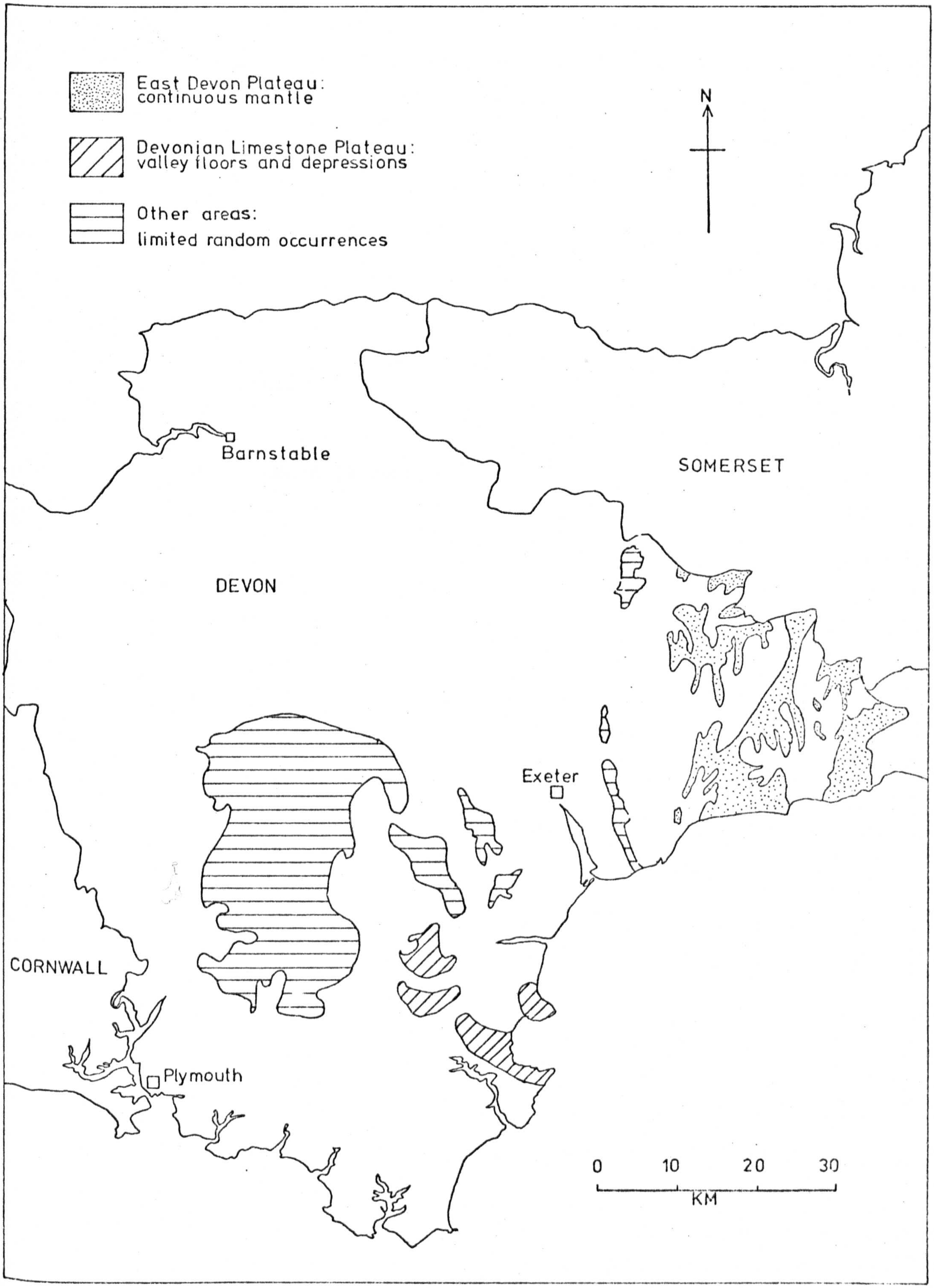
Loess in Devon:

Silty drift in Devon occurs in the southern part of the county and from mineralogical and mechanical analysis Harrod, Catt and Weir (1973), suggest that this is comprised mainly of loess that has been weathered and partly mixed with the deposits beneath. These deposits are regarded by these investigators to be aeolian having been derived at least in part from the glacial outwash deposits of the North Sea Basin during the later part of the last glaciation, probably during the Upper Pleniglacial of van der Hammen et al (1967), or late Devensian as it is referred to in Britain. The distribution of these silty drift deposits are shown in Fig.2.20.

Other deposits of loess and loess containing deposits have been described from Scotland by Galloway (1961), from Derbyshire by Pigott (1962), by Bullock (1971) in the Malham Tarn area, and in Westmoreland by Furness and King (1972. Welsh loess has been recorded by Wirtz (1953).

FIG 2·20

DISTRIBUTION OF SILTY DRIFT DEPOSITS IN DEVON



After Harrod, Catt, & Weir 1973

CHAPTER THREE

LOESS IN EUROPE

CHAPTER THREE

LOESS IN EUROPE

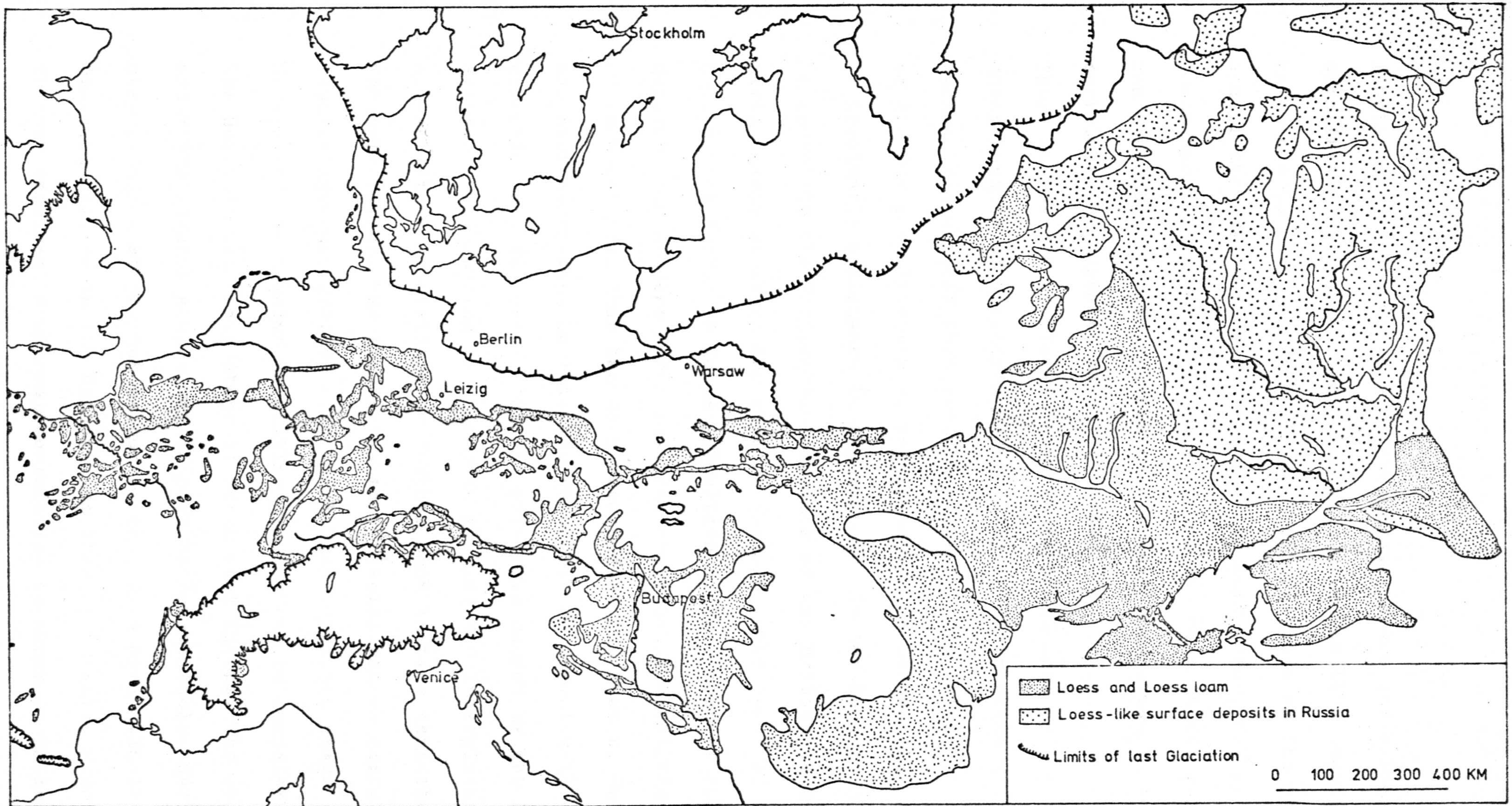
The distribution of British loess was discussed in the previous chapter along with the probable ages of the individual deposits. The location of the British deposits cannot be considered in isolation from those of Europe, particularly the sediments of south eastern and southern England which appear to show a relationship to those of northern France and Belgium.

European loess deposits can be seen to extend along an east-west band from the Ural mountains of Russia through to Poland, East Germany, West Germany, South Limburg, Belgium and into the Seine and Somme valleys and further west to Britanny. Deposits are also located in the Danube valley in Czechoslovakia, Austria, Hungary and extending southwards into Yugoslavia. Italian and southern French deposits have also been shown to occur in the Po and Rhone valleys respectively. Grahmanns map (1932), of the distribution of most of these deposits is shown as Fig.3.1, although more recent work has contributed further knowledge regarding the location of loess.

The periglacial belt that is seen today across Europe has been the result of repeated changes from a humid and temperate climate to a dry and cold one and vice versa which left their mark in the succession of weathering soils and beds of loess.

The present area of this loess belt includes part of the northern temperate zone although an oceanic influence on the climate at the western end of the land is seen with northern France and southern England affected by mild winters and summers whilst the eastern end in Russia has more climatic extremes with severe winters and hot summers, a continental type of climate.

FIG 3·1 DISTRIBUTION OF LOESS IN EUROPE



After Grahmann 1932

A brief description of the distribution, nature and climatic significance of the European loess is given in this chapter with reference to particular localities, mainly those at the western end of the east-west band. Although in some areas the age of the loess has been established this is not the case in all regions and consequently difficulties have arisen when attempts to correlate the deposits have been made.

There can be few people who have contributed more to the understanding of stratigraphy of European Pleistocene deposits during this century than Frederick Zeuner. His interpretation of the European literature, particularly the German has been of invaluable assistance to those whose aim has been to attempt to correlate the Pleistocene deposits of the British Isles, particularly southern and eastern England, with those of Continental Europe. A large proportion of this chapter has been derived from Zeuners works as these are readily available sources of much material that has been recorded by the French, Germans and East Europeans. Correlation with British deposits is only possible in a few cases, this is primarily caused by the lack of agreement in equating the European glacial and interglacial stages with the British ones further back in time than the Hoxnian interglaciation. The Ipswichian interglacial can be correlated on biostratigraphic grounds with the Eemian temperate stage of north Europe and the Hoxnian on similar grounds can be correlated with the Holstein temperate stage of north west Europe. The Wolstonian and Saale glacial stages may in part be correlatable. Earlier stages cannot at present be correlated, with more climatic stages being identified in the Netherlands than in Britain, presenting further problems. A general correlation is shown in Table 3.1. after Mitchell et al (1973).

TABLE 3.1

British Stages		Continental usage e.g. The Netherlands, N. Germany		Alps
FLANDRIAN	General agreement	HOLOCENE		
DEVENSIAN	General agreement	WEICHSELIAN	Probable	WÜRM
IPSWICHIAN	Palaeontology	EEMIAN		?
WOLSTONIAN	Cold	? SAALE (parts)		
HOXNIAN	Palaeontology	HOLSTEIN		
ANGLIAN	Cold	?SAALE ?ELSTER		
CROMERIAN and earlier		?		

after Mitchell et al (1973).

Loess of the Ukraine:

The largest loess area of Europe is that of the Ukraine in southern Russia where Krokos recorded up to six loess beds (1927, 1935), which were separated by well developed soils, mostly of the Chernozem type. The third loess as numbered from the top is seen to be contemporary with the Saale glaciation which penetrated the loess leaving a sheet of moraine. Krokos considered the higher two loess layers to be equivalent to the two phases of the Last Glaciation. These younger loess horizons are separated by thinner soil horizons than that which separates the lowest Younger Loess from the Older Loess. Krokos (1930) showed this in a section at Sbranki in north-western Ukraine where in horizons

B and D are the Younger Loess with a thin soil C separating them and a thicker soil E separating them from the Older Loess F

A. 0.40m = Recent soil, partly denuded

B. 2.50m = Yellow loess

C. 0.45m = Grey humous loam with tubules of $CaCO_3$

D. 2.00m = Yellow loess

E. 1.79m = Grey forest soil, developed by degradation on an original Chernozem

F. 3.40m = Yellow loess-like loam with tubular concretions of $CaCO_3$

G. 1.46m = Reddish-brown, sandy boulder clay

The penetration of the ice of the Dnjepr lobe of the Saale Glaciation, leaving the moraine (G), into the succession of the upper Older Loess during the formation of the latter does not appear to have been observed elsewhere.

Loess of Hungary:

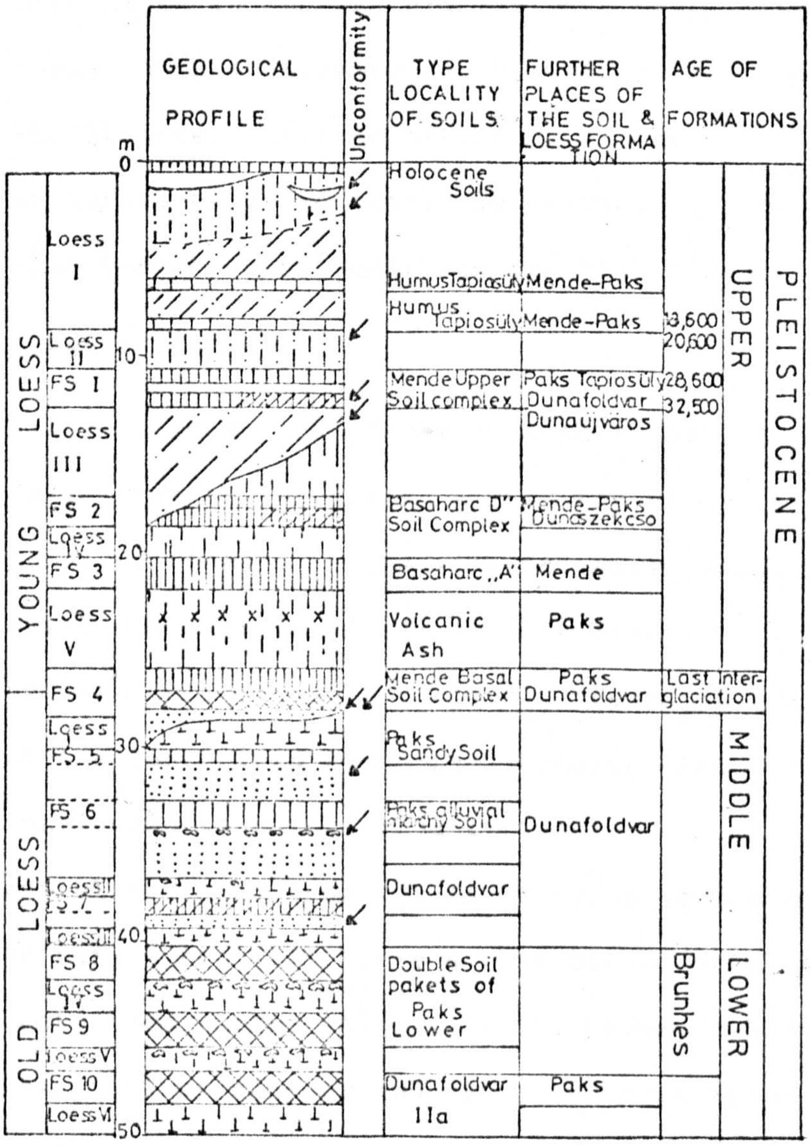
Until Scherf worked on the Hungarian Loess little consideration had been given to its subdivisions. Using pedalogical methods he was able to study the weathered horizons and in 1936 he reported his findings to the International Association for the Study of the Quaternary Period in Vienna, the most important site being that at Paks, 30 kilometres south of Budapest where several weathering horizons in the loess are seen.

The current work on the Hungarian Loess is being undertaken by the Geographical Institute under the direction of Marton Pecsi. Pecsi is systematically studying the main loess outcrops in Hungary and the rest of the Pannonian Basin and the Danube Valley sites by means of radio-carbon dating of the fossil soils that have developed on each successive loess horizon. A generalised chronological profile of the Hungarian Loess after Pecsi (1972), is shown in Fig.3.2.

As in the Ukraine the loess can be divided into the Younger Loess and the Older Loess, the Younger Loess comprising a series of approximately 30 metres in thickness the upper part of which is associated with the sandy loess and the sand horizon and is termed the first loess series. Below this is a second loess series of typical loesses with two humic loess horizons. The lower two thirds of the Younger Loess is divided by the occurrence of three well developed forest/steppe soils which are locally doubled. In the Mende loess exposure the upper of the doubled soils occur at about 10 metres and is dated by radio-carbon as 28,000 years B.P. and has never been dated older than 32,000 years B.P. On the basis of Pecsi's work this has been termed the Upper Mende soil complex and denotes the Upper-Middle Wurmian boundary. Beneath the Upper Mende occur two additional forest steppe soils, first described by Pecsi (1965), from the Basaharc brickworks. The upper soil, the Basaharc D is a doubled soil series 14 - 16m down the succession and the lower soil, the Basaharc A, is a thick humic soil occurring at a depth of 18 - 20m. According to Pecsi, the Basaharc D corresponds to the interstadial at the end of the lower Wurm and the Baraharc A, was formed during the later part of the lower Wurm. The loess beneath the Basaharc A is the oldest memeber of the Younger Loess. The Mende Basal soil divides the Younger Loess from the Older Loess, a soil complex comprising a dark steppe soil that overlies a well developed brown forest soil, the thickness of the complex is about 2m and is dated as belonging to the second part of the last interglacial and beneath it are the Older Loess series. The Older Loess

FIG 3·2

GENERALIZED CHRONOLOGICAL DIVISION OF THE HUNGARIAN LOESS PROFILES.



FS. Fossil Soil

After Pécsi 1972

profiles are infrequent in Hungary but 4 to 6 fossil soils have been recognised from the Older Loess being augmented by 4 additional soils proven by borings at Paks and Dunafoldver. Most of the soils in the Older Loess are reddish brown, reddish yellow and clays. The upper three soils, two rust coloured hydromorphous clay soils and a brown forest soil are attributed by Pecsi to the Middle Pleistocene. The oldest soils in the loess succession in Hungary are the Paks basal double soil complex, these reach a thickness of 5m and are assigned to the Lower Pleistocene. The base of the Pleistocene at Paks and Dunafoldver is marked by a red clay, the weathering product of the upper Pleistocene which underlies the Pleistocene.

Loess in Germany:

The term loess originates from this part of Europe having been taken from the brickmaking industry of the Rhine area by von Leonhard (1823), to describe the river deposit that was used in brick manufacture. Lyell in 1834 described the loess he observed between Cologne and Heidelburg, recording the lobe like intrusions of the loess into the gravel beneath. These features Lyell considered to have formed by the loess filling hollows in the gravel that had been cut as trenches by the river. The appearance of this loess fill bears a resemblence to those observed by Foster and Topley (1865), in the Medway valley as mentioned in the previous chapter and which are seen today in parts of Britain where brickearth is found associated with involutions that have resulted from periglacial activity. The predominence of shells of a terrestrial nature led Lyell to conclude that the loess had been deposited gently by fluviatile or lacustrine means but having stated this he was not convinced that his own theory was adequate with the final remark " the more I have studied the more difficult I have found it to form a satisfactory theory."

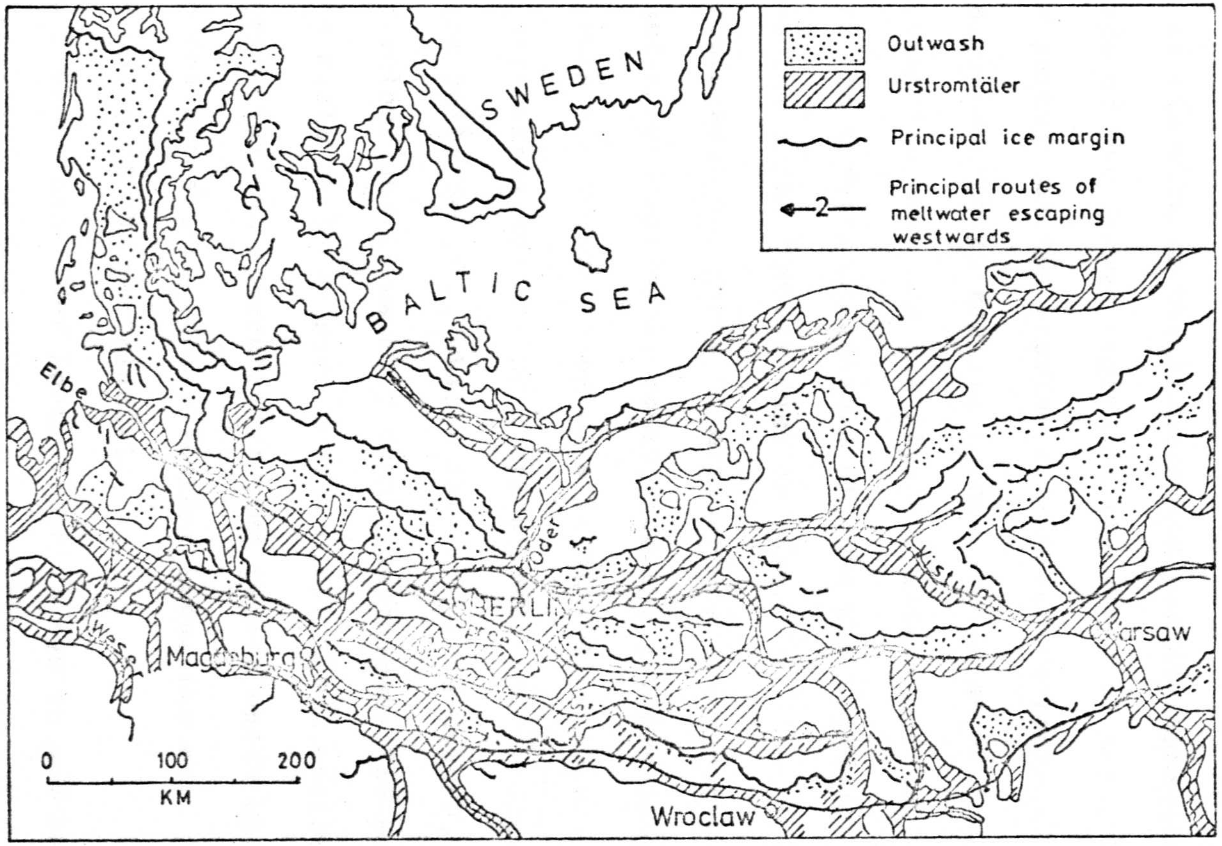
Flint (1971), contrasts the deposits of the Rhine with those of north central Germany. The loess of the Rhine he states to be thicker and more widespread to the east of the valley than to the west and to be thicker on west facing slopes than on those facing east. From this it is inferred that the westerly winds were the dominant transporting agency for the outwash of the Alpine glaciers that was carried down the Rhine during periods of melting to be left high above normal river level and redeposited at a later stage by aeolian processes. The loess to the north is found to be thicker on north east facing slopes and is thought to have been transported by north easterley winds from the outwash in and around the Urstromtäler.[1] The wind patterns of the Pleistocene and the pressure systems during the glacial periods which affected the distribution of the loess are considered in Chapter 4. The Urstromtäler of north Germany, Denmark and Poland which is shown in Fig.3.3 after Woldstedt (1955), is taken from Embleton and King (1968), who state that the southernmost of the main five Urstromtäler as being generally considered to date from the Warthe glaciation while the remainder existed at various stages of Baltic ice retreat in the Weichsel stage.

From this it may be inferred that the loess of north Germany is of Weichselian or post-Weichselian age. Although this observation may be self evident, with any loess found to occur on the surface

1. Urstromtäler (Germany) or Pradoling (Poland) are great meltwater channels formed peripherally to the Baltic ice at various stages and now carry lengthy segments of the Weser, Elbe, Oder, and Vistula rivers along with other streams of lesser importance.

FIG 3·3

MORAINIC LIMITS, OUTWASH AND URSTROMTÄLER OF NORTH GERMANY, DENMARK AND POLAND



After Woldstedt 1955

in an area glaciated during the last 60,000 years, it does allow such deposits to be equated with the loess of Pegwell Bay, the Medway valley and other localities of the Kent region of England.

At the beginning of this chapter the general climate of the regions across the loess belt that exists today was referred to. Zeuner (1959), in his work on the Pleistocene period emphasises the importance of the German region in the study of the periglacial zone, in particular the prominenc of river terraces and loess deposits. This area of central Europe was situated between the Scandinavian ice mass and the Alpine glaciers and was more able to record the minor oscillations of cold and temperate phases than were the areas further east or west.

In the south west and parts of mid Germany there has long been recognised a subdivision of loess into the younger and older complex with the former being of a light yellow colour and fresher appearance and having comparatively poorly developed weathering soils in them, whilst the latter is darker, yellowish brown in colour and is usually deeply weathered. The well developed soils that are seen on the Older Loess indicates that the interglacial and interstadial time period which occurred prior to the deposition of the Younger Loess was much greater than the whole of the postglacial.

Both the Younger and Older Loess deposits can be subdivided Soergel (1919), recorded a fossil soil, thin and not representing a long and intense period of weathering, but subdividing the Younger Loess into two phases, I and II. The Younger Loess, with both its phases represents the latest period of cold steppe conditions and is associated with two river terraces that post-date the Saale Glaciation in Thuringia. Younger Loess often rests unconformably on older moraines but it is not found on the moraines of the Weichsel phase. A Younger Loess occurs in certain districts on the moraine of the Warthe phase but both Younger Loesses have not been found on the Warthe moraine. Zeuner (1959 op cit), considers the two Younger Loesses to be contemporary with Warthe and Weichel Phases respectively, although he points out the possibility of the Warthe Phase being earlier that the Younger Loess I.

The Older Loess usually antedates the Last Interglacial, a period much longer than the Postglacial resulting in weathering and denudation which did not assist the preservation of good loess sections.

The section at Achenheim near Strasburg displays both the Older and Younger Loess horizons, Wernet (1929), this is shown below along with the ages of each horizon:

11. Recent soil : Postglacial
10. Younger Loess II : second cold phase of the Last Glaciation
9. Weaker weathering soil : interstadial
8. Younger Loess I : first cold phase of the Last Glaciation
7. Weathering Loam : Minimum age: soil of Last Interglacial
6. Upper Older Loess : Penultimate Glaciation - probably second phase.
5. Weathering Loam, slightly decalcified surface of Middle Older Loess, interstadial
4. Middle Older Loess : Penultimate Glaciation : First phase.
3. Weathering Loam, humous formed on Older Loess : Interglacial

2b. Fresh lower Older Loess : Antepenultimate Glaciation, probably second phase.

2a. Sand Loess : Probably first phase of Antepenultimate Glaciation.

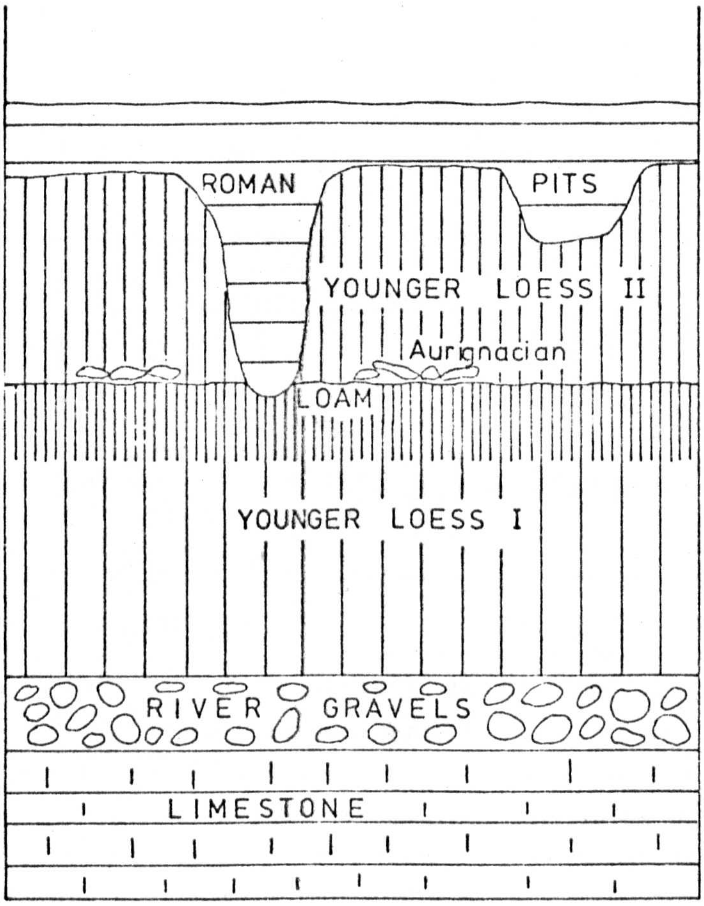
1. Marls and fluviorite sands of the Rhine : Antipenultimate Interglacial.

At Linsenburg & Wallertheim on the Rhine the subdivision of the Younger Loess are seen, Figs: 3.4 and 3.5.
Schmidtgen (1930, and Neeb (1924), described the Linsenburg section here, on the Younger Loess I surface was discovered an Aurignacian resting place with fauna remains, this was covered by Younger Loess II. The bones were fresh and Schmidtgen inferred that humid weathering had not taken place since deposition and that this layer dates from the cold phase of the Younger Loess II. The bones would have been destroyed if they had belonged to the intervening mild interstadial.
At Wallertheim, Schmidtgen and Wagner (1929), found a Mousterian hunting site which post dated the main mass of the first Younger Loess with loamified Younger Loess I and the fresh Younger Loess II covering the site. The Younger Loess II is subdivided by a thin band of loam which Schmidtgen and Wagner interpret as a mild oscillation of short duration. Zeuner (1959 op cit), reviews this point with interest considering the possibility of a Younger Loess III as has been suggested at other localities.

The loesses of central and west Germany are able to indicate the Glacial and Interglacial periods of the Pleistocene. The two Younger Loesses are later than the Saale Glaciation, occurring outside the limits of the Last Glaciation they are considered by Zeuner (1959 op cit), to be contemporaneous with this glaciation. The last Interglacial is represented by intense weathering of the Older Loesses of which there are at least three as seen at Mauer near Heidelberh (Soergal 1928) Fig.3.6. Here two Younger Loesses separated by a thin weathering loam are seen to overlie a thicker weathering loam formed on the Upper Old Loess. Middle and Lower Older Loesses are seen and the chronological

FIG 3·4

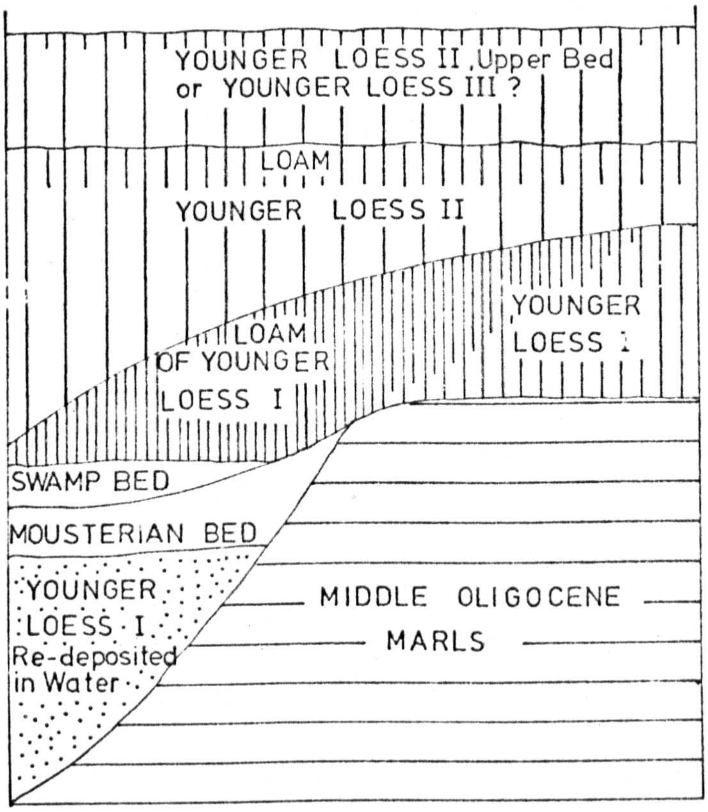
SECTION OF THE LINSENBERG
NEAR MAINZ, RHINE VALLEY



After Schmidtgen 1930

FIG 3·5

SECTION OF WALLERTHEIM
NEAR MAINZ, RHINE VALLEY



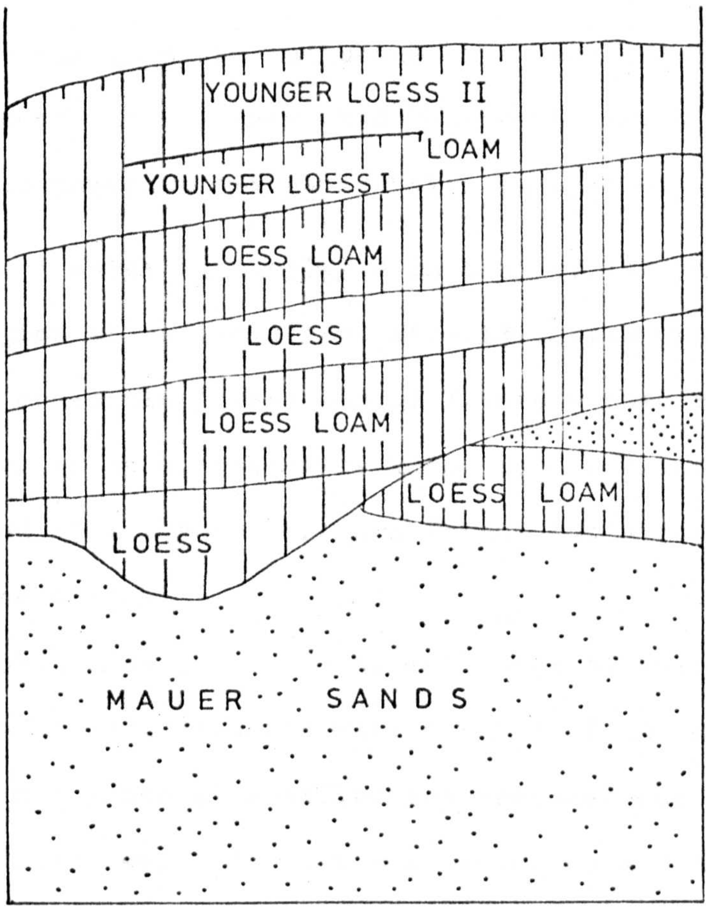
After Schmidtgen & Wagner, 1929.

Chronological Interpretation of Fig.3.6

Bed, and climatic character	Chronological interpretation (minimum age)
Recent soil: temperate	Postglacial
Younger Loess II: cold phase	LGI, second phase
Weathering loam: temperate	interstadial LGI_1/LGI_2
Younger Loess I (only in the north wall): cold phase	LDI, first phase
Weathering loam: temperate	Last Interglacial
Upper Older Loess: cold phase	PGI, second phase
Weathering loam: temperate	interstadial PGl_1/PGl_2.
Fresh middle Older Loess: cold phase	PGl, first phase
Weathered fluviatile sands and lower Older Loess, completely weathered, loamy. Weathering: temperate phase of long duration	Penultimate Interglacial
(Deposition of lower Older Loess), and Fluviatile sands subjected to solifluction. Solifluction and deposition of loess: cold phase	ApGl, second phase
(Gap, produced by denudation)	
Weathering horizon Floodloam Sandy Calcareous floodloam Mauer Sands. A-D, including gap: temperate	Antepenultimate Interglacial or interstadial $ApGl_1/ApGl_2$

FIG 3·6

LOESS SECTION OF MAUER NEAR HEIDELBERG, NECKAR VALLEY



After Soergel 1928

interpretation as given by Zeuner is shown opposite Fig.3.6.

Loess of Northern France:

For much of the nineteen thirties L'Abbe H. Breuil was the most prolific of workers on the loess deposits of northern France, particularly those of the Somme and Seine valley. Like most continental workers he recorded loess as being an aeolian dust deposited under cold and comparatively dry conditions, (1931) but he also realised the influence that precipitation either in the form of rain or snow, had had on the types of loess that are found in northern France and also in southern England.

The effect of water is displayed in many of the loess deposits of this region where indistinct stratification and small layers of pebbles or angular fragments of flints worked down by rain or meltwater or snow, these are known as ' cailloutis ' and are not confined strictly to northern France but are found in places in the Rhine valley.

Breuil (1934), also realised the influence of solifluction on the formation of French deposits with several of the sections showing that a phase of solifluction preceded the formation of a sheet of loess which in turn was weathered and transferred into a loam. This is well seen in the sections at Marcaing, Monley, Lambersert, Saint-Romain, Goderville, Mesnil-Ednard, St-Pierre les Elbeuf, Sergines, Breau and Eguisheim as shown in Fig.3.7 after Latridou (1969).

The inference that can be drawn from such a cycle is one of a climate that turned damp and cold at first, with the frozen soil causing solifluction, followed by a cold and dry period with aeolian dust, i.e. loess being deposited under steppe conditions, these eventually returned to normal temperate conditions with the

FIG 3·7

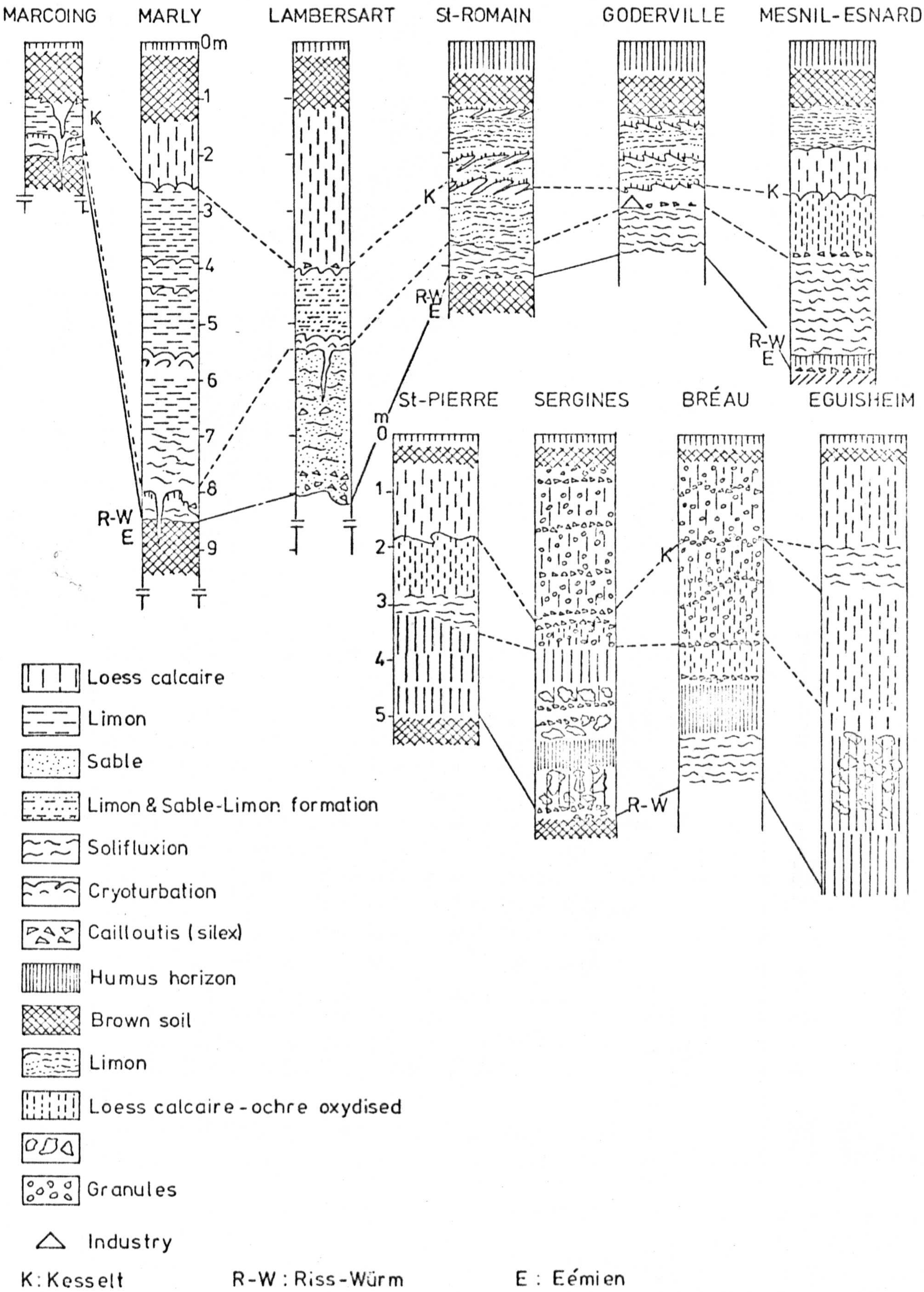
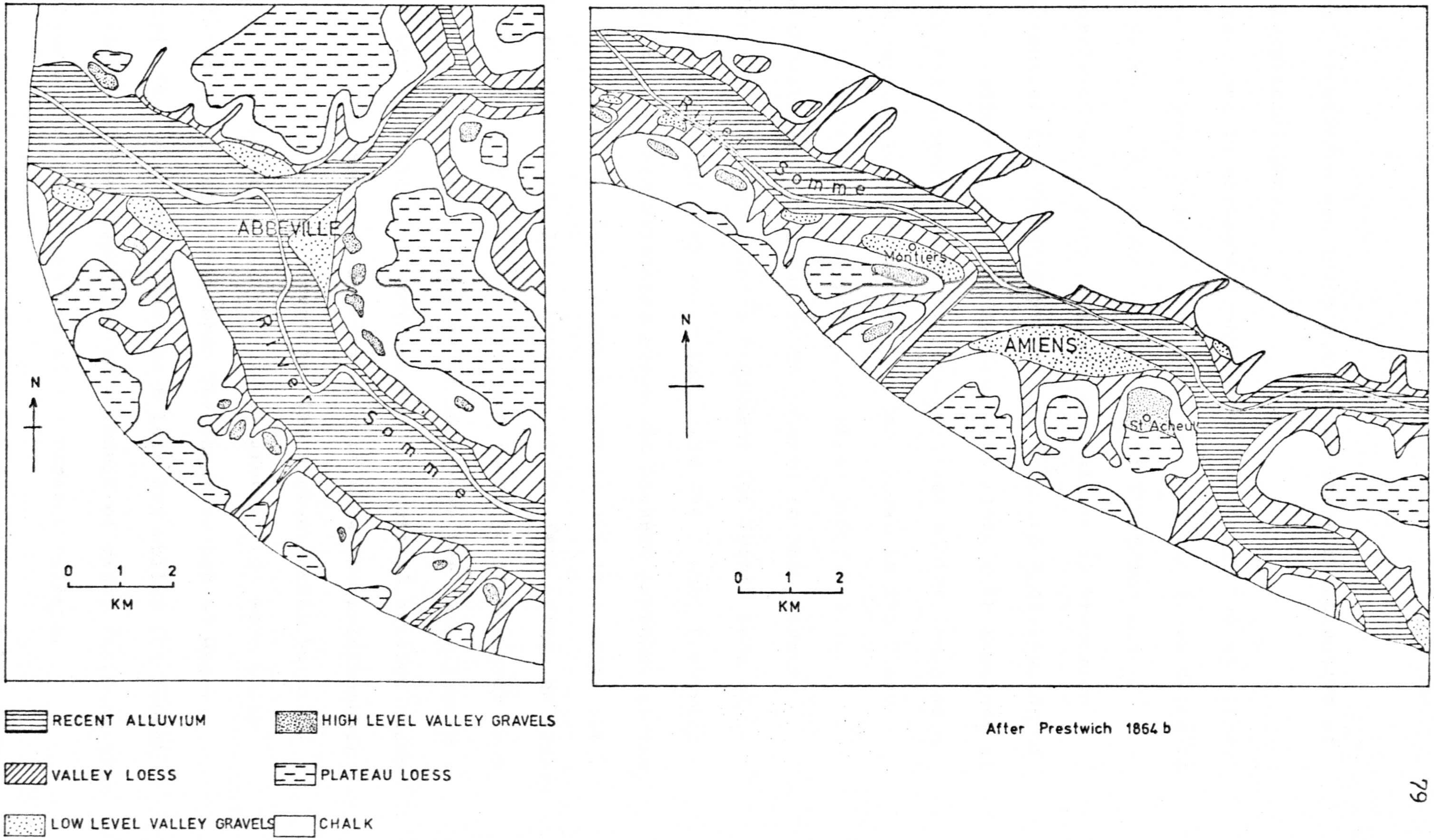

MARCOING
MARLY
LAMBERSART
St-ROMAIN
GODERVILLE
MESNIL-ESNARD
St-PIERRE
SERGINES
BRÉAU
EGUISHEIM
0m
1
2
3
4
5
6
7
8
9
m
0
1
2
3
4
5
K
R-W
E
Loess calcaire
Limon
Sable
Limon & Sable-Limon formation
Solifluxion
Cryoturbation
Cailloutis (silex)
Humus horizon
Brown soil
Limon
Loess calcaire-ochre oxydised
Granules
Industry
K: Kesselt
R-W: Riss-Würm
E: Eémien

FIG 3·8

GEOLOGICAL MAPS OF PARTS OF THE SOMME VALLEY SHOWING THE LOESS AND GRAVEL DISTRIBUTION



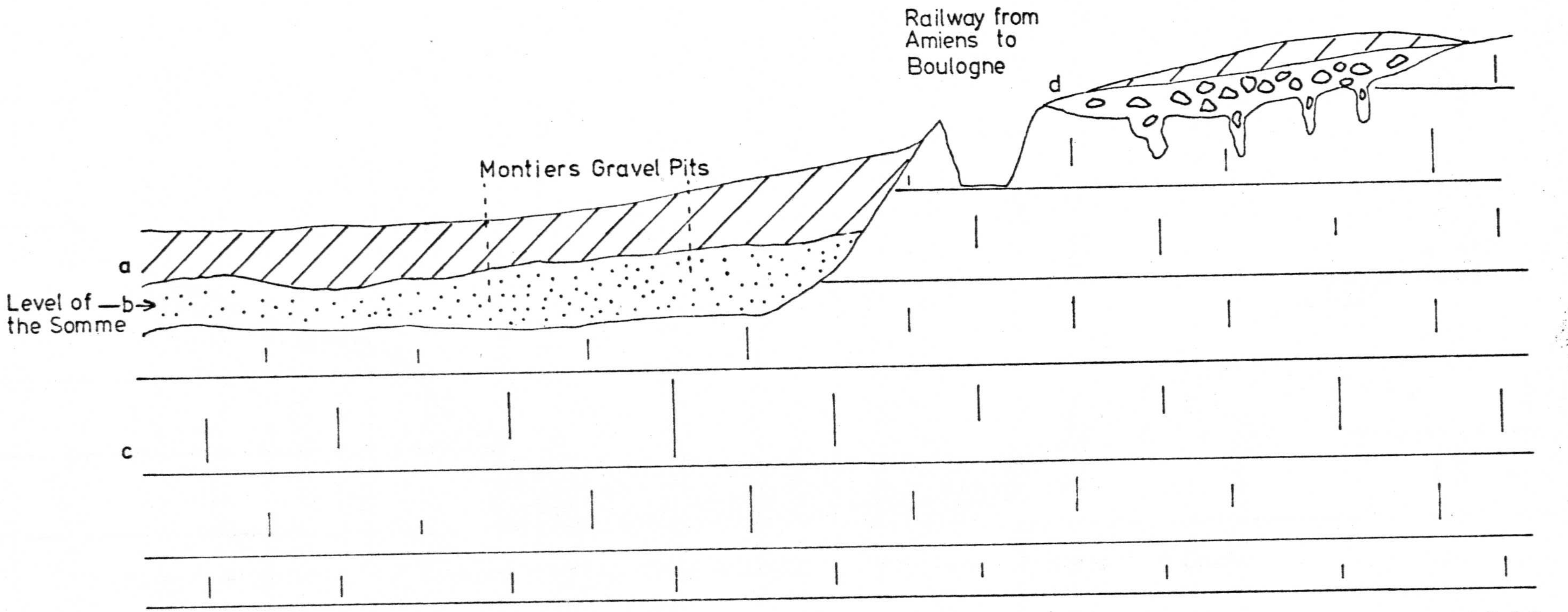
After Prestwich 1864 b

abundant vegetation and loamy weathering that is indicative of the Interglacial phase.
Loess sections in northern France have been described by workers for over one hundred years. The similarity of the loess deposits of the Seine and Somme valleys to that of the Rhine and to the brickearths of south east England was realised by Prestwich in his account of the French deposits in 1864. The distribution of the Somme sediments as shown by Prestwich along with sections at Montiers and Abbeville indicate the position of the loess as a terrace deposit in a similar way to that shown in the Thames valley (Chapter 2) are displayed in Figs: 3.8;3.9;3.10. Prestwich believed the loess to be related to the gravels, assuming the higher gravels to represent the former beds of rivers. In every locality where the loess was found, Prestwich was able to show its existance above the highest gravels. In the Somme valley the high level gravels rise to 100 feet above the present river with the loess observed at 150 feet above the river. In the Seine valley the loess was also found 50 feet higher than the gravels whilst in the valley of La Breste the loess occurs 70 feet above the highest gravels. The theoretical section shown as Fig.3.11, is that used by Prestwich to show the relationship between these two types of deposit. The highest loess beds (b) were formed at the time the high level gravels (d) were being accumulated in the old river bed. The loess of bed b' was deposited after the gravels had been left dry whilst the lowest loess beds (b'') were deposited as a result of river flooding that took place after the excavation of the present valleys.

Breuil (1939), discussed the Pleistocene succession in the Somme valley, taking his evidence for the age of the deposits from the terraces and the contained flint implements and fauna. As Zeuner

FIG 3·9

SECTION ON THE SIDE OF THE VALLEY OF THE SOMME AT MONTIERS

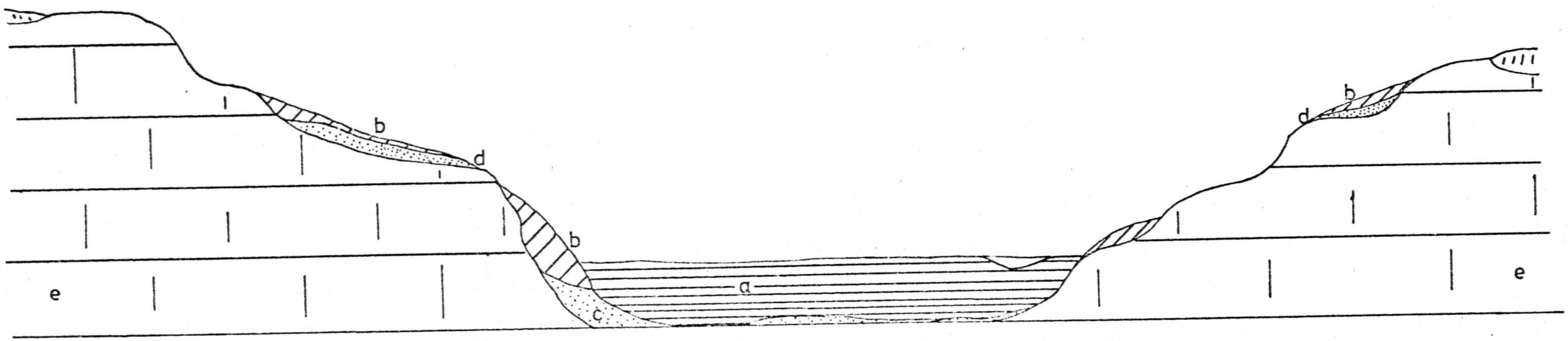


a. Loess 0·9 - 3·6 m b. Sands and Gravels 6 - 7·5 m c. Chalk d. Coarse Gravel 3-3·6 m

After Prestwich 1864 b

FIG 3·10

SECTION ACROSS THE VALLEY OF THE SOMME NEAR ABBEVILLE

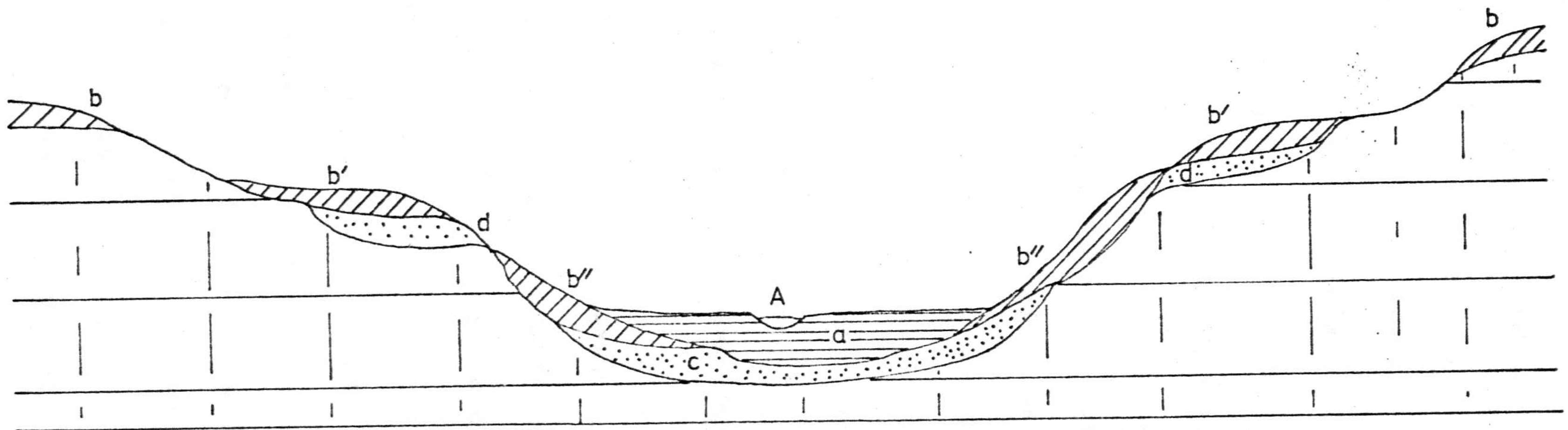


a. Recent Alluvium   b. Loess   c. Low-level Gravels   d. High-level Gravels   e. Chalk

After Prestwich 1864b

FIG 3·11

THEORETICAL SECTION ACROSS THE VALLEY OF THE SOMME



A. River   a. Recent Alluvium.   b, b′, b″. Loess on different levels and of different ages.

c. Low-level Gravels.   d. High-level Gravels.

After Prestwich 1864 b

(1959), indicates France is the classic region for the study of pre-history, particularly the Palaeolithic, several of the major sites are described below. Breuil made full use of the implements and remains in order to date the deposits. From Table 3.2 the relationship between the terraces, the deposits, the implements and the fauna being indicated in order to relate to the glaciations, at this time referred to it in Alpine terms. Zeuner (1935), outlined the dangers in placing too much emphasis upon the data provided by the remains of human cultures when he stated " the possibility of chronological overlapping of cultures should prevent us from stating the age of river terraces and other deposits purely with the aid of their archaeological contents ". This view he substantiated later (Zeuner 1937), when he shows the overlapping of the cultures along side the radiation curve-time scale of Milankovic 1930, see Fig.3.12.

The use or mis-use of the Palaeolithic data probably lies in the fact that the implements have been used to date the deposits rather than using the deposits to date the implements. At St. Acheul in the suburbs of Amiens is one of the most important sites in the context of the European chronology of the Palaeolithic the section of this site is shown in Fig.3.13 adapted by Zeuner 1959 op cit from the works of Commont (1909 and 1912) and Breuil and Kazlawski (1931). The following is a brief description of the deposits in the section.

I. A gravel with loess of coarse sand, covered and partly interstratified with fluviate sands and is interglacial.

II. Sands covered by coombe rock formed under cold conditions.

III. Lens of white chalk with freshwater shells indicating a moderately warm climate.

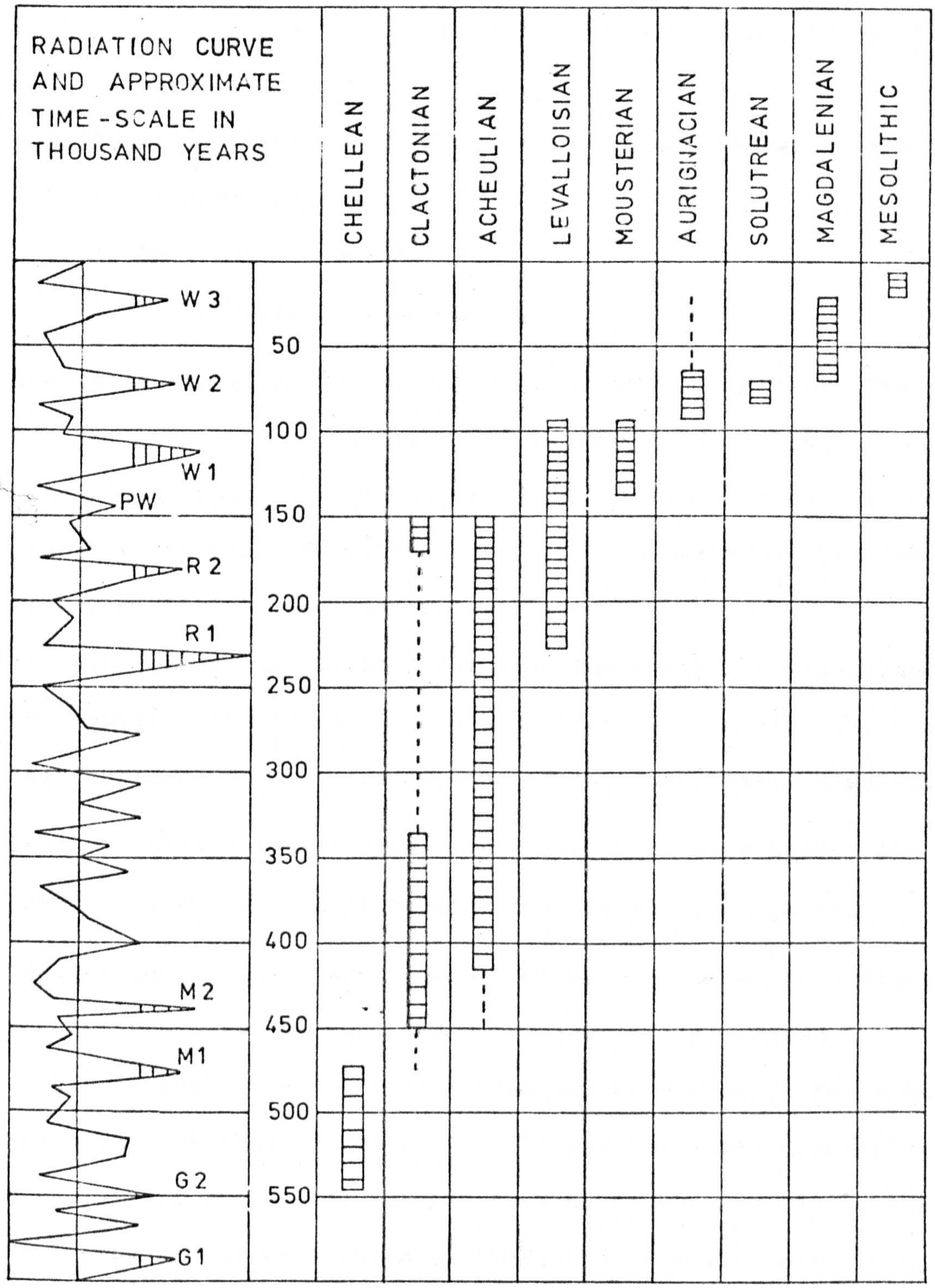
TABLE 3.2

CHART OF LEVELS, INDUSTRIES, AND FAUNA OF THE SOMME VALLEY

Solifluctions (S) Fluviatile Deposits (F)	Sub-aerial deposits	Industries * = Derived	Fauna	Glaciations
S1 (40m terrace) F1 (40m terrace)		Abbevillian Clactonion I	E.meridionalis R.etruscus	Gunz?
S2 (40m terrace)	Sub-aerial deposits of this age have been totally destroyed or are only to be found as rafts dragged into lower levels by solifluction	*Abbevillian & Clactonian I		Pre-Mindel?
F2 (40m terrace)		Acheul I	E.antiquus R.merckii	
S3 (40 & 30m terraces) F4 (30m terrace)		*Acheul I Acheul II	E.antiquus R.merckii	Mindel I
S4 (40 & 30m terraces) F4 (30m terrace)	Pockets of partially washed out clay (30m)	*Acheul II Acheul III Clactonian II or III	idem	Mindel II
S5 (all the terraces)		*Levallois I	Mammoth R.tichorinus	Riss I
F5 (30m terrace)	Very old loess, weathered into reddish sand. Partially washed out clay. Humic earth	Acheul IV	E.antiquus, etc	
S6 (all the terraces)	Old loess (40-30m terrace) Peaty clays etc. (30m Thennes, Bourdon) Partially washed out clay (30m)	*Levallois II Acheul V	Mammoth, R.tichorinus Reindeer	Riss II
S7 (slight; all the terraces)		*Levallois III	Idem.	Pre-Wurmian
F6 (Lower terraces)	Fissured red clay on all the terraces except the lowest, often partially washed out. Clay with Succinea (lower terrace)	Acheul VI & VII Levallois IV	last E.antiquus, R.Merckii, Hippopotamus; later Mammoth, R.tichorinus	
S8 (all the levels)	Humic earth Recent Loess I	*Levallois VI Levallois V	Mammoth, R.tichorinus, Reindeer	Wurm I
S9 (all levels)	Humic earth Recent Loess II	*Levallois V Levallois VI	Idem	Wurm II
S10 (all levels)	Humic earth Recent Loess III	*Levalois VI Levallois VII	Idem	Wurm III
S11 (all the levels)	Humic earth	*Levallois VII	Idem	Wurm IV
	Very recent Loess IV on the edge of the marsh; elsewhere Brick-earth	Upper Palaeolithic Mesolithic Neolithic	Present Fauna	

After Breuil 1939

FIG 3·12


RADIATION CURVE AND APPROXIMATE TIME-SCALE IN THOUSAND YEARS
CHELLEAN
CLACTONIAN
ACHEULIAN
LEVALLOISIAN
MOUSTERIAN
AURIGNACIAN
SOLUTREAN
MAGDALENIAN
MESOLITHIC
W 3
W 2
W 1
PW
R 2
R 1
M 2
M 1
G 2
G 1
50
100
150
200
250
300
350
400
450
500
550

IV. Bed of Red Sand, probably formed as a hill wash during the initial stage of the Older Loess.

V. Older Loess with large concretions of calcium carbonate.

VI. Weathered layer of Older Loess, Argile range.

VII. Younger Loess I sandy in the lower part and loess in the upper part.

VIII. Loamy weathered horizon following the Younger Loess I

IX. Younger Loess II.

X. Post-glacial weathering.

XI. Agricultural redeposition.

The following climatic phases are seen in this section. The two Younger Loesses show evidence of two phases of the Last Glaciation with a prolonged period of intense chemical weathering preceding the Last Glaciation and the post dating of the Older Loess this is the last interglacial.
The Older Loess cannot be later than the second or main phase of the Penultimate Glaciation and was preceded by a mild phase, a cold oscillation, the first phase of the Penultimate Glaciation.

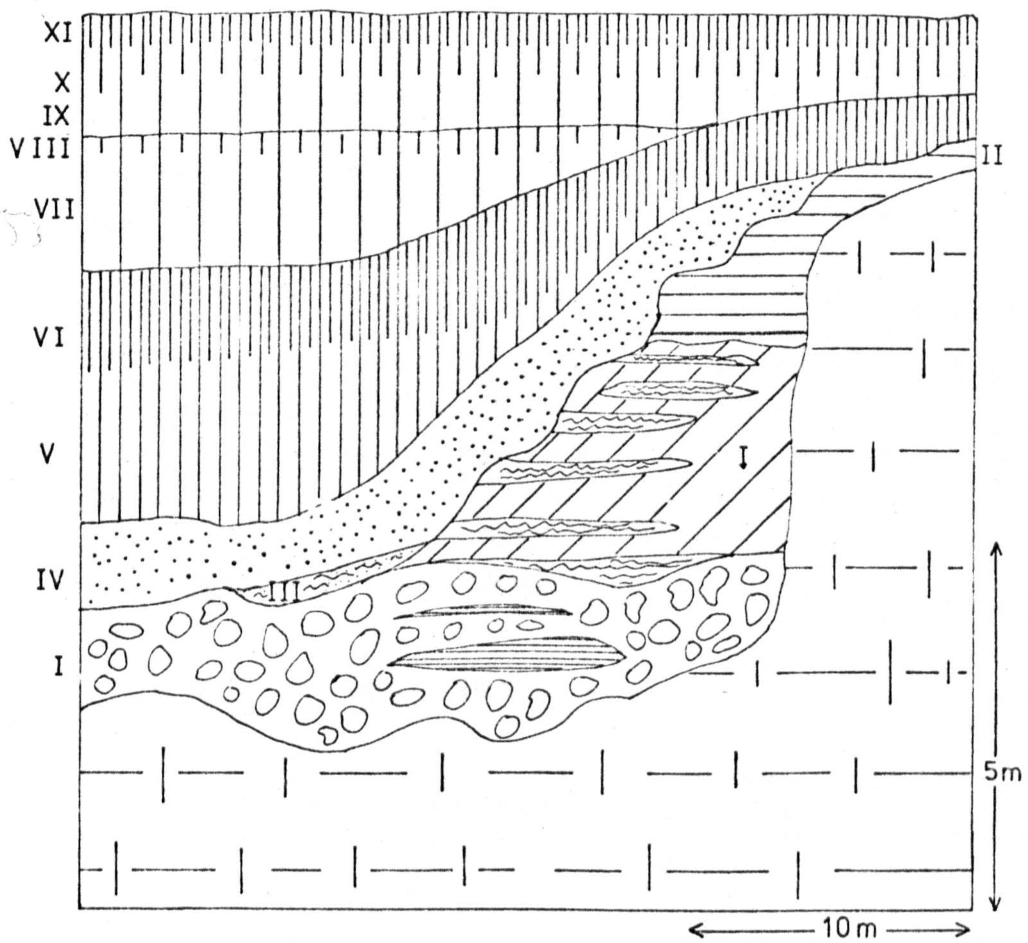
The penultimate interglacial was a prolonged mild period when the gravels of the Middle Terrace of the Somme were aggraded.

The section at St. Pierre les Elbeuf on the Seine, is another section where two Younger Loess horizons are separated by a weathered soil from the Older Loess and at Abbeville the site where Palaeolithic implements were first described associated with extinct species of mammals (Bouche de Perthes 1849). The following is the succession at Abbeville, after Commont 1920, Breuil and Koslawski(op cit 1931) in ascending order.

FIG 3·13

SECTION OF THE CARRIERES BULTEL-TELLIER,

SAINT-ACHEUL, NEAR AMIENS

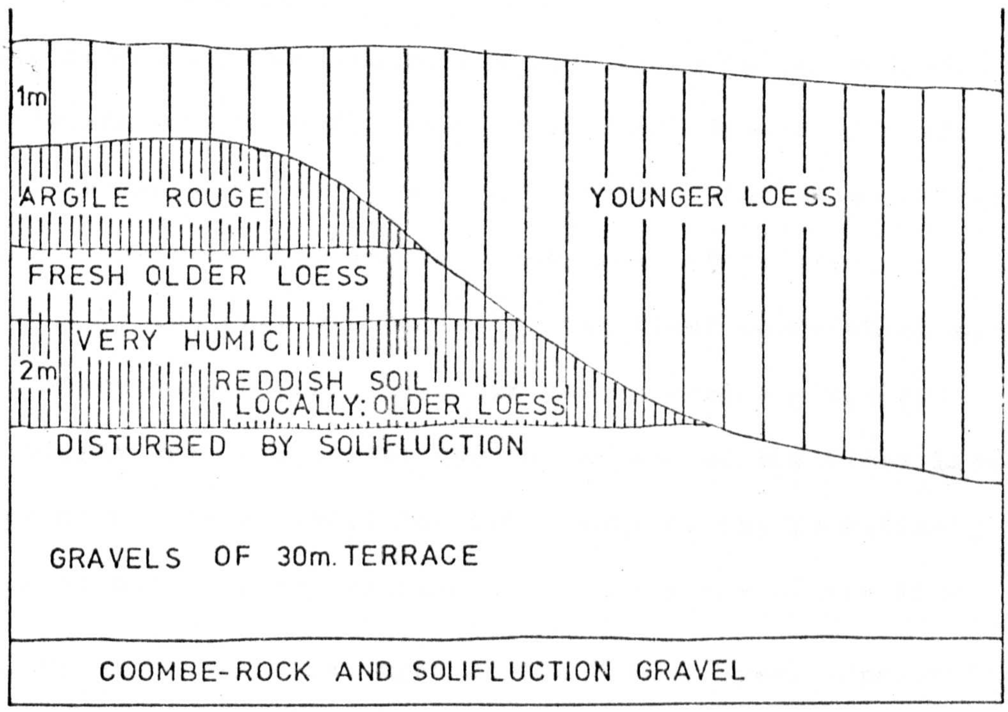


For explaination of symbols see page

Adapted by Zeuner 1959 from the works of Commont 1909, 1912, and Breuil & Kozlowski 1931.

FIG 3·14

SECTION OF THE CARRIERE CHEMIN-DE-FER, AT MONTIERES, NEAR AMIENS



After Breuil 1934

A. fluviatile gravel - mild climate

B. Greenish chalky sand with freshwater shells

C. White Marl

D. Unconformity with a small peat bed

E. Upper gravels and sands - interglacial correlated.

F. Cailloutis - cold phase

G. Older Loess - weathered and transformed into argile rouge

H. Top layer possibly containing some younger loess

The section at Montieres allows the Pleistocene succession to be extended further back with Older Loesses seen buried by a Younger Loess, Fig.3.14.
The sections described indicate a similarity in the climatic subdivisions of the Pleistocene of northern France with those of west Germany. The two phases of the Last Glaciation, shown by the two Younger Loesses and the long Last Interglacial indicated by the deep weathering of the Older Loess which shows almost everywhere a transformation to the argile rouge are particularly well displayed. The two phases of the Older Loess as seen at Montieres indicates two phases of the Penultimate Glaciation with earlier glaciations seen in the Coombe Rock.

A summary of the relative ages of the French loess deposits is given in Table 3.3. This was compiled by Lautridou (1969), as part of the French contribution to the New Zealand INQUA meeting and is based on his own studies as well as those of Bordes, Somme and Blanck Wacquant.

TABLE 3.3

TABLEAU DE LA CHRONOSTRATIGRAPHIE DU WURM-WEISCHEL DANS LA MOITIÉ NORD DE LA FRANCE, SELON LES DIFFÉRENTS AUTEURS

A - Zone orientale (SOMME), séquanienne (LAUTRIDOU) B - Zone occidentale

B.P.	LEROI-GOURHAN (Arcy)	BORDES (loess)	LAUTRIDOU A	LAUTRIDOU B	SOMME A	SOMME B	BLANCK WACQUANT
10 000 15 000	ALLERØD BOLLING PRE BOLLING		loess 4 *cailloutis*				
	LASCAUX LAUGERIE	?					
20 000		Wurm III c ?	loess 3 *cailloutis*	limon KESSELT ter			
25 000	TURSAC	Wurm III b Wurm III b ou a ? *cailloutis*	loess 2 PLEN. SUP. *cailloutis*	limon à doublets KESSELT bis	loess 2 PLEN. SUP. fentes *cailloutis*	loess 2 PLEN. SUP. fentes *cailloutis*	loess
30 000	KESSELT ARCY	Wurm III a *cailloutis*	loess 1	limon à doublets	loess 1 *cailloutis*	loess 1 *cailloutis*	colluvion
35 000		Wurm II - III	KESSELT ou *cailloutis*	KESSELT	KESSELT loess lité PLEN.	KESSELT limon sableux lité	paléoranker
40 000	HENGELO	Wurm II	loess oxydé PLEN. INF.	limon à doutlets	tacheté limon lité MOYEN tacheté		loess
55 000			*cailloutis*	nassboden *cailloutis*	fentes *cailloutis*	PLEN. INF. fentes *cailloutis*	
	ODDERADE BRØRUP AMERSFOORT	limon Wurm I b *cailloutis* paléosols Wurm Ia *cailloutis*	niveau humifère niveau humifère niveau humifère *cailloutis*	solifluxion *cailloutis*	niveau humifère limon	sables-limons sables graviers	paléoranker paléosol brun de steppe pseudo-gley
	INTERGLACIAIRE	limon fendillé	Elbeuf I		sol de Rocourt	limon tourbeux	

After Lautridou 1973

The importance of the stratigraphical studies relating to the loess of central and eastern Europe is apparent from the brief review already given. This aspect of study predominated prior to 1950 as was the case concerning the British brickearths with the interpretations of the deposits in the nineteenth century in terms of mode of origin eventually leading to correlation studies being undertaken with the aid of the extensive stratigraphical evidence that was being provided. Although the British deposits have not received the same amount of attention as those in Europe during the last twenty years, the emphasis in the two regions of study appear to have diverged. The European workers have generally continued with correlation work along with a limited amount of material analysis , this latter being pursued more extensively by British workers both on British and European loess sediments.

The widespread and abundant nature of the loess accross eastern and central Europe has created difficulties in correlation with other deposits within regions although to a limited extent correlation has been possible on a wider basis with the cover-sands of Holland being the most notable attempt, Rutten 1954. Kukla (1968, 1970) established a correlation between the Czechoslovakian and Austrian loess sequences, which contain a continuous sedimentary record of the Pleistocene, with deep sea cores. Kukla realised that temperature changes of the glacial and interglacial phases which were reflected in the climatostratigraphy were best observed in the lithological and palaeontological evidence which he was able to derive from both the loess and from the deep sea cores, while at the same time, he observed a correlative pattern.

The sedimentary loess cycles that were first established by Kukla (1961) and subsequently developed in Czechoslovakia by Kukla and Lozek (1961) and Kukla (1968, 1969) begin with the redeposition of the loess interlayered with poorly developed humic soil. As the climate ameliorated the molluscan fauna marked the beginning of the interglacial and were followed by forest soils containing richer molluscan assemblages of the broadleaf forest habitat; this is indicative of a warmer maritime type of climate prevailing. The forest soils are overlain by calcareous aeolian silts that are attributed to large scale dust storms. Above these are hill-wash sediments built from redeposited fragments of soil material and generally referred to as 'Pellet Sand' a material that Kukla and Lozek (1961 op cit) suggest to be formed by torrential rains,that followed a relatively hot dry season, beating down upon a surface sparsly covered with vegetation.

The molluscan fauna in the soils above the forest soils indicate a continental type climate with hot summers and hard cold winters showing a distinction from the underlying glacial soils. The upper part of the glacial section of this cycle is mainly a thick loess with poorly developed humus layers, in general more poorly developed than the soils of the older section. Cyclic sequences relating to climtic changes were similarly observed in the deep sea sediments with the most detailed register of climatic oscillations within the last glacial coming from the North Atlantic although the most complete records that extend to the Middle Pleistocene exist in the Carribbean cores and the best sequences covering the entire Pleistocene are in the Pacific cores. Although Kukla used the deep sea cores he realised the problems of using such sediments with erosion, redeposition and slumping being common on the ocean floor. Using loess and deep sea cores three glacial cycles occurring in the last glaciation were detected; however, the loess enabled Kukla to further subdivide the main glacial and interglacial intervals, a feature that emphasises the importance that loess plays in the stratigraphy and correlation studies in eastern and central Europe.

Recent work by Lozek (1976) using molluscs that are found to occur in the Czechoslovakian loess and by Fink et al (1976) as part of the studies relating to the Quaternary Glaciation in the Northern Hemisphere have given support to the extensive stratigraphical loess studies in Europe.

Discussions of central European loess deposits by western researchers have proceeded along various and diverse lines; this is probably a result of geographical remoteness from the source of study and also in an attempt to proceed with an alternative approach to the stratigraphical one followed by those working in the regions.

In a recent account, Smalley (1975) discusses the possible ways in which the Danube loess arrived in its present position and indicates the significance in the part played by the Danube, and other drainage lines leading from the Alps, in transporting such large quantities of material, much of which was initially transported and deposited in the upper and middle Danube regions by aeolian processes.

The comparative studies of the Hungarian and Polish loess deposits reported by Leach (1975) contributed a substantial amount of information about these sediments, particularly concerning their mineralogical and microscopical nature. Specific studies using scanning electron microscopy by Smalley and Cabrera (1970 , 1971) Smalley (1970), Cegla , Buckley and Smalley (1971) and Smalley, Krinsley and Vita-Finzi (1973) have enabled a greater understanding of the nature of the particles that are found in various European loesses and also for the microtexture of the deposits to be recorded.

This chapter has attempted to show the general relationship between the European loess deposits and the Brickearths of Britain , particulaly those in the south east of the country that appear to have similarities to those accross the Channel in the Somme and Seinne valleys. The different approaches that have been placed on the stratigraphical aspects of the loess compared with the material studies that have been undertaken on various deposits by using mineralogical and microscopical techniques have also been assessed.

In such a short chapter it has only been possible to give a brief analysis of a few of the many studies that have and are been carried out in Europe. It is unfortunate that much of the material is not readily available in English although several works carry substantial bibliographies which include English papers. Cegla(1972) quotes many in his Sedymentacja Lessow Polski and numerous others can be found along with the various reprints given in the Loess Benchmark, Smalley (1976).

CHAPTER FOUR

CLIMATIC SIGNIFICANCE OF LOESS DISTRIBUTION AND FORMATION:

CHAPTER FOUR

CLIMATIC SIGNIFICANCE OF LOESS DISTRIBUTION AND FORMATION:

The distribution of loess in the British Isles and across Europe from Russia through to France has been discussed in the previous chapters. Several authors have, in the past, attempted to relate the formation of loess deposits and their distribution to the palaeoclimatic conditions that existed during the Pleistocene. The European loess deposits have been shown to be periglacial sediments that were formed contemporaneously with the glacial deposits. In Britain the brickearths are thought to be interglacial deposits, the only periglacial loess's being the later deposits occurring mainly in Kent, which display solifluction effects as at Pegwell Bay in the eastern part of the exposure (see Chapter 5) and at Allington near Maidstone. The deposits of eastern Yorkshire are also believed to be contemporary with the Devensian glaciation. Throughout the Pleistocene Britain formed the western part of the continental area of Europe with the Straits of Dover not having been formed. Schild (1976), showed the area covered by this continental region at approximately 12,000 - 13,000 B.P. during the Devensian, (Fig.4.1), a similar situation probably existing for much of the Pleistocene. The presence of ice over much of Scandinavia for most of the Pleistocene and its extension towards central Europe and Britain during periods of glacial maximum influenced the climatic situation of this period.

Eckardt (1909), showed that barometric anticyclones developed above the cold Scandinavian areas causing the depression to move along the Mediterranean. The resulting air flow was one from the north east away from the ice with an easterly flow dominating as a result of the coriolis effect. In the northern hemisphere air

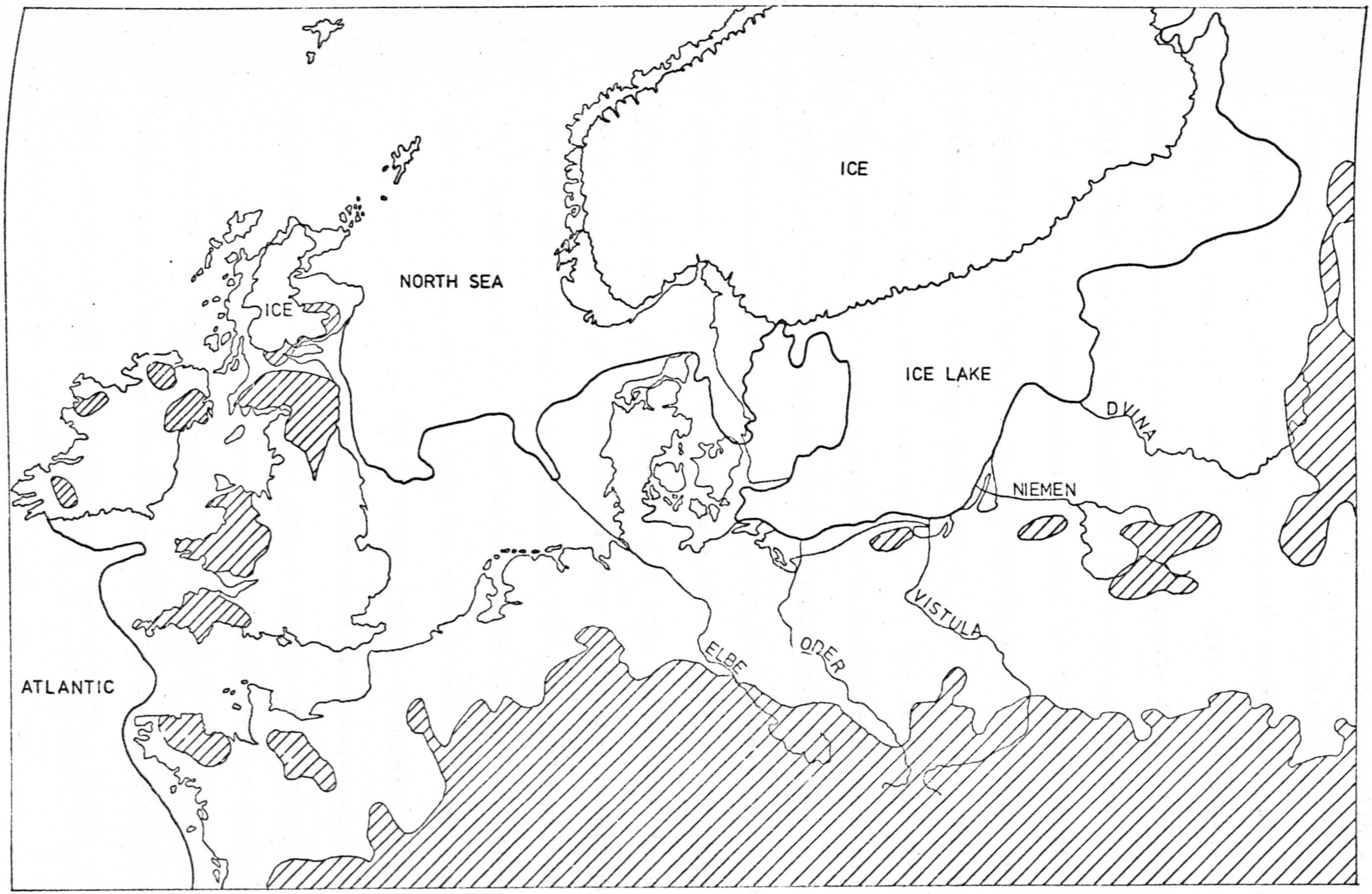


FIG 4·1

PALAEOGEOGRAPHY OF NORTHERN EUROPE 13,500-12,500BP

SHADED AREA INDICATES REGIONS ABOVE THE 300m. CONTOUR

After Schild 1976

circulates in a clockwise direction around a high pressure region (anticycylonic) general parallel to the isobars with a slight deflection as a result of the earths rotation.

Enquist (1916), believed anticyclonic conditions, with the cold ice winds, were restricted to the summer whilst westerly winds with precipitation influenced the climate during the winter, a view that was not in accordance with that of Zeuner (1937), who put forward an alternative proposal for the atmospheric situation during the glacial periods. The periglacial area was heated by the sun throughout the warm season with anticycylones persisting over the Scandinavian ice all through the year. The winds that blew off the ice Zeuner regarded to be the result of different atmospheric temperatures that existed above the ice and the periglacial region. The anticyclones were considered to be more extensive during the colder part of the year as they occurred above the snow covered periglacial belt which meant that the temperature and pressure differences that were present during the summer were virtually non existant throughout the winter resulting in comparatively quiet air masses. Wind as the main form of transport of material during the summer months as suggested by Zeuner was not borne out by Hobbs (1942), who made extensive studies of the extramarginal zones of continental glaciers, particularly Greenland. The summer months were considered, by Hobbs, when meltwater was the predominant transporter of material ground by the ice and washed from the face of the glaciers. The winter period brought about a general drying up of the streams and the increased predominance of the wind as a means of transportation was observed.

Hobbs, in two accounts, proposes anticyclonic conditions over continental glaciers as contributing towards the trapsortation and deposition of loess in North America (1943a), and in Europe (1943b).

Kaiser (1969), in his review of the climate of Europe during the Quaternary Ice Age, cites the work of Poser (1951), who showed that the loess, wind transported sands and inland dunes were deposited predominantly by westerly winds. This view is also the one proposed by Williams (1975), in his discussion of the British climate during the Last Glaciation. The association of the wind blown sands and the dunes which they often form along with the loess deposits appears to have resulted in erroneous conclusions being drawn as regards the origin of the transport of the loess. It is true as Williams points out that the sand required stronger winds for its deposition because of its greater fractional size, it is however this very reason that distinguishes it from loess transportation. Very few winds are strong enough to transport sand for vast distances and certainly not in the upper atmosphere. The deposition of sand must therefore be regarded in comparison to loess as generally only of local origin, and short distance - low elevation transportation has to be assumed for the formation of the dunes. Loess, as a result of its silty nature, is able to be transported great distances at great heights in the atmosphere and ' dumped ' at the point where the barometric gradient becomes insufficient for further transportation.

The thinning of the loess in a westerly direction was also regarded by Williams as evidence for the predominance of westerly winds as the mode of transport and the predominant wind direction in Britain during the Last Glaciation. Unfortunately, loess being the deposit it is, a sediment without stratification, and other features indicating palaeocurrents does not help in the solution of this problem.

If the source of the loess was from the west it would pose a major problem as to where the material was derived from to be carried by the wind. The Atlantic Ocean area was ocean at the time and therefore unable to provide material. The limestones and Chalk country of southern England and northern France also would be unable to provide this large quantity of quartz silt. The influence of the westerly winds was regarded by Williams as diminishing in an easterly direction and to be insignificant in eastern Europe, this being the case it would not account for the wide distribution of thick loess deposits from the Rhine to the Urals.

Lambe and Woodroofe (1970, in their conclusions on the atmospheric circulation during the last ice age state that the polar anticyclone extended far south to the mid Atlantic and blocked most of west to east, or south west to north east progressions of the cyclonic systems that are characteristic of the post glacial climate and also of the present day. This anticyclonic blocking was shown to appear more marked during the glacial maximum and successively less marked in the subsequent epochs.

Having shown that a westerly air flow did not dominate the Last Glaciation at its maximum it is likely that such a flow did not have any influence during previous glacial episodes, when loess deposition was taking place in central Europe. The alternative is an easterly flow of air as suggested by Hobbs (1943b op cit), who regarded the barometric gradient that existed throughout the year to be stronger during the winter period and to contribute towards loess deposition during the colder part of the year. Although Hobbs was not very specific about his European model, high pressure appears to have dominated over Scandinavia which allowed winds to blow over the north European plain lifting the silt that had been washed from the glacier and carrying it westwards. Most of the east European material appears to exist in a primary position whereas the most westerly deposits have been reworked in many cases to form secondary loess deposits duch as schwemmloess (see Chapter 1 for the term as proposed by the Loess Commission, Fink 1974.)

At the beginning of this chapter it was noted that some of the British loess deposits were not glacial sediments but interglacial sediments, which is in contrast to the majority of continental deposits. The larger quantities of brickearths that are found in the Thames Valley region occur in many places as non laminated silts containing a terrestrial fauna suggesting these to be floodloam deposits. The problem that arises concerns the origin of large quantities of quartz silt that must have been readily available for transportation and deposition by the Thames and its associated tributary streams. The source of these streams is the Chalk and the Jurassic limestones which, as mentioned above, would not be able to provide loess material. The lack of any other evidence along with proposed dominant easterly air flow indicates that the quartz material has been brought into the south east of England by aeolian means during the glacial period. During the succeeding interglacial period the anticyclonic dominance on the west European climate was reduced, this along with the close proximity of the Atlantic to Britain resulted in the climate being influenced by cyclonic conditions as found today. A maritime type of climate replaced most of the continental influence giving higher precipitation and allowing redepositon of the primary loessic sediments as hillwash, but, mainly as floodloam deposits in the form of brickearth.

Fig.4.2 is a reproduction of the meteorological forecast for noon on Saturday March the 6th 1976. High Pressure over Scandinavia and a trough of low pressure over the Atlantic have given rise to several important factors. The south east region of England along with northern France is influenced by an easterly and south easterly air flow that is affecting northern and central Europe. The south west and southern central England is under the influence of a more southerly air flow. If these two conditions were prominent during the Pleistocene they would allow material from eastern Europe to be carried over northern France into south east England, some being carried over to eastern England and then in an north easterly direction to the North Sea, where the record is lost. Any material deposited on the land area would be confined almost totally to the Weald with the East Anglian region and Middle Thames Valley catching the fringe deposits. The western part of the country because of the influence of more southerly winds from the Bay of Biscay, Southern France and Northern Spain, would not be receiving glacially ground material.

The combination of these two factors leaves the Wealden area as the main region of loess deposition, and may be described as a loess trap with brickearths found at all elevations.

Post deposition forces have been strong in the region with solifluction predominating during periglacial conditions. The action of the Thames in depositing floodloam brickearth is also important. Smalley (1972), discussed the interaction of Great Rivers with the major Primary Loess deposits of the World showing schematic diagrams for the Hwang Ho, Mississippi and four of the major rivers draining the Alps; the Danube, Rhine, Rhone and Po.The nature of the Thames Valley Brickearth supports a floodloam mechanism of deposition, in the area around Crayford

FIG 4·2

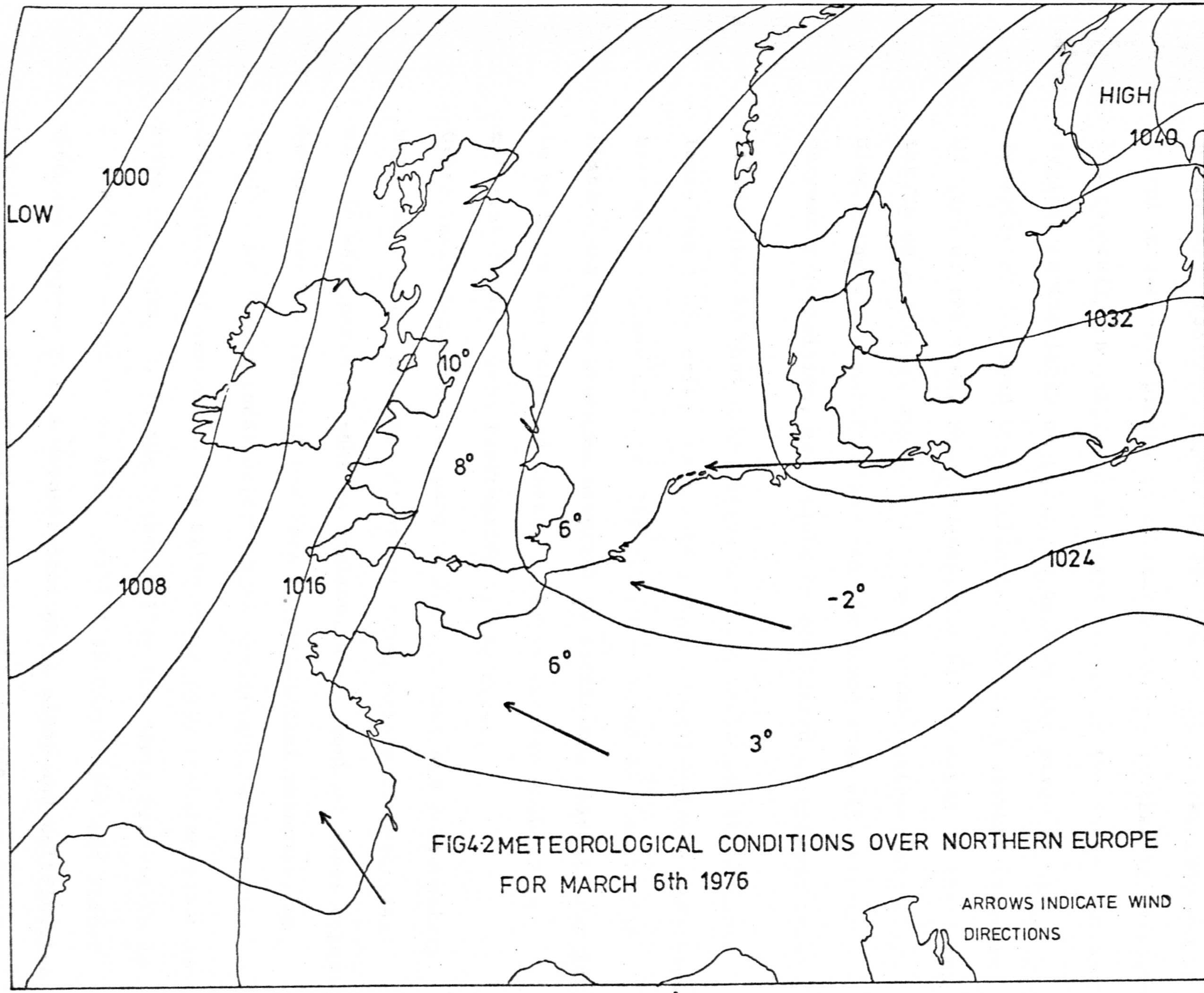


FIG 4·2 METEOROLOGICAL CONDITIONS OVER NORTHERN EUROPE FOR MARCH 6th 1976 as outlined by Kennard (1944), and around Ilford it is found in positions that indicate backwater situations of a sizable nature that were large enough to allow commercial exploitation from the seventeenth century. Higher up the Thames the brickearths are found in numerous places in similar positions to that at Crayford but generally in smaller quantities whilst in the Thames estuary region, particularly on the north bank of the river in the locality of Southend the brickearths take on a blanket coverage of much of the area. This redeposition has resulted in the loess taking on a fluvial appearance in many areas, without actually displaying any stratification that is associated with strong current redeposition, and should be considered as schwemmloess.

It may also be that other loess deposits including the Chinese loess owe their origin to the influence of anticyclonic conditions over cold regions of land. The glaciated areas of the Tibetan Plateau may have produced material in sufficient quantity for it to be blown out into the Hwang Ho region and for much of the material to have been redeposited by the river.

Other loess deposits are found in Britain that are contemporary with the glacial deposits of other areas, mainly of Devensian age. In many parts of eastern England, where most of these deposits occur, they are found in the form of periglacial phenomena as involutions formed under solifluction conditions, a full description of several of the sites where such features occur is given in Chapter 5. In the Thames Valley the Upper Brickearth is in places referred to as the ' trail ' (Kennard 1944 and Fisher 1866 see Chapter 2.), a deposit that shows slump and solifluction features; it is possible that this deposit has undergone three phases of deposition. Primary aeolian deposition was followed by secondary fluvial deposition in the ensuing interglacial which in turn was followed by solifluction activity in the periglacial zone of the succeeding glacial stage. At Folkestone the brickearth was shown by Mackie (1851) to lay on an angular flint and to be banked up against the Gault Clay and Lower Greensand, (see Fig.2.1.). It is possible that this may represent one stage deposition with the brickearth deposited by the wind. Alternatively secondary deposition by fluvial means may have followed the primary aeolian deposition resulting in the brickearth appearing in this position. In east Yorkshire loess containing deposits lie on the edge of the Devensian Till, (Weir, Catt and Madgett 1974). It is possible that the silt in these deposits has only been transported a short distance from the ice margin and mixed with other glacial deposits. At some localities these deposits are seen as periglacial features which probably formed after the glacial maxima but before the full retreat of the ice from the area.

CHAPTER FIVE

FIELD WORK

CHAPTER FIVE

FIELD WORK

A review of the British loess deposits and their recordings was given in Chapter 2. Many of the earlier accounts of brickearths of the Lower Thames Valley cannot now be substantiated in terms of field relationships with the demand for urban space resulting in the closure, infilling and building upon the old brickpits. More recent accounts of loess deposits have been undertaken primarily by workers of the soil survey who have considered certain groups of soils to have a percentage of loess within their composition. In Durham a true loess deposit appears to have been recorded by Trechman (1919), but the expansion of the coal mining industry since this time has resulted in the loss of this particular exposure, now covered with a spoil tip. The field work that has been carried out during this study has been done in order to provide data which may establish two criteria. Firstly to determine which deposits may actually be considered as loess on the basis of the INQUA definitions as outlined in Fig. 1.2. If many of the fringe deposits are established as loess or as another deposit the distribution of loess may be attained. Secondly the material provided from the field studies has been used in order to study the full mineralogical character of the British loess along with a microscopical study of the individual particles and in some cases of the whole soil fabric.

The major problem arising during the studying and collecting of the samples has been one of scale of the exposure, with many of the sites having a short lateral extent and often only a thin cover of deposit overlying the solid geology. This has meant that only disturbed samples have been able to be collected for analysis with small stones being distributed throughout the material which have prevented the collection of 38mm diameter hand-core-auger samples for laboratory shear strength measurements. Whenever possible shear strength tests were carried out insitu using a shear vane tester. The results of the laboratory shear strength tests along with the mechanical analysis are given in Chapter 6. The mineralogical and microscopical studies are recorded in Chapters 7 to 11. Comparative data of clay deposits has also been obtained from samples of a Quaternary brick clay from Broomfleet in east Yorkshire. The site is briefly described below along with the Yorkshire deposits although it must be emphasised that this deposit is not considered as a loess or to be loess-like. The presence of calcium carbonate in loess deposits and the phenomena of calcareous silts having similar properties to those of the quartz silt loesses was discussed in Chapter 1 and are considered by several workers to be true deposits. In order to compare the nature of the two types of deposit a dolomite silt of Permian age was obtained from Sutton near Tadcaster to the east of Leeds. This particular deposit has been studied from the microscopical point of view with a report given in Chapter 11. The chapter is concluded with a description of a loess from Palmerston North, New Zealand, from where samples have been supplied.

In this chapter the field relationship of the individual deposits are considered; in many cases it is the relationship which holds the final clues as to whether a sediment presenting most of the features associated with a loess deposit can be considered as a true loess. Maps are included of various sites along with suggestions concerning the means by which the material has been deposited and the probable palaeodirectional forces of transportation existing prior to and during deposition.

The site descriptions are given systematically region by region in a geographical pattern from the south to the north. This has been done primarily to assist the continuity and also to show the contrast that exists between the generally thicker well developed deposits of the south east of England with those of the north. Pegwell Bay may perhaps be regarded as the standard by which other sites may be compared.

Loess Deposits of Kent:

Extensive deposits of brickearth occur throughout Kent, their distribution is shown on map 1 (back folder), taken from the Geological Survey of England and Wales.

Samples were taken from six sites, these are indicated on the map and the National Grid Reference is given in the text for each locality.

Isle of Thanet:

Head Brickearth comprises most of the superficial deposits of the Isle of Thanet with Pegwell Bay (TR 3564), to the west of Ramsgate, providing the best exposures. The brickearth here, although described in the last century by Prestwich (1852), and Gardner (1883), was not referred to as loess until it was described by Pitcher et al (1954). The cliff section at this locality can be considered in two parts, i) that part lying directly behind the hoverport, the western section and ii) the cliff to the east of the hoverport service road, the eastern section.

i) The Western Section:

The western section is exposed for a length of approximately 350 metres along a north-east, south-west line facing south east. The height of the cliff is generally uniform throughout its length, eight to ten metres, with a lowering towards the east. The Tertiary beds at the base of the section are represented by the Thanet Sands, a buff yellow sediment having an apparant gentle dip of 5° - 10° in an easterly direction, this is observable in the interbedded shelly

PLATE 5.1.

PEGWELL BAY WESTERN SECTION

Photograph showing the current bedding features in the Thanet Sands with shell bands above and below the sands.

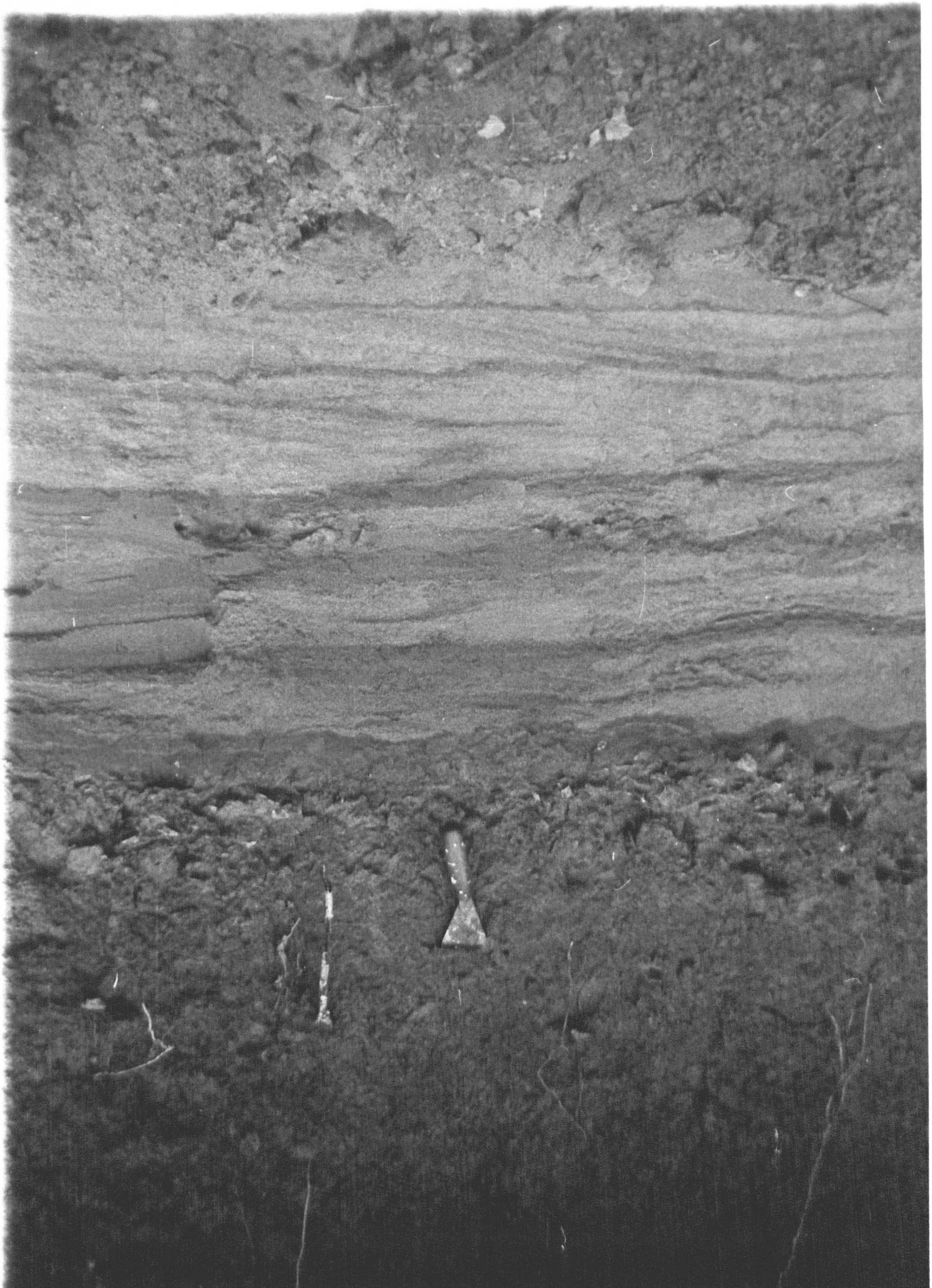


PLATE 5.2.

PEGWELL BAY.

A general view of the western section showing the two brickearth horizons overlying the Thanet Sands. The gentle dip of the Thanet Sands in an easterly direction can be seen.

PLATE 5.3.

PEGWELL BAY WESTERN SECTION

A close-up view of the Thanet Sands - Brickearth boundary showing a line of well rounded black flint pebbles. These probably indicate a former shore line deposit.

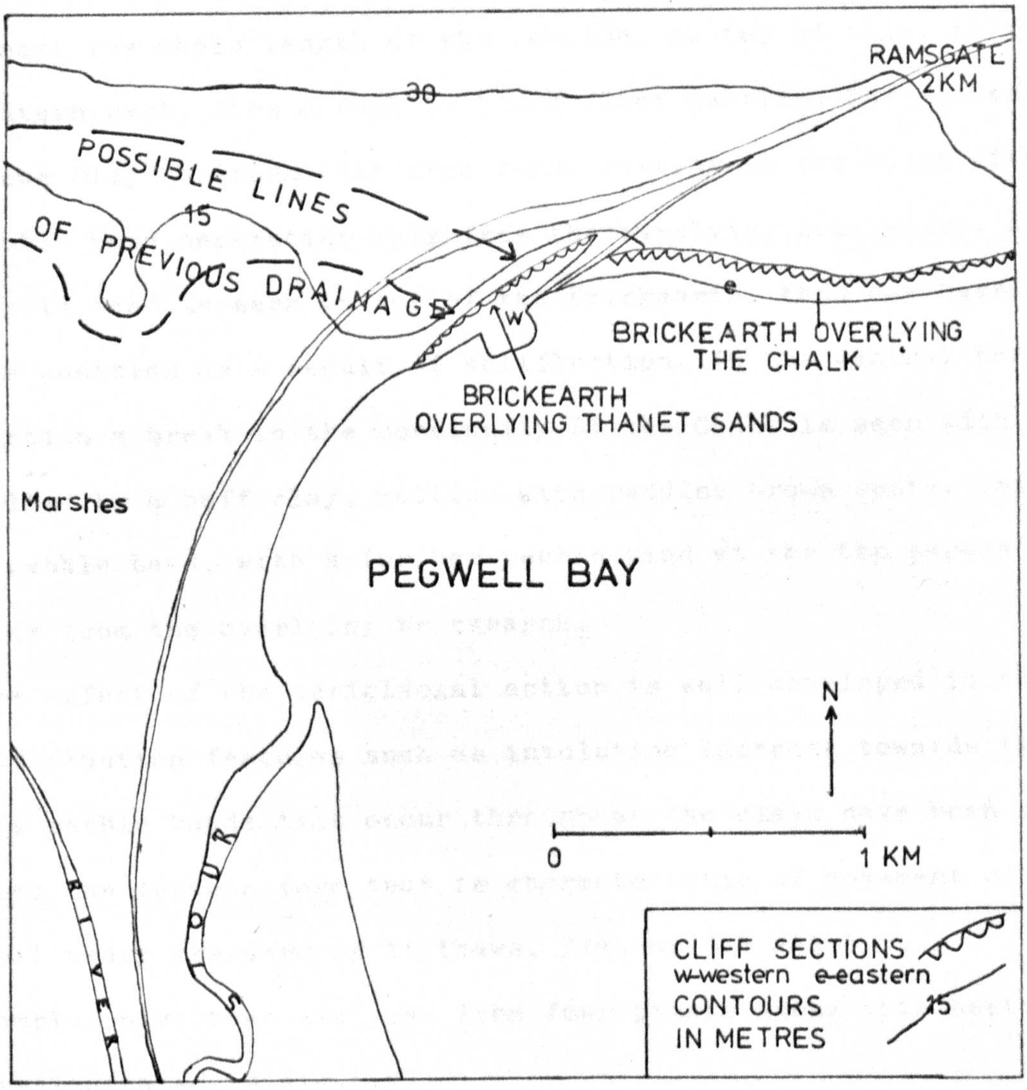
horizons. The Thanet Sands show sedimentary structures with current bedding being more prominant, (Plate 5.1). Two fragmentary shell bands having a thickness of 10 - 15cm separated by a Thanet Sand horizon approximately 1.5 metres thick are also seen in Plate 5.1. The whole of the Thanet Beds are at least 5 metres thick between the base of the brickearth and sea level, although the lower part of the exposure is covered by debris from the cliff face, (Plate 5.2.). The Thanet Sands are overlain by 3 - 5 metres of brickearth. At the base of the brickearth a bed of well rounded black pebbles were found, Plate 5.3. The brickearth itself may be divided into two groups, the lower and upper brickearths. The lower brickearth is a light buff coloured sediment up to 3 metres in thickness, its lower surface is straight and horizontal on the Thanet Sand. The upper surface is generally horizontal but irregular along the boundary with the upper dark brown coloured brickearth. The difference in colour appears to be accounted for by the iron content of the two soils, with the upper layer being more iron rich. This upper horizon is from 0 - 2 metres in thickness and is capped by a thin organic layer.

Several samples were obtained from the brickearth by means of augering from the top of the cliff (sampling from the base not being possible). In order to be able to measure the shear strength four $1\frac{1}{2}$" diameter tube samples were obtained from both the upper and the lower brickearth: these were waxed immediately they were extracted from the cliff in order to preserve the moisture and allow for extrusion in the laboratory, (Chapter 6).

ii) The Eastern Section:

Part of the cliff section to the east of the hoverport access road is shown in Fig.5.1 which stretches 500 metres towards Little Cliffsend. The whole exposure is more complex than the western section with evidence of extensive periglacial activity. The height of the

MAP 5.1



MAP SHOWING THE LOCATION OF THE PEGWELL BAY SECTIONS AND LINES OF PREVIOUS DRAINAGE cliff increases from 8 metres at the western end to 15 metres in the eastern end. The solid geology is represented by the Chalk throughout almost the whole length of the section, on top of this, in the western part, lies a bank of black flint pebbles. The western part shows Clay horizons with iron bands resting on the Chalk with a flint pebble band separating this from the overlying brickearth. A further pebble band is seen on top of the brickearth, this may have occupied the position as a result of solifluction. In the central part of the section a break in the continuity of the Chalk is seen with the gap filled by a buff clay, mottled with reddish brown spots. This contains a pebble band, with a further pebble band at the top separating this clay from the overlying brickearth.

The effect of the periglacial action is well developed in the section; solifluction features such as involution increase towards the east. The pebble bands that occur throughout the clays have been contorted into the festoon form that is characteristic of movement of liquified soil under pressure as it thaws, Plates: 5.4 and 5.5.

Samples have been analysed from four points along this section, these are indicated in Fig.5.1.

Deposition of the Pegwell Bay deposits appears to have taken place along a former course of the river Stour. This particular river having meandered across the low lying ground separating the Isle of Thanet from the rest of Kent now occupies a position on the south side of the marshes. Map 5.1 indicates the possible route the river may have taken; the fifteen metre contour shows a line suggesting a former river bluff to the west of Pegwell Bay. As a result of the southerly migration of this revier the course appears to be defined across this low lying ground, by a line of brickearths. Other sites described below appear to show that deposition of brickearths along the river Stour and other water courses throughout Kent took place by fluvial processes.

PLATE 5.4.

PEGWELL BAY EASTERN SECTION

The brickearth at the top of this section has been affected by periglacial activity. Involutions are seen penetrating the local Chalk.

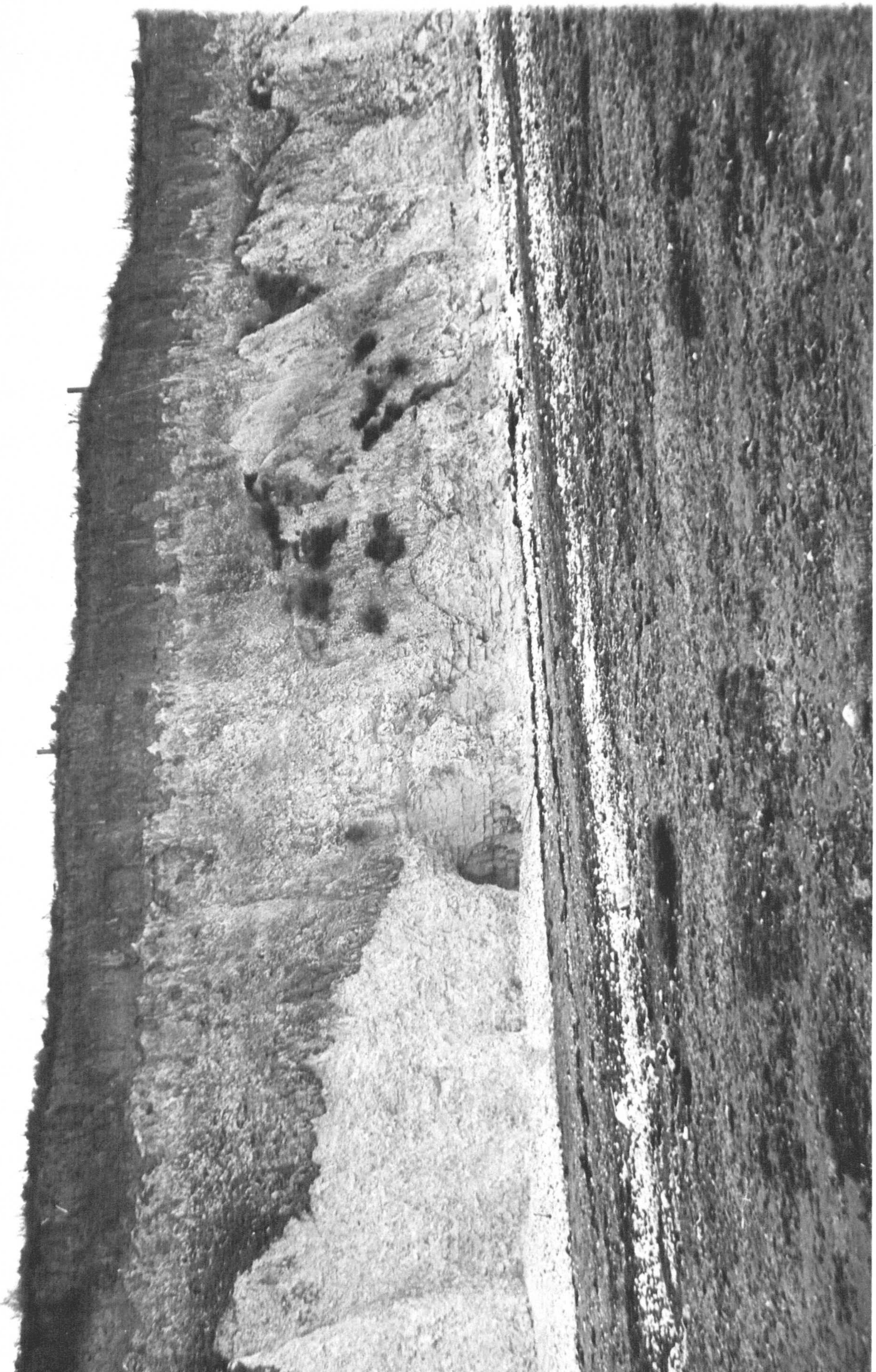
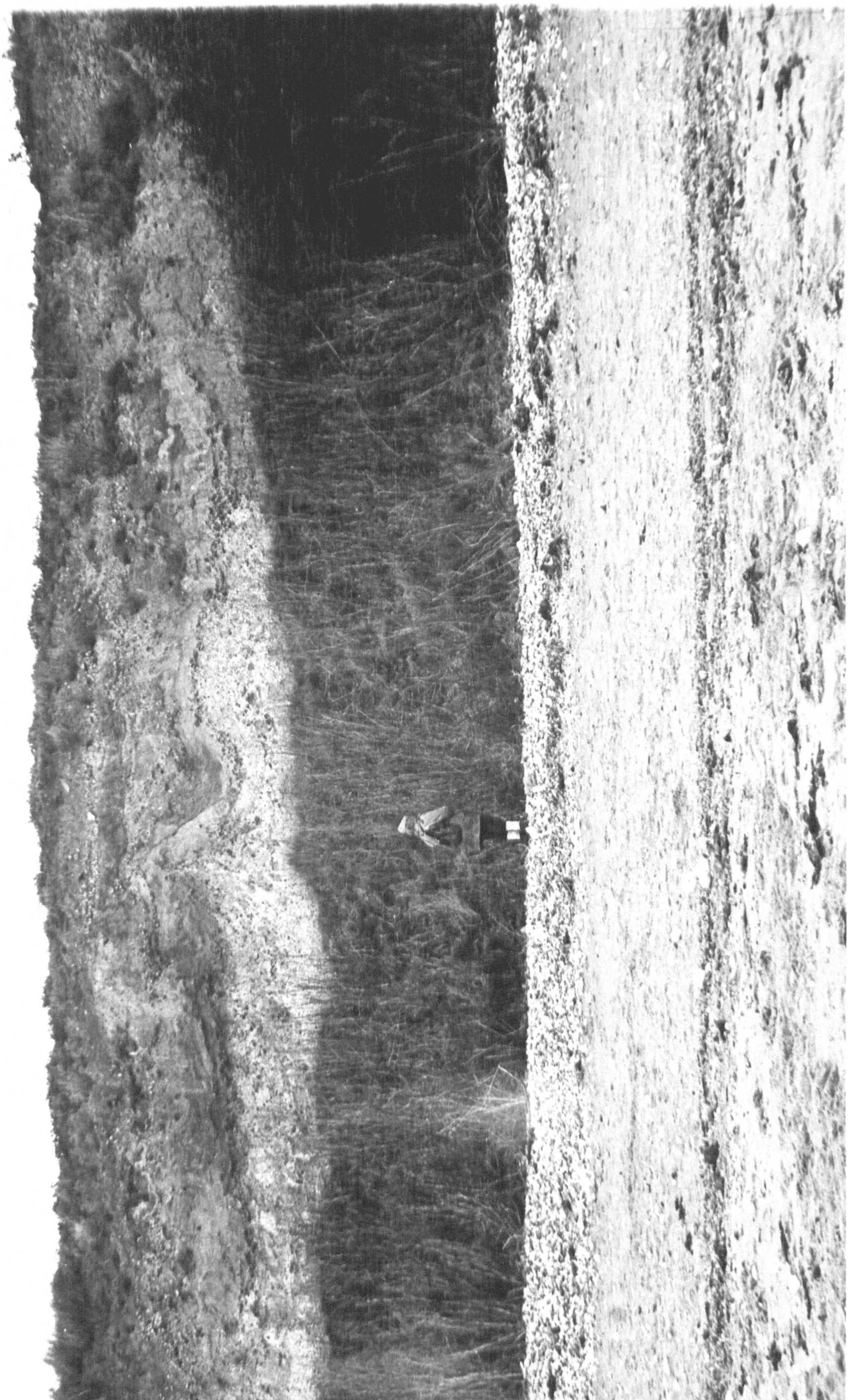
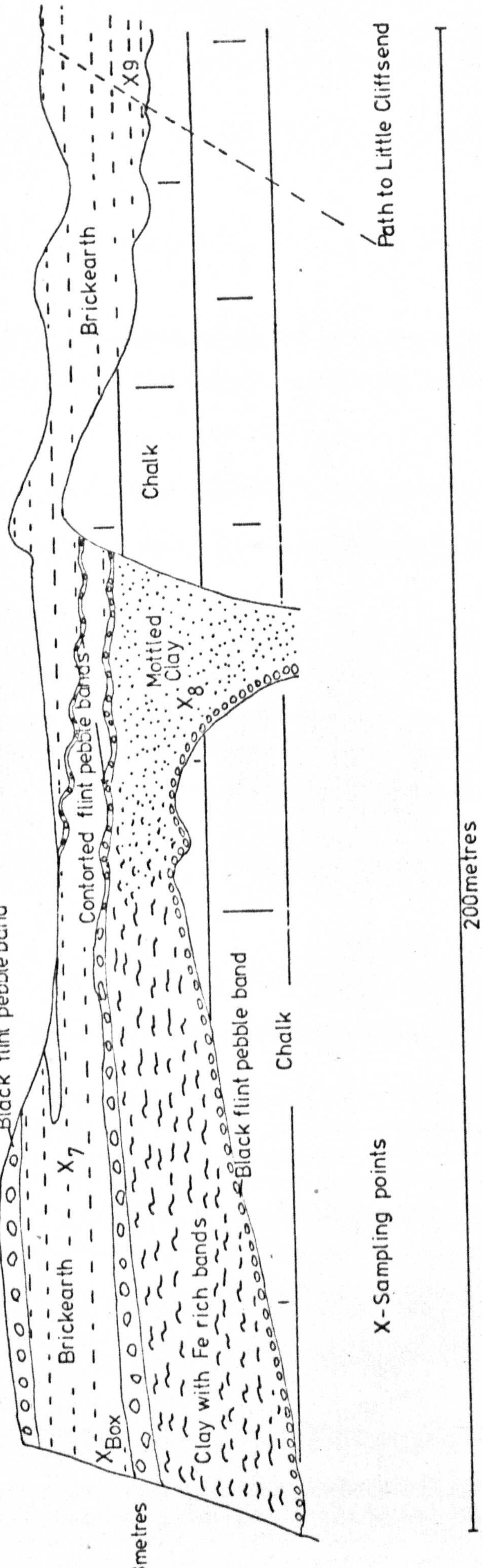


PLATE 5.5

PEGWELL BAY EASTERN SECTION

Photograph showing the contorted nature of the brickearth with flint pebble bands; this is a feature of periglacial action.





Path to Little Cliffsend
X9
Brickearth
Chalk
Mottled Clay
X8
Contorted flint pebble bands
Black flint pebble band
Black flint pebble band
Chalk
X7
Brickearth
XBox
Clay with Fe rich bands
X-Sampling points
200metres
8metres

PLATE 5.6

ALLINGTON

Photograph of a Quarry Gull ' let into ' the Ragstone.

Monkton (TR 285656):

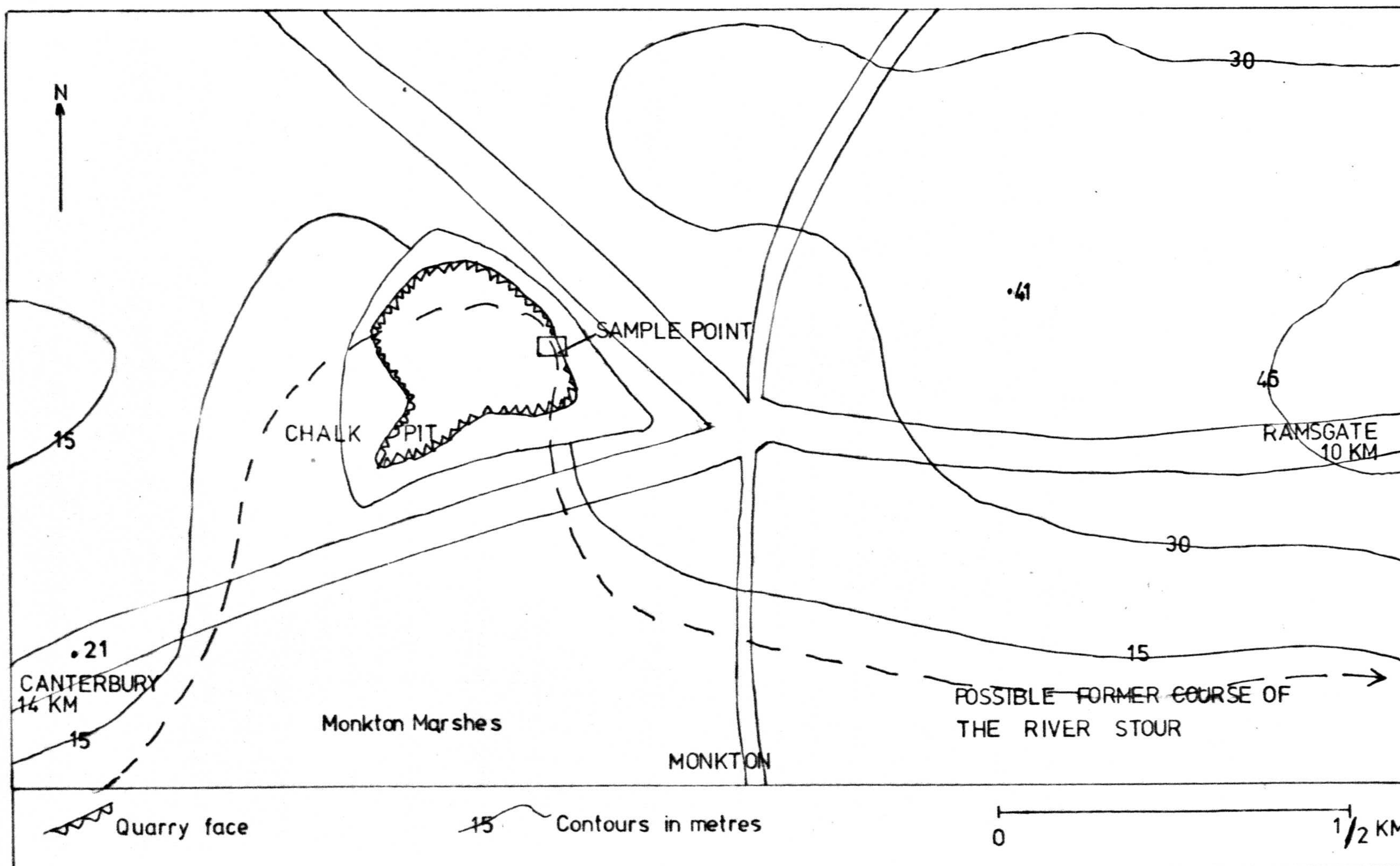
This large, disused Chalk Quarry had a thin cover of material on top of the eastern face. A sample of this was removed for laboratory analysis. An attempt to obtain a 38mm triaxial tube sample was prevented by the dryness of the soil. The thickness of the soil appeared typical of the central part of the Isle of Thanet with much of the fields containing large portions of chalk pebbles ploughed from beneath. The thicker exposures of superficial deposits appeared more prominant near the coast. The location of this particular deposit supports the suggestion proposing the former course of the river Stour. Its previous northerly course accounts for the Pegwell Bay deposits and may also be interpreted to be the reason for the brickearth cover at this point. Much of the terrain to the eat of this particular site is substantially elevated, Map.5.2, but the line of the fifteen metre countour makes a sharp meander at this point, The brickearth preserved may be a result of the meander with the deposit having been washed on to the river bank during the period of flood and remaining in this position when normal flow was resumed.

Allington (TQ 741577 and 739577):

This site is that of a Ragstone Quarry 3Km north west of Maidstone. Solution pipes or Quarry Gulls of various sizes, generally 2 - 3 metres across are seen let into the Ragstone. The pipes have been infilled with a rock weathering material which is probably the Sandgate Beds (Prestwich 1855b and Foster and Topley 1865 see Chapter 2), overlain by Brickearth. Samples were collected from a pipe at the western edge (TQ 739577) of a long east-west trending north facing wall and from another part of the quarry 200 metres to the east (TQ 741577).

At the eastern edge samples were obtained from a pipe at 1.5m and 3 metres (Plate 5.6) from the surface. Fiberous, colourless threads

MAP 5.2



MAP INDICATING THE LOCATION OF THE MONKTON CHALK PIT AND A SUGGESTED FORMER COURSE OF THE RIVER STOUR

PLATE 5.7

ALLINGTON

Photograph showing a general view of the north facing wall of the Ragstone face, with brickearth filled Quarry Gulls.

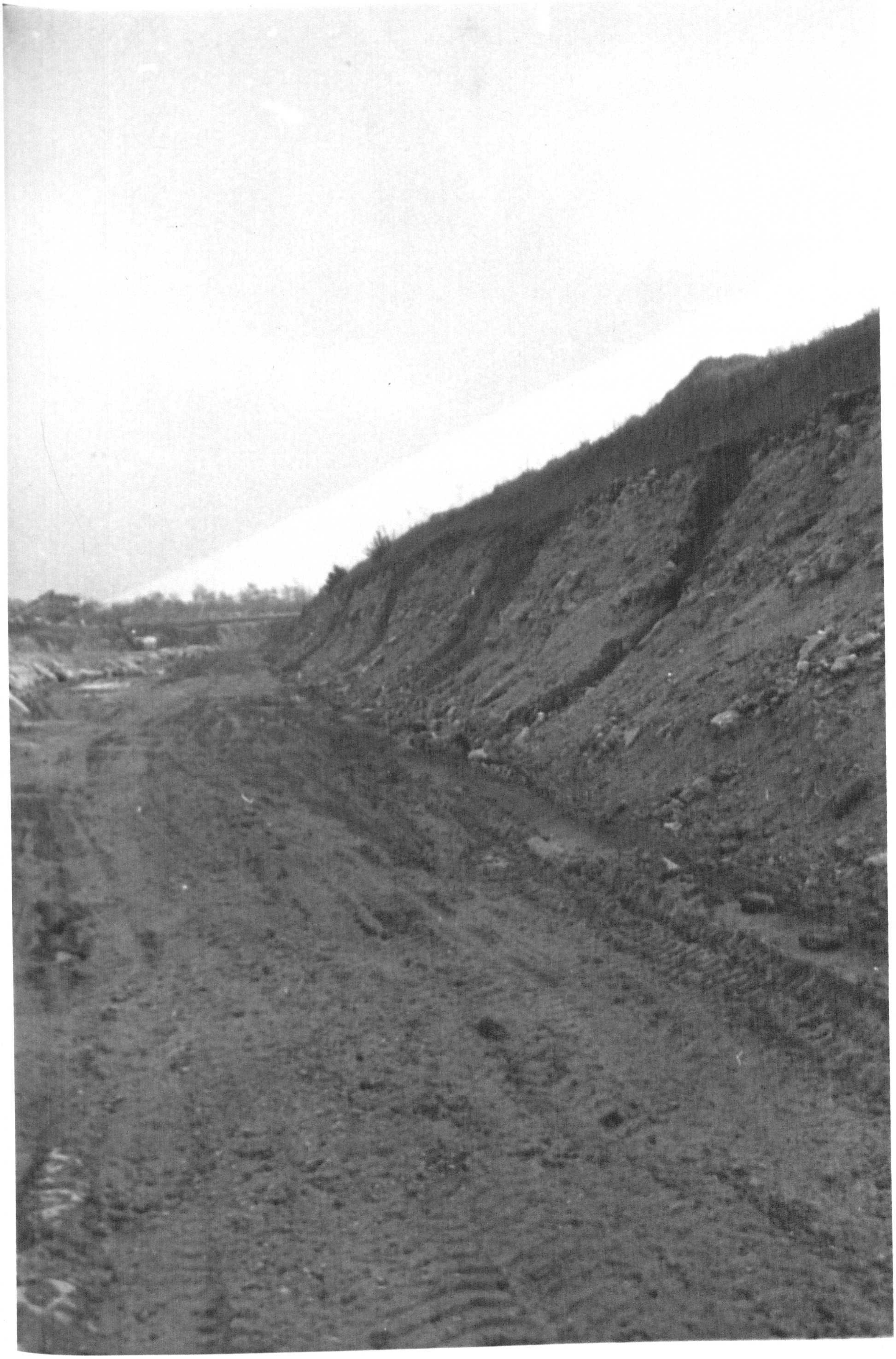
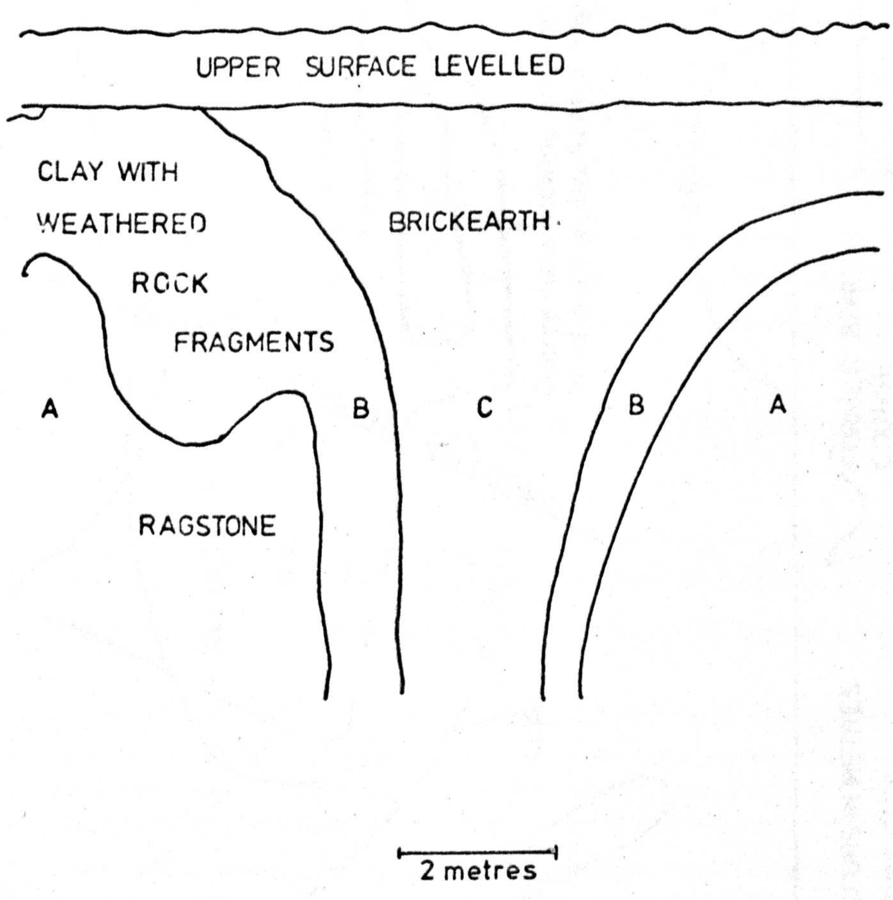


PLATE 5.8.

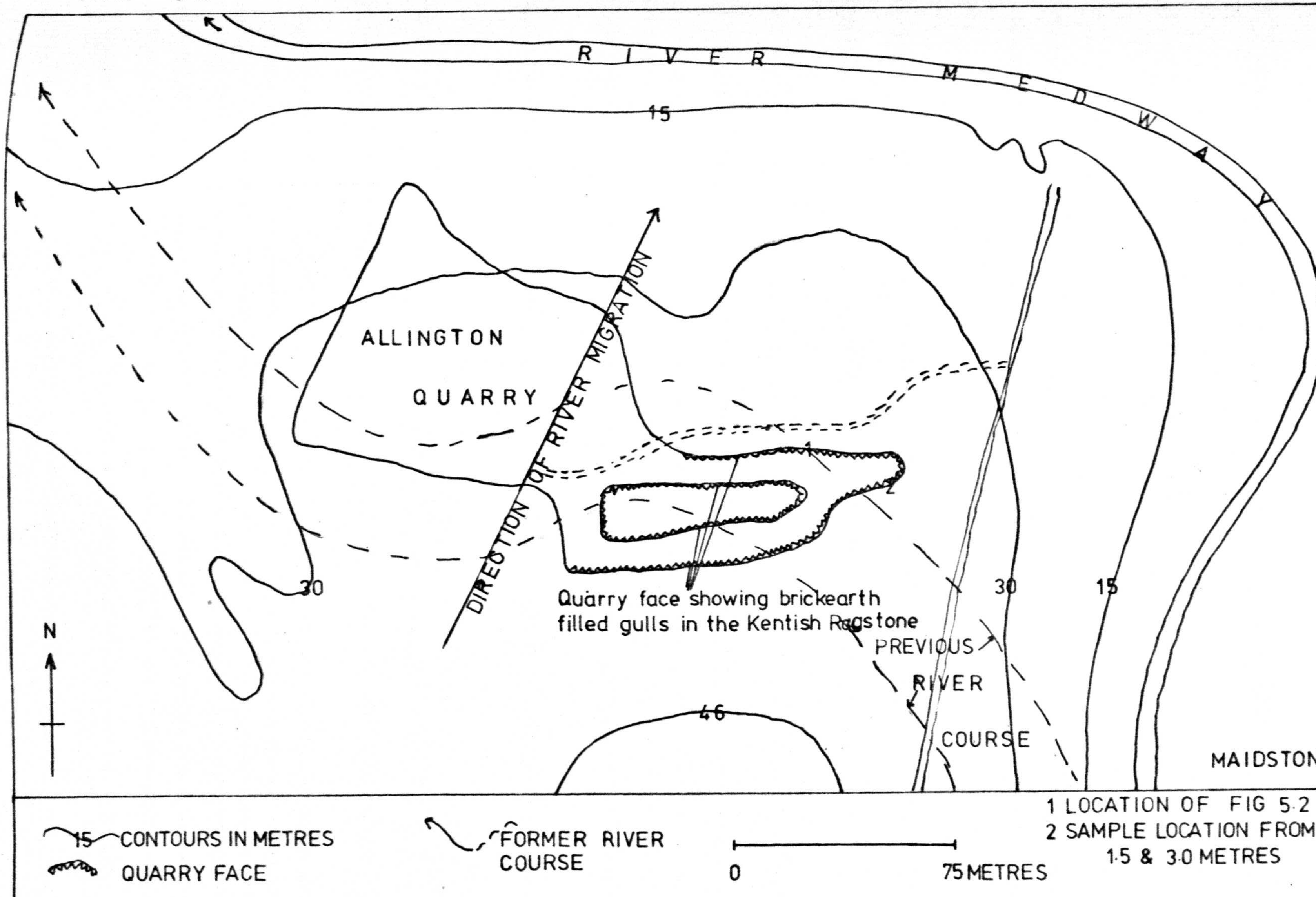
ALLINGTON

Photograph of a Quarry Gull showing the clay with weathered rock fragments between the brickearths and the Ragstone, (see Fig.5.2).

FIG 5.2 SECTION OF A QUARRY GULL AT ALLINGTON, NEAR MAIDSTONE [SEE PLATE 5.8]



MAP 5·3



MAP SHOWING THE LOCATION OF THE ALLINGTON BRICKEARTH DEPOSITS

PLATE 5.9.

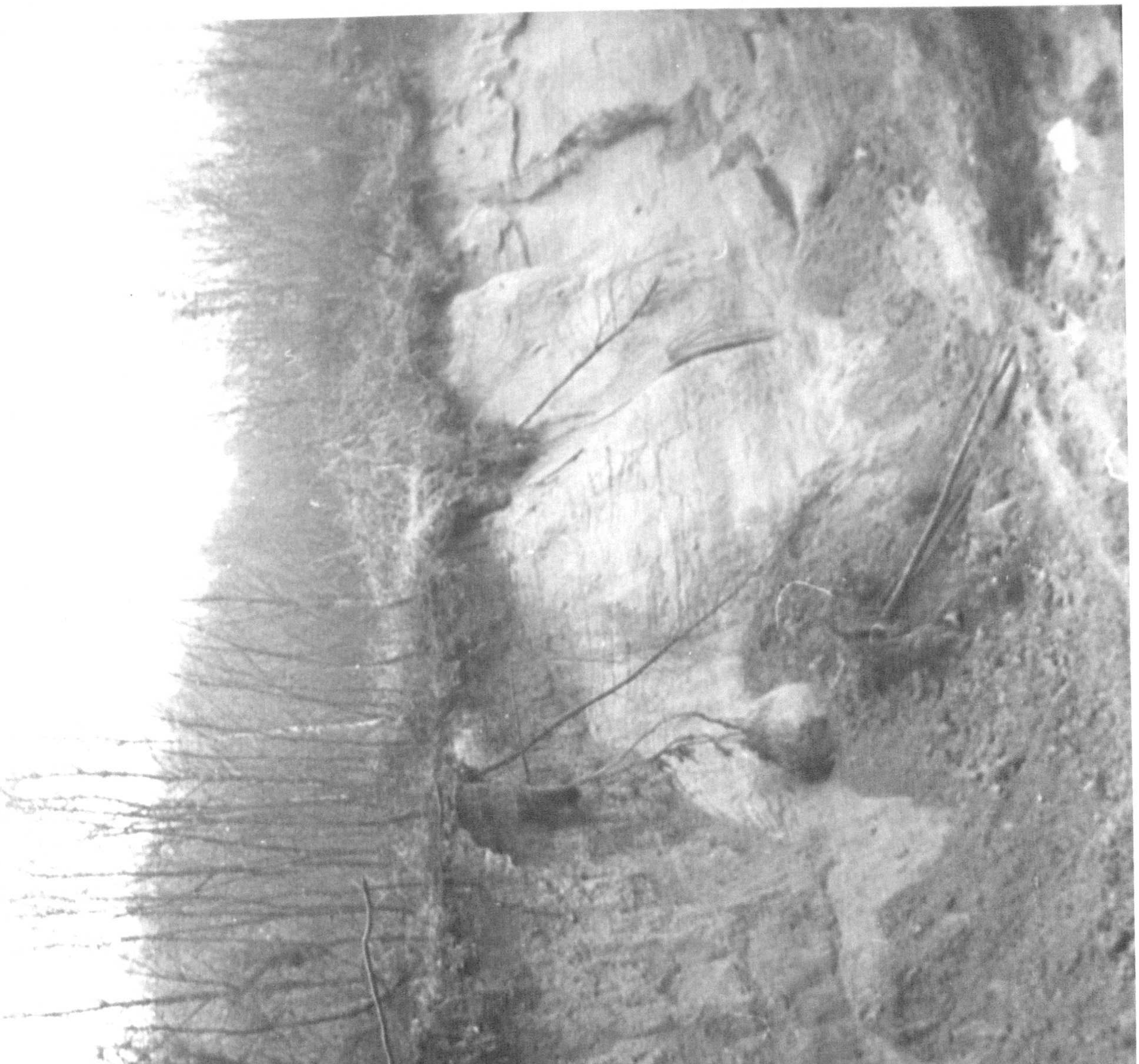
DENSTEAD WOOD

View of the western part of this section showing the brickearth banked-up against the gentle slope of the Woolwich Beds.

PLATE 5.10

DENSTEAD WOOD

Photograph showing the steep eastern bank of the Woolwich Beds with the brickearth lying unstratified and unconformably against them.



were observable below 2.5m from the surface whilst above this level colourless deposits were not observable. Leaching of the soil is possibly the cause of the presence of the colourless material in the lower horizon. Undisturbed samples were obtained for the purpose of impregnating the material for preparation into thin microscopic sections, (Chapter 11). These were collected by using a small open tin 75mm x 50mm and 18mm deep with one of the open edges sharpened in order to provide a cutting balde. The insides were lubricated with petroleum jelly to ease the cutting into the soil, helping to prevent disturbance of the sample.

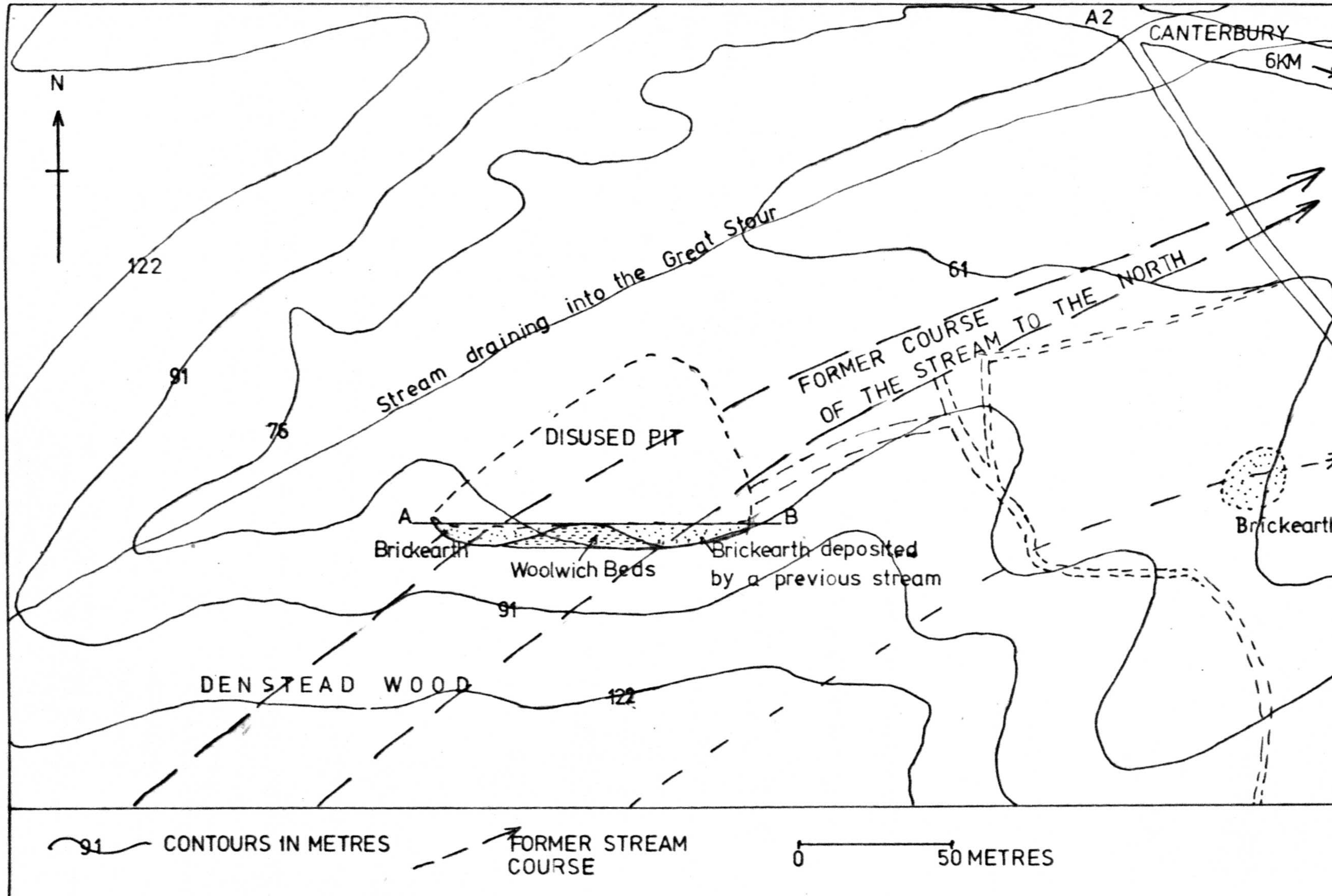
A general view of the north facing wall of this quarry is shown on Plate 5.7 and Fig. 5.2 is a sketch section showing the relationship between the Ragstone, the brickearth and the soil with weathered rock fragments. This particular section is shown in Plate 5.8.

The topography of the area around the Allington quarry with the river Medway flowing in a general northerly direction along the eastern and northern edge of the quarry is shown on Map 5.3. The deposition of the brickearth in order to appear as the central deposit throughout the gulls; Fig. 5.2, occurred prior to the opening of the pipes. Fluvial processes of deposition have been suggested at the previous sites described in order to account for the brickearth deposition; similar processes are considered to have operated here although the line of previous drainage are only tentatively suggested. If the former course of the river Medway was such as to have flowed along a line setween the present thirty and forty six metre contours the meadner would have had a smaller radius than that at present and may have assisted accumulation of silt along the inside of the curve.

Denstead Wood (TR 090575):

At this site a dark brown brickearth is found exposed in an old quarry face, the quarry now being used for the disposal of refuse,

MAP 5.4

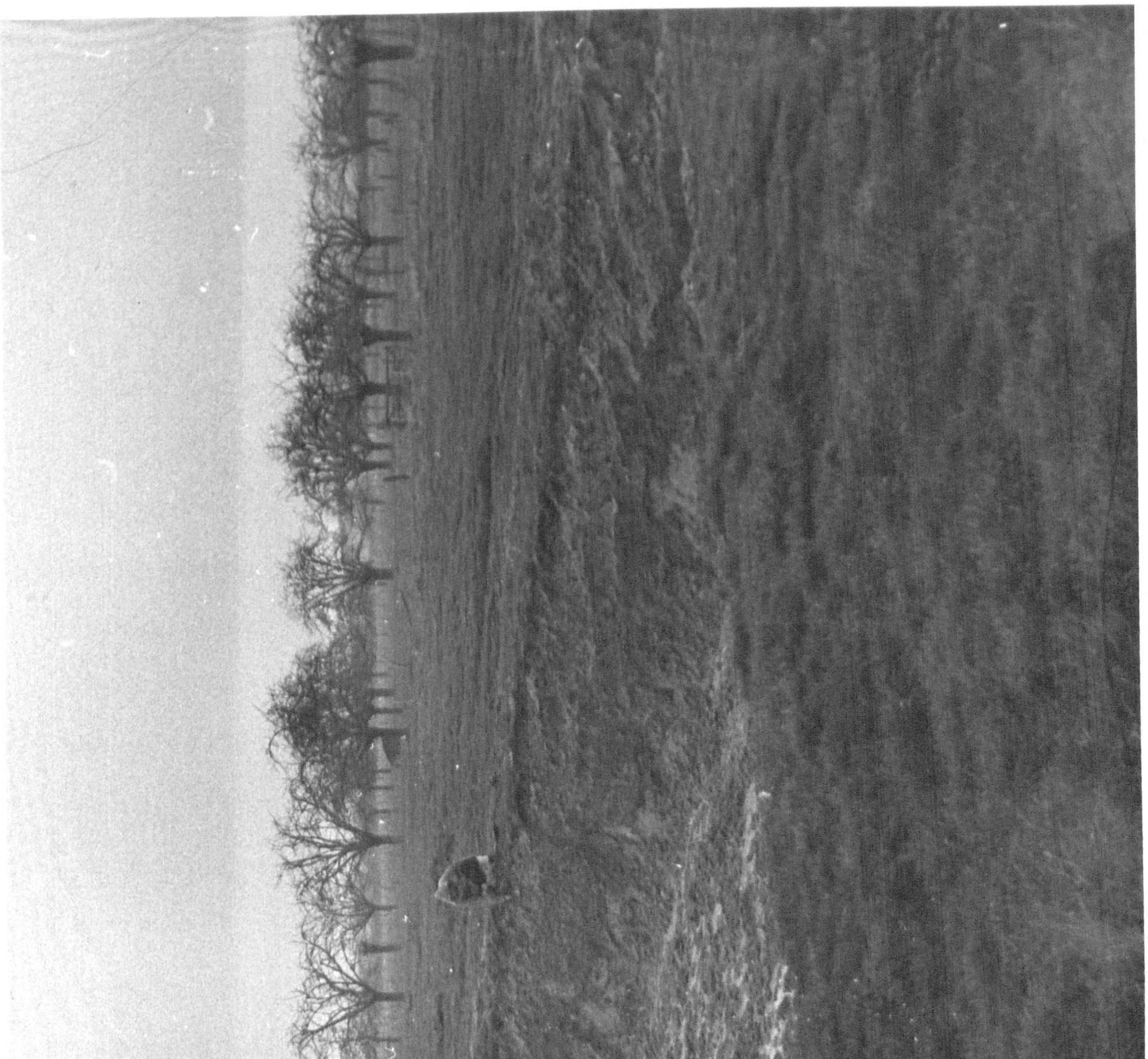


MAP SHOWING LOCATION OF THE DENSTEAD WOOD BRICKEARTHS AND THE FORMER COURSE OF STREAMS RESULTING IN THEIR DEPOSITION

PLATE 5.11

FUNTON

A general view of the shallow brickpit at this site. Excavation takes place to a depth of approximately 2.5 metres below which the calcium carbonate content is excessive for brickmaking.

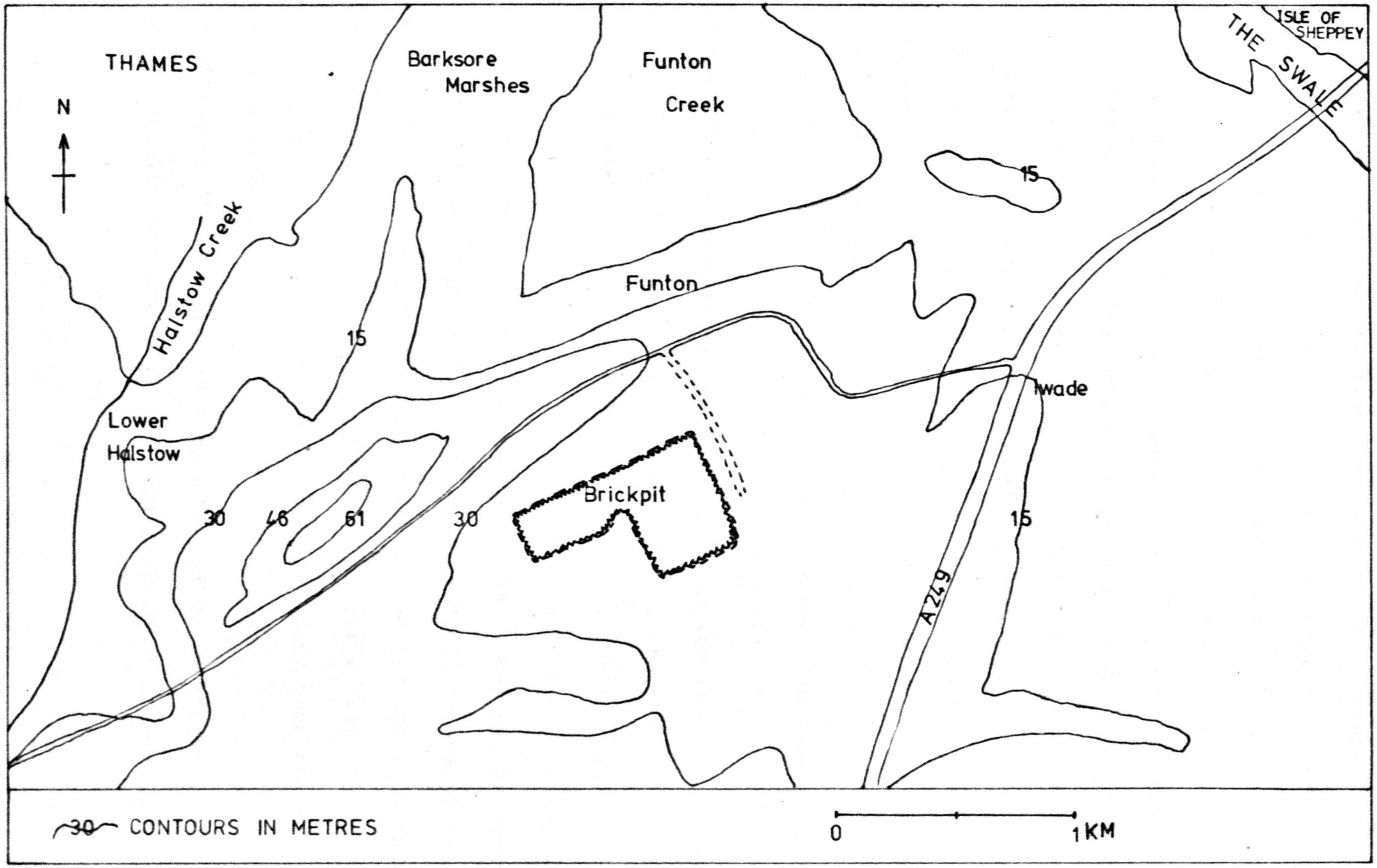


overlying the dune-like structure of the light yellow sands of the Woolwich Beds, (Plates 5.9 & 5.10). The exposed face is approximately 100metres along an east-west line facing north, having a depth of 8 metres. In the eastern part of the section the brickearth attains a thickness of approximately 6 metres, thinning over the crest of the Woolwich Beds in a westerly direction and thickening to 3 metres at the western edge. The base of the brickearth in the western section rests on a 10cm thick pebble bed which lies between the brickearth and the sands. The pebbles are small and well rounded and indicate that water deposition has been predominant. From the field evidence, it appears that the sand represents a bank within a stream with a channel forming on both its eastern and western sides. The pebbles have been deposited during a period of strong current and this has been followed by the deposition of the brickearth. The brickearth may have been originally deposited as an aeolian material but subsequent fluvial action has resulted in redeposition. Sedimentary features are totally absent from the brickearth suggesting that the sediment had been ' dumped ' in its present position rather than carried.
A generalised sketch of the present relief and drainage around this quarry is shown in Map 5.4. Transportation and deposition of brickearth may have taken place along a former course of a river that currently flows to the north of this site and which has since migrated approximately fifty metres in a north easterly direction. The whole region may have had several more surface water courses than are present today which may account for the scattered patches of brickearth found across north east Kent.

Funton Brickworks (TQ 880670):

This paticular brickworks on the south bank of the Thames is very similar to those of the Southend region of Essex, a few miles across the river on the north bank. Shallow pits (Plate 5.11), have been dug,

MAP 5.5



MAP INDICATING THE LOCATION OF THE FUNTON BRICKEARTH DEPOSITS in this brown brickearth, at this site as part of the process of extracting material, by dragline, for making into bricks. The pits are 2.5 - 3.0 metres deep with only the upper part being extracted, this is lime free and suitable for the brickmaking industry. Below the 3.0 metres depth the presence of lime is noticable with nodules being present in small quantities. Samples at 1.0 metre and 1.5 metres from the surface were extracted from the side of the pit for laboratory testing. By means of a shear vane tester the insitu shear strength of the material was tested at the 1.5 metre level, giving a value of 6 tons/sq.m; this is generally much less than that obtained from the brickearth of Star Lane in Essex but comparable with that of Cherry Orchard Lane (see Essex report).

The relationship of these deposits to the present drainage does not appear to be as easily indentifiable to those observed at other sites, Map. 5.5. Whether deposition has occurred as a result of a stream flowing into the Thames, bringing material from the south and then loosing its force at the point where it reached the main river or whether the deposits are a flood feature of the Thames is a matter for conjecture. The possibility of flooding of the Thames may be seen in the light of the theories proposed by Hollin (1964), where it is suggested that rivers were rapidly dammed by ice surging into their estuaries resulting in a rapid ponding of the valley water causing widespread flooding and deposition of material away from the main course of drainage.

The position of the deposits at this site may be interpreted by either cause with any traces of the former drainage pattern having been obscured by subsequent deposition.

Beacon Hill Quarry (TQ 758710):

This site lies on the north side of the Medway estuary 3Km north east of Rochester. A gully running down the north wall of this quarry was

PLATE 5. 12.

CHERRY ORCHARD LANE

Photograph showing the drainage trench following a course almost due south from the brickworks.

found to be filled with the deposits of a flow slide, having occurred several years prior to this visit, resulting from water being trapped in the clay and eventually causing part of the hillside to slump. The clay deposit was mixed with boulders and pebbles, probably due to the slide. A small disturbed sample was obtained for laboratory analysis in order to compare this with the other north Kent and also south east Essex deposits on a mechanical and mineralogical basis.

Essex Sites:

The extent of the brickearth in south east Essex was shown in Fig.2.15. The number of exposed sites, where brickearth material is at present being extracted has declined to two commercially operated brickpits, these are at Cherry Orchard Lane, Southend (TQ 859899) and at Star Lane, Great Wakering (TQ 935870). The deposits at Cherry Orchard Lane were studied on two separate occasions when new faces were cut. The Star Lane section allowed study to take place on an old face. At this site extraction is not continuous and during the period of field work a freshly cut face was not available for inspection. A brickpit further north, at Marks Tay near Colchester was examined for brickearth. Here the material was found to contrast with that of the sites around Southend.

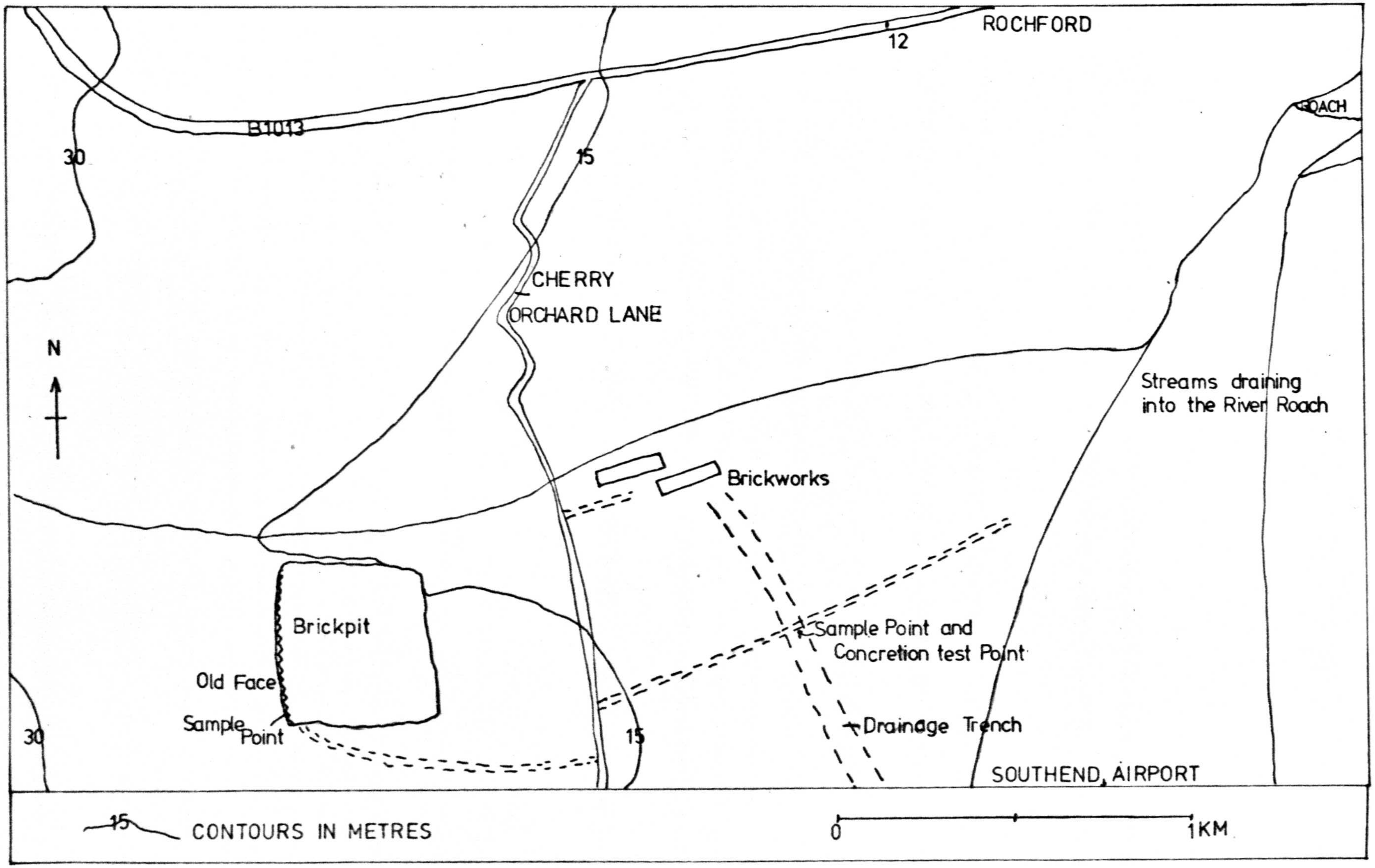
Cherry Orchard Lane (TQ 857898 & 860897):

This site lies approximately 800 metres beyond the north western perimeter of Southend Municipal Airport. Two separate faces were studied and are referred to here as the old face and the drainage trench. The location of these faces is given by the grid reference TQ 857898 for the old face and TQ 860897 for the drainage trench, (Map 5.6).

Old Face

At this point in the brickfield a 2 metre deep trench had been cut by

MAP 5.6



MAP SHOWING THE LOCATION OF CHERRY ORCHARD LANE BRICKWORKS

PLATE 5. 13.

STAR LANE BRICKWORKS

Photograph showing the freshly cleaned section to a depth of 1.65 metres.

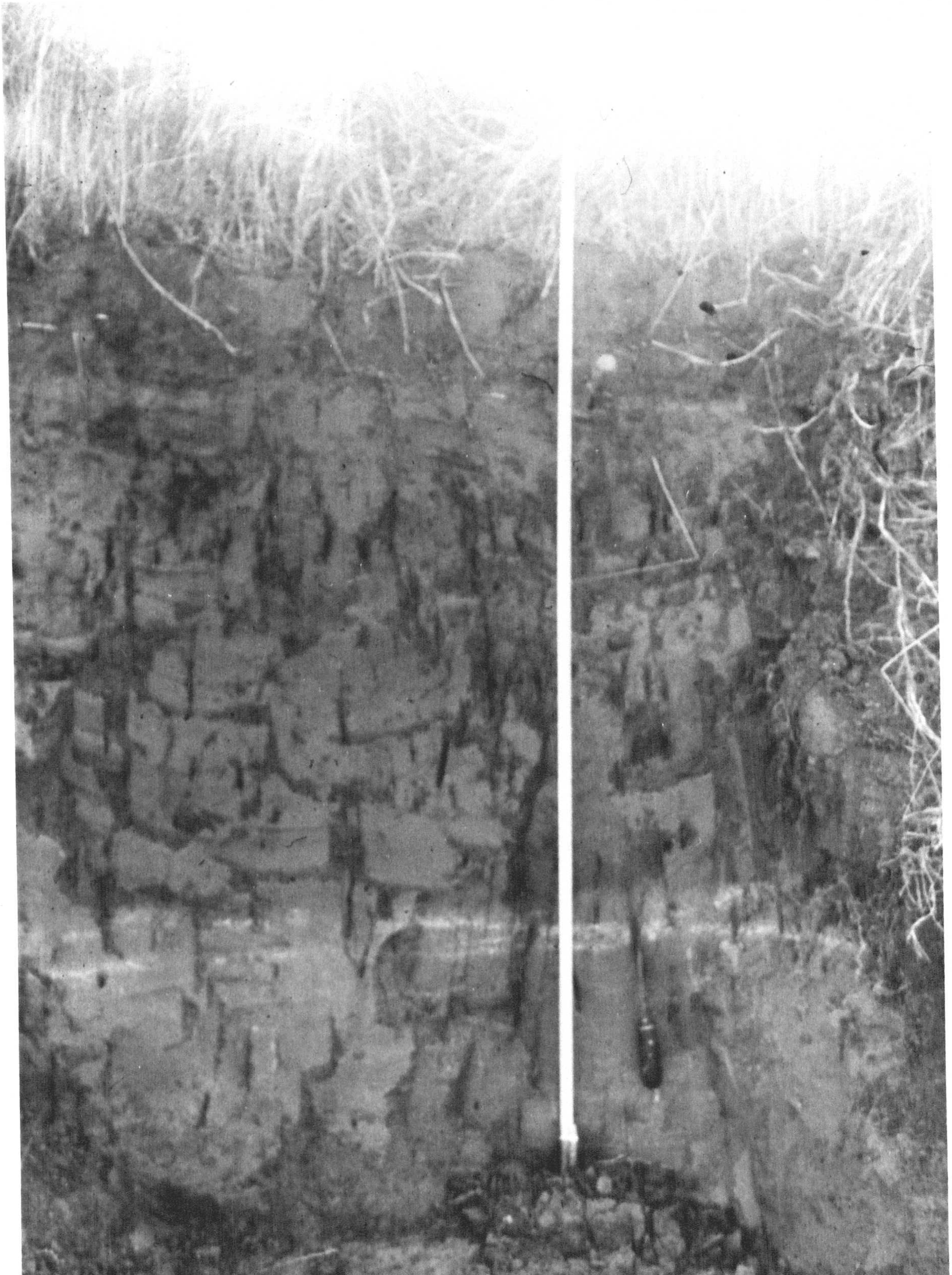
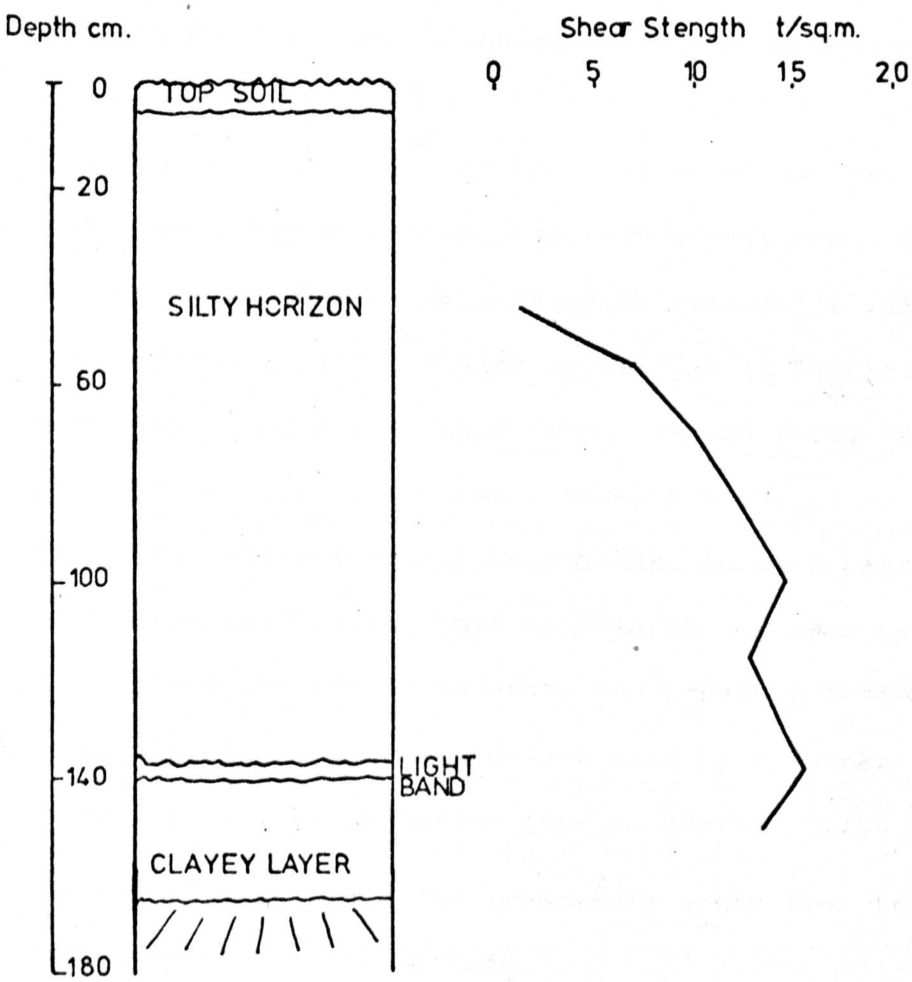


FIG 5.3 SECTION AT STAR LANE BRICKWORKS SHOWING THE VARIATION IN IN-SITU SHEAR STRENGTH WITH DEPTH



TQ 935870

means of dragline for extracting the upper layer of brickearth. Below this depth the brickearth became more calcareous with small irregular shaped concretions becoming prominent (Chapter 10). The calcareous rich brickearth is of little economic value as the presence of lime within the bricks causes ' blowing out' to take place during firing. Samples were taken at 0.5 metres from the surface and from below 2 metres. In Chapter 9 the derivative thermogravimetric histograms for these two samples shows the presence of $CaCO_3$ in the lower one and its almost absence from the upper deposit (Figs:9.6a and 9.6b).

The Drainage Trench

A further visit to Cherry Orchard Lane revealed that the old face had been fully worked and that new workings had commenced along the line of a drainage trench following a course almost due south from the brickworks (TQ 859899) for a distance of approximately half a kilometre (Plate 5.12). The depth of the trench was 3.5 metres with the bottom 12cm consisting of a blue grey clay with gravel. Above this rested 1.5 metres of dark brown calcareous brickearth with an abundance of concretions, varying in size up to 50mm in length. Most of the forms were similar to those found below the old face, being irregular although one concretion had a tubular form.

Above this calcareous brickearth lay almost 2 metres of non-calcareous dark brown brickearth. Both brickearth horizons were unlaminated showing the absence of currents and possibly indicating these deposits to be floodloams which have been laid by a former river Thames. Insitu shear strength measurements gave an average value of 7 ton/sq.m.

Samples were obtained for laboratory study from this location along with many of the concretions.

The relief of this region is indicated on Map 5.6 with the widely spaced contours showing the subdued topography. The reason for such a widespread area of brickearth appears to rest in the proximity of this locaility to the Thames with the possibility that the river flowed or flooded over the area carrying large quantities of silt grade quartz particles. The origin of such large amounts of homogenous silt may be difficult to explain in terms of bedrock erosion of the Thames catchment area with much of the solid lithology being of a calcareous nature.

The soting and grading of superficial deposits, much of which has possibly been wind transported and deposited higher in the valley, may account for this type of widespread accumulation. The absence of stratification in the Cherry Orchard Lane sediments and in the other deposits described above suggests that a rapid process of deposition has dominated without the continuous presence of disturbing and recycling currents that would normally supply the deposits with sedimentary structures.

Star Lane Brickworks (TQ 935870):

At this locality a working face was not available to study as the different brickearths extracted meant stock piling had to be undertaken in order to blend the materials in the correct proportions for brickmaking. At a point TQ 935870 part of an abandoned face was scraped clean to a depth of 1.65m (Plate 5.13). The whole face was north facing approximately 400 metres in length in an east-west direction.

Below the top soil of 5.6cm lay two distinct horizons both of which appeared to be unstratified. The two layers consisted of an upper, more silty bed, dark brown in colour having a homogeneous nature throughout. This upper layer extended to a depth of 1.37m below the surface. The lower horizon appears to be finer grained and is buff in colour, between the two layers a thin, 4cm, light yellowish-brown band is present, possibly indicating a former horizon. A section at this point is shown in Fig. 5.3 with a series of insitu shear vane tests taken at various depths. As expected the greater shear strength values were obtained from the lower horizons with its finer grain size fraction. The highest average value was found to occur in the thin light coloured band at 1.38m depth. The upper layer gave a value to 14.75sq.m at 1m depth. The lower coarser grained layer gave a value of 13.4/sq.m. at 1.5m depth.

Samples from both the upper and lower horizons were obtained for laboratory analysis and three small tins of undisturbed samples, for impregnation and microscopical analysis were obtained at 0.72m, 1.37m and 1.5m depths, (see Chapter 11).

Marks Tay (TL 910244):

Investigations in the Colchester area showed that much of the superficial cover consists of sands and gravels. To the west of Colchester a small brick works producing special bricks and pipes at Marks Tay reveals several horizons along a 5 - 8 metre deep working face, Turner (1970), records the sediments here as being Pleistocene lacustrine, occupying a trough cut into the subglacial surface, underlain by chalky boulder clay. Two strata were recognised by Turner from bore-hole data obtained near the brick pit, these were laminated clay muds, partly brecciated and overlain by laminated grey clays.

Palaeobotanical evidence suggested the basin to have been formed during the Lowestoft glaciation, and to have been infilled during the course of the entire Hoxnian interglacial and the earliest part of the ensuing Gipping glacial period.

Samples were obtained for examination for the upper laminated clays, the deposits used for brickmaking. A comparison of the results obtained from this type of brickmaking material with that from the Southend area of Essex is made in Chapters 6 and 7.

Norfolk:

The distribution of coverloam in north Norfolk was studied by Catt et al (1971 see Chapter 2), who believed that the silt content represented the loess fraction of the deposit. An investigation of the deposits at sites recorded by these authors and at other sites was undertaken during two field excursions in this region. Many of the localities revealed sand and gravels, these were not studied further, whilst none showed any similarities to the types of deposits found at Pegwell Bay and other sites of Kent. Samples from three localities were considered for laboratory investigation these were Costessey, Burlingham Green and Aylmerton.

Aylmerton (TG 173392):

A small sample was obtained at this site from the edge of a field at a depth of approximately 0.5 metres below the surface by means of a screw auger. Beneath the soil cover a reddish brown sand was reached, these being the glacial sediments described by Catt et al (1971 op cit), at a site 800 metres to the north.

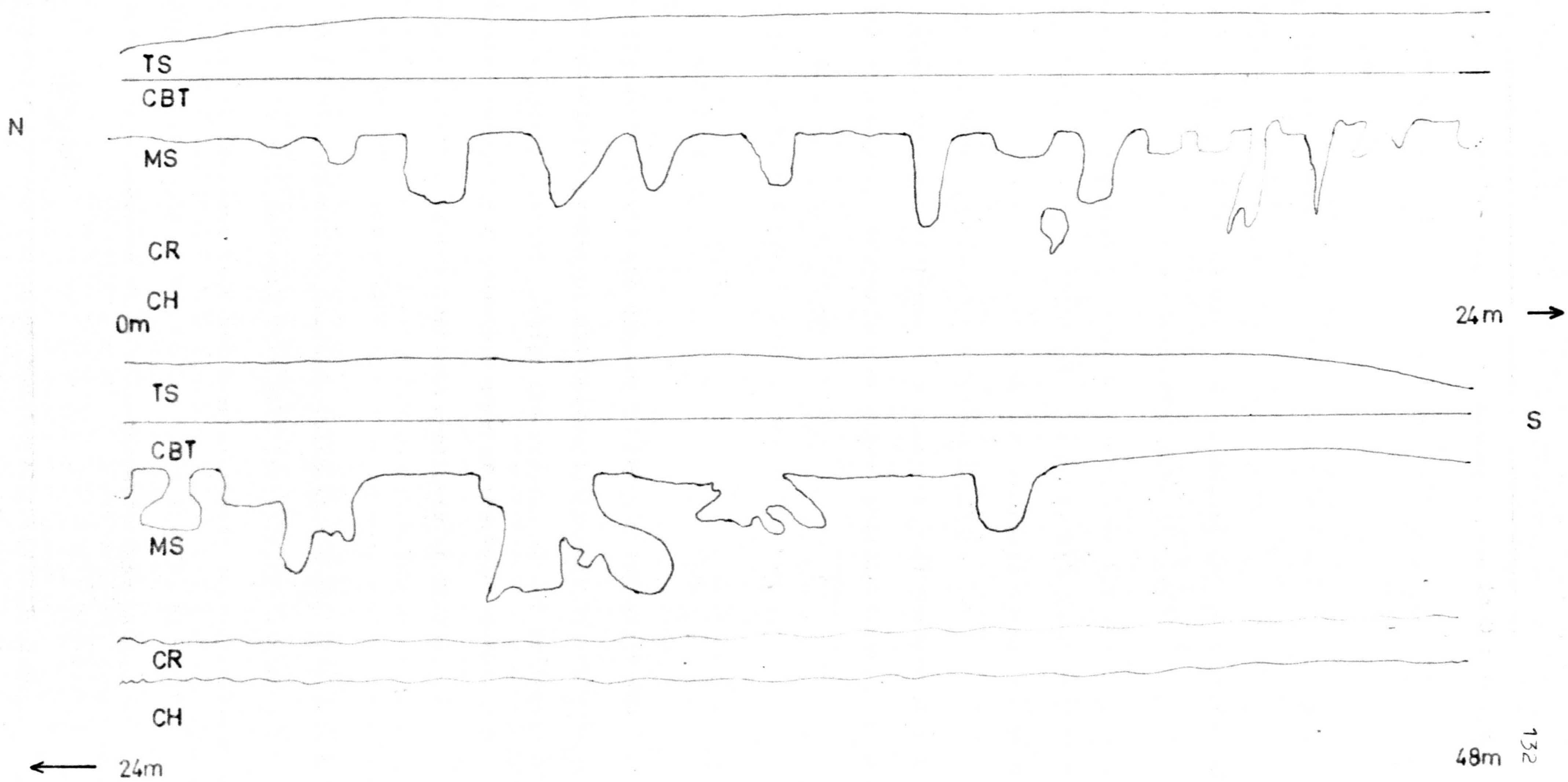
Costessy (TG 152123 & TG 152119):

This site lies on the edge of a large sand and gravel quarry approximately eight kilometres west of Norwich. Catt et al (1971 op cit), found examples here having a sand content of 42% and a silt content of 49% with 7% clay present. Analysis of two samples obtained from this quarry at sites TG 152123 and TG 152119 gave sand contents of around 65% and silt and clay content of only 35% (Chapter 6). It appears that any silt which is present in a high proportion from samples obtained from this locaility, is of coincidence and that the vast majority of the soils of the region contain a very high proportion of sand.

Burlingham Green (TG 366109):

At Burlingham where the thin soil cover overlies the Norwich Brickearth, samples of a silty nature were obtained. By using a 38mm diameter tube

FIG 5·4 SECTION OF EAST FACE AT EPPLEWORTH CHALK PIT EAST YORKSHIRE



TS: TOP SOIL - CBT: CRYOTURBATION FEATURES - MS: MIDDLE SOIL - CR: CHALKY RUBBLY SOIL - CH: CHALK

TA 022325

auger, samples for shear strength measurements were obtained from below 0.4 metres depth.

Corton Cliffs:

At this point the Lowestoft Till is exposed on the Suffolk coast. The mixture of the till with recent blown sand near the surface prevented sampling of any deposit that possessed any properties that would lead to a possible conclusion regarding its loessic nature.

Other sites that were visited included Frettenham (TG 2417), Buxton Heath (TG 2420), Wyndmonham (TG117004), and the Old Wood (TG 160416) south of Sheringham where in all cases the deposits appear to be the characteristic heath deposits of sand and gravels.

The presence or absence of loess in the deposits of Norfolk is a matter for conjecture. The problems of loess definition were outlined in Chapter 1, a discussion of the position of British ' loess ' deposits in the European context is given in Chapter 4.

Yorkshire Deposits:

The deposits of Yorkshire are considered here in two parts the Quaternary glacial deposits of the Wolds, lying east of the Vale of York are the most important, whilst the Permian desert sediments of the Tadcaster region of the western edge of the Vale of York are discussed in relation to the problems mentioned in Chapter 1.

Deposits of the Yorkshire Wolds:

Catt et al (1974), described drift deposits in eastern Yorkshire which possessed a high silt content. This silt fraction was reported by these authors to be loess that had been weathered and partially mixed with subsequent deposits. Three of the sites studied by these investigators were observed along with three further sites.

Huggate (SE 875548):

This site is a small disused Chalk pit, half a kilometre east of Huggate village. A thin brown soil overlies the Chalk and nowhere exceeds 0.5 metres in thickness. On the east side of the quarry evidence of periglacial activity is present with small poorly developed solifluction forms. Samples from four parts of the quarry, on the northern and western sides were obtained for mineralogical and mechanical analysis (Chapters 6, 7 & 9).

Eppleworth (TA 022325):

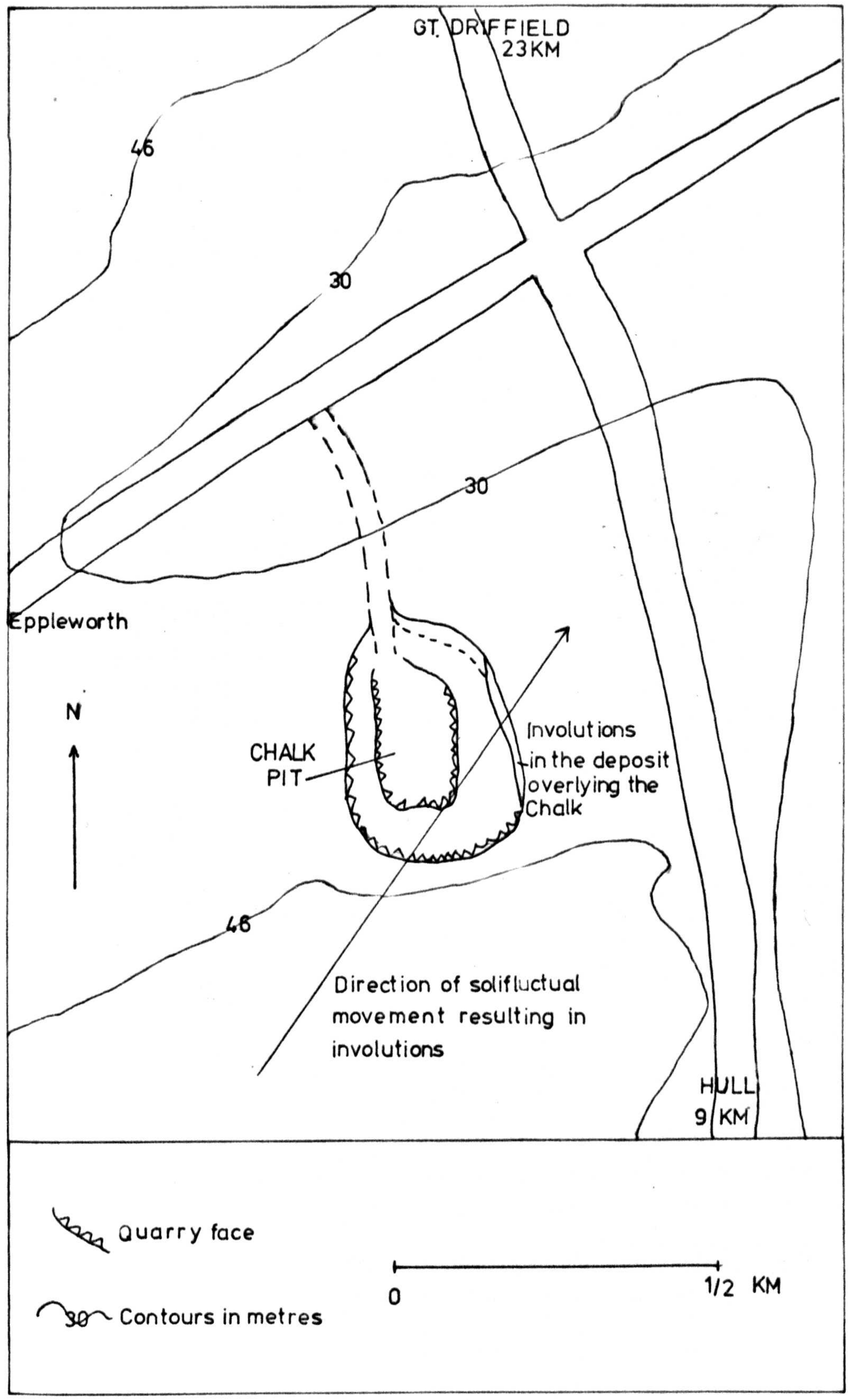
This location is also a small disused chalk pit, nine kilometres north west of Hull. A thin brown soil cover similar to that at Huggate covers the top of the Chalk and on the eastern face of the quarry well developed involutions are seen. The solid massive Chalk at the base of the quarry passes into shattered and fragmented chalk towards the top, with involutions to a depth of 1.0 metre along a 50m. section (Fig. 5.4). The whole surface is covered by a thin layer of top soil. Disturbed samples were obtained from the involutions but an attempt to obtain 38mm triaxial samples was prevented by the small pebbles that were present both within the involutions and in the top soil.

The possible direction of movement that took place in this deposit under solifluctual conditions is indicated on Map 5.7 with a general north-north easterly direction suggested in terms of the present topography. The involutions that resulted are sketched in Fig. 5.4.

Callis Wold (SE 828560):

The Callis Wold site is the third described here that was studied by Catt et al, where the soil was considered to have a silt and clay content of 87%, although only 60% was found in this study (Chapter 6), with a sample that was obtained from a shallow pit in the corner of a field. The pit may possibly have been used for obtaining clay for making bricks in order the build the nearby farmhouse as is the case with several localities in this area. The pit does not resemble those

MAP 5.7



MAP OF EPPLEWORTH CHALK PIT AND AN INDICATION OF THE DIRECTION OF THE MOVEMENT OF THE GLACIAL CLAY UNDER PERIGLACIAL CONDITIONS

PLATE 5. 14.

HORNHILL TOP

Photograph showing involutions festooning into the rubbly Chalk.

of south east Essex and north Kent and the material does not appear to show any similarities.

Etton (SE 970433):

The site of this small disused Chalk pit is at the road junction one kilometre west of Etton Church. The brown drift cover displays solifluction features with poorly developed involutions. Disturbed samples were obtained for analysis but the soil was too thin (c0.25m) for 38mm tube samples to be extracted.

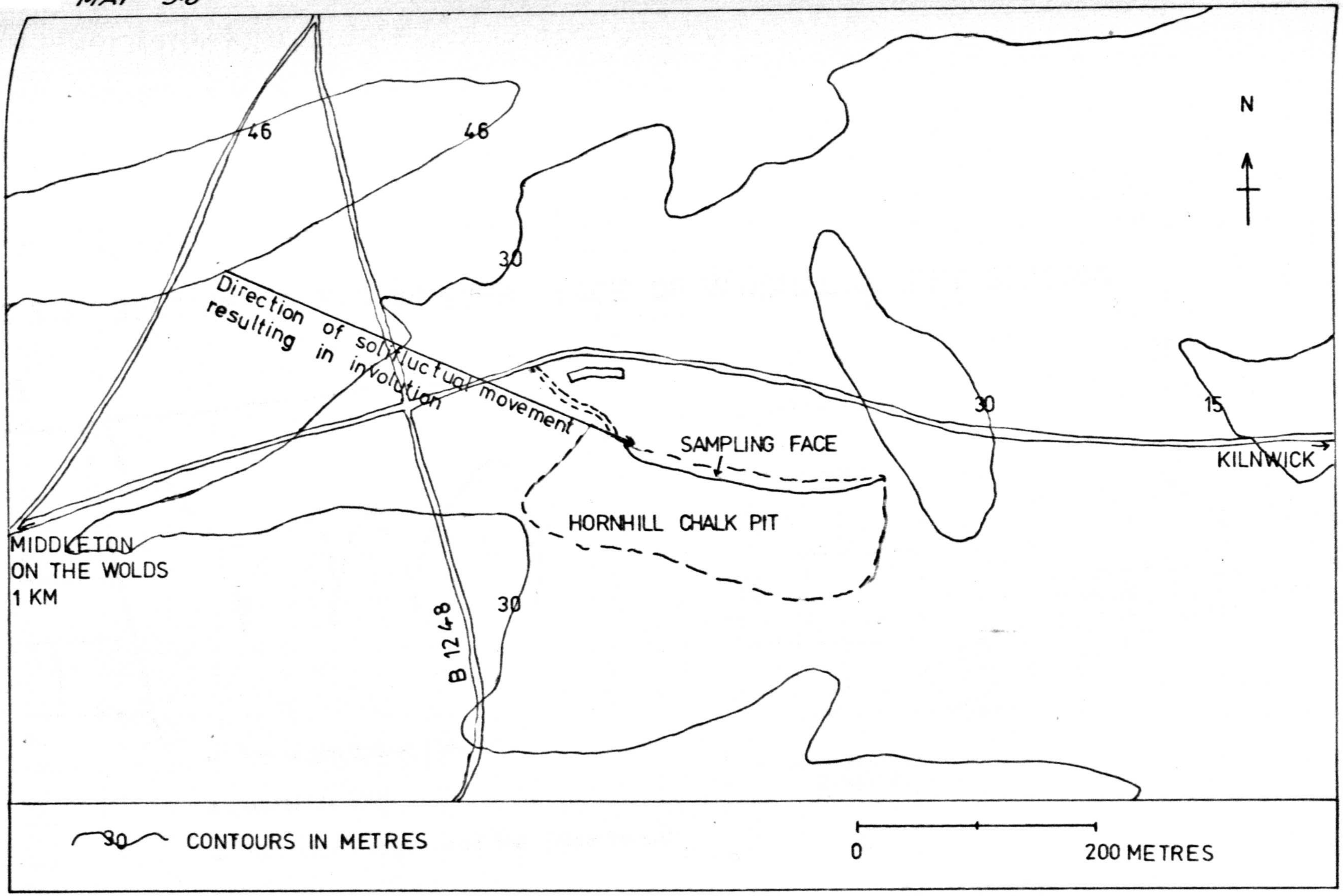
Hornhill Top Quarry (SE 9749):

The disused part of this quarrying operation shows some of the best developed periglacial features of this area. The quarry was opened for the extraction of Chalk but development at this point ceased because of the need for pure material. The face of the quarry trends in a general north west - south east direction facing south for 200m, (Map 5.8). Above the Chalk a dark brown drift deposit is found, containing very small angular and sub-angular stones.

The western and eastern ends of the face show a massive drift bed, up to 3m in depth. The central part of the section displays festoon features with the involutions penetrating the rubbly chalk below (Plate 5.14), and the broken pebbles and stones showing alignment with the flow of the deposit during this solifluction stage of formation. Samples from the western (SE 974499) and eastern (SE 976497) end as well as from the involutions (SE 975498) were obtained for mineralogical and mechanical analysis.

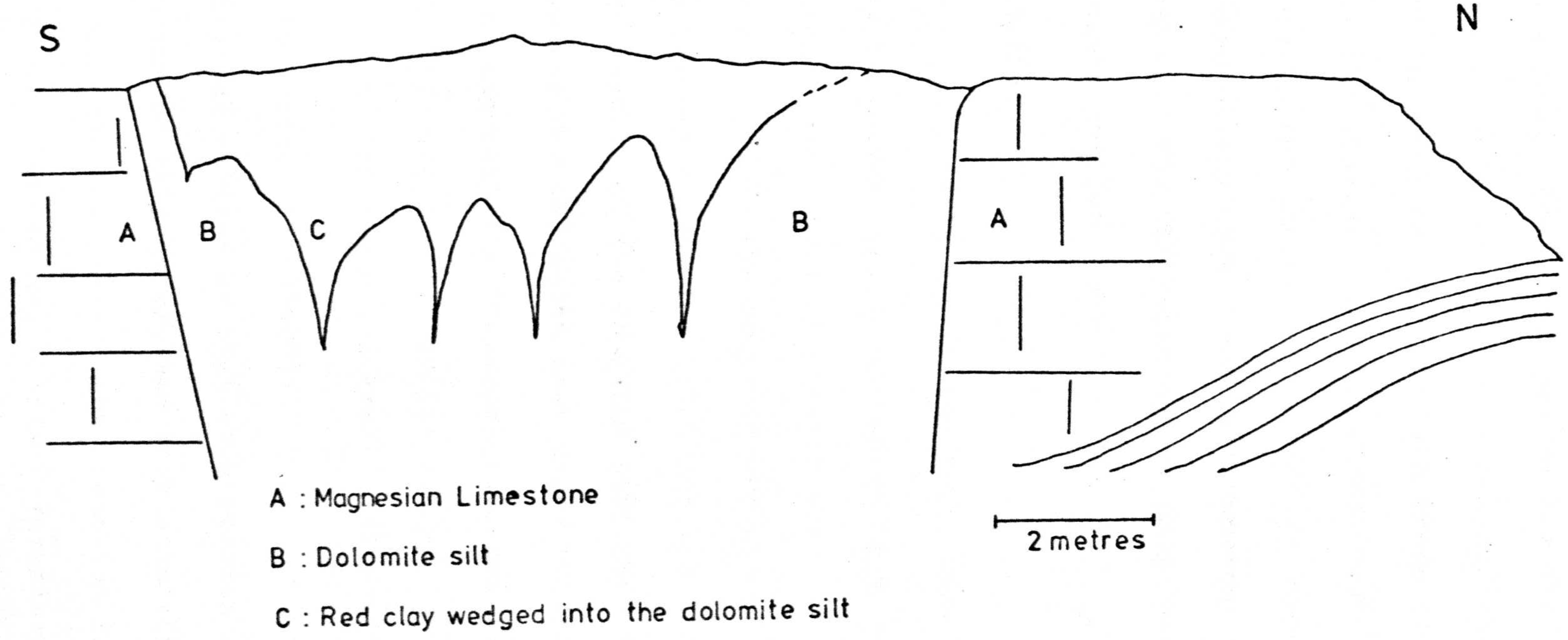
The direction of solifluction movement that resulted in the formation of the involutions has been interpreted from the present topography and the trend of the involutions. Movement of the soil has taken place in such a way as to form involutions along the line of movement and not across such a line. With movement having occurred in a downward direction a south-easterly flow of material is indicated at this

MAP 5.8



MAP SHOWING THE RELATIONSHIP OF THE SAMPLING FACE WITH EXPOSED INVOLUTIONS TO THE DIRECTION OF SOLIFLUCTUAL MOVEMENT AT HORNHILL TOP

FIG 5.5 SECTION OF THE WESTERN FACE OF WINDMILL QUARRY, STUTTON



SE 475420

site, Map 5.8.

Hessle (TA 013264):

The drift at Hessle has been well documented in the past (Reid 1885, Bisat 1939, Catt and Penny 1966). This particular disused Chalk Pit was selected for its drift deposits displaying involutions in order that the sample obtained may be compared with those of other sites in the region. The section studied followed an east-west line on the top of the northern face of the quarry. Dark, reddish brown drift solifluctеd into involutions were found with numerous erratics, including Red Sandstone. The involutions were only 1.0m in depth with a well developed humus horizon above them.

Broomfleet (SE 863275):

This is the site of a large brick pit on the north bank of the Humber. Dark blue and grey laminated clay is extracted to a depth of 4 metres for brickmaking, these are generally uniform over the whole of the area but any interruptions in the sequence are caused by the occasional lens of sand. The primary reason for obtaining samples from this site was to compare the results of the triaxial test with those of the brickearths of Pegwell Bay and south east Essex (Chapter 6). The laminated nature of the deposits indicates a lacustrine mode of origin, no aeolian inferences are possible and as such cannot be compared on this basis with those brickearths of south east England.

Windmill Quarry, Tadcaster (SE 475420):

This site was mentioned earlier as that of a Permian Silt deposit. The former excavation of this quarry has left a narrow channel 10 metres wide of Dolomite silt exposed between the Magnesium Limestone (Fig.5.5). This white, almost pure deposit was obtained for microscopical analysis in order to compare the quartz grains of a normal loess deposit with that of a possible aeolian carbonate sediment. The results of this comparison are given in Chapter 11 with a discussion of a Scanning Electron Micrographs.

This section completes the British field work apart from to record a visit to Warren House Gill, on the Durham coast where Trechmann reported Interglacial loess (Chapter 2). This stie has now been covered by coal waste and can no longer be observed.

New Zealand Deposit:

A deposit of New Zealand loess from near Palmerston North was supplied by Dr. M J Selby from the University of Waikato. The following section at the type locality of the Aokautere Ash is that supplied with the samples and the asteriscks indicate the position from which they were obtained, (Table 5.1).

Mechanical and mineralogical analysis are given in Chapters 6,7 and 9, these may be readily compared with the British loess deposits.

TABLE 5. 1.

Section at Type Locality of Aokautere Ash (N149/132313)

	LOESS	cm
	Dark brown friable silt loam	17.8
	Pale brownish-grey silt loam, many small reddish concretions	7.6
	Grey compact clay loam, many yellowish brown mottles	38.1
	Grey compact clay loam, many fine yellowish-brown mottles and many grey vertical veins	45.7
1.*	Grey fine sandy loam, few vertical grey veins	73.7
	AOKAUTERE ASH	
	White fine pumiceous sand, diffuse lower boundary	6.4
2.*	Pale grey medium pumiceous sand, sharp lower boundary	5.1
	White pumiceous silt, sharp and undulating lower boundary	1.1
	LOESS	
3.*	Grey fine sandy loam, many fine yellowish brown mottles	182.9
	FOSSIL SOIL	
	Grey plastic clay, many brownish mottles, many black concretions	121.9
	OLD ASH	
	Yellowish-brown slightly greasy silty clay loam	190.5
	OTAKI SANDSTONE	
	Banded sands at least	61.0

CHAPTER SIX

GEOTECHNICAL PROPERTIES OF LOESS

CHAPTER SIX

GEOTECHNICAL PROPERTIES OF LOESS

In the 1930s when the properties of loessial soils were not sufficiently understood in terms of a foundation material, a great deal of settlement of structures took place in several parts of the world as a result of subsidence. In the USSR this was particularly common in the region of irrigation canals and reservoirs. During the last forty years a great deal of information on the engineering behaviour of loessial soils has been collected as a result of extensive research, the main purpose of which has been to establish qualitative and quantitative estimates of subsidence.

The problems confronting the east European and Russian engineers are not as prevalent in Britain, mainly because the loess deposits form only a thin superficial cover and any serious difficulties they may present as a foundation material would result in their removal.

The initial part of this chapter concerns a brief description of the engineering properties of loess, mainly from studies undertaken outside Britain, the latter part consists of an analysis of the results obtained from mechancial testing of the soils from sites described in Chapter 5.

Denisov (1953), demonstrated that the subsidability of loessial soils was a result of their underconsolidation, high porosity, silty composition and the presence of thin carbonate and sulphate films cementing silt particles which are easily destroyed by water. Denisov found the degree of subsidability to be determined by its total porosity and not by the quantity of macropores with the walls of the macropores being strengthened and incrusted with salts giving the structure a certain rigidity and acting as a framework. As a result of abundant wetting the total porosity decreases as the framework is broken and the soil structure collapses.

A typical loess deposit, having a tendency to subside, was considered by Denisov to have formed under conditions of a cold and dry climate of the arid steppes and semi deserts during the glacial ages of the Pleistocene with the loess-like clayey soils, having a low degree of subsidability, being formed during the interglacial periods when the humidity was higher. Maksimov (1956) in reference to an earlier work by Denisov (1951), suggests that the strength and compressibility of loessial soils depends on the strength and destructibility of their structural bonds, with varieties of loessial soils demonstrating different properties in regard to losing strength on wetting. Bonds of individual varieties offer different degrees of resistance to water with some becoming weaker and some being totally destroyed. Obruchev (1954), considered subsidability to be characteristic of the upper part of unstratified aeolian loess whilst Lysenko (1955), distinguished two types of subsidability indicating that the degree of subsidability of loessial soils depends on their genesis; proper subsidence occurs only under the influence of wetting of the soil whilst additional subsidence occurs as a result of the wetting of the soil under the influence of the weight of wetted soil and the structure. Additional subsidence was considered to take place where the process of natural subsidence of loess soils is already completed. Kriger and Moskalev (1953), studied loess on the northern and western ranges of Tien Shan finding a zonal distribution of subsidable properties dependent on elevation with a decrease at higher elevations because of changes in precipitation.

Consolidation was considered by Clevenger (1956), to be probably the most outstanding structural property of loess, finding test specimens at low natural moisture to consolidate little whether the material was high or low density, but low density specimens that had been prewetted were found to consolidate excessively, in some cases by as much as 15 - 20%.

As a result of the influence of water on the compressibility of loess, Kane (1969) suggests that the natural water content and possible variations are particularly important. Loess deposits in Iowa were reported by Davidson and Sheeler (1952), to have natural water contents varying from 5% for soils with a 10% clay content to 30% for soils with a 30% clay content. The natural water content is also related to the average annual rainfall and is subject to seasonal variation as reported by Peck and Ireland (1958).

In an attempt to explain the behaviour of loess under consolidation, in relation to its water content, Kane (1969 op cit) suggests that the open structure is maintained by the clay coatings on the silt particles and that the behaviour of the soil prior to the breakdown of the structure depends on the percentage and strength of the clay binder. At a given clay content the strength of the clay binder depends on the water content with the water being distributed in the voids of the clay coatings on the silt particles and, when sufficient water is present, in the silt-sized voids between the coated silt particles.

How much actual clay mineral any one particular loess contains is difficult to ascertain but from Kane's observations a clay mineral content is essential to maintain the open structure of the loess. In the analysis of the British loess deposits the clay size fraction is very small for almost all the samples, and the clay

mineral percentages as indicated from the X-Ray diffraction and thermogravimetric results (see Chapters 7 and 9) are not high, being generally concentrated in the less than 2u zone. If the clay mineral percentages are as low as these results suggest the role played by the clay minerals in maintaining an open structure may be questioned in the case of the British deposits. In Britain few studies have been undertaken on loess deposits. Fookes and Best (1969), included loess sections in their study of metastable soils in the south east of England and concluded that the consolidation properties exhibited by the material was in accordance with those found in other parts of the world.
A number of criteria have been proposed for recognising soils that may exhibit subsidence when wetted at low overburden pressures and under low applied foundation loads, Denisov (1951 op cit), states that subsidence is probable when:-

$$\frac{e_L}{e_O} < 1$$

where e_L is the void ratio at the liquid limit and e_O is the natural void ratio. This has been used on a wide range of partially saturated soils including loess by Holtz and Hilf (1961). A further criteria is that proposed by Feda (1966), which states subsidence to be probable when the subsidence index $k_L > 0.85$ where k_L is defined as :-

$$k_L = \frac{\frac{Wo}{So} - Wp}{W_L - Wp}$$

where Wo is the natural water content, So is the natural degree of saturation, W_L is the liquid limit and Wp the plastic limit.

In comparison to the criteria proposed by Denisov, the subsidence index k_L can be rewritten as:-

$$k_L = \frac{e_O - e_p}{e_L - e_p}$$

where e_O = the natural void ratio

e_L = the voids ratio at the liquid limit

e_p = the voids ratio at the plastic limit

The shear strength of loessial soils does not appear to have attracted the same degree of interest as that of the consolidation properties. Schultze (1967), reported the results of tests carried out on undisturbed, unsaturated and artificially saturated samples of Rhineland silts. Further measurements on undisturbed samples gave shear paremeters of $\emptyset' = 32^{o}$ and $c' = 0.12$ Kg/ cm^2 in comparison to $\emptyset' = 35.5^{o}$ and $c' = 0$ for disturbed material.

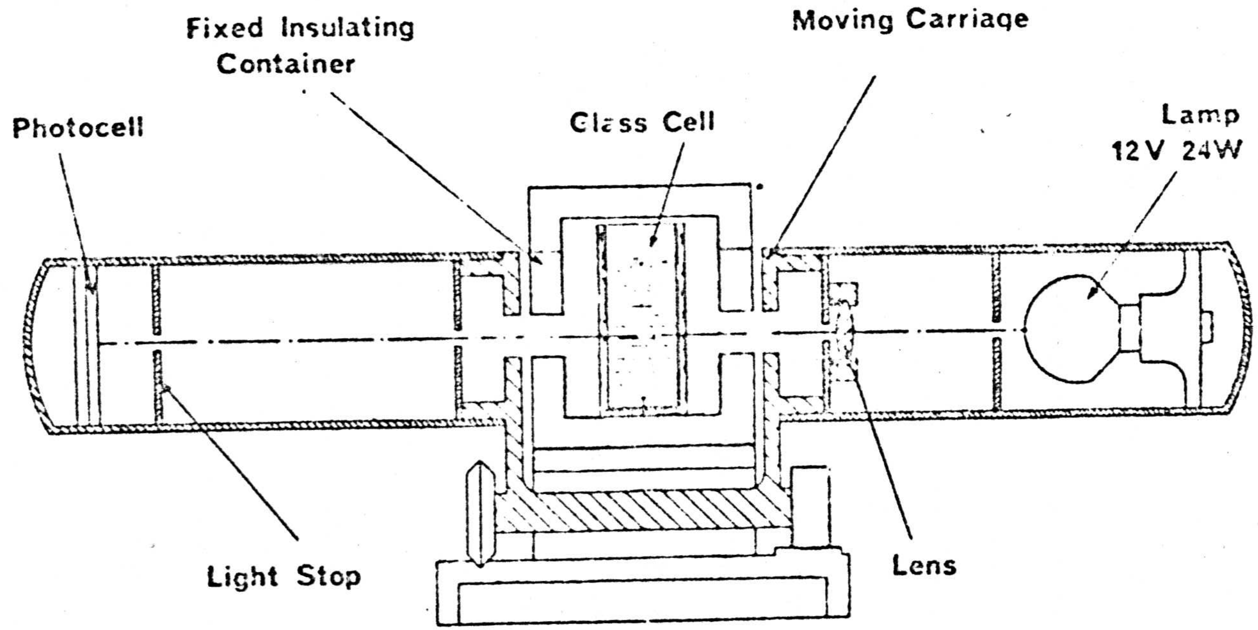
Mechancial Properties of British Loess Sediments:

1. Grain Size Analysis.

The determination of the particle size distribution was carried out as a two stage process. The samples were sieved through a set of B. S. sieves of sizes 30(500µ); 60(250µ); 120(125µ) & 200(75µ) for a coarse analysis. The fraction passing the 200 sieve (<75u) was separated from the remainder of the sample for the second stage of the process - the fine analysis.

Several methods were considered for undertaking the second stage including a sedimentation tube, hydrometer and sedimentation balance techniques. A method was required that would give reliable results rapidly and for this reason an EEL Photo-Extinction Sedimentometer was used, enabling several samples to be analysed

FIG 6.1 THE EEL PHOTOSEDIMENTOMETER



at the same time and only requiring a short time (2 hours) to undertake. It appears that any one given method is unlikely to give the same result as that of another method for the same sample. For this reason it is only possible to compare the results carried out by the same method by the same operator, by using one of the samples as a standard. The sample chosen in this study is one from Pegwell Bay and may be used with care as a comparison with the results from other investigators who report both results from this site and from other localities.

The EEL Photo-sedimentometer (Fig.6.1), combines gravitational settling with photoelectricmeasurement. The equipment consists of six glass cells 75mm deep which are filled with distilled water to a line 25mm from the top. Five of the cells had a small quantity of sample placed in them, this was well dispersed in an ultrasonic bath, the sixth cell being used without a sample as a means of a standard. A narrow horizontal beam of parallel light was projected through the suspension at a depth of 50mm from the top of the cell. As the particles fall from the surface through the light zone the emergent light flux through the cell gradually begins to increase registering on a linked Unigalvo Type 25, measuring the amount of light passing through the cell on a logarithmic scale. Readings were obtained at pre-determined time intervals, (0.5; 1; 2; 3; 5; 10; 15; 30; 60; 120 minutes) these are equivalent to grain size fractions - 68μ; 48μ; 34μ; 28μ; 21μ; 15μ; 12μ; 8μ; 6μ and 4μ respectively. The results were programmed on a Wang 2200 terminal (see Appendix for the programme) from which grain size percentages of the 0.5μ; 1.0μ; 2.0μ; 3.0μ; 4.0μ fractions and at intervals of 4μ to the 54μ fraction were obtained. These results have been plotted for each sample on a semi-logarithmic scale as particle size distribution curves,

FIG 6·2

PEGWELL BAY WESTERN FACE PARTICLE SIZE DISTRIBUTION

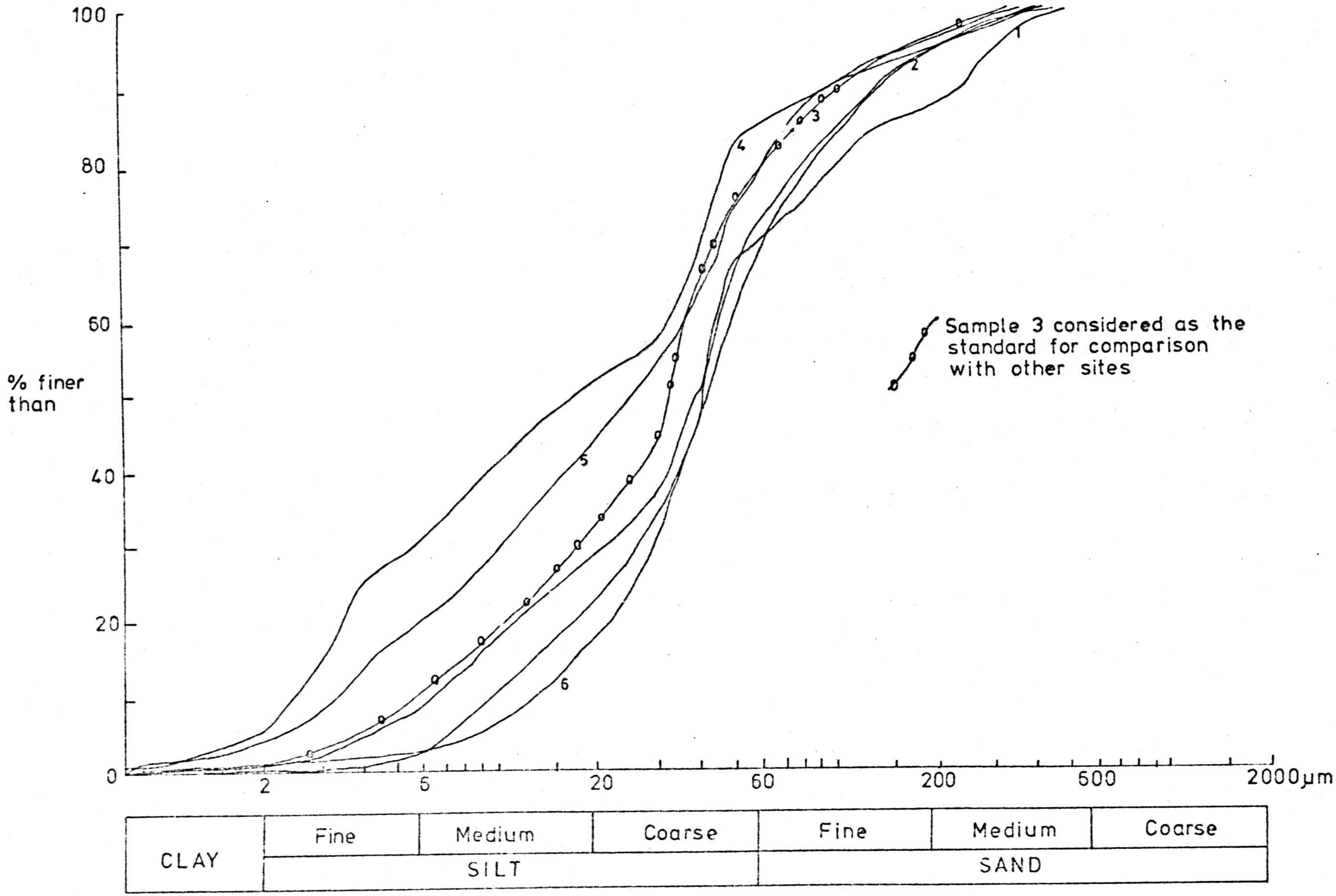


FIG 6·3

PARTICLE SIZE DISTRIBUTION

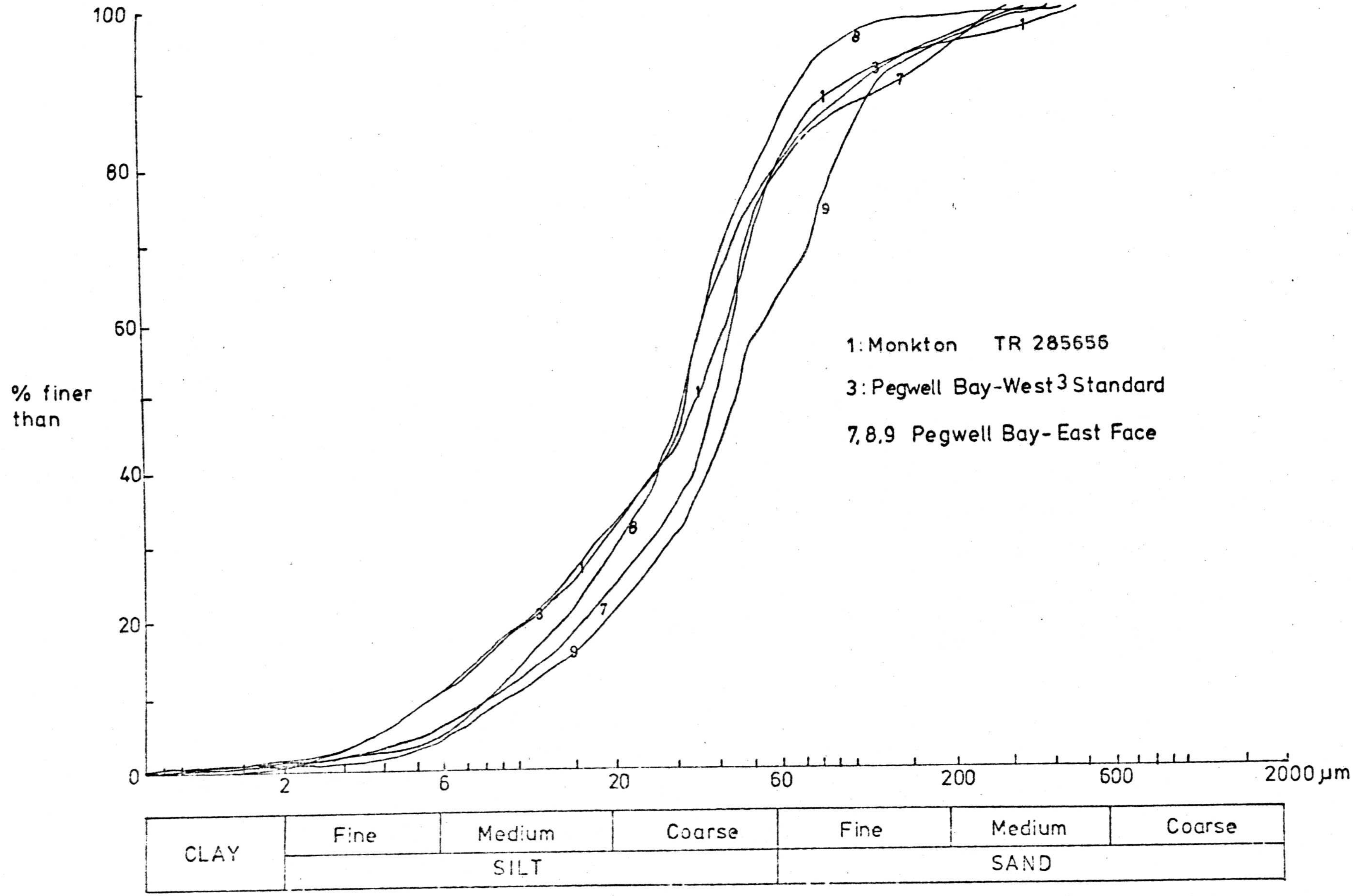


FIG 6·4
PARTICLE SIZE DISTRIBUTION

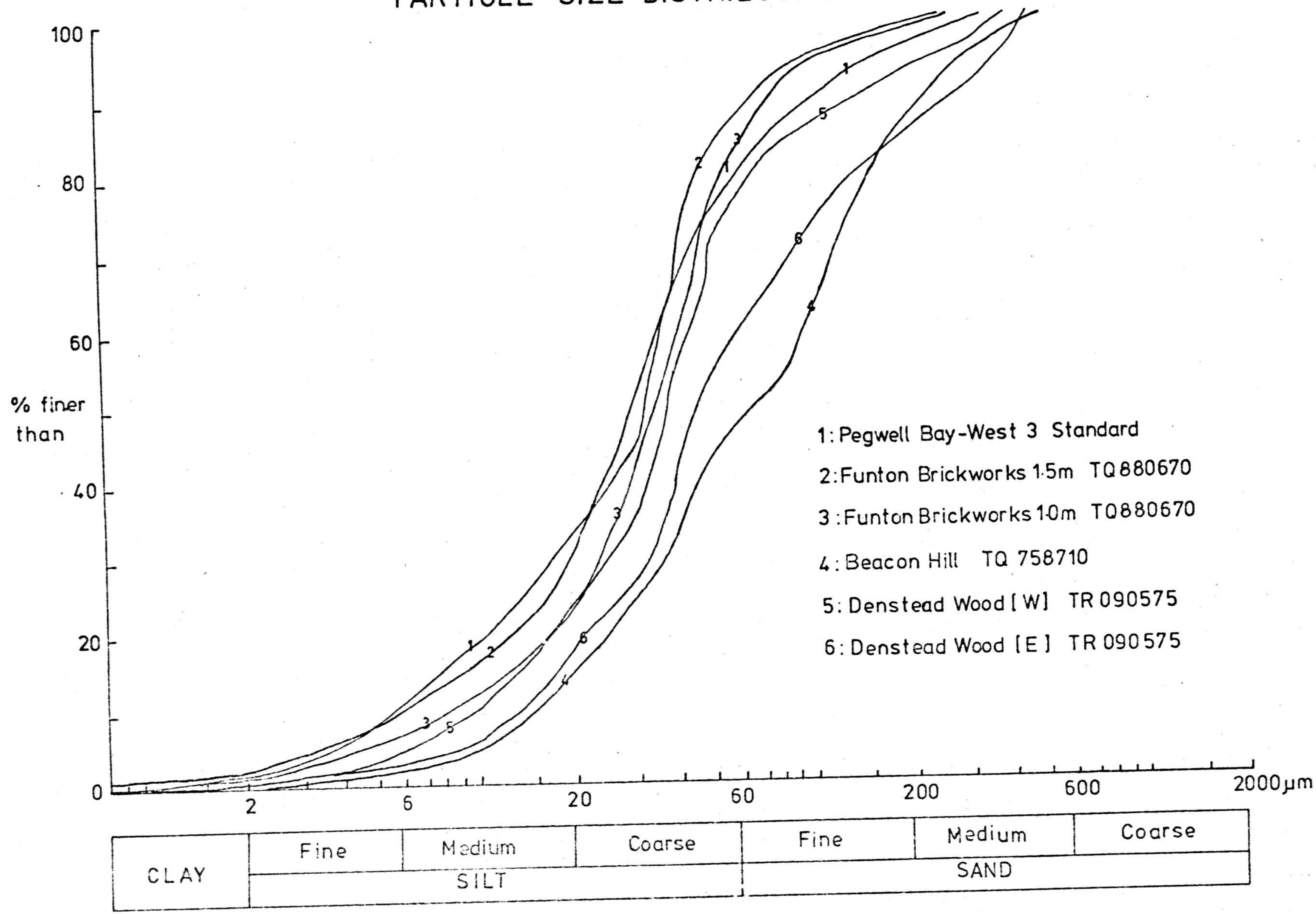


FIG 6·5
PARTICLE SIZE DISTRIBUTION

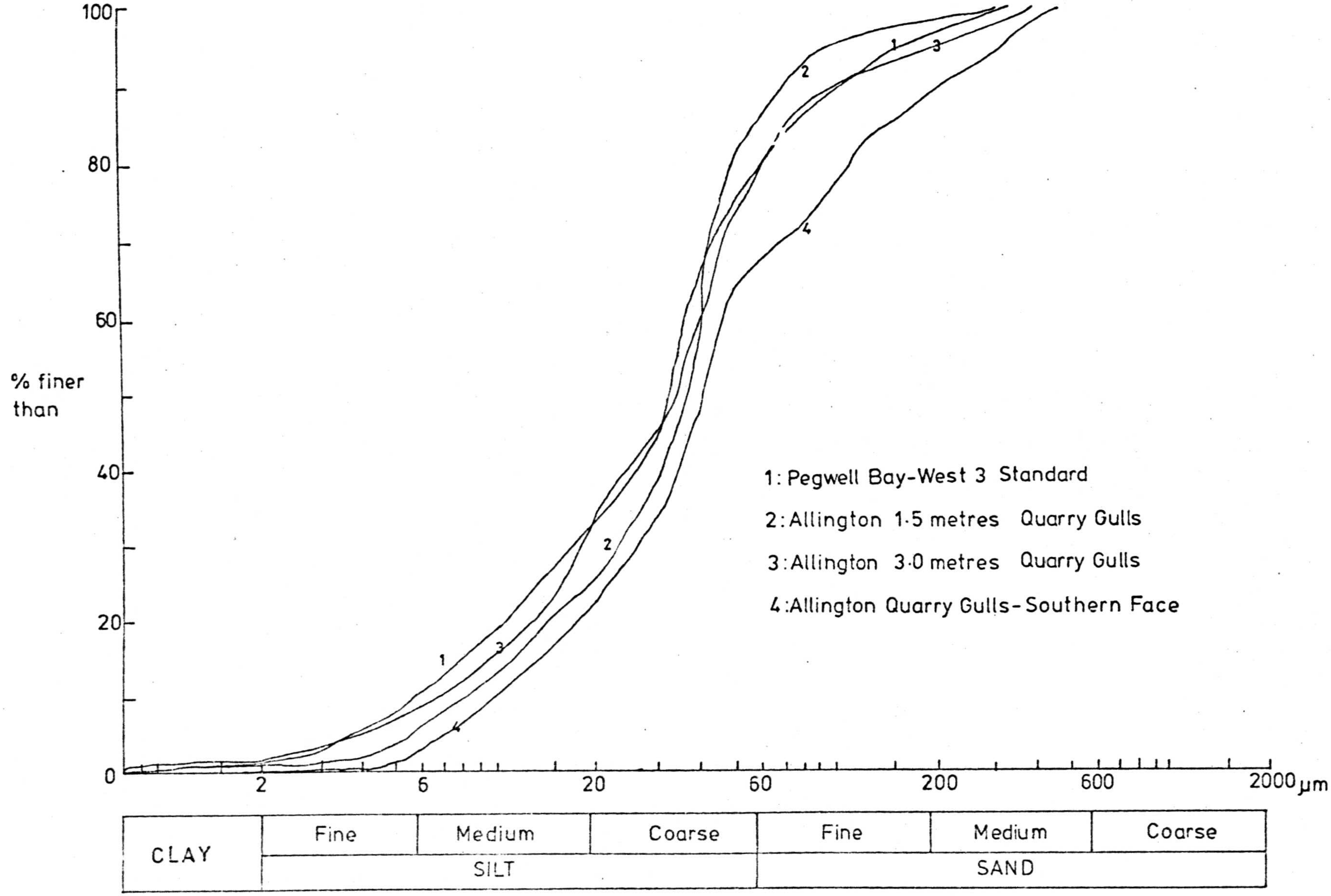


FIG 6·6
PARTICLE SIZE DISTRIBUTION

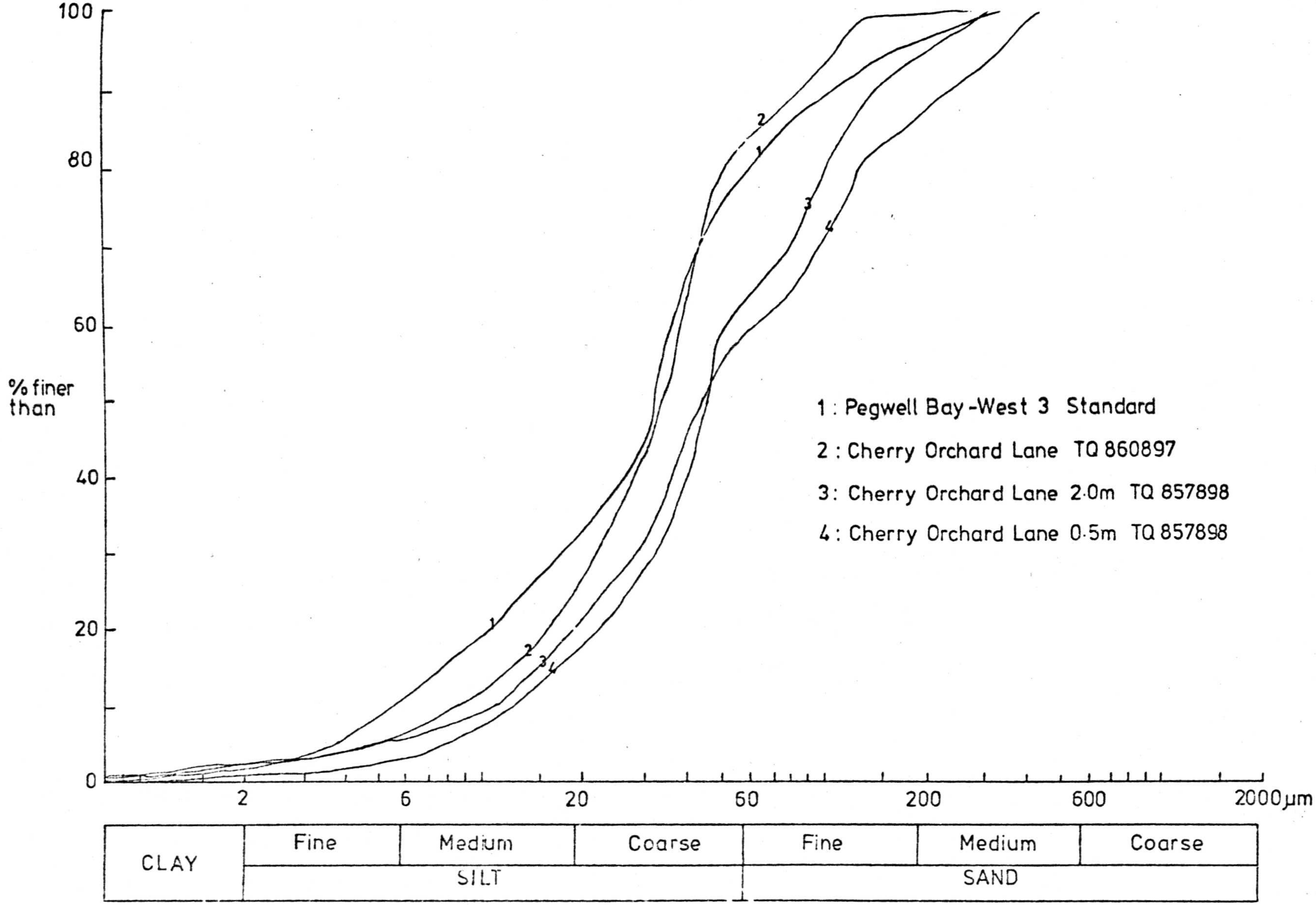


FIG 6·7
PARTICLE SIZE DISTRIBUTION

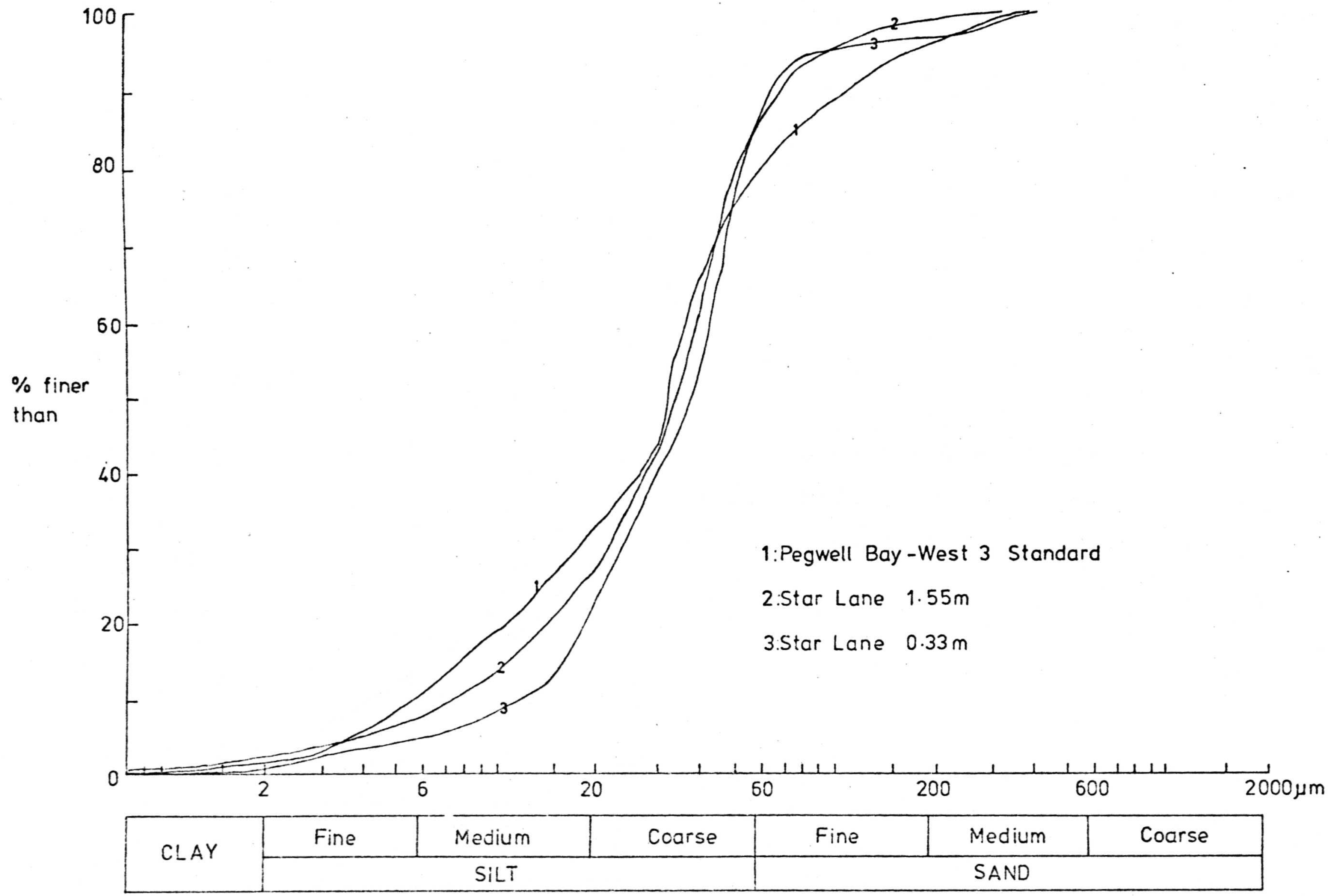


FIG 6·8 PARTICLE SIZE DISTRIBUTION

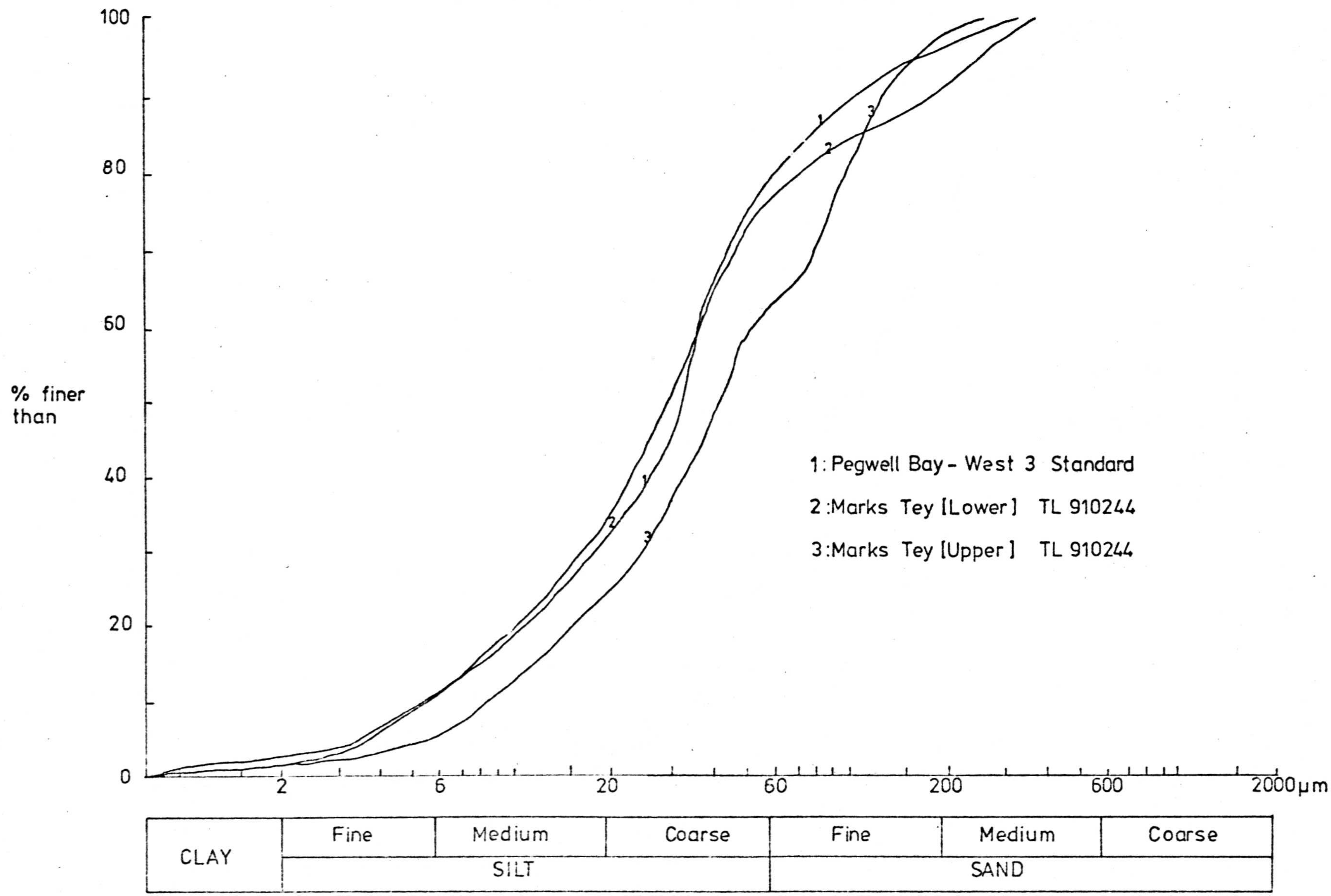


FIG 6·9

PARTICLE SIZE DISTRIBUTION

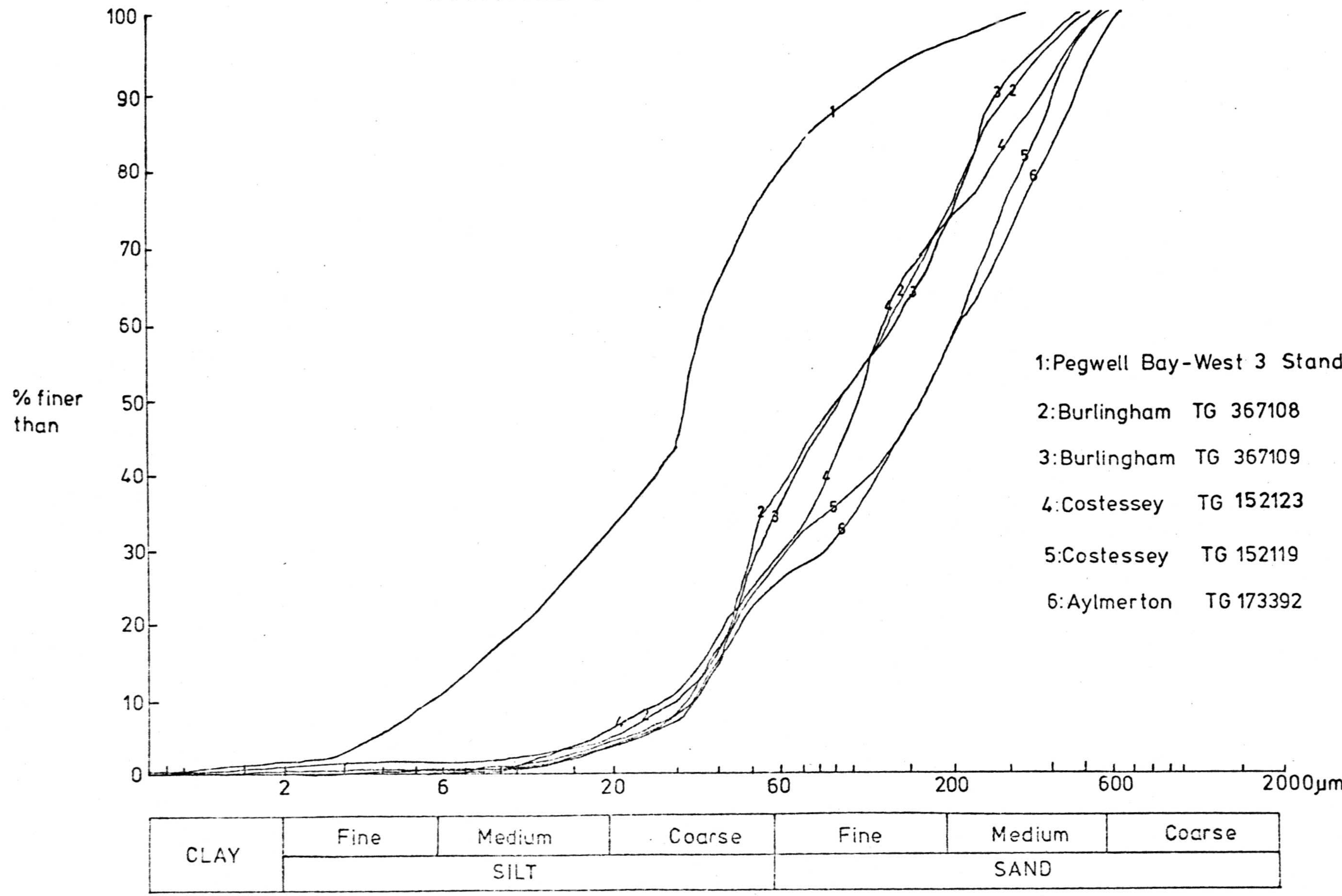


FIG 6·10
PARTICLE SIZE DISTRIBUTION

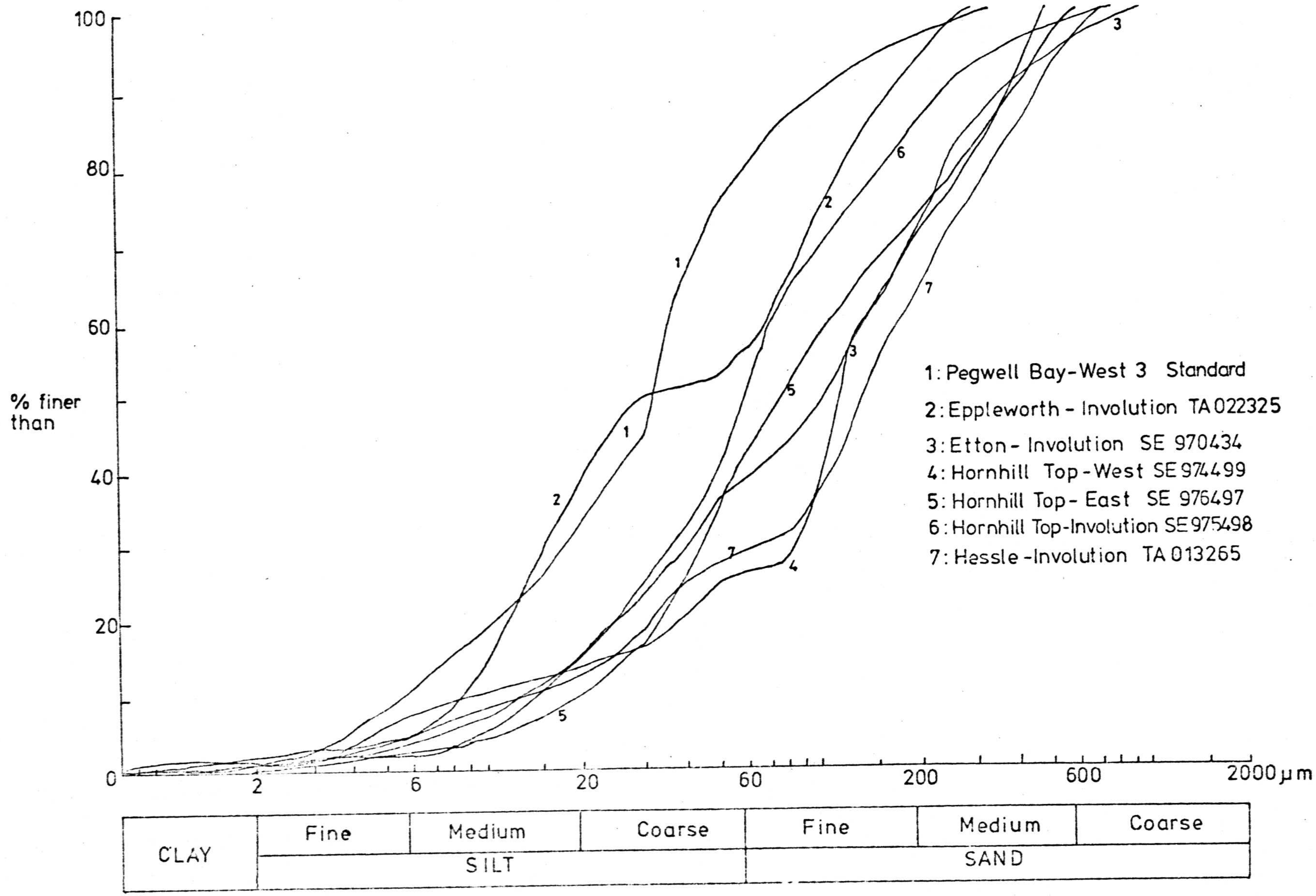


FIG 6·11
PARTICLE SIZE DISTRIBUTION

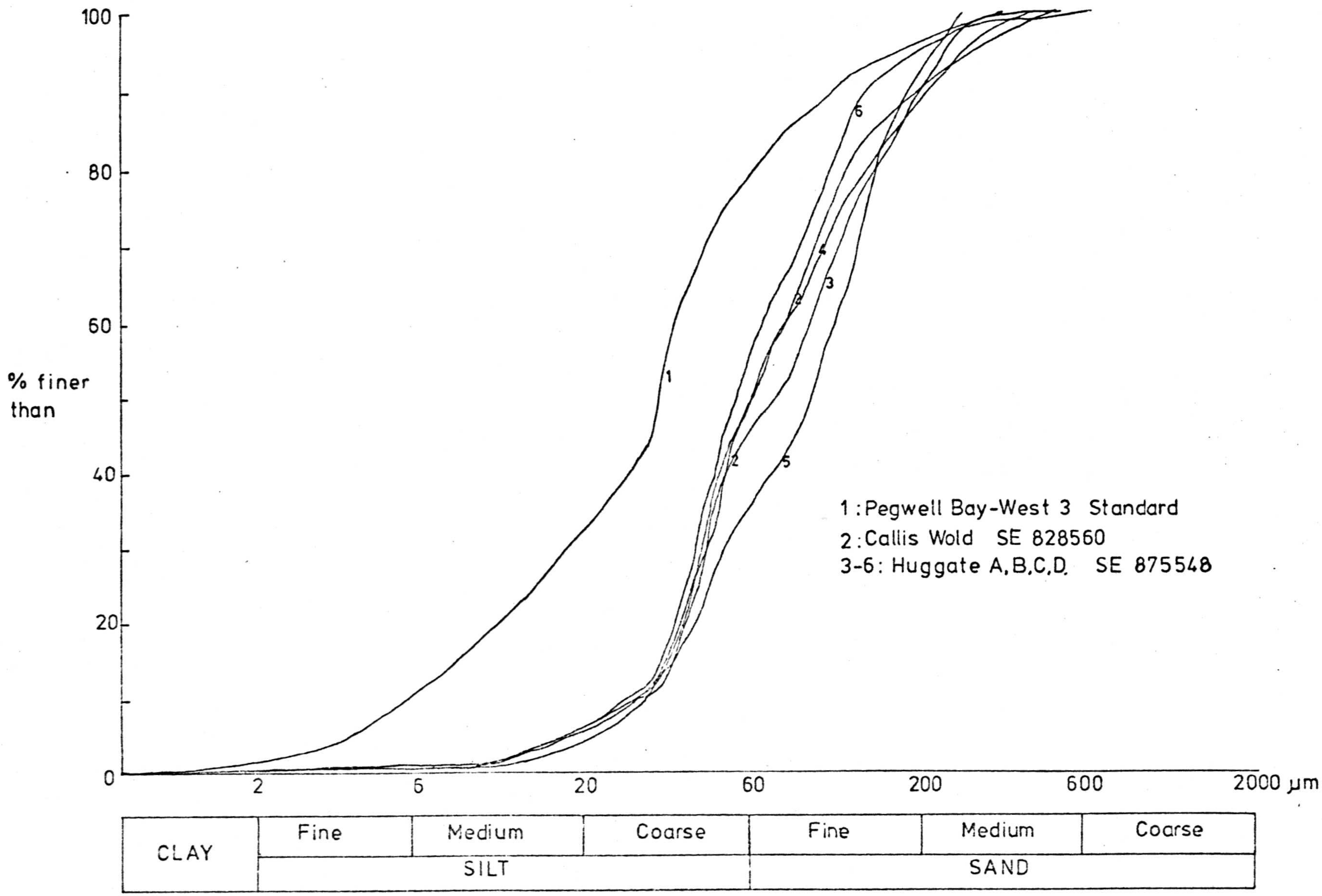


FIG 6·12 PARTICLE SIZE DISTRIBUTION

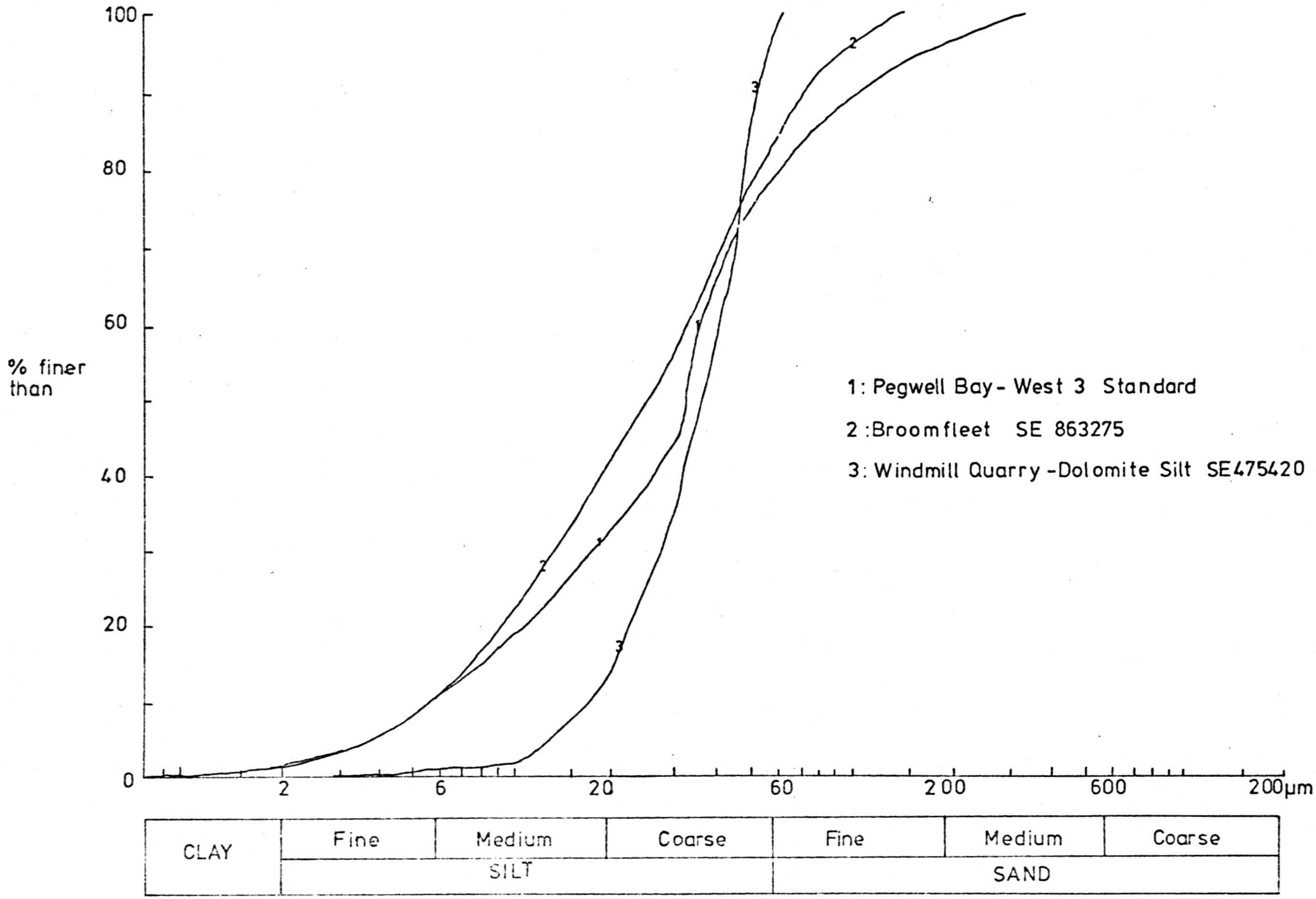


FIG 6·13

PARTICLE SIZE DISTRIBUTION

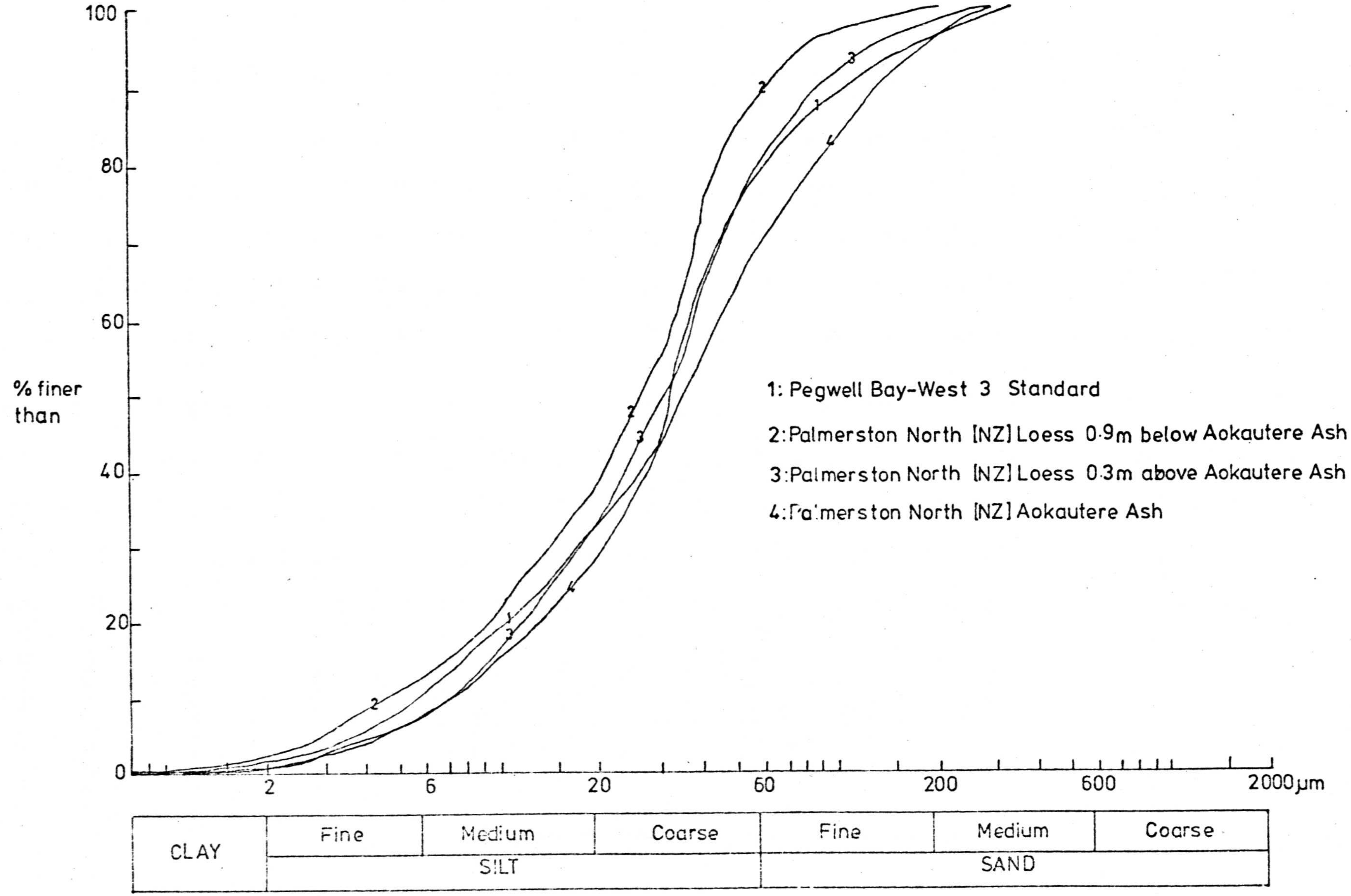


TABLE 6.0 Particle size distribution of samples recorded on Figs: 6.2 to 6.13

∅ Divisions	um Equivalent		Pegwell Bay No.1. %	Pegwell Bay No.2. %	Pegwell Bay No.3. %	Pegwell Bay No.4. %	Pegwell Bay No.5. %	Pegwell Bay No.6. %	Pegwell Bay No.7. %	Pegwell Bay No.8. %	Pegwell Bay No.9. %	Monkton %	Denstead West %	Denstead East %	Allington 1.5m %	Allington 3.0m %	Allington Quarry Gulls %	Funton 1.0m %	Funton 1.5m %
0 - 1	1000 - 2000		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1 - 0	500 - 1000		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2 - 1	250 - 500	SAND	9.3	3.2	1.3	1.1	2.5	4.7	0.7	0.2	1.9	3.5	5.9	11.1	0.8	0.2	7.8	0.8	0.2
3 - 2	125 - 250		5.7	9.0	6.7	6.6	5.5	7.0	10.4	1.8	7.5	4.2	5.0	11.2	2.6	4.6	15.3	3.1	3.6
4 - 3	63 - 125		12.1	11.9	9.3	6.7	9.1	15.9	8.6	6.1	21.1	8.9	9.6	14.3	6.2	10.3	7.8	8.3	7.6
5 - 4	31 - 63		34.2	40.4	37.5	38.6	29.3	41.6	43.6	46.4	39.6	40.2	41.2	36.0	48.6	37.9	33.1	46.7	39.4
6 - 5	16 - 31		13.6	19.1	15.8	9.6	14.5	17.4	17.2	22.7	16.0	15.1	18.2	14.4	22.1	18.7	18.2	20.5	23.9
7 - 6	8 - 16	SILT	11.1	9.9	14.1	17.9	13.5	7.9	10.3	13.0	7.3	12.5	11.9	8.1	10.2	14.8	8.9	10.8	8.6
8 - 7	4 - 8		9.6	5.7	9.7	13.4	9.8	3.8	6.8	7.2	5.5	9.9	4.9	3.0	6.5	7.6	5.7	5.7	12.4
9 - 8	2 - 4		3.0	0.6	3.9	4.6	11.4	1.2	2.3	1.7	2.0	3.9	1.7	1.4	2.1	2.9	2.3	3.0	3.1
⊳ 9	⊲ 2	CLAY	1.4	0.2	1.7	2.1	4.4	0.5	0.2	0.8	0.3	1.7	0.7	0.2	0.8	1.1	0.8	1.2	1.2

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TABLE 6.0 Continued

ϕ Divisions	um Equivalent		Beacon Hill	Cherry Orchard Lane 2.0m	Cherry Orchard Lane 0.5m	Cherry Orchard Lane D.T.	Star Lane 0.33m	Star Lane 1.55m	Marks Tey Upper	Marks Tey Lower	Aylmerton	Burlingham 1	Burlingham 2	Costessey 1	Costessey 2	Callis Wold	Eppleworth
			%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
0 - 1	1000 - 2000		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1 - 0	500 - 1000		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	3.8	3.5	0.0	0.0
2 - 1	250 - 500	SAND	6.6	1.5	9.4	0.3	1.8	0.9	0.1	5.0	36.5	13.4	12.4	27.4	17.2	6.1	1.6
3 - 2	125 - 250		19.4	10.4	9.6	0.5	1.3	1.0	9.7	8.1	21.8	27.6	30.0	28.3	19.7	11.2	17.7
4 - 3	63 - 125		26.3	23.6	16.6	12.5	8.3.	9.3	22.8	6.8	14.3	16.7	15.2	9.6	26.5	27.3	20.1
5 - 4	31 - 63		23.6	32.1	34.9	41.5	48.3	45.3	29.3	29.2	16.4	34.0	33.9	22.6	23.1	45.2	10.5
6 - 5	16 - 31		14.6	16.1	16.1	23.6	20.7	21.7	17.4	21.7	6.4	6.1	6.7	6.9	7.7	8.0	20.6
7 - 6	8 - 16	SILT	5.4	9.7	8.4	11.6	10.1	11.7	10.2	13.8	2.3	1.4	1.5	1.1	1.8	1.8	18.6
8 - 7	4 - 8		2.7	4.0	3.8	5.9	6.8	6.1	6.3	8.2	1.9	0.3	0.2	0.2	0.4	0.3	9.5
9 - 8	2 - 4		1.0	1.9	0.8	2.9	1.9	2.8	3.1	5.2	0.3	0.0	0.0	0.0	0.0	0.0	1.0
$\triangleright$ 9	$\triangleleft$ 2	CLAY	0.4	0.7	0.3	1.1	0.8	1.0	1.2	2.0	0.1	0.0	0.0	0.0	0.0	0.0	0.4

TABLE 6.0 Continued

ϕ Divisions	um Equivalent		Etton %	Hessle %	Hornhill Top (E) %	Hornhill Top (W) %	Hornhill Top (INV) %	Huggate A %	Huggate B %	Huggate C %	Huggate D %	Windmill Quarry %	Broomfleet %	New Zealand No.1 Loess %	New Zealand No.2 Ash %	New Zealand No.3 Loess %
0 – 1	1000 – 2000		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1 – 0	500 – 1000		7.5	7.8	4.6	0.0	2.9	0.1	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
2 – 1	250 – 500	SAND	23.0	20.7	17.3	23.4	6.2	0.7	5.1	0.0	1.0	0.0	0.0	0.3	0.1	0.0
3 – 2	125 – 250		23.9	27.4	14.9	20.7	16.0	23.0	16.2	29.5	8.9	0.0	0.8	5.8	8.8	2.7
4 – 3	63 – 125		10.4	13.8	19.3	26.8	27.1	27.1	23.9	30.9	28.7	0.0	11.6	8.7	16.5	4.4
5 – 4	31 – 63		11.6	11.2	26.8	9.6	21.9	37.3	44.3	28.1	48.4	65.8	31.2	35.4	29.3	37.3
6 – 5	16 – 31		11.3	7.5	9.6	4.5	14.1	8.4	7.6	7.2	10.2	25.1	19.1	19.7	21.2	22.2
7 – 6	8 – 16	SILT	6.5	5.3	4.2	5.1	7.3	2.6	1.5	3.3	2.4	7.5	20.5	17.1	12.5	15.2
8 – 7	4 – 8		3.9	3.4	2.3	5.4	3.7	0.6	0.5	0.9	0.3	1.4	10.6	7.6	7.2	10.0
9 – 8	2 – 4		1.9	2.1	0.7	2.3	0.6	0.1	0.1	0.1	0.1	0.1	4.4	3.9	3.2	5.9
⊳9	⊲2	CLAY	0.9	0.8	0.3	1.1	0.2	0.0	0.0	0.0	0.0	0.0	1.8	1.5	1.2	2.2

(Figs:6.2 - 6.13). In Chapter 5 the Pegwell Bay site was given prominance because of its good exposure and its general appearance as a loessial material. Because of the importance of this site in terms of British loess one of the samples (No.3) has been chosen as a standard for the purposes of comparing the particle size distribution of soils from other sites.

Fig.6.2 shows the distribution of grain size from six samples obtained from the western section of Pegwell Bay. Sample 3 appears to give an average distribution (see Table 6.1 for analysis), with sample 4 on the fine grained extremity and sample 6 appearing to be the coarsest grained. Sample 3 has been reproduced on all the distribution curves for readily observable comparisons to be made.

The samples from the eastern side of Pegwell Bay and the one from Monkton are shown in Fig.6.3 appearing generally coarser than the standard.

The samples from Funton, Denstead Wood and Beacon Hill (Fig.6.4), are also coarser grained than the standard with the latter having 50% of its fraction greater than 68μ.

Samples analysed from Allington (Fig.6.5) show a similar gradient of curve but are slightly coarser than the standard as are those of the Cherry Orchard Lane deposits, (Fig.6.6).

The curves for Star Lane (Fig.6.7) are much steeper than the Pegwell Bay curve with a slightly smaller percentage of particles less than 50μ.

The curves for Marks Tey Lower follows a similar line to the standard in its finer fraction (Fig.6.8), but that of Marks Tey Upper indicates a higher percentage of fine sand.

The Norfolk and Yorkshire Wolds samples (Figs:6.9 - 6.11), are not as silty as the Pegwell Bay sample most of which have less than

30% silt. These are the deposits that have been described as having a loess fraction in the silt content (see Chapter 2), if these are to be considered as loess deposits they must be referred to as Sandy loess (see Fig.1.2).

In Chapter 5 the brickclay pit at Broomfleet on the north bank of the Humber was described. Although this deposit is not considered as a loess, samples were obtained in order to compare the geotechnical parameters with the brickearths in the south east of England. The material from this site is shown to be finer than that from Pegwell Bay (Fig.6.12), and also finer than from the other sites of Kent and south east Essex.

The dolomite silt described in Chapter 6 from the Windmill Quarry near Tadcaster has a very steep particle distribution curve with 83% of the particles in the 20 - 60μ range, the coarser part of the silt fraction, (Fig. 6.12)

The loess deposits of Pegwell Bay show a similar size distribution to those of Palmerston North in New Zealand with the interbedded ash being slightly coarser, (Fig.6.13).

From this series of curves it is possible to establish two distinct groups, the generally silty deposits of the south east part of England and those of Norfolk and Yorkshire that are much coarser.

Lysenko (1973), believed that a distinction between the loess-like and loess deposits could be made on the basis of particle size, citing several criteria in order that the two types of deposit may be differentiated. Loesses are considered to have steep cumulative frequency curves whilst those of loess-like materials are relatively flat. From Figs: 6.2 - 6.13 it would appear that most of the samples would be included as loess. Further criteria include an inhomogeneity ratio, K_{in}, and a sorting index, S_0;

where:-

$$K_{in} = d_{60} / d_{10}$$

and

$$S_0 = \sqrt{d_{75} / d_{25}}$$

d is the diamter of the particles and the subscripts 60, 10, 75, 25, indicate percentages (by weight) of particles with diameters smaller than the given diameter.

The values of K_{in} are in the range of 2 - 11 for loess, usually between 3 and 7 whilst those for loess-like materials are greater than 11. In the case of the sorting index loesses have a value equal to or less than 2.5 whilst this is greater than 2.5 for loess-like deposits.

The ratio of coarse to fine dust particles, $d_{50\mu - 10\mu}/d_{10\mu - 2\mu}$, is recommended by Lysenko as an index of the relative content of the 50µ - 10µ fraction, sometimes called the loess fraction. In loesses this ratio exceeds 1.3 - 1.5 but in loess-like material this is less than 1.3 - 1.5.

The median diameter, M_d, is considered to be equal to or greater than 25µ in loesses and less than 25µ in loess-like deposits.

From these criteria it is clear that Lysenko only considers loess-like deposits in terms of loams and clays and not in terms of coarser loess-like sediments.

The value for these parameters derived from an analysis of the British deposits are given in Table 6.1 with Cd/Fd indicating the ratio of coarse to fine dust particles.

Column 2 in Table 6.1 gives the median diameter of the particles with only the Pegwell Bay No. 4 sample giving a value of less than 25µ. The coarser deposits give high values with Aylmerton and Costessey No. 2 being 160. The average values for the six Pegwell Bay samples taken on the west side is 32.5, the standard sample

TABLE 6.1

PARTICLE-SIZE DISTRIBUTION COEFFICIENTS

SAMPLE	Md	K_{in}	S_0	Cd/Fd
Pegwell Bay No.1	40	7.5	2.17	2.93
Pegwell Bay No.2	42	4.6	1.64	5.66
Pegwell Bay No.3	32	6.78	1.96	3.09
Pegwell Bay No.4	16	12.66	2.32	2.27
Pegwell Bay No.5	24	10.86	2.5	1.57
Pegwell Bay No.6	41	4.36	1.56	6.97
Pegwell Bay No.7	40	5.12	1.61	4.77
Pegwell Bay No.8	32	3.28	1.63	5.17
Pegwell Bay No.9	45	5.2	1.75	5.17
Monkton	35	7.71	1.94	2.78
Denstead (W)	38	4.4	1.58	6.71
Denstead (E)	46	3.86	1.98	7.53
Allington 1.5m	36	4.72	1.54	6.03
Allington 3.0m	34	5.48	1.83	3.98
Allington Quarry Gulls	41	5.00	2.08	4.91
Funton 1.0m	35	4.89	1.58	5.29
Funton 1.5m	29	4.93	1.69	4.48
Beacon Hill	68	5.28	1.88	7.18
Ch.Orch.Ln 2.0m	44	3.85	1.86	7.33
Ch.Orch.Ln 0.5m	45	4.77	2.07	5.76
Ch.Orch.Ln. DT	34	4.69	1.60	5.45
Star Lane 0.33m	38	4.88	1.56	5.27
Star Lane 1.55m	34	4.94	1.63	5.51
Marks Tey Upper	40	6.0	2.12	3.88
Marks Tey Lower	30	6.38	1.98	3.14

TABLE 6.1 Cont.

SAMPLE	Md	K_{in}	S_0	Cd/Fd
Aylmerton	160	7.37	2.6	6.53
Burlingham 1	90	4.12	2.06	29.3
Burlingham 2	90	4.26	2.04	27.6
Costessey 1	110	4.15	1.98	23.9
Costessey 2	160	7.0	2.36	24.3
Callis Wold	60	2.5	1.58	39.5
Eppleworth	32	7.5	2.74	2.15
Etton	105	10.0	2.68	2.89
Hessle	140	12.86	2.46	2.93
Hornhill Top (E)	78	7.05	1.92	7.58
Hornhill Top (W)	120	14.0	2.28	2.66
Hornhill Top (INV)	58	5.07	2.04	7.81
Huggate A	70	3.05	1.74	39.4
Huggate B	60	2.5	1.39	32.0
Huggate C	92	3.62	1.68	28.5
Huggate D	55	2.15	1.48	47.2
Windmill Quarry	37	2.5	1.37	26.75
North Hall Quarry	24	5.89	1.78	27.77
New Zealand No.1 Loess	31	5.43	1.90	3.65
New Zealand No.2 Ash	35	6.13	1.85	3.37
New Zealand No.3 Loess	28	6.57	2.02	2.99

No. 3 gave a value of 32.

The inhomogeneity ratio gave most of the values between 2 and 11, the exceptions being Pegwell Bay No. 4 at 12.66, Hessle at 12.86, and Hornhill Top West at 14. Of the 46 samples analysed 31 gave values between 3 and 7. The average for the Pegwell Bay samples from the west side was 7.8 with the standard giving 6.78. The sorting index in column 4 shows that only three samples exceed the 2.5 value suggested as the difference between the two types of deposits, these being from Aylmerton, Eppleworth and Etton.

The standard sample gives a value of 1.96 in comparison to the average of 2.02 for all the samples from this section. The Cd/Fd ratio of column 5 shows the standard with a value of 3.09 with an average of 3.75 being that for the section.

None of the samples are less than the 1.3 - 1.5 ratio that Lysenko gives as a boundary between the loess and loess-like deposits, however some of the values are high, between 25 and 50. If an upper limit of 10 were established for the Cd/Fd ratio many of the coarser deposits would be excluded.

Atterberg Limits:

The Atterberg limits were measured using the standard Casagrande apparatus for the liquid limit determinations. The plastic limits were determined using the standard procedure for rolling the sample (BS1377).Kane (1969 op cit) found the loesses he studied in Iowa to have liquid limit values of between 27% and 35% and plasticity indices of between 4 and 11. Kasymov and Dzhurayev (1973), give liquid limit values between 26% and 39% averaging 29% and plastic limits constantly giving values of 21% for the loess deposits in the region of the Chartak reservoir in the USSR. Values for the plasticity index vary from 6 to 16.

In comparison.the values from Pegwell Bay gave liquid limit values of between 28.5% and 34.6% and plasticity indices between 7 and 8. Results obtained from other deposits are generally lower although the upper deposit at Star Lane and several of those from the Yorkshire Wolds gave higher values. Table 6.2 summarises these values and Fig.6.14 is a Casagrande plasticity chart showing their position, the majority fall in the ML range of classification, this describes silt deposits with low plasticity. Low plasticity is considered as soils with liquid limit values of less than 35%.

The Iowa values are placed on the chart as a means of comparison.

Shear Strength Measurements:

At a few sites the material was sufficiently homogenous to allow 38mm diameter tube auger samples to be obtained without small stones being present. Small pebbles have the dual disadvantage of tending to buckle the blade of the auger and giving the soil a weak plane along which to shear. The samples collected were waxed immediately to prevent drying and to ease the extrusion process in the laboratory.

The problem of being unable to collect several samples at the same point at each site meant that testing had to be undertaken using one tube sample. Using a triaxial compression test apparatus, samples generally 91mm in length, (76.2mm samples were used when sufficient length was not available for 91mm samples), were fitted between rigid caps and covered with a latex sheath, then placed inside a perspex cell. The cell was filled with water to which pressure was applied to give a uniform compressive stress, σ_3 . An additional stress (σ_1 - σ_3) was then applied in a vertical direction, by loading the sample

FIG 6·14 PLASTICITY CHART OF SAMPLES RECORDED ON TABLE 6·2 AND OF IOWA LOESS DEPOSITS

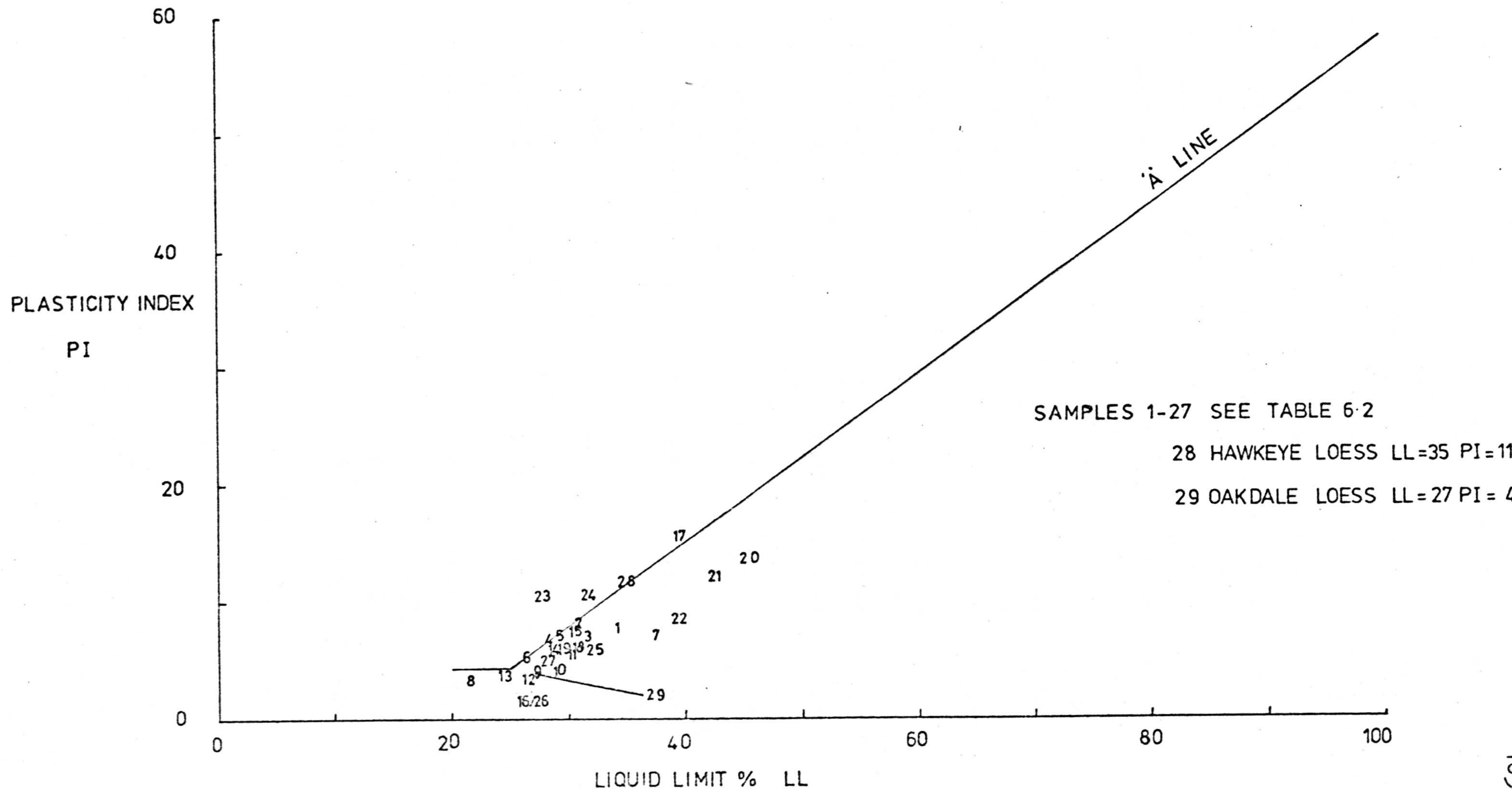


TABLE 6.2.

ATTERBERG LIMITS

Sample No. Fig.6.14	Sample	LL	PL	PI
1.	Pegwell Bay No.1	34.6	26.8	7.8
2.	Pegwell Bay No.2	31.0	23.0	8.0
3.	Pegwell Bay No.3	32.0	25.0	7.0
4.	Pegwell Bay No.4	28.5	21.5	7.0
5.	Pegwell Bay No.5	29.5	22.5	7.0
6.	Monkton	26.6	21.4	5.2
7.	Denstead (W)	37.5	30.0	7.5
8.	Debstead (E)	22.0	19.0	3.0
9.	Allington 3m	27.5	23.0	4.5
10.	Allington 1.5m	29.0	24.5	4.5
11.	Funton 1m	30.5	24.7	5.8
12.	Funton 1.5m	26.5	22.5	4.0
13.	Beacon Hill	24.7	21.0	3.7
14.	Ch.Orch.Ln 2m	28.85	22.25	6.6
15.	Ch.Orch.Ln 0.5m	30.25	22.5	7.75
16.	Ch.Orch.Ln DT	25.75	23.9	1.85
17.	Star Lane 0.33m	39.5	24.25	15.25
18.	Star Lane 1.55m	30.5	24.5	6.0
19.	Marks Tey U.	30.0	24.3	5.7
20.	Callis Wold	45.5	31.75	13.75
21.	Huggate C	43.0	31.0	12.0
22.	Huggate D	39.35	30.6	8.75
23.	Eppleworth	27.8	17.4	10.4
24.	Hornhill Top (NW)	32.1	20.85	11.25
25.	Hornhill Top (INV)	31.5	23.95	7.55
26.	New Zealand No.1 Loess	26.0	23.8	2.2
27.	New Zealand No.3 Loess	28.2	22.7	5.5

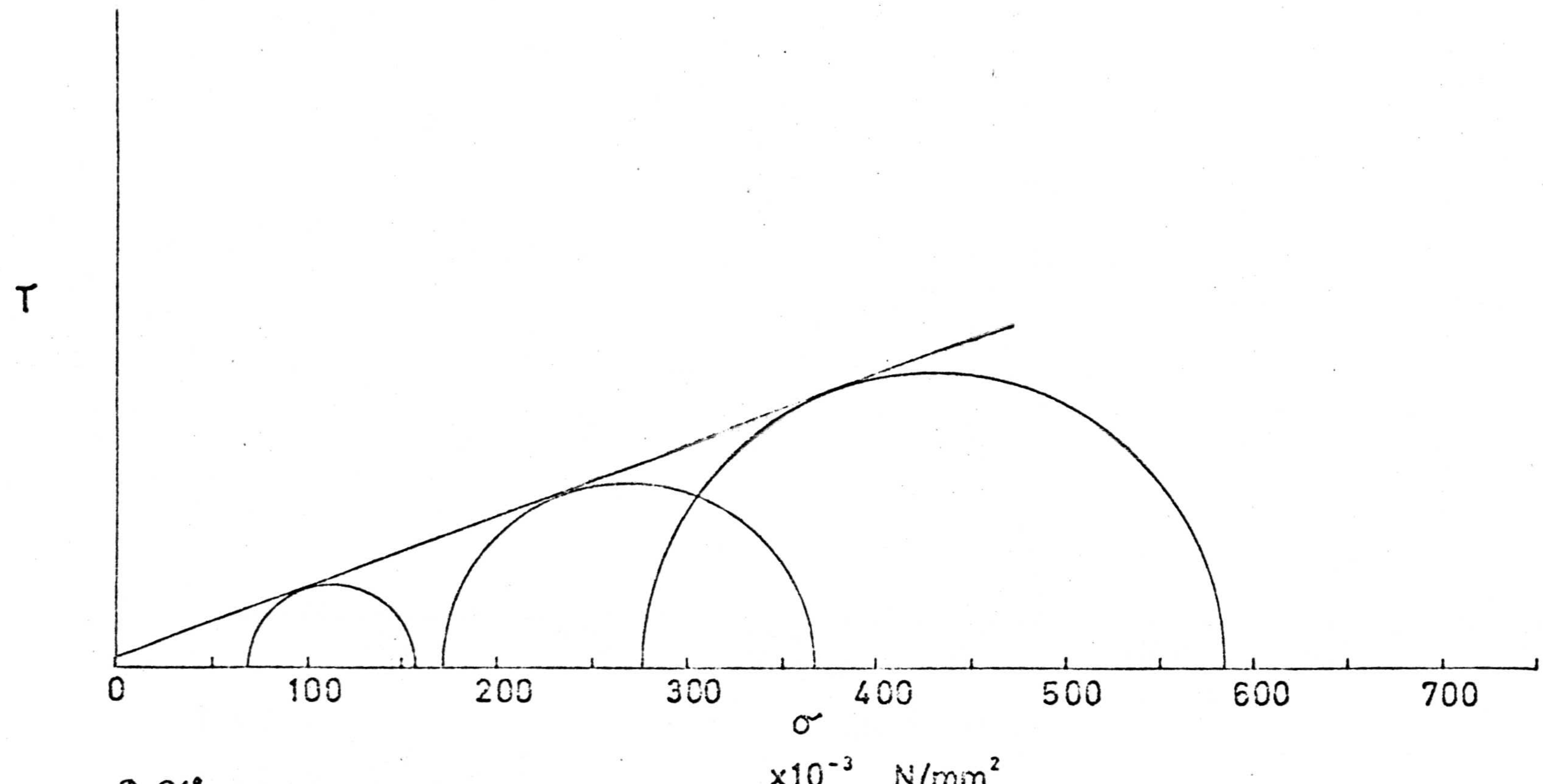
through a plunger bearing on the top end caps. The load on the plunger was increased to a point where failure was about to occur. At this point further water pressure was applied and further vertical stress loaded the sample again until failure was about to occur. This procedure was repeated for a third time allowing three values of σ_3 and three values of $\sigma_1 - \sigma_3$ to be determined in order to produce a series of Mohr's circles and obtain values for the shear parameters. Values of σ_3 were kept constant for all the tests, these were 69, 172 and 276 x 10^{-3}KN/mm^2. The Mohrs circles and the Mohr envelope drawn tangential to the circles for each sample are shown in Figs: 6.15 - 6.24. The results of the angle of shearing resistance in terms of total stress (ø) and the apparant cohesion in terms of total stress (c) are given in Table 6.3.

TABLE 6.3.

Cohesion and Shearing Resistance Values for Samples shown in Figs: 6.15 - 6.24.

SAMPLE	c x10^{-3} KN/mm^2	ø °
Pegwell Bay 1	5	21
Pegwell Bay 2	45	18.5
Pegwell Bay 3	15	15
Pegwell Bay 4	64	13
Star Lane Upper Horizon	2	13
Star Lane Lower Horizon	23	10.5
Cherry Orchard Lane Drainage Trench	4	7.5
Burlingham 1	2	10
Broomfleet horizontal	29	9
Broomfleet vertical	4	6

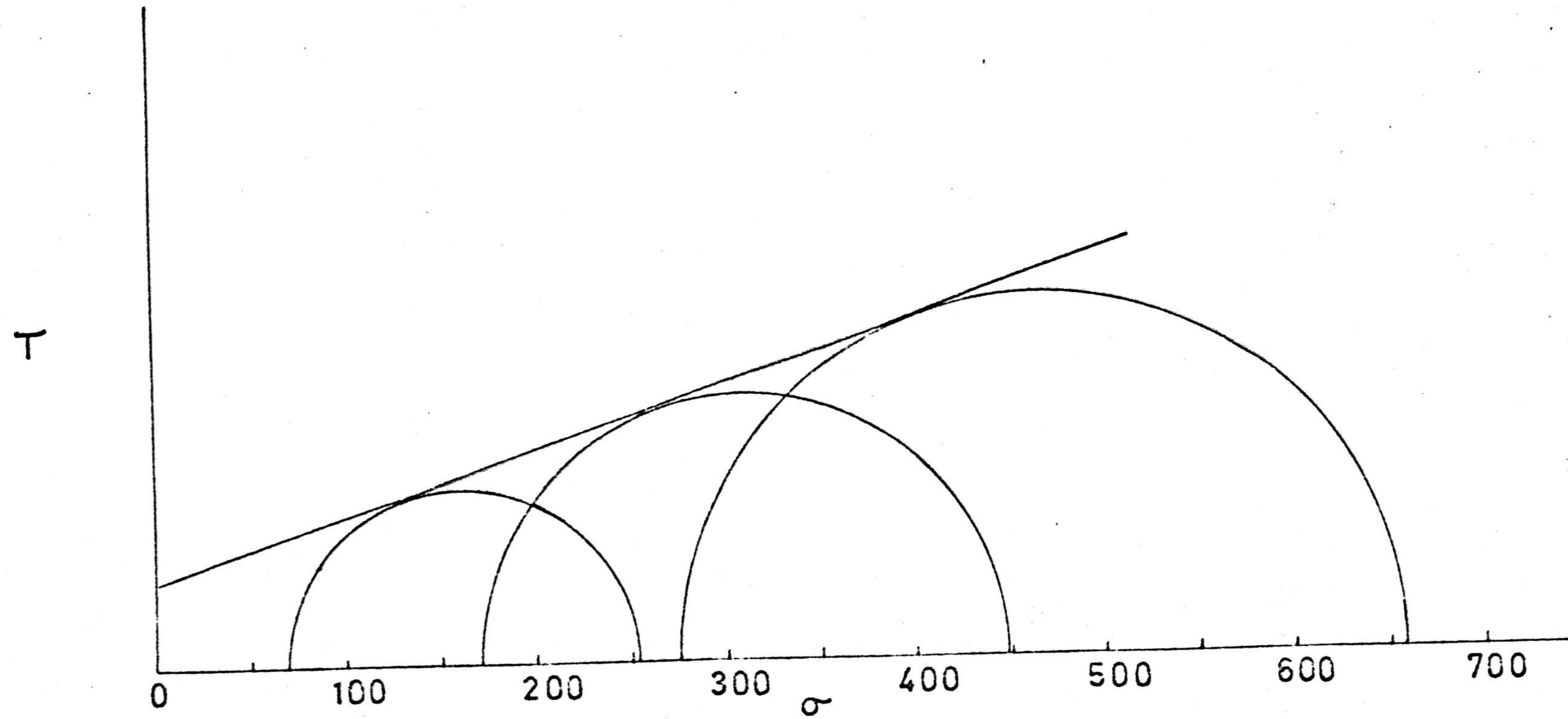
FIG 6·15 TRIAXIAL TEST OF PEGWELL BAY No.1



$\emptyset = 21°$

$c = 5 \times 10^{-3}$ N/mm^2

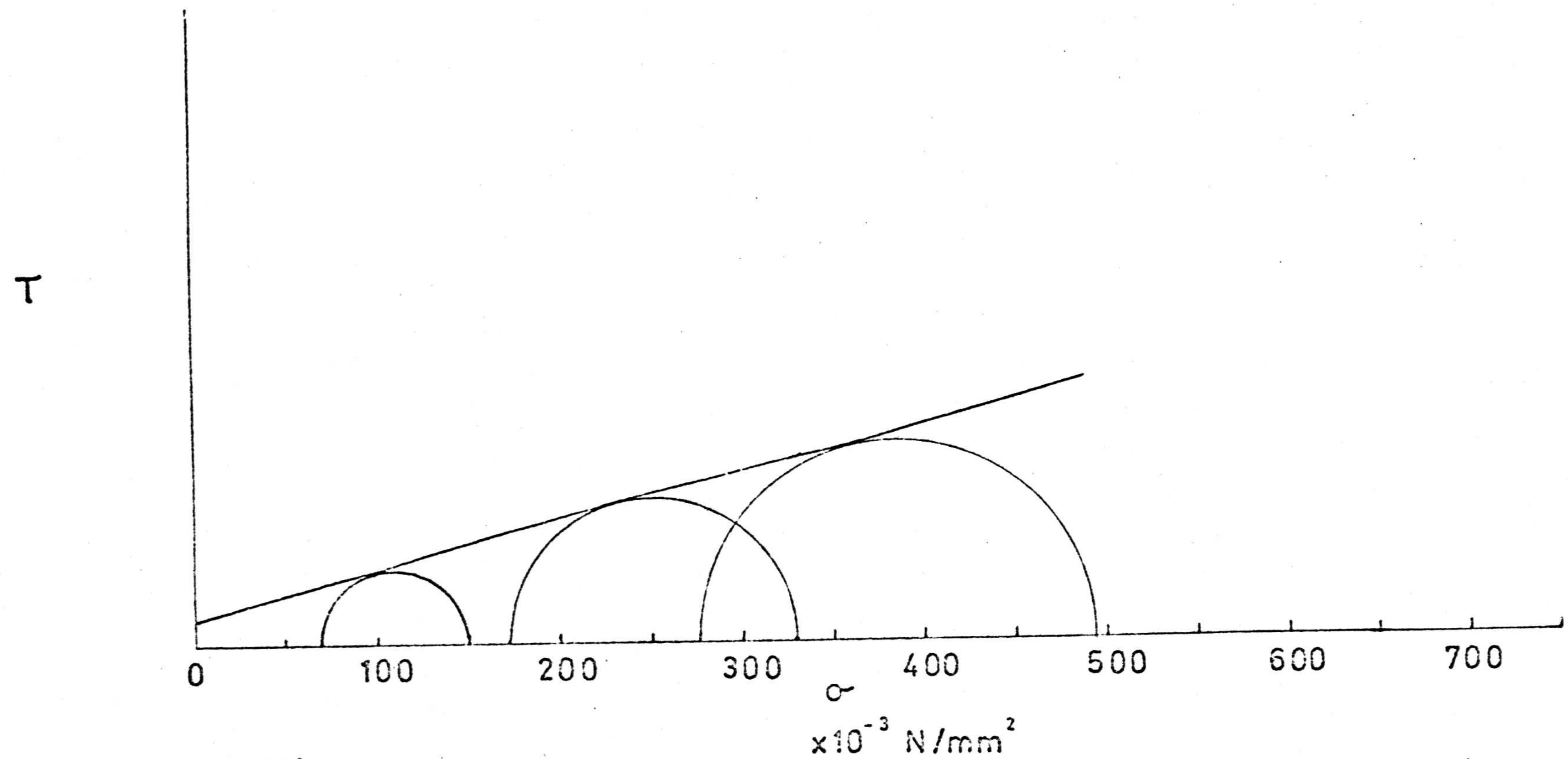
FIG 6·16 TRIAXIAL TEST OF PEGWELL BAY No.2



Ø = 18·5°

c = 45 x 10^{-3} N/mm^2

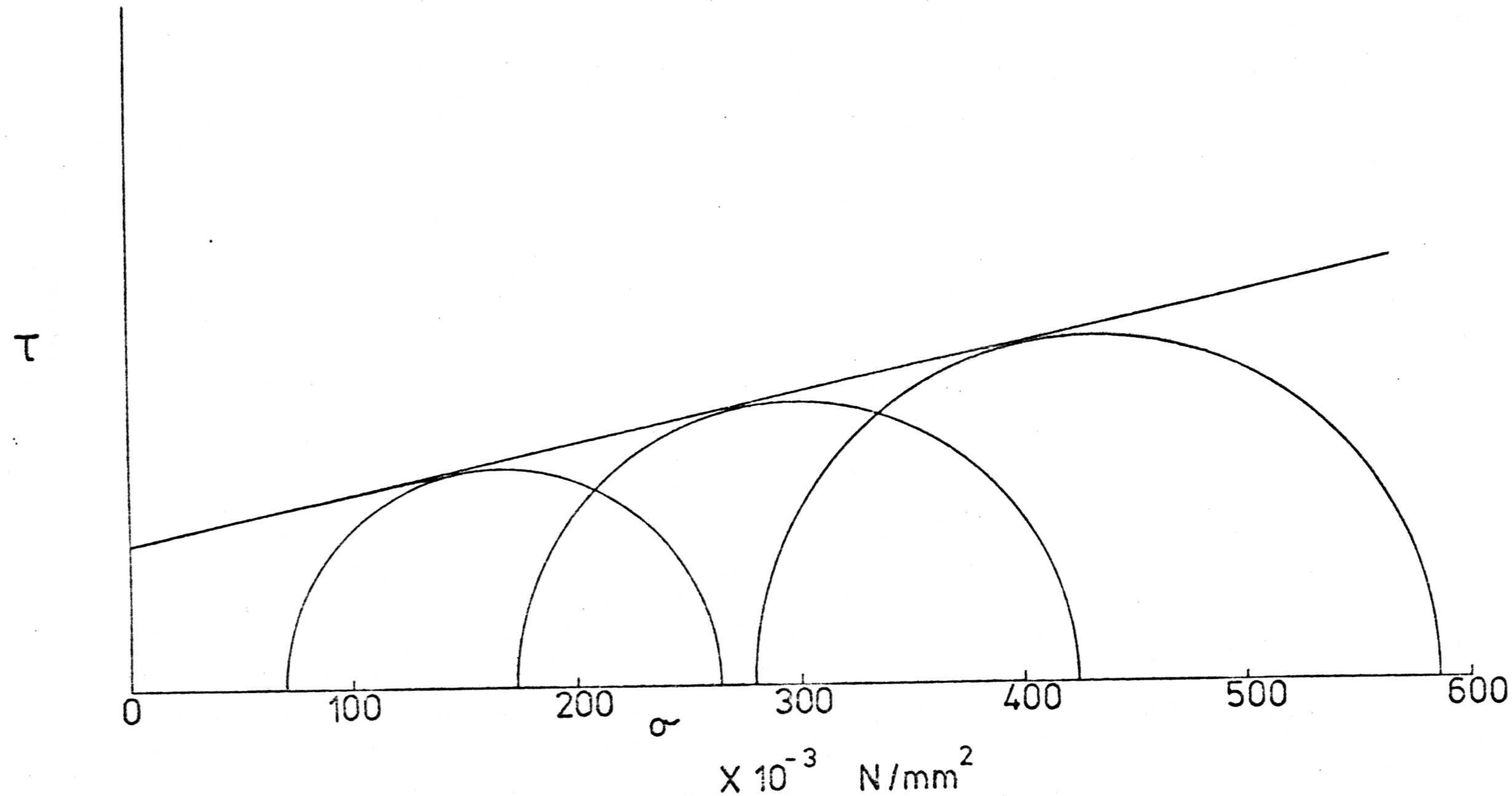
FIG 6·17 TRIAXIAL TEST OF PEGWELL BAY No. 3



$\phi = 15°$

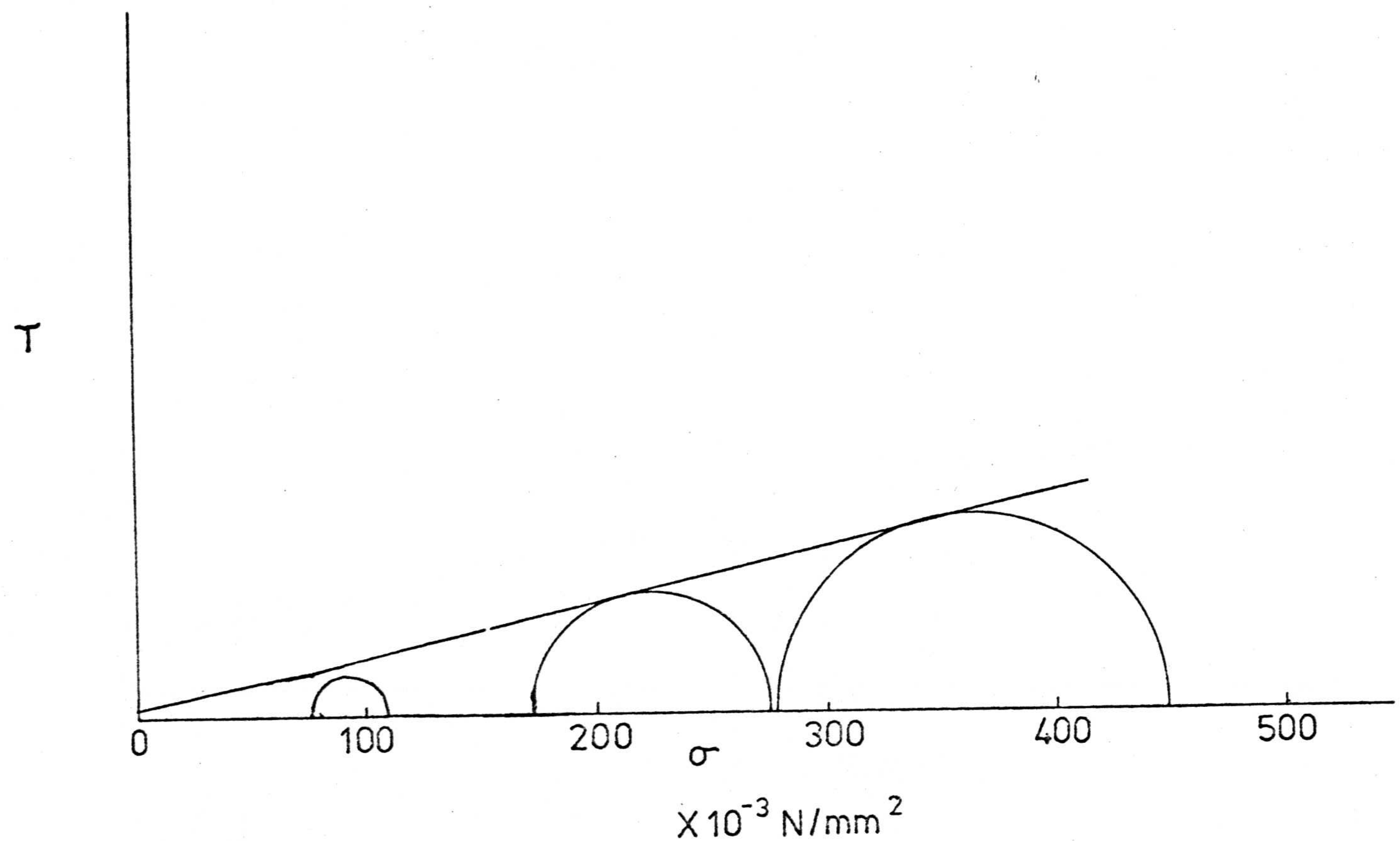
$c = 15 \times 10^{-3}\ N/mm^2$

FIG 6.18 TRIAXIAL TEST OF PEGWELL BAY No. 4



$\phi = 13°$
$c = 64 \times 10^{-3}\ N/mm^2$

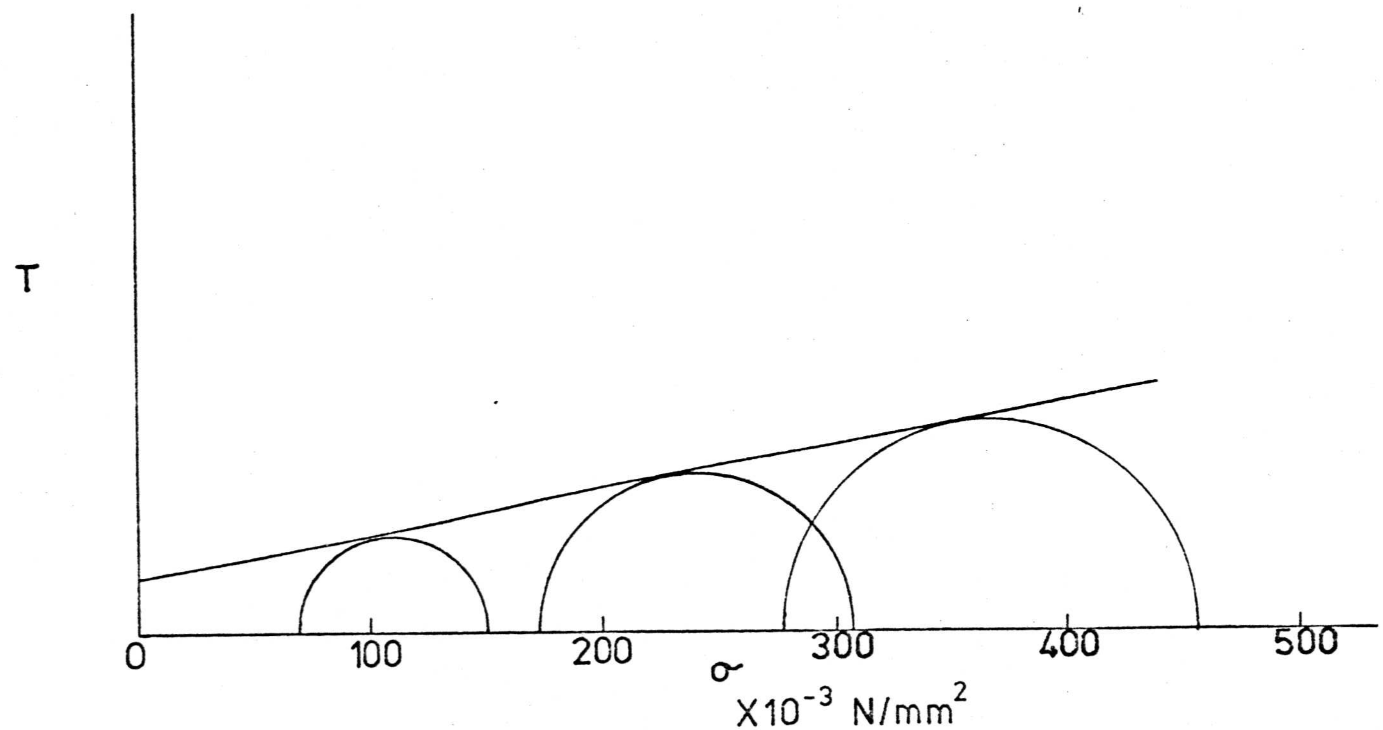
FIG 6·19 TRIAXIAL TEST OF STAR LANE UPPER HORIZON



$\emptyset = 13^{\circ}$

$c = 2 \times 10^{-3}$ N/mm^2

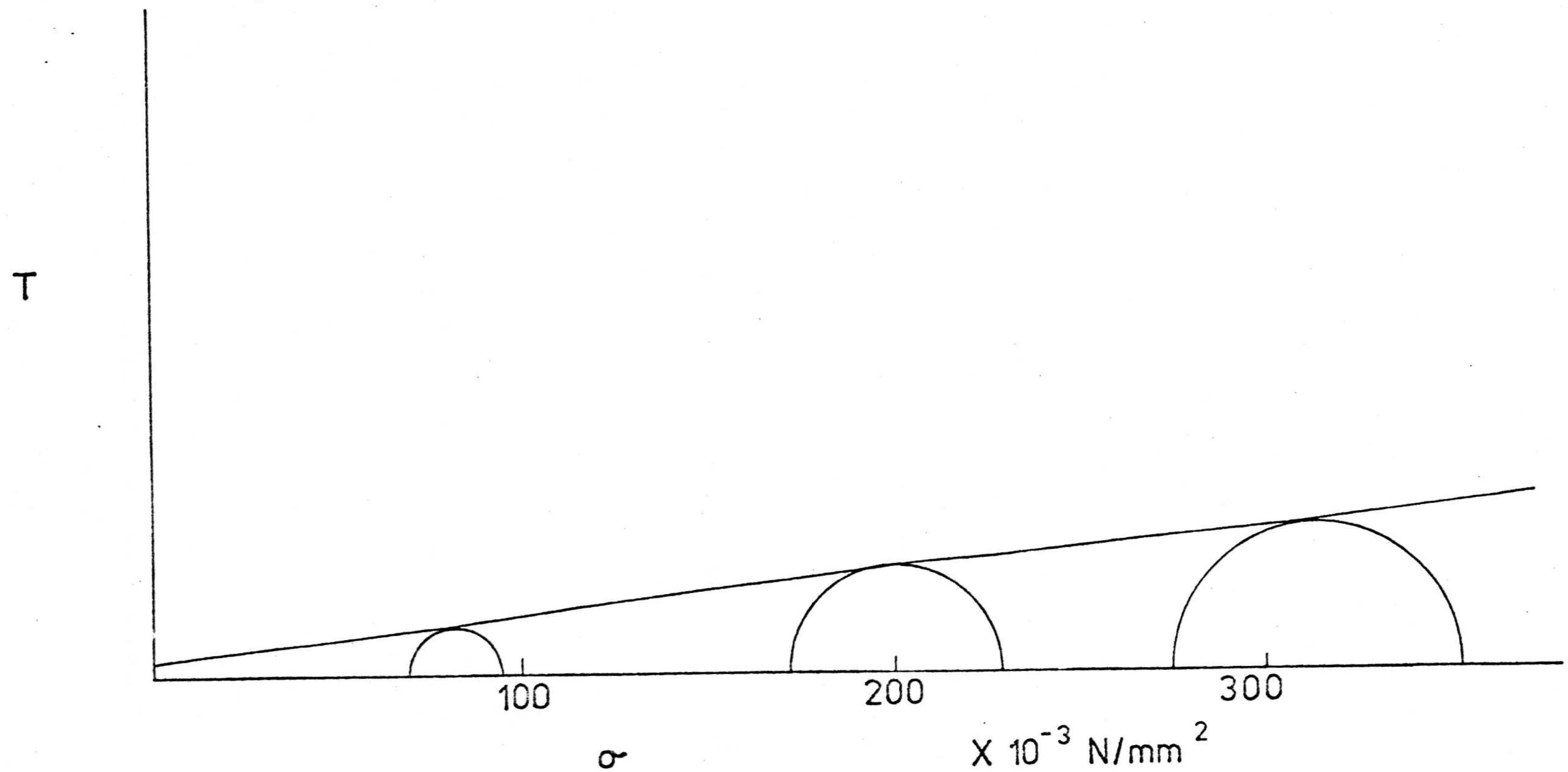
FIG 6.20 TRIAXIAL TEST OF STAR LANE LOWER HORIZON



$\emptyset = 10 \cdot 5^\circ$

$c = 23 \times 10^{-3}$ N/mm^2

FIG 6·21 TRIAXIAL TEST OF CHERRY ORCHARD LANE DRAINAGE TRENCH



$\emptyset = 7{\cdot}5^{\circ}$

$c = 4 \times 10^{-3}$ N/mm^2

FIG 6·22 TRIAXIAL TEST OF BURLINGHAM SAMPLE

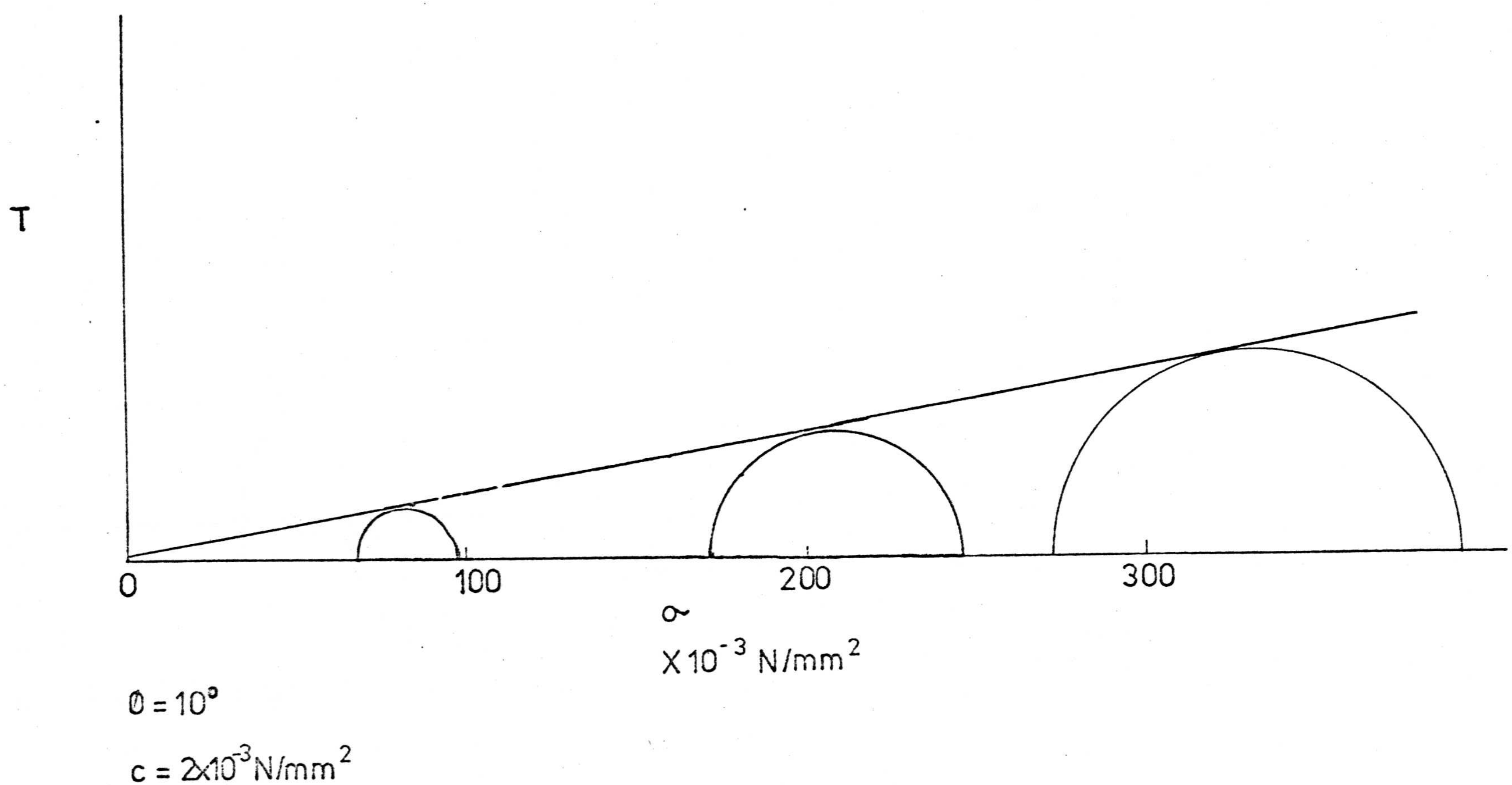
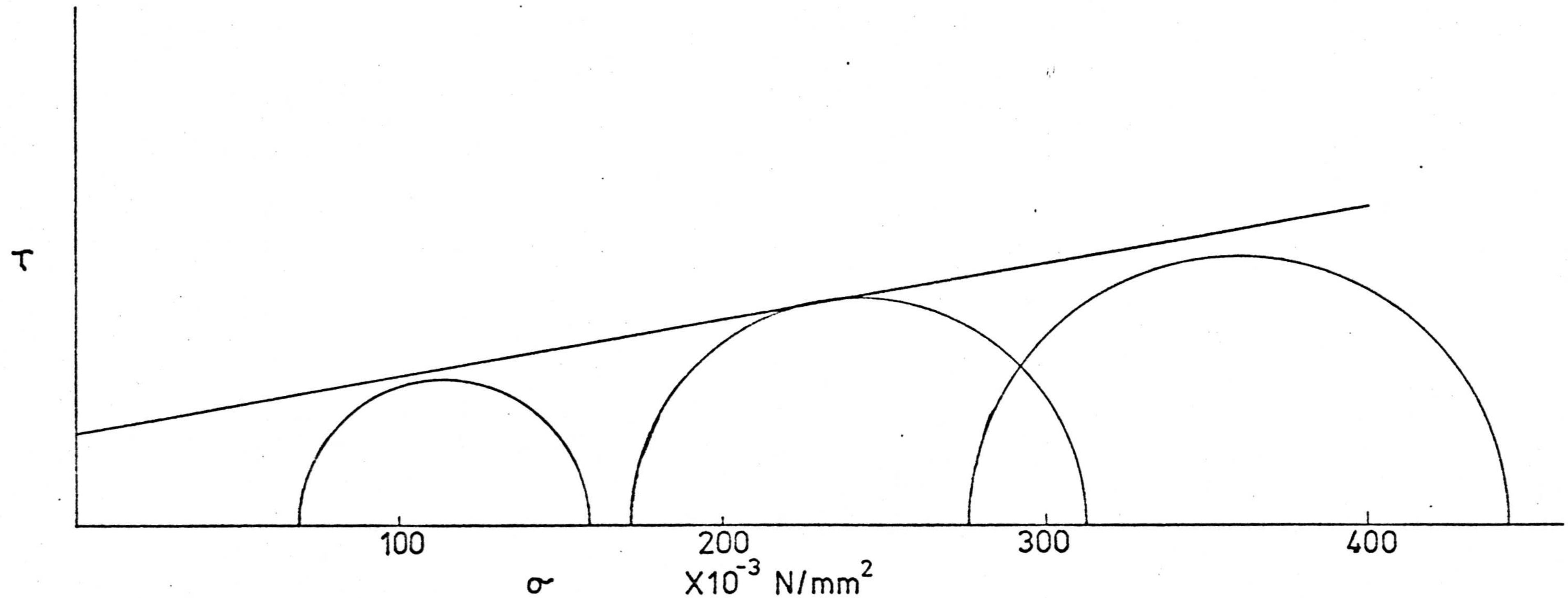


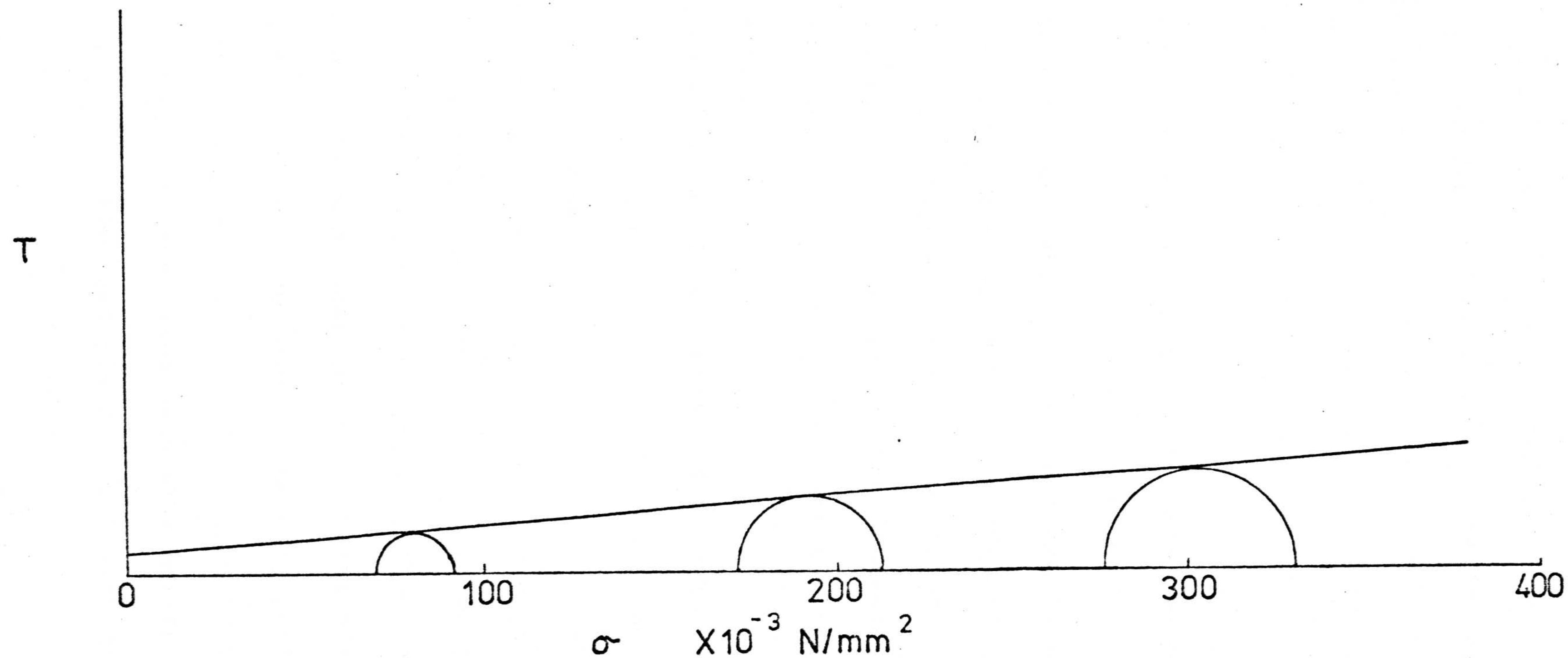
FIG 6·23 TRIAXIAL TEST OF BROOMFLEET HORIZONTAL SAMPLE



$\emptyset = 9^\circ$

$c = 29 \times 10^{-3}$ N/mm^2

FIG 6·24 TRIAXIAL TEST OF BROOMFLEET VERTICAL SAMPLE



$\emptyset = 4^\circ$

$c = 6 \times 10^{-3} N/mm^2$

The results presented show a substantial degree of contrast between samples from different localities and also between those from the same site. The degree of cohesion at Pegwell Bay varies from 5 to 64 x 10^{-3}KN/mm^2. The higer value for cohesion given for sample 4 may be due to its finer nature as indicated in Fig. 6.2.

The cohesion values for the two Star Lane samples give 2 and 23 x 10^{-3}KN/mm^2 for the Upper and Lower horizons respectively. The major difference between the two horizons is that of calcium carbonate content, with the lower horizon being abundant in lime and the upper containing very little. If the lime has formed a support structure within the framework of the soil pores it may be this that has given the lower horizon its greater cohesiveness.

The Broomfleet samples were obtained in the conventional vertical manner and also in the horizontal plane, to ascertain if any difference in the values would be produced from what appeared as an homogenous clay. The laminations present were mainly the effect of the colour and did not appear to have any structural significance. The results obtained from the shear strength measurements show a greater cohesion in the horizontal sample. The reason for this is not clear; the clay particles may be less resistant to shearing when loaded parallel to their ' platy structure ' and in such cases gradually buckle, whereas a load applied normal to the clay plates may induce shearing along a natural plane.

CHAPTER SEVEN

MINERALOGY

CHAPTER SEVEN

MINERALOGY

Most definitions of loess include a high percentage of quartz minerals as a statutory part of their composition although it has been argued that the presence of calcium carbonate in substantial quantities is also of importance, (Russell 1944 see Chapter 1).

The composition of the deposits collected have been analysed using both X-Ray and thermogravimetric techniques. This chapter is concerned with the results obtained from the X-Ray analysis, Chapters 8 and 9 being primarily concerned with thermogravimetry.

Very little work has been carried out using radiation techniques on British loess deposits, with Sabine et al (1963), presenting a very brief account of a comparison of the brickearth with the clay with flints of Kent, and Fookes et al (1969), recording results from east Kent as a comparison with Iranian samples.

a) X-Ray diffractometry:

X-Ray diffractometry of the samples was undertaken using both MoKα and CuKα radiation.

i) MoKα Radiation

A Philips X-Ray diffractometer was used with tube settings at 46KV and 12MA. Traces were made mainly of samples finer than 75u as those of greater size were considered to consist mainly of quartz. The samples were rotated in the holder in order to increase the strength of the reflections. Table 7.1 summarises the results in terms of the major minerals present; this style of presentation is similar to that of Seppälä (1971), and provides for easy comparison of the samples. Illite was considered to be

TABLE 7.1. MoK α Radiation

SAMPLE		ILLITE 10A°	QUARTZ 4.26A°	ILLITE & QUARTZ 3.33A°	ORTHOCLASE 3.24A°	PLAGIOCLASE 3.20A°	CALCITE 3.04A°	DOLOMITE 2.89A°
Pegwell Bay No.1	(<75u)	–	s	vs	vw	vw	vw	–
Pegwell Bay No.3	(<75u)	–	s	vs	vw	vw	w	–
Pegwell Bay No.4	(<75u)	–	m	vs	–	–	–	–
Pegwell Bay No.5	(<75u)	–	s	vs	w	–	m	w
Pegwell Bay No.6	(<75u)	–	m	vs	vw	vw	m	m
Pegwell Bay No.7	(<75u)	–	m	vs	–	–	vw	–
Pegwell Bay No.9	(<75u)	–	m	vs	–	–	m	–
Pegwell Bay No.9	(75u>)	–	m	vs	–	–	m	–
Monkton	(<75u)	–	m	vs	w	vw	s	vw
Allington 1.5m	(0.2–2.0u)	m	m	vs	w	vw	w	w
Allington 1.5m	(<75u)	vw	s	vs	w	vw	w	w
Funton 1.5	(<75u)	vw	vs	vs	vw	vw	vs	–
Funton 1.0	(<2.0u)	vw	w	s	–	w	m	vw
Ch Orch Ln Original T.2.0m	(<75u)	–	s	vs	–	vw	s	w
Ch Orch Ln New Trench	(<0.2u)	–	w	w	–	vw	s	w

vw = very weak;w = weak;m = moderate;s = strong;vs = very strong.

TABLE 7.1. MoKα Radiation

SAMPLE		ILLITE 10A°	QUARTZ 4.26A°	ILLITE & QUARTZ 3.33A°	ORTHOCLASE 3.24A°	PLAGIOCLASE 3.20A°	CALCITE 3.04A°	DOLOMITE 2.89A°
Marks Tey Upper	(<75u)	vw	m	s	–	vw	s	–
Marks Tey Lower	(75u >)	vw	m	vs	vw	vw	vs	–
Marks Tey Lower	(<75u)	vw	s	vs	w	w	vs	–
Costessey No.1	(75u >)	–	s	vs	–	vw	vw	–
Costessey No.1	(<75u)	–	s	vs	vw	vw	vw	–
Costessey No.2	(75u >)	–	s	vs	vw	vw	w	–
Costessey No.2	(<75u)	–	s	vs	vw	vw	w	–
Huggate A	(<75u)	–	s	vs	vw	–	vw	–
Callis Wold	(75u >)	–	s	s	vw	vw	–	–
Callis Wold	(<75u)	–	s	s	vw	vw	–	–
Eppleworth CBT	(<75u)	–	m	vs	vw	–	vw	–
Etton	(<75u)	–	m	s	vw	vw	vw	–
Windmill Quarry		–	–	–	–	–	–	vs
New Zealand No.1	(0.2–2.0u)	–	vw	s	m	–	w	w
New Zealand No.1	(<75u)	–	s	vs	s	–	m	–

vw = very weak;w = weak;m = moderate;s = strong;vs = very strong.

the main clay mineral present but distinguishing this from the background noise was difficult. The strongest peaks in almost all cases were the 3.33A° Quartz/Illite and the Quartz 4.26A° peaks; this indicates the high percentage of quartz that is present in most of the samples; Plagioclase and Orthoclase are the other silicates present but only in very small quantities.

Several of the samples produced high calcium carbonate peaks. The samples from Funton Brickworks produced a strong carbonate peak in the 1.5 metre depth sample but only a weak peak in the upper part at 1.0 metre. This leaching of the lime is also prevalent at other sites, including Cherry Orchard Lane, Star Lane and Allington (see Table 7.2 and the analysis of the DTG Histograms Tables 9.1 and A.1). Dolomite in most cases was found to be absent or to produce only a weak peak. The sample from Windmill Quarry, near Tadcaster produced a very strong dolomite peak as expected, this being the only mineral recorded.

ii) CuK α Radiation

Using a Philips X-Ray diffractometer at tube settings of 40KV and 20MA, several of the samples were analysed.
In the previous section the samples analysed were mainly of a finer than 75µ fraction and produced high quartz peaks. A knowledge of mineral breakdown in the different size fraction was required, particularly those minerals present in the 2 - 10µ and the less than 2µ fraction. Samples finer than 75µ were sedimented (see Chapter 9 for an outline of the procedure), in order to produce the size distribution required. Copper radiation was used as this was considered to give stronger reflections of any clay minerals that were expected to be present in the so called clay fraction ($<2\mu$). The results of this analysis are

TABLE 7.2 CuK α Radiation

SAMPLE		ILLITE 10A°	QUARTZ 4.26A°	ILLITE & QUARTZ 3.33A°	ORTHOCLASE 3.24A°	PLAGIOCLASE 3.20A°	CALCITE 3.04A°
Pegwell Bay No.1	(<2u)	w	w	s	vs	vw	vw
Pegwell Bay No.2	(2–10u)	w	s	vs	vw	vw	vw
Pegwell Bay No.2	(<2u)	w	vw	s	vw	w	m
Monkton	(2–10u)	w	w	vw	vw	vw	vs
Monkton	(<2u)	m	m	m	vw	vw	vs
Denstead 60°	(2–10u)	m	s	vs	vw	w	vw
Denstead 60°	(<2u)	m	w	s	vw	vw	vw
Denstead 240°	(2–10u)	m	s	vs	vw	w	vw
Denstead 240°	(<2u)	w	w	s	vw	vw	–
Allington 3m	(2–10u)	w	m	vs	vw	w	m
Allington 3m	(<2u)	m	m	s	vw	vw	s
Funton 1m	(2–10u)	m	s	vs	–	vw	vw
Beacon Hill	(2–10u)	m	s	vs	–	vw	s
Beacon Hill	(<2u)	m	w	s	vw	vw	s

vw = very weak; w = weak; m = moderate; s = strong; vs = very strong.

TABLE 7.2 CuKα Radiation

SAMPLE		ILLITE 10A^o	QUARTZ 4.26A^o	ILLITE & QUARTZ 3.33A^o	ORTHOCLASE 3.24A^o	PLAGIOCLASE 3.20A^o	CALCITE 3.04A^o
Ch Orch Ln Trench	(< 2u)	s	w	s	–	vw	w
Star Lane Upper	(< 75u)	w	vs	vs	s	m	–
Star Lane Upper	(2–10u)	w	s	vs	w	w	–
Star Lane Upper	(< 2u)	w	vw	s	vw	–	–
Star Lane Lower	(< 75u)	w	vs	vs	w	m	vs
Star Lane Lower	(2–10u)	w	m	vs	vw	w	vs
Star Lane Lower	(< 2u)	vw	vw	m	w	vw	s
Etton	(2–10u)	m	m	vs	vw	w	vw
Etton	(< 2u)	m	w	s	vw	w	w
Hornhill INV	(2–10u)	w	m	vs	–	m	–
Hornhill INV	(< 2u)	m	w	s	–	–	–
Hornhill SE	(< 2u)	w	m	s	–	vw	m
Hornhill NW	(2–10u)	w	vw	m	vw	w	s
Hornhill NW	(< 2u)	w	w	m	vw	vw	vs

vw = very weak; w = weak; m = moderate; s = strong; vs = very strong.

tabulated on Table 7.2 in a similar way to Table 7.1.
The Illite 4.44A° peak is present to some extent in all the samples but the presence of a strong quartz peak is evident in many of the finer than 2u fractions. The feldspars - orthoclase and plagioclase - are also present in most of the samples but only in small quantities.
The calcium carbonate peak,as already mentioned,is present in samples from several sites that were taken from depth but not in the samples from nearer the surface. At Hornhill Top in east Yorkshire three sets of samples were analysed; the involutions which did not present a calcite peak, the featureless deposit on the south eastern part of the section which only gave a moderate calcite peak and the thick deposit on the north western part of the section which gave a very strong calcite peak which is supported by the DTG and calcimetry data presented in Chapter 9, (Fig.9.8 and Table 9.2). The position of the Hornhill deposits on top of the Chalk would suggest that calcite should be present throughout but this is not the case and its presence at the western edge of the section is probably the localised influence of natural water levels. At Etton and Eppleworth (Table 7.1) the calcite content is low which is unusual considering the close proximity of the deposits to the underlying Chalk.

b) X-Ray Fluorescence

This technique of analysis was undertaken on several of the samples in order to compliment the X-Ray diffraction results.
A Philips PW1212 machine using a silver tube target with settings of 36KV and 44MA was used. The results are presented in Table 7.3 as percentages of elemental oxides. The large proportion of silica occurring in all the samples is indicative

TABLE 7. 3 PERCENTAGES OF ELEMENTAL OXIDES AS DETERMINED BY X-RAY FLUORESENCE

SAMPLE & PARTICLE SIZE:	Pegwell Bay 1 (2–10u)	Pegwell Bay 6 (<75u)	Pegwell Bay 7 (0.2–2.0u)	Denstead W (2–10u)	Denstead W (<75u)	Allington 1.5m (<2u)	Allington 3m (<75u)
Si	54.91	61.51	51.44	60.33	66.77	50.12	71.51
Ti	0.99	0.6158	1.022	1.167	0.8459	0.79	0.8409
Al	16.04	7.520	22.45	20.08	10.19	23.09	10.12
Fe	8.96	3.151	12.40	8.887	4.490	9.01	4.600
Mn	0.14	0.0451	0.1721	0.0550	0.0344	0.12	0.0724
Mg	1.91	1.733	2.600	2.023	0.9554	2.20	1.027
Ca	1.54	8.774	2.071	0.3259	0.4402	9.10	5.957
K	3.14	1.997	3.131	3.099	2.224	2.85	1.980
P	0.52	0.2280	0.2417	0.1632	0.0872	1.52	0.1557
Na	0.92	3.449	1.021	0.4943	2.124	0.36	0.8394
Total:	89.07	89.02	96.55	96.62	88.16	99.16	97.10

SAMPLE & PARTICLE SIZE:	Funton 1m (<75u)	Ch.Orch.Ln DT (<2u)	Star Lane 0.33m (2–10u)	Star Lane 0.33m (<75u)	Star Lane 1.55m (2–10u)	Marks Tey Middle (0.2–2.0u)	Marks Tey Lower (0.2–2.0u)
Si	62.05	36.85	64.21	75.92	40.38	50.30	39.82
Ti	0.6706	0.7845	1.10	0.8605	0.6925	0.79	0.7748
Al	7.933	16.97	16.35	9.169	11.97	23.09	19.15
Fe	3.643	8.329	7.93	3.462	5.745	9.01	9.732
Mn	0.0481	0.0496	0.15	0.0741	0.0648	0.12	0.1101
Mg	1.247	2.225	1.58	0.6507	2.308	2.30	2.318
Ca	5.236	3.231	1.26	0.8567	15.17	9.20	7.899
K	1.915	2.425	3.23	2.210	2.363	2.95	2.641
P	0.1530	0.1780	0.24	0.0959	0.2721	1.52	0.9718
Na	0.8179	0.2636	0.98	1.125	0.8319	0.38	0.2910
Total:	83.71	71.31	97.03	94.42	79.80	99.66	83.71

TABLE 7. 3 Cont.

SAMPLES & PARTICLES SIZE:	Hornhill SE (2–10u)	Hornhill NW (2–10u)	Etton (≤ 2u)	New Zealand 1 Loess (≤ 75u)	New Zealand 2 Ash (≤ 75u)	New Zealand 3 Loess (≤ 75u)
Si	56.26	39.23	41.40	64.95	55.88	65.85
Ti	1.12	0.78	0.9216	0.5668	0.2473	0.5263
Al	17.94	16.34	21.13	13.31	12.50	13.14
Fe	8.06	5.77	8.574	4.123	2.558	3.613
Mn	0.07	0.06	0.1185	0.0549	0.0638	0.0264
Mg	2.86	1.71	2.230	0.9985	0.3964	0.5776
Ca	7.23	29.05	2.761	1.538	1.398	1.128
K	3.32	2.33	2.931	1.899	2.355	1.336
P	0.26	0.45	0.3072	0.0952	0.0615	0.0632
Na	0.92	0.52	0.4984	3.760	4.856	3.072
Total:	98.04	96.24	80.87	91.29	80.32	89.34

SAMPLES & PARTICLES SIZE:	New Zealand 3 Loess (≤ 2u)
Si	51.36
Ti	1.331
Al	25.98
Fe	10.55
Mn	0.0496
Mg	1.940
Ca	0.8936
K	2.003
P	0.1370
Na	1.337
Total:	95.57

of the high quartz content although in several of the samples, particularly those of finer grain, the silica is combined with the alumina in the form of clay minerals and feldspars, e.g. Etton < 2μ, Allington (1.5m) < 2μ. The alumina content tends to be greater in the finer fractions where it is combined with silicon and not as large in the coarser fractions where the silica is generally in a free state, e.g. Star Lane o.33m < 75μ and Allington 3.0m < 75μ. Calcium Oxide is present in variable quantities, with the larger amounts in those samples that showed strong calcite peaks on both XRD and DTG curves, e.g. Hornhill N.W. 2 - 10μ and Star Lane 1.55m 2 - 10μ. The calcium in the non-calcite rich deposits is generally combined with the aluminium silicate in the form of plagioclase. Potassium and Sodium are also combined with the clay minerals and the feldspars.

Summary

The results in Tables 7.1 - 7.3 summarising the mineralogical and elemental contents of the samples collected clearly indicate the large percentage of silica in the form of quartz that is present in almost all cases. The XRD results show a slight increase in the proportion of Illite in the fine grained fractions although there is still a predominence of quartz. Aluminium appears from the XRF results to be greater in these finer fractions, being in combination with potassium, sodium, calcium and silicon in the clay minerals and feldspars. Calcite is variable from one deposit to another and appears to be controlled by local factors such as leaching and the possible level of the ground water.

CHAPTER EIGHT

PRINCIPLES OF THERMOGRAVIMETRY

CHAPTER EIGHT

PRINCIPLES OF THERMOGRAVIMETRY

Introduction:

Thermogravimetry is the method by which the wieght of a sample is continuously recorded during the process of heating and in some cases cooling. This is carried out in a thermobalance.
The means of heating substances has been used by man for several thousand years whilst the art of weighing has been known from Ancient Egypt almost 5,000 years ago (Partington 1935), but the means of continuous weighing during the heating of a sample has only been fully developed in the past sixty years. The first fully developed thermobalance appears to be that of Honda (1915), who in a paper entitled ' On a Thermobalance ' implied that the term ' thermobalance ' was in common usage, although the comment is made by Hondu that all his results are not altogether original, in spite of this he does not refer to any earlier attempts at recording weight changes which occur whilst a substance is being subjected to gradually varying temperatures.

Apart from further developments of the thermobalance by Guichard at the Sorbonne (1923 and 1925), further production was not undertaken until 1943 with the introduction of the Chevenard Thermobalance which was later modified as a result of criticism from Duval (1953). During the last twenty years improvements and modifications have been made to thermobalances as commercial development has proceeded. The main features of the thermobalance are considered in this chapter along with a discussion of the nomenclature as established by the International Confederation of Thermal Analysis (ICTA). The heating of a sample in a thermobalance is recorded by means of a thermogravimetric curve, the factors affecting the shape of these curves are discussed at the end of this chapter.

Chapter 9 concerns work that has been carried out for this study and the techniques which have been applied within the scope of the equipment available.

Instrumentation:

Three basic requirements have to be fulfilled by the instrumentation of a thermobalance in order to proceed with thermogravimetric work; i) a precision balance, ii) a furnace capable of being programmed for a linear rise of temperature with time, iii) a recording instrument.

The Furnace:

The furnace must be designed such as to produce a linear rise of temperature throughout the period of the programme and also to maintain a uniform temperature throughout the furnace. The size of available furnaces varies, those of low mass tend to cool quickly but hold little heat, a disadvantage is that a linear rise in temperature is more difficult to control. High mass furnaces may hold an isothermal temperature but requires a considerable time to achieve this. All modern thermobalances have electrically powered furnaces, usually through resistive heating. The resistance wire is coiled around an insular tubular support and held in place with an electrically insulating packing or cement, this should preferably be a good thermal conductor. The outside should also be well insulated. A single uniformly spaced helical winding is not satisfactory because a) it generates a magnetic field which may interfere with electrical sensors and b) a temperature gradient will occur between the middle and each end of the furnace, this reduces the size of the hot zone. For these reasons a furnace should be non-inductively wound, that is it should have two similar windings carrying current in opposite directions so that their magnetic fields cancel (bifilar winding), and non-uniformly wound with the spacings of the winding decreasing towards the ends of the furnace to compensate for heat losses in these regions. The measurement of the temperature within the furnace is generally carried out by means of a thermocouple. The choice of material for the thermocouple is governed as a rule by the maximum working temperature required by the operator. For this particular work a platinum/13% rhodium + platinum thermocouple was used (Chapter 9), but for lower temperatures Chromel/alumel thermocouples are used. Temperatures above 1750^{o} a tungsten/rhenium type is required. The thermocouples should also be of a compostion that does not react with the products of decompostion.

The shape of the furnace is usually cylindrical with the long axis in a horizontal or vertical position. In the former case heat loss by radiation through both open ends may occur and location of the sample along the axis of symmetry in order to maintain uniform heating is difficult. A furnace in the vertical position may induce convection currents during heating in a gaseous atmosphere. The effects of these disadvantages have to be accounted for such that they do not influence the weighing system.

The Balance:

The essentials of an automatice and continuously recording balance are similar to those of an analytical balance and include accuracy, sensitivity, reproducibility and capacity. It should also have an adequate range of automatic weight adjustments, a high degree of mechancial and electronic stability, a rapid response to weight changes and to be unaffected by vibration.

There are basically two different types of weighing systems, i) the deflection and ii) the null point balances. The former type is that used in the Stanton-Redcroft TR02 as outlined in Chapter 9.

Very few studies have been made concerning the accuracy of the balance in comparison to the analytical balance. Simons et al (1957), compared 24 samples which were weighed before and after heating on an analytical balance. The difference between these and the thermobalance weighings varied from — 3.4mg to +5.4mg with an average value of 0.7mg.

The Recorder:

The recording system should have the ability to record both temperature and weight continuously.

Thermogravimetry and Derivative Thermogravimetry:

Thermoanlytical methods applied for the purpose of measuring weight changes fall into two catagories, i) Static; this is measuring weight under either constant pressure (isobaric) or at constant temperature (isothermal); ii) Dynamic; this is the method of primary interest in this study, these include Thermogravimentry (TG) and Derivative Thermogravimetry (DTG). The definitions of these techniques are given below, taken from Mackenzies (1969), report on behalf of ICTA*

* The numerous methods of presenting data that were used in the 1950s and 1960s along with the lack of strict definition regarding various terms led ICTA to appoint a committee in the late 1960s with the task of standardizing definitions and presentation of data. Data presented in this chapter and Chapter 9 is in accordance with the rulings laid down.

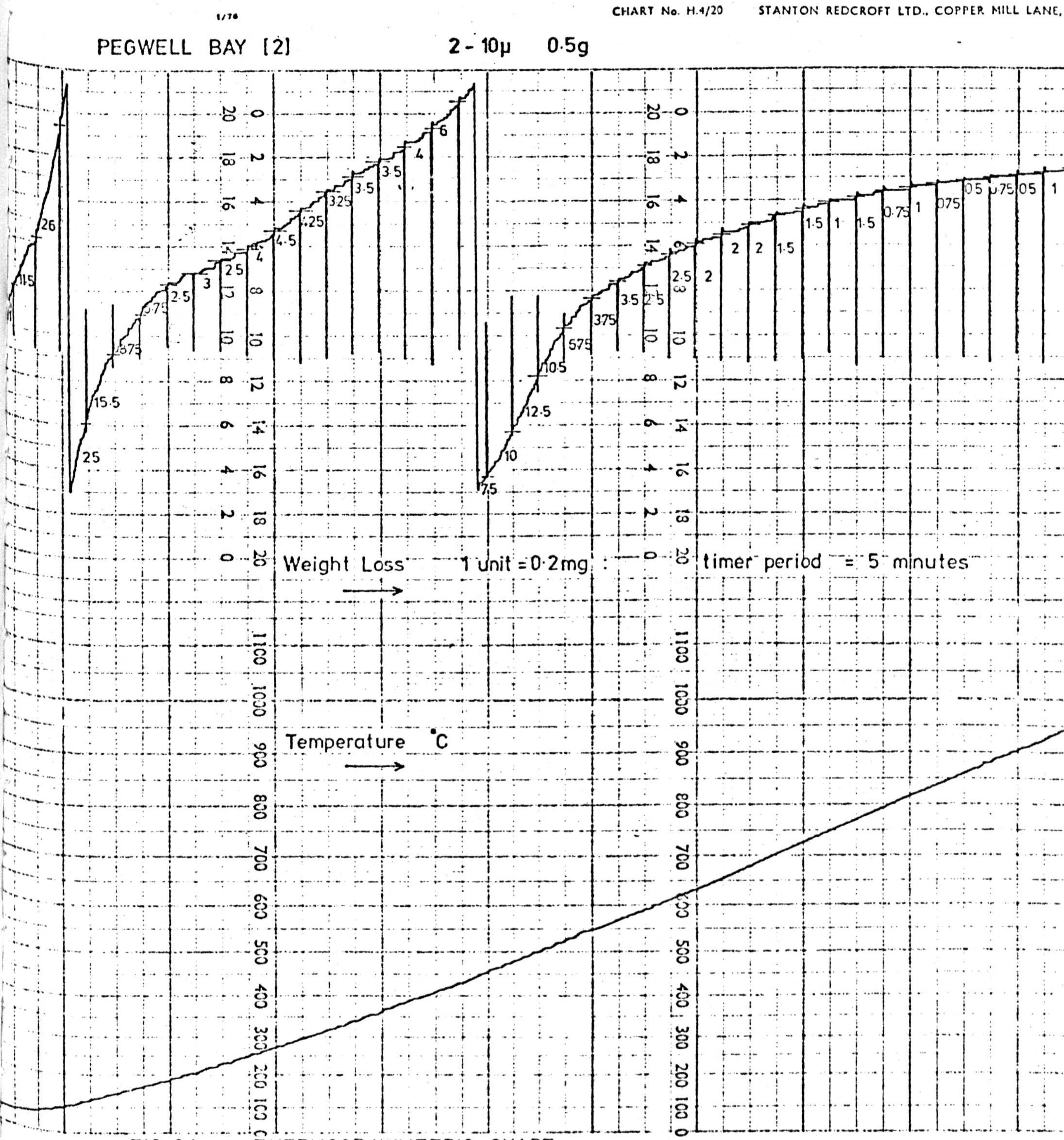


FIG 8.1 THERMOGRAVIMETRIC CHART

Thermogravimetry: This is a technique whereby the weight of a substance, in an environment, heated or cooled at a controlled rate, is recorded as a function of time and temperature. The record is the thermogravimetric or TG curve; the weight should be plotted on the ordinate with the weight decrease downwards and t (time) or T (temperature) on the abscissa increasing from left to right.

Derivative Thermogravimetry: A technique yielding the first derivative of the thermogravimetric curve with respect to either time or temperature. The curve is the derivative thermogravimetric or DTG curve; the derivative should be plotted on the ordinate with the weight losses downwards and t or T on the abscissa increasing from left to right. TG and DTG curves for a sample of Pegwell Bay Loess are shown in Figs:8.2a and 8.2b respectively, these have been obtained from the data recorded on the thermobalance, Fig.8.1. In Fig.8.1 the weight loss that takes place with respect to temperature increase is directly recorded, this in itself is a form of TG curve. Fig. 8.2a shows the same features of cumulative weight loess but in this case several of the features as defined by Mackenzie et al (1972), can be observed. These are described with Fig.8.2a. Fig. 8.2b is the DTG curve which appears as a histogram being the first derivative of the TG curve. The temperature intervals are equivalent to the five minute time periods recorded by the thermobalance and, because the heating rate is approximately 4.7° per minute, they represent a temperature increase of 23.5°. The ordinate is plotted in terms of percentage weight loss per minute although a further technique is to plot the angle of the curve for each five minute interval against the temperature, Fig.8.3 compares this method with the histogram of percentage

FIG 8·2a THERMOGRAVIMETRIC CURVE OF FIG 8·1

Pegwell Bay [2] 2-10µ 0·5g

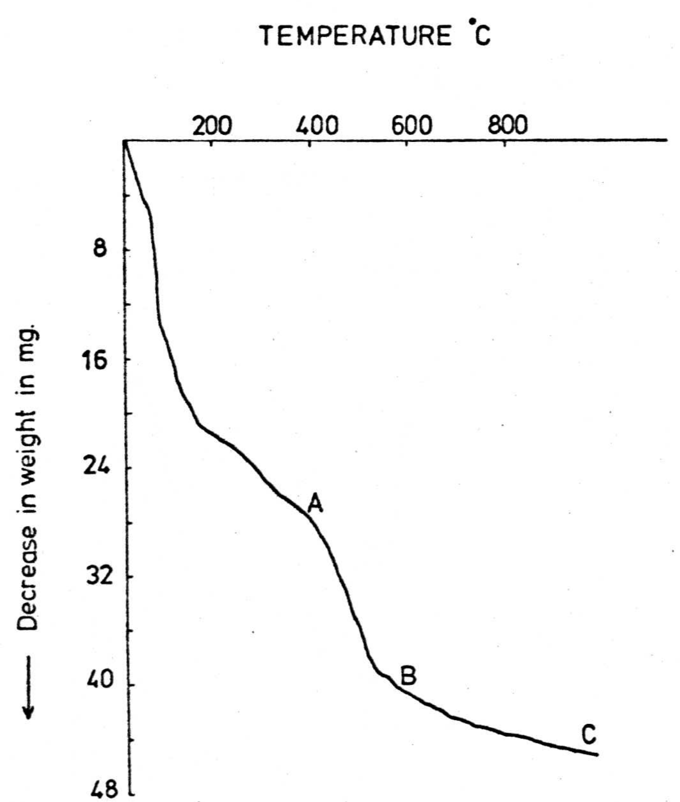


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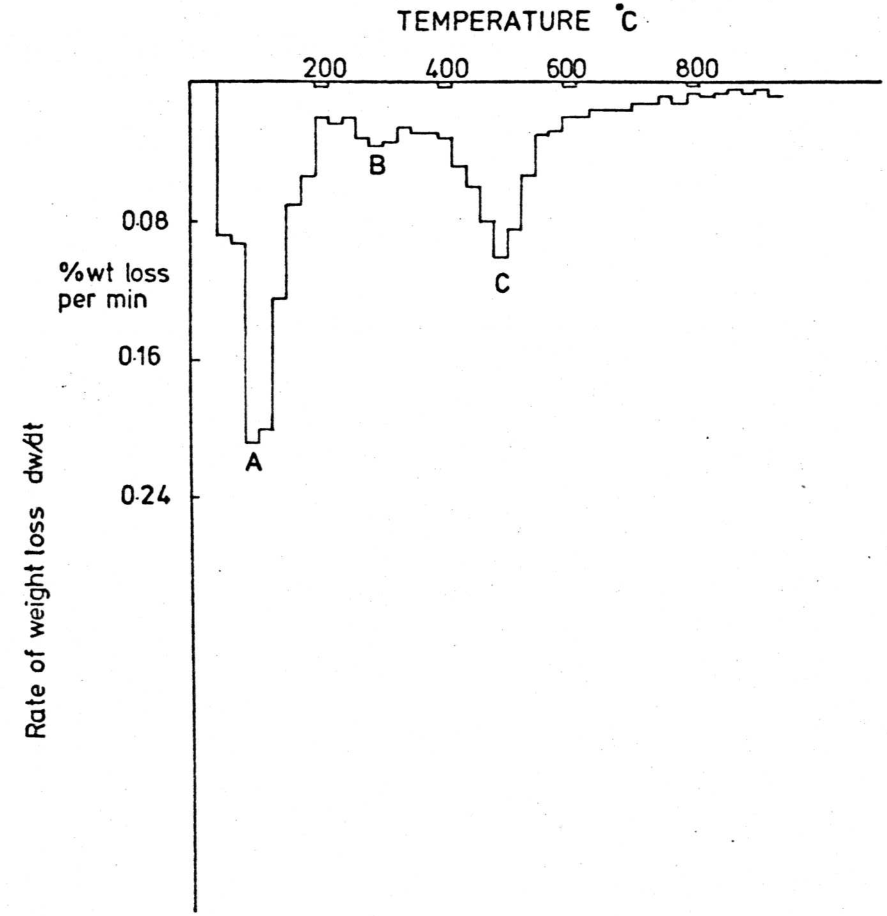
FIG 8·2b DERIVATIVE THERMOGRAVIMETRIC CURVE OF FIG 8·1

Pegwell Bay [2] 2-10µ 0·5g



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Explanation of nomenclature

Ti - initial temperature A - a temperature at which the cumulative weight change reaches a magnitude detectable by the thermobalance

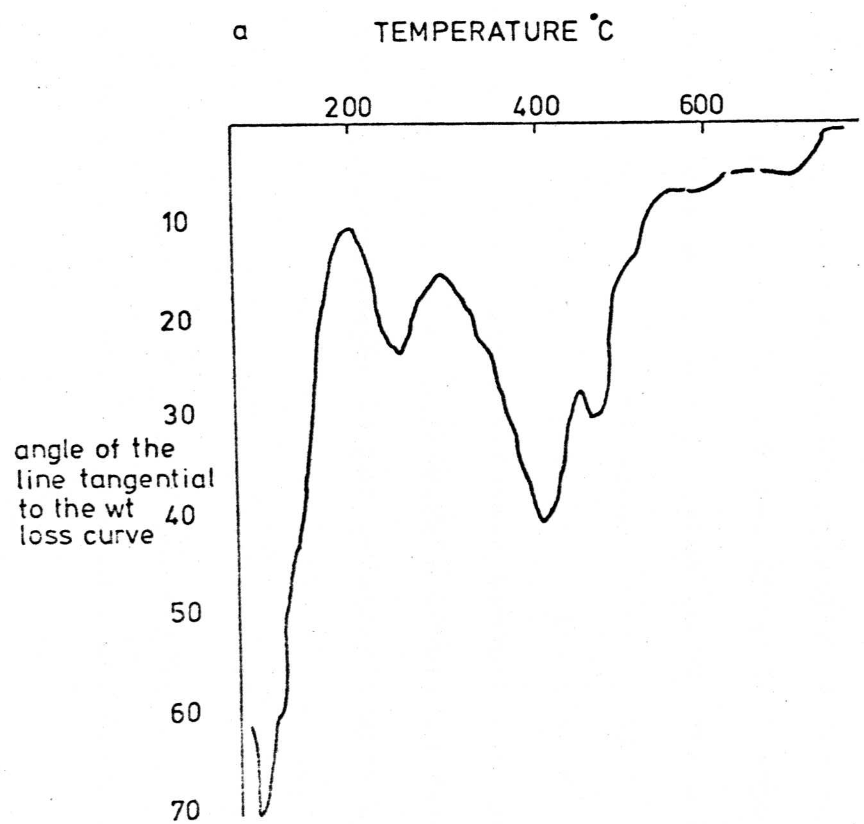
Tf - the final temperature B at which the cumulative weight reaches a maximum

A-B[Ti Tf] = the reaction interval

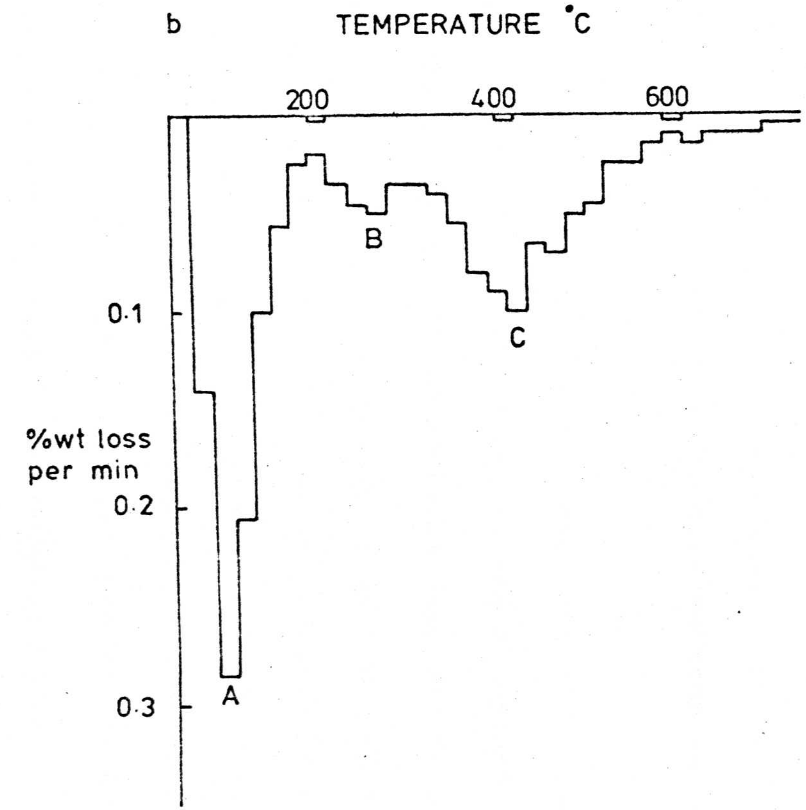
B-C a plateau, part of the curve where the weight is essentially constant

FIG 8·3 COMPARISON OF TECHNIQUES FOR PRESENTING DTG CURVES

Pegwell Bay [1] 2-10μ 0·38g



a: METHOD OF ANGLES



b: DIRECT WEIGHT LOSS

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weight loss against temperature.

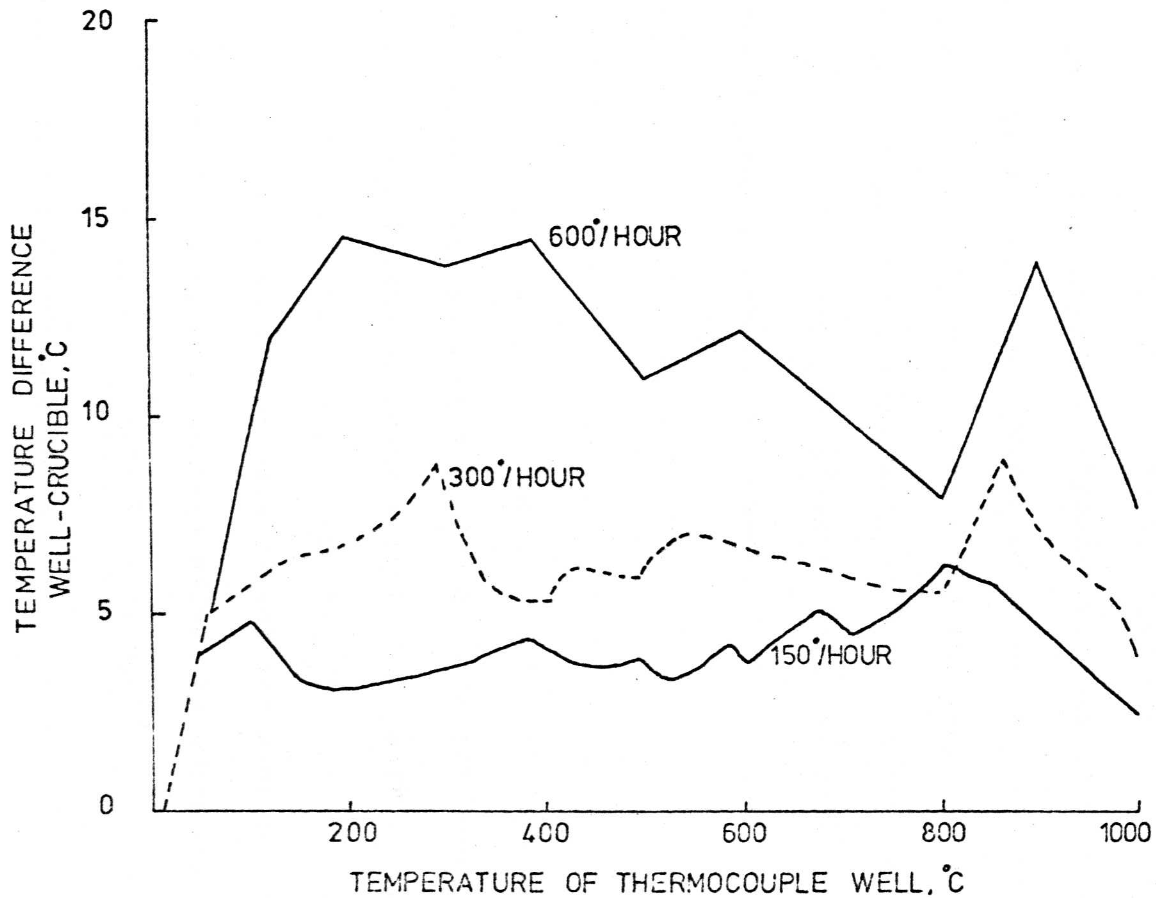
Smalley et al (1976), briefly discuss the relative merits of the TG and DTG curves and state that ' the derivative curve represents a potent way of presenting TG information and .....its neglect by practioners may have contributed to the relative neglect of the entire range of gravimetric methods in thermal analysis. '

The shape of the TG curve and consequently the DTG curve may be affected by several variable factors, these include the rate of heating, the design of the crucible as well as the composition of the crucible, the state of aggradation of the sample and the amount of sample used, and by the bouancy effect. The means by which the temperature is measured may have an effect on the curve with the position of the thermocouple inside or outside the sample container being of importance. The effect of these variables is discussed briefly systematically below

Rates of Heating and Heat Transfer:

Thermogravimetry requires heating and weighing of the sample simultaneously, therefore there must not be contact between the sample and the furnace wall. Heat transfer is the means by which the sample is heated, this is controlled by the properties, size and nature of the sample. The properties of the sample are the primary cause of the temperature gradient between the sample and the furnace wall and may have considerable effect on the TG curve in cases where the thermocouple is not actually placed in the sample, but is located in the neighbourhood of the sample or in the furnace wall. Newkirk (1960), showed the effect of the position of the thermocouple and the resulting thermal lag that occurs at different heating rates, (Fig.8.4). The difference

FIG 8·4 EFFECT OF HEATING RATE ON CRUCIBLE TEMPERATURE



After Newkirk 1960

between the temperature of the crucible and that of the furnace wall appears greater with a higher heating rate. Newkirk (1960 op cit), also showed that the thermogravimetric curve can be influenced by the heating rate alone. The degree of decompostion was shown to be greater with a slower heating rate when Calcium oxalate monohydrate was heated at 150°/hour and 300°/hour, Fig. 8.5. The two curves in Fig.8.5 are plotted to the same temperature scale and corrected for differences in the apparent weight gain. For each of the three reactions - dehydration, loss of CO and loss of CO_2 the temperature of apparent onset of decompostion 'Ti', is lower at the lower heating rate and the decomposition is completed at a lower temperature with a lower heating rate. A heating rate lower than 150°/hour Newkirk believed would result in the thermogravimetric curve being moved to lower temperatures.

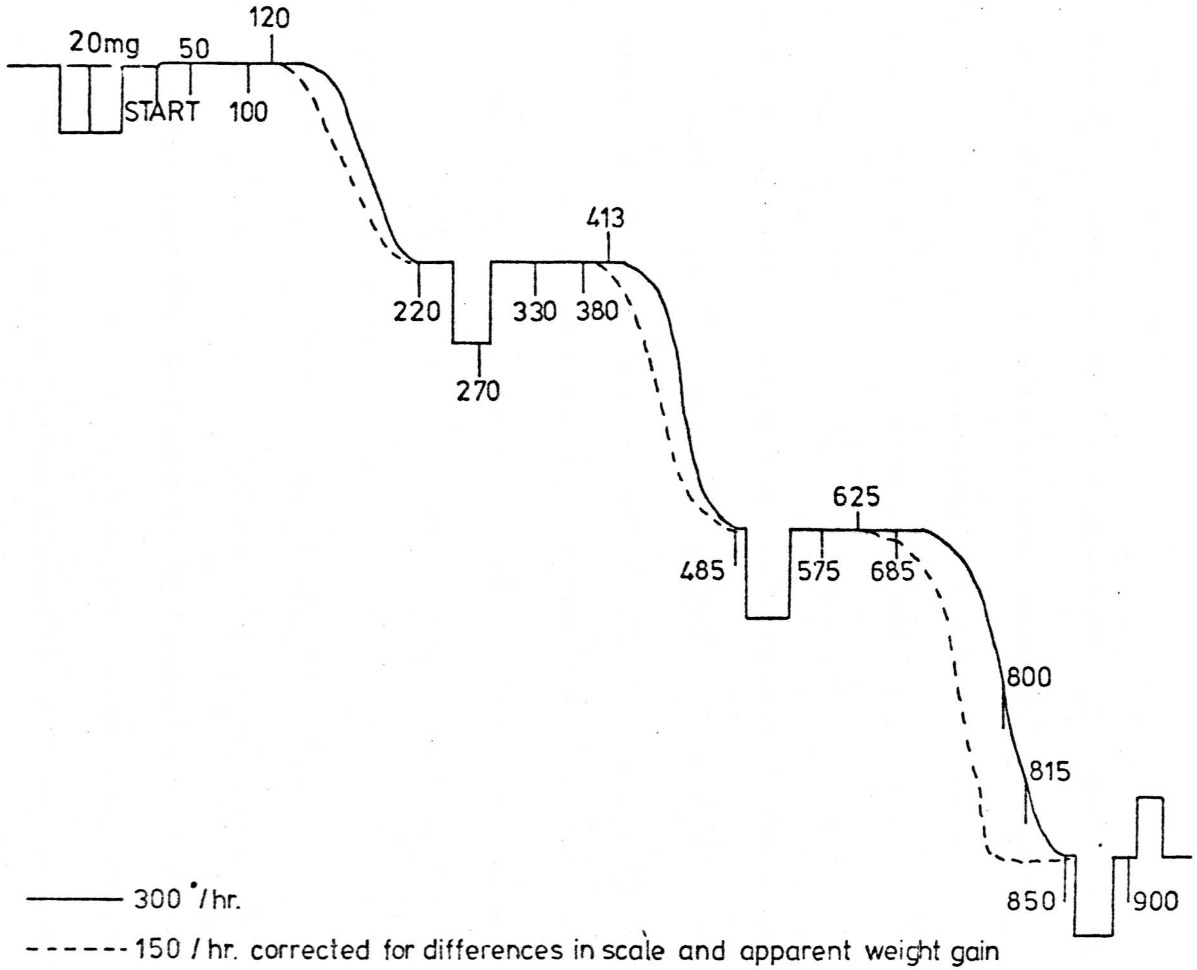
Bouyancy effect:

Owing to heat transfer effects, the furnace walls are hotter than the sample, (see previous section). Heat transfer takes place by means of convection at lower temperatures with a rising of gas along the furnace walls displacing the gas down the centre of the furnace resulting in an apparent weight increase of the sample. Duval (1953 op cit) reduced this effect by suitable ventilation of the furnace with variable size openings at the top.

Crucible shape, size and composition:

The crucible shape and size used for thermogravimetric work may have an appreciable influence on the resulting curve. In accounting for the design of the sample holder and also its compostion the nature of the material under investigation must be considered. Liptay and Sarkany (1968), commenting on ceramic

FIG 8·5 EFFECT OF HEATING RATE ON THE THERMOGRAM OF $CaC_2O_4H_2O$



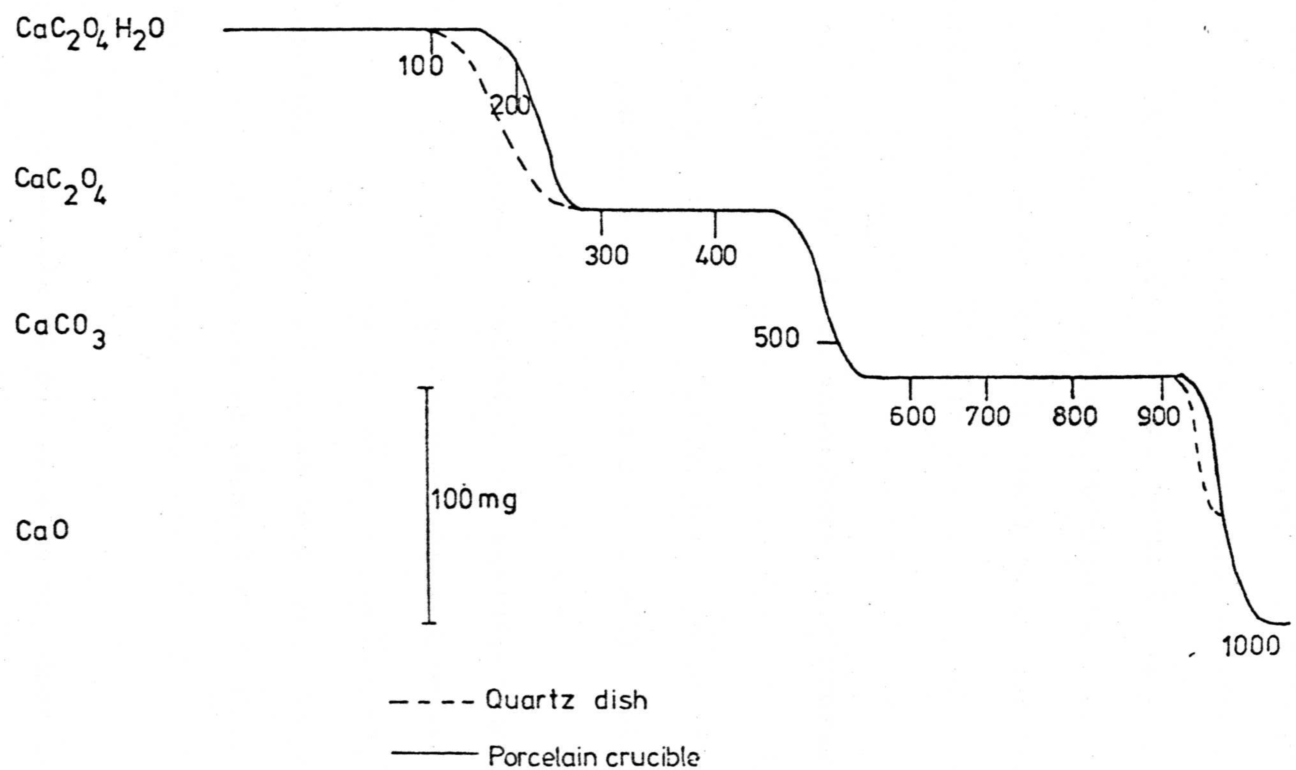
After Newkirk 1960

crucibles, remark that these and quartz crucibles had not been widely used up to this date because the walls were too thick and lacked uniformity which resulted in errors of measurement. For their own purposes they developed heat resistant ceramic crucibles with uniform thin walls (0.5mm), which they showed to be more useful than the previously used platinum type which assisted catalytic oxidation at about 300° when magnesium ammonium phosphate was heated.

Various crucibles under different atmospheres were used by Newkirk and Laware (1962), when testing potassium hydrogen phthalate in a Chevenard thermobalance. A slight weight gain was observed between 425° and 450° when they used a porcelain crucible in an air atmosphere. The evaporation of phthalic anhydrite from the furnace walls with an increase of temperature and its condensation on the crucible support rod caused this slight weight gain effect. Fig.8.6 shows the effect on the TG curve of calcium oxalate monohydrate heated in a quartz dish and a ceramic crucible after Simons and Newkirk (1964), see also Fig.9.1. Keattch (1967), and Garn and Kessler (1960), recommend that the sample holder should be a shallow dish, this helps to prevent low rates of weight loss from being recorded during rapid reactions. Partly enclosed holders encourage secondary reactions by retaining the self generated atmosphere in the vicinity of the sample and unless this is quickly swept away the products may dissolve in the molten reactants, giving low weight losses. This interaction of the sample with the atmosphere is avoided with open plate or shallow dish type holder, but this may not be used in the case of highly volatile materials where a lidded crucible is necessary.

Throughout the experimental work undertaken in this study of the

FIG 8·6 THE EFFECT OF SAMPLE CONTAINER ON THE TG CURVE FOR $CaC_2O_4 H_2O$



After Simons and Newkirk 1964

British loess deposits, porcelain crucibles have been used. The small samples (1 gramme or less) that have been heated for analysis have allowed the use of this type of holder without a lid.

Sample Quantity and State of subdivision:

Keattch and Dollimore (1975), regard the state of subdivision of the sample to be of great importance. Martinez (1961), studied the effects of particle size of chrysotile and platy serpentine on the shape of DTA and DTG curves. The results of this study showed that the starting peak temperature of the dehydroxylation reaction decreased with a decrease in the particle size.
The effect of the particle size has been studied here on soil samples. In the preparation of the fine fraction of the soil samples, the coarser fraction, (this is that part greater than 2µ or 10µ) are sedimented through a 500cc glass cylinder. The finer fractions are siphoned off in accordance with Stokes Law and for samples of less than 0.2µ an MSE centrifuge was used leaving the 0.2µ - 2.0µ fraction at the base of the centrifuge bottles. Each fraction is dried separately on a water bath, this method of drying maintains the moisture on the inside of the beaker throughout the drying, preventing the incrustation of fine particles along the side of the beaker. Once dried the samples form in a flaky manner at the base of the beaker, this has allowed a comparison of the DTG curves to be made on several soils in both the ground and pre-ground (flaky) form. Grinding of the samples was carried out using a hand operated agate pestal and mortar.
The results of these experiments do not show in the case of the soil samples analysed that grinding prior to heating resulted in

any effect on the shape of the DTG curve. Figs:8.7 and 8.8 compare the results from two of the samples.

Large grained crystals may cause a significant weight loss in the case of volatile materials as a result of mechancial loss with the sample being ejected from the holder.

Simons and Newkirk (1964 op cit), in their study of calcium oxalate monohydrate give Tf values for the three reactions of dehydration, decomposition of anhydrous material to carbonate and decarbonation, showing that this value increases with sample weight. This however was only the case in a dry nitrogen atmosphere and not when carried out in an air atmosphere.

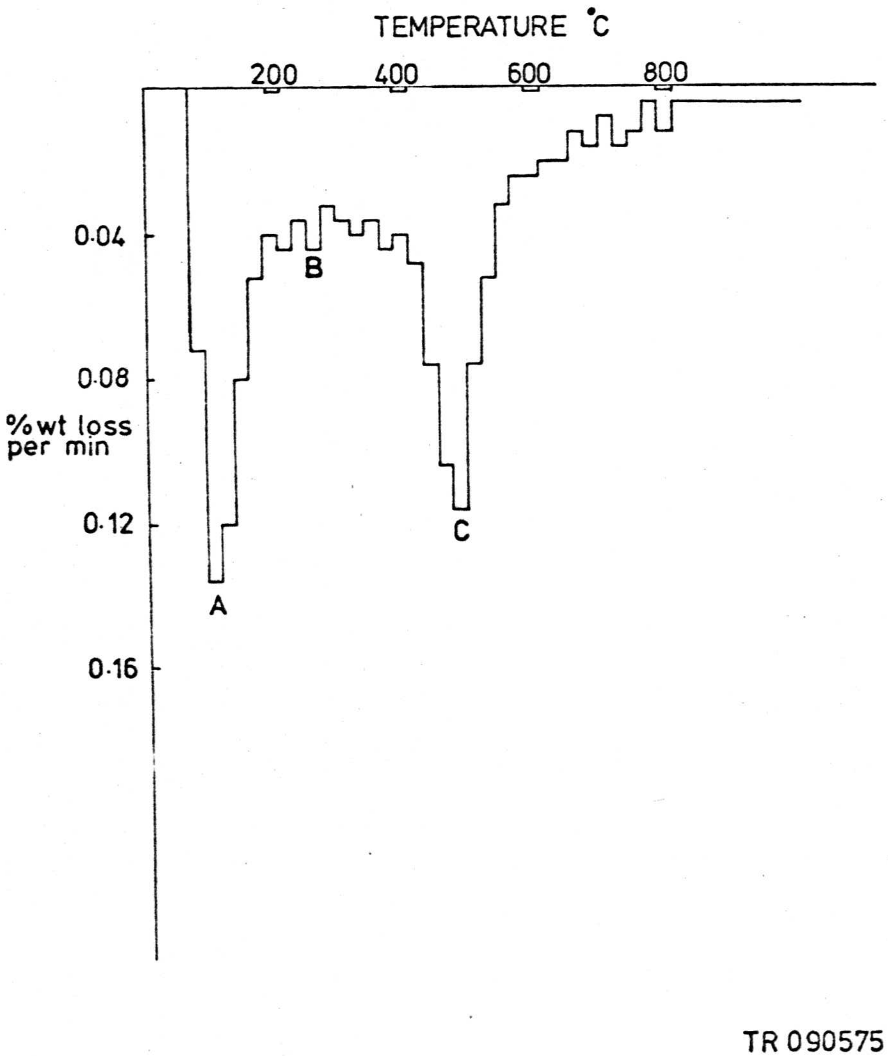
Chart Speed

A comparison was made of the DTG histograms produced after recording the weight losses at different Chart Speeds, 2.5 and 1.25mm per min. Three major peaks can be recognised in Figs: 8.9a and 8.9b, but the Ti appears lower for both peaks B and C at the faster chart speed. Tf is also lower as are the peak temperatures.

Table 8.1. is an analysis of Figs:8.2c; 8.3; 8.7; 8.8 and 8.9. An explanation of this Table is given in Chapter 9 with details relating to Tables 9.1 and A.1.

FIG 8·7 DTG CURVES FOR DIFFERENT STATES OF SUBDIVISION OF THE SAME SAMPLE

a: Denstead Wood [W] Flakes 2-10μ 0.5g



b: Denstead Wood [W] Ground 2-10μ 0.5g

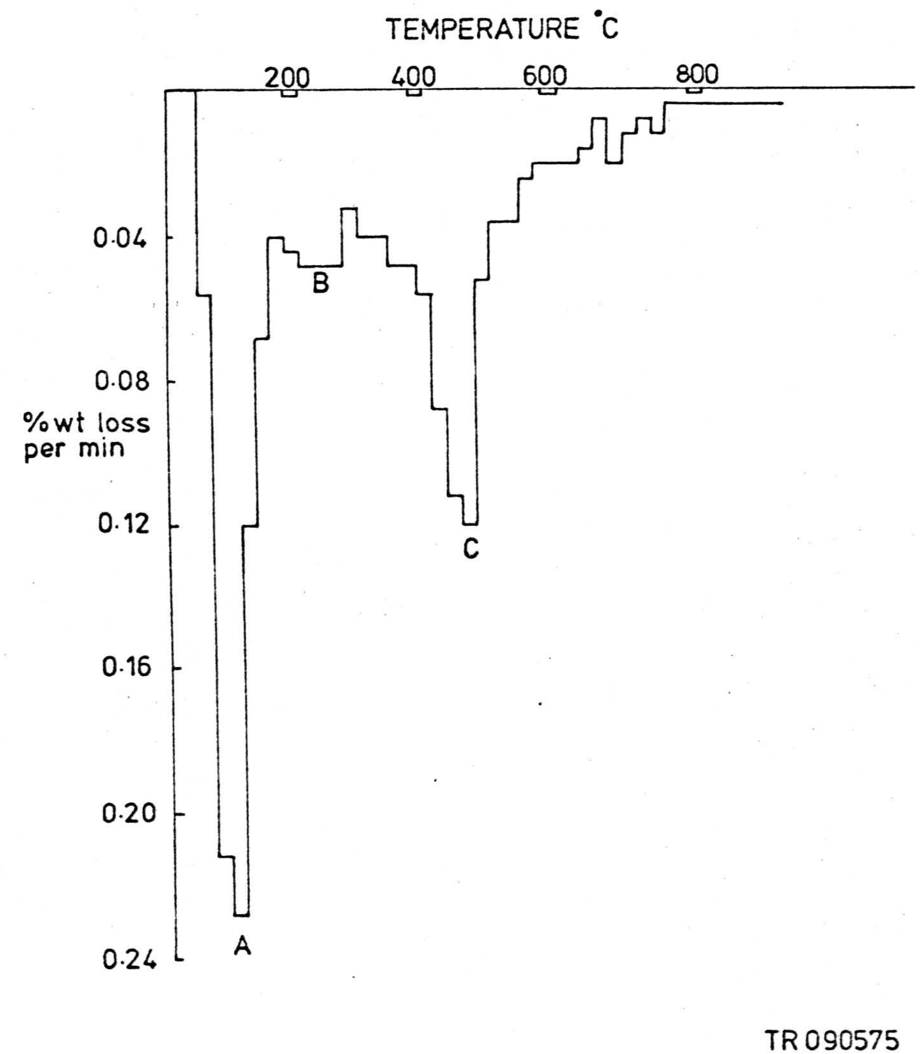


FIG 8·8 DTG CURVES FOR DIFFERENT STATES OF SUBDIVISION OF THE SAME SAMPLE

a: Etton Chalk Pit [Flakes] <2μ 0·5g

b: Etton Chalk Pit [Ground] < 2·0μ 0·5g

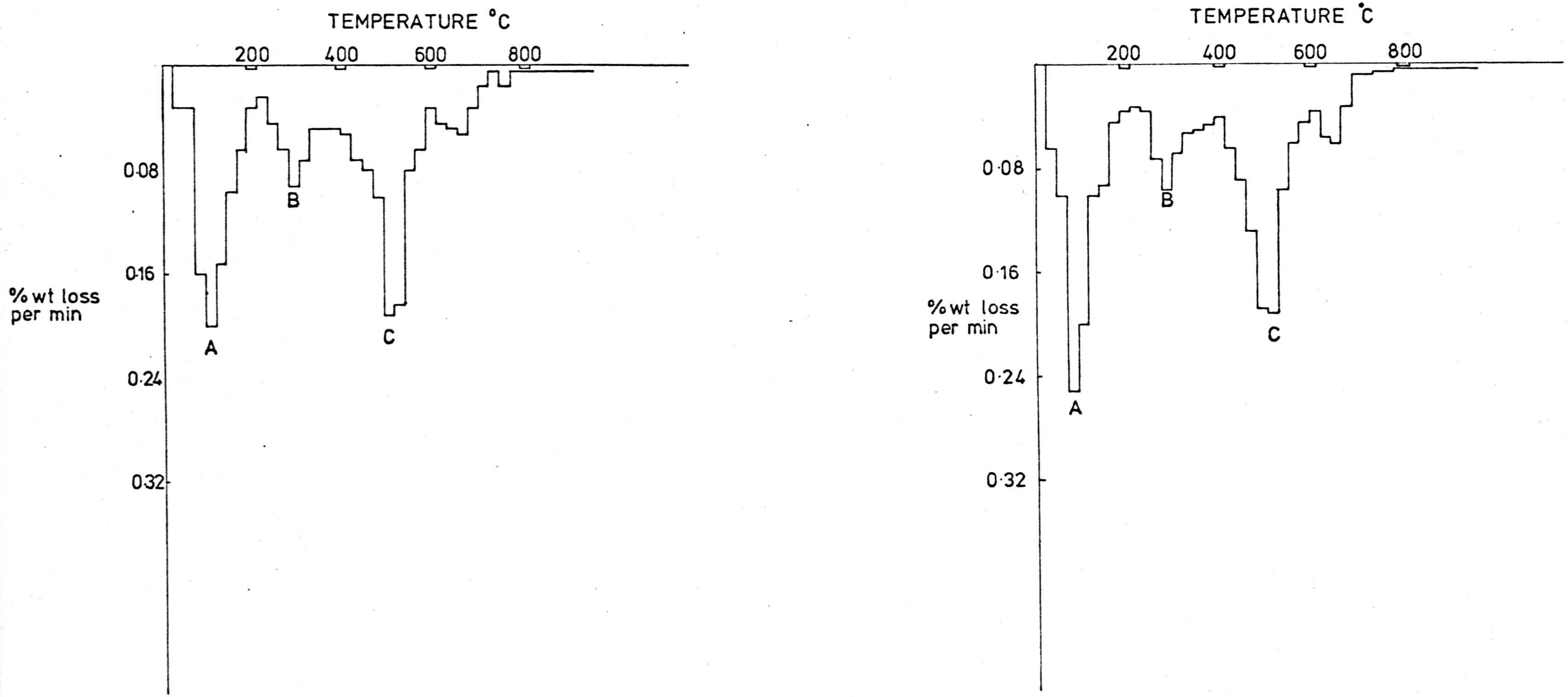


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FIG 8·9 DTG CURVES FOR DIFFERENT CHART SPEEDS OF THE SAME SAMPLE

a: Star Lane Brickworks [0·33m] 2–10μ 0·5g

b: Star Lane Brickworks [0·33m] 2–10μ 0·36g

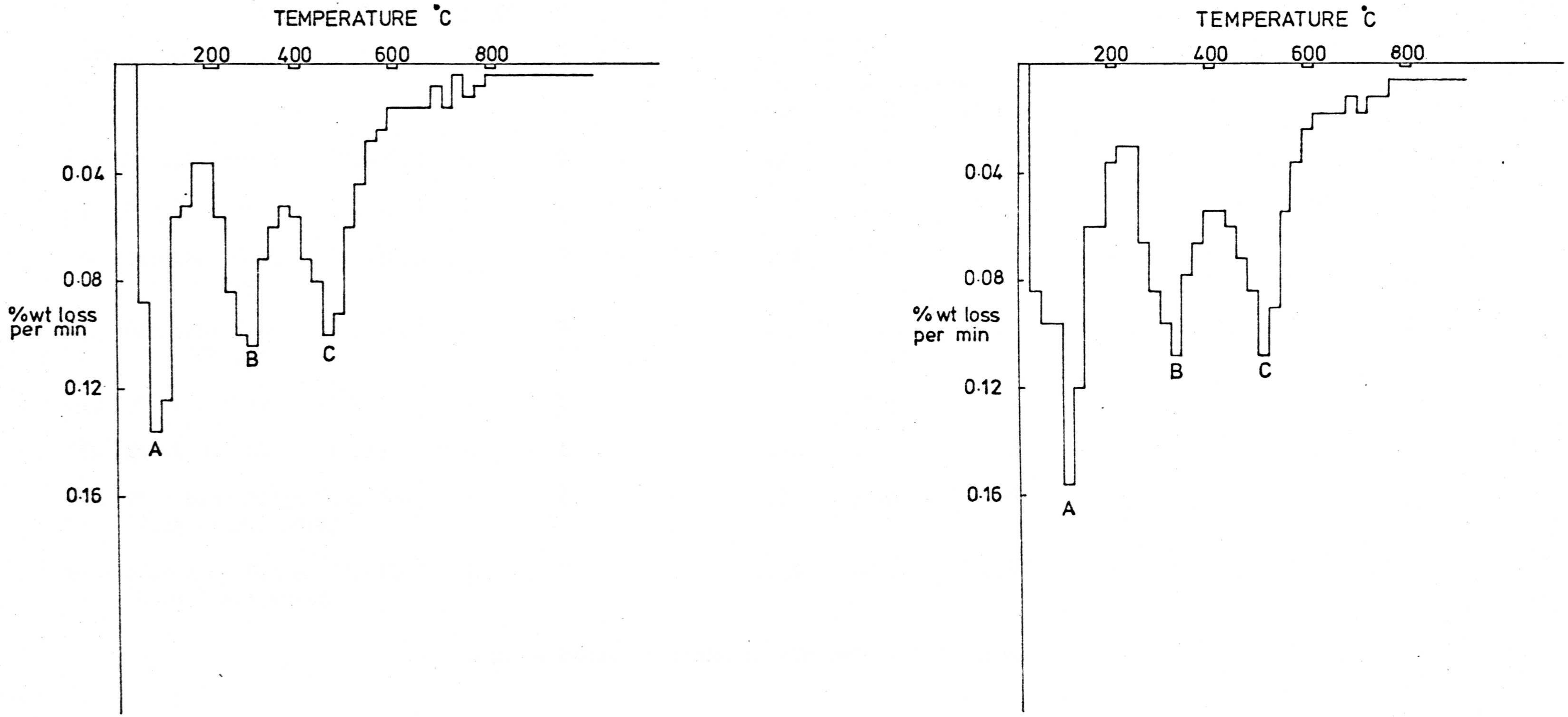


Chart Speed 2·5mm/min TQ 935870

Chart Speed 1·25mm/min TQ 935870

TABLE 8. 1.

ANALYSIS OF DTG HISTOGRAMS 8.2; 8.3; 8.7 – 8.9

Fig. No.	SAMPLE		100–150°C	260–310°C		ILLITE 370 – 610°C %wt loss	wt of illite in mg	% of illite
82b	Pegwell Bay 2	(2.–10u)	A	B	C	3.0	75.0	15.0
83b	Pegwell Bay 1	(2.–10u)	A	B	C	3.47	66.0	17.37
87a	Denstead Wood Flakes	(2.–10u)	A	B	C	3.04	76.0	15.2
87b	Denstead Wood Ground	(2.–10u)	A	B	C	3.0	75.0	15.0
88a	Etton Flakes	(<2u)	A	B	C	5.2	130.0	26.0
88b	Etton Ground	(<2u)	A	B	C	5.36	134.0	26.8
89a	Star Lane 0.33m Fast Chart Speed	(2.–10u)	A	B	C	3.0	75.0	15.0
89b	Star Lane 0.33m Slow Chart Speed	(2.–10u)	A	B	C	3.34	60.0	16.67

Letters refer to peaks on the relevant figures.

CHAPTER NINE

THERMOGRAVIMETRIC STUDIES OF BRITISH LOESS DEPOSITS

CHAPTER NINE

THERMOGRAVIMETRIC STUDIES OF BRITISH LOESS DEPOSITS

The application of thermogravimetric techniques to the study of the mineral and chemical composition of soils has not been extensive, with workers in the field of soil mineralogy preferring to use the well established methods such as X-Ray diffraction and X-Ray fluorescence. Schnitzer et al (1959), indicated that thermogravimetric studies of soils were useful as a preliminary investigation into their constitution and as a support for evidence obtained from other methods of analysis. Thermogravimetric work on loess deposits is limited to a few records; Bidlo (1971) at Budapest, used the technique in conjunction with X-Ray diffractometry to determine the mineral composition of the Dunaujvaros loess deposits, and Punakivi et al (1972), analysed the Mende deposits of Hungary concluding that the mineral composition of the deposits depended upon the degree of weathering that had occurred. An increase in the weathering showed a decrease of the carbonate content, an increase in the clay mineral content. Leach (1975), carried out thermogravimetric studies on Hungarian and Polish loess deposits and attempted to establish quantitative values for the minerals present. The complex mineralogy of the clays prevent exact measurements from being calculated although a value of 2% weight loss for the 500° - 600° peaks was recorded. If this is interpreted as being Illite then a value of 10% can be suggested as the amount present with Illite losing approximately 20% of its weight resulting from the loss of its lattice water. The carbonate content was more readily determined by Leach as the reaction between 650° and 800° is represented by the simple release of CO_2 leaving the elemental oxide as residue.

One of the major problems of thermogravimetry has been that of correlation of the results presented by the various workers in similar fields of study. The variability of laboratory or commercially constructed apparatus has led to variance in the decomposition temperatures* recorded by different authors. Duval (1963), was unable to find any compound which gave the same decomposition temperature on five commercial thermobalances, although the heating conditions were identical.

As a means of overcoming this problem the use of thermal standards has become prominant during the last twenty five years; these are materials which should undergo a weight change reaction at a definable temperature in order that the behaviour of the apparatus may be characterized by the investigator and at the same time allow other workers to understand the results.

McAdie (1971), in a report of the ICTA committee of standardization states the prime requirements for standards as being:-

i) to provide a common basis for relating independently aquired data;

ii) to provide the means for comparing and calibrating all available instrumentation regardless of design;

iii) to provide the means for relating thermoanalytical data to physical and chemical properties determined by conventional

* Decomposition temperature: In thermogravitmetry this term is a misnomer. Although a particular temperature may be the lowest at which the start of a weight change can be observed with a certain apparatus under a given set of conditions, the term ' procedural decomposition temperature ' is generally used in preference to decomposition temperature.

isothermal procedures.

Two further requirements for standards exist:-

iv) to define good practice, both in experimentation and reporting, so that the information obtained and communicated is of maximum value.

v) to promote ease of communication through uniform nomenclature and data presentation.

These last two requirements are considered below along with the presentation of the results of this study.

Several compounds have been used as thermal standards of which calcium oxalate monohydrate (COM) and potassium hydrogen phthalate (PHP) are probably the two most reported. Duval (1951), used COM when adjusting thermobalances after they had been assembled, cleaned or repaired. Wilson (1959), suggests that the extremities of the plateaux of its thermogravimetric curve can be used as temperature calibration points, but Keattch and Dollimore (1975 p25), regard this as unwise as the points are not dependant purely on the sample. In Fig.8.6 (from Simons et al 1964), the effect of crucible shape and composition was shown on the TG curve for COM. Having shown the effect of several variables Simons et al (op cit) conclude that this compound is ideally suited for demonstrating many of the factors that effect the quality of thermogravimetric measurements and if heated under carefully controlled conditions it can be used as a standard for judging the performance of a thermobalance. Forsyth et al (1965), in an aid to the study of heavy element oxalates used the DTG peak temperatures as a critical reference point whereas previous workers had used the procedural decomposition temperatures of the TG curve.

Keattch (1967), in a study of 26 compounds considered as thermal standards, included PHP, which he found to show agreement for reference temperatures of 240° - 250° and 365° - 370°. Other reference temperatures at 565° and 670° Keattch could not recommend because of the lack of explanation of their divergence other than that the samples were obtained from different suppliers. Earlier work reported by Wendlandt (1964 p106), in his review of four different investigations concerning the drying and decomposition temperatures of PHP emphasised some of the hazards involved in using this as a standard. Four different results were obtained, Dupois et al (1951), first reported that the decomposition of PHP began at 172°, Duval in a later study (1955), found a decomposition temperature of 240° at 150°/hour heating rate, and 236° at 300°/hour. Belcher et al (1960), recorded the compound as decomposing at 200° whilst Newkirk et al (1962), reported a procedural decomposition temperature at about 260°.

Four major reactions take place during the heating of PHP;

i) the volatilization of water and phthalic anhydride and the formation of a residue of dipotassium phthalate $C_8H_4O_4K_2$;

ii) decomposition of the latter compound to form potassium carbonate and carbonaceous material;

iii) the carbonaceous material loses weight slowly and finally burns giving a residue of K_2CO_3;

iv) potassium carbonate decomposes with the evolution of carbon dioxide and K_2O is formed which reacts with the crucible if it is porcelain or quartz.

Smalley et al (1976), have recently observed six peaks whilst heating PHP in a Stanton-Redcroft TR02 deflection balance. The heating rate used for these experiments was recorded as 42 five minute time periods from room temperature to 1000°C, a 980° rise in 210 minutes, a rate of 4.7°/ minute or 282°/ hour in an air atmosphere at atmospheric pressure and temperature at the commencement of the test. The tests were carried out using both 'vitreosil ' transluscent silica and ' Royal Worcester ' porcelain crucibles.

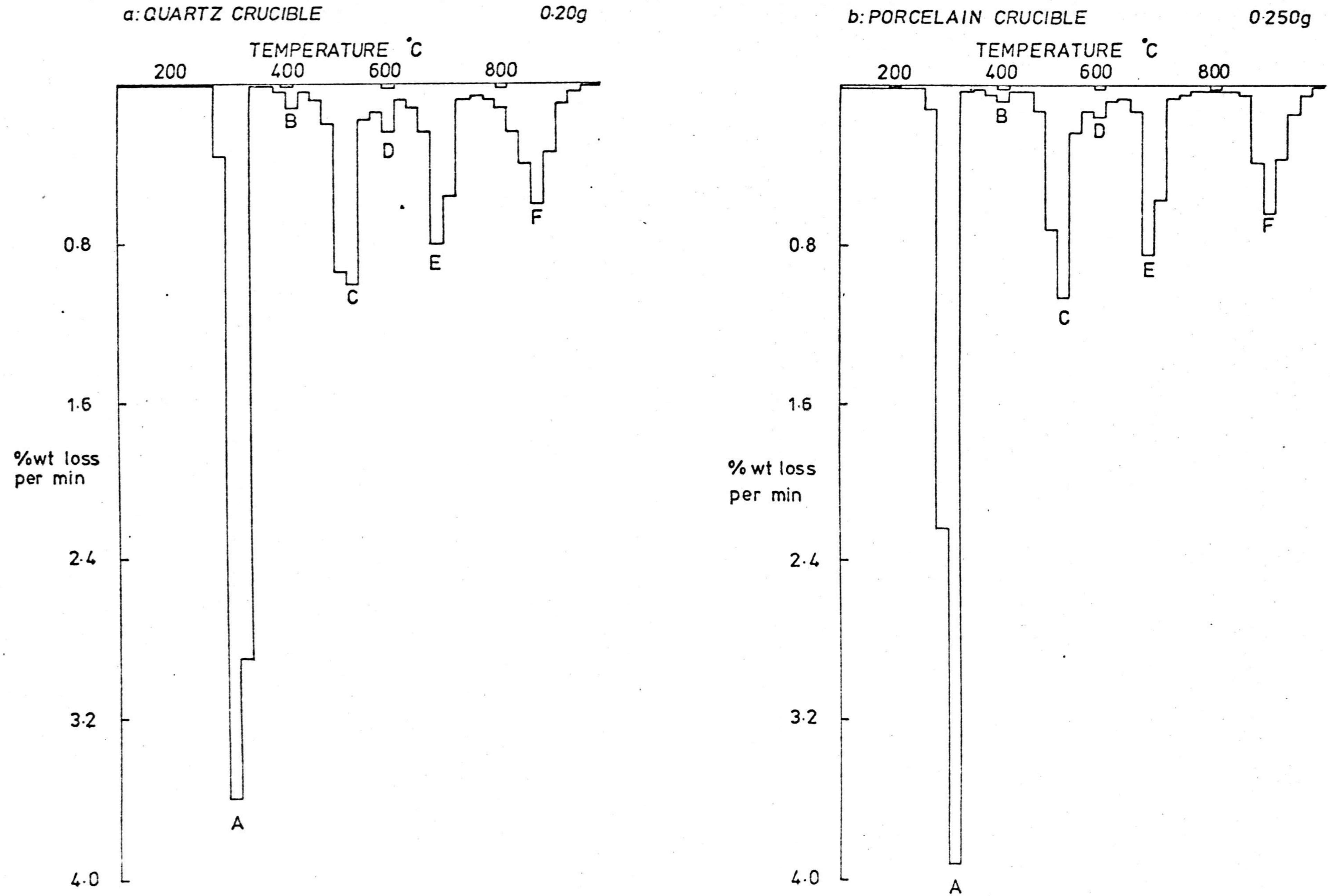
The six peaks are shown in Figs: 9.1a and 9.1b these are labelled A - F for ease of reference.

Reaction A, the transition from $C_8H_5O_4K$ to $C_8H_4O_4K_2$ is extremely rapid starting slowly and ending abruptly suggesting that the end of the reaction interval would be a more suitable reference point than the beginning as used by Keattch (1967 op cit), although this point varies more with variation of the heating rate. The start temperature in Fig.9.1 is 260°, as observed by Newkirk et al (1962 op cit). The peak temperature was judged to be 300° $\pm$ 10°. Reaction C, the transition to potassium carbonate and carbonaceous material shows a well defined peak at 510° and reaction E represents the removal of carbonaceous material with a peak temperature of 680° - 700°. Reaction F is the breakdown into K_2O and CO_2. Peak B is more significant that its size suggests as this defines the reaction interval (with a starting temperature of 370°) which Keattch (1967 op cit), lists as a reference temperature. Peak D appears to correspond to the 565° temperature which Keattch was not able to obtain.

Smalley et al conclude from their results that as PHP is readily available and is already in use as a pH standard that it should be established as a TG standard.

Stewart (1969), considered a different approach to calibration by using materials that had known reproducible temperature transitions to give direct measurement of the temperature rather

FIG 9.1 DTG HISTOGRAMS FOR PHP USING QUARTZ AND PORCELAIN CRUCIBLES



After Smalley, Lill, Bentley and Wood 1976 than measure weight loss points. Three distinct advantages to this method were stated by Stewart to be: i) the temperature is actually measured and plotted in most commercial instruments; ii) temperature changes not asscoiated with weight loss (change to vapour state) could be used to calibrate the temperature axis; thus eliminating the need for atmosphere control; iii) the same materials selected for DTA calibration could be used for TG calibration.

British Loess Deposits

Samples of British loess deposits have been analysed thermogravimetrically using the same thermobalance as that used by Smalley et al (1976 op cit), namely an unmodified Stanton-Redcroft TR02 deflection balance with a full scale weight loss of 20mg and a total weight loss of 180mg being possible without rebalancing. The thermocouple is a platinum/ 13% rhodium platinum couple, each wire being 0.5mm in diameter located adjacent to but outside the sample containing crucible. The thermal lag at low temperature has been measured using the method outlined by Newkirk (1960), with a drop of water; a constant weight was reached at 122^{o}, exactly the same as that achieved by Newkirk. A heating rate of 4.7^{o} per minute, as in the PHP experiments described above, was maintained and the sample holders for all the samples were of ' Royal Worcester ' porcelain with a diameter of 29mm, a depth of 19mm and a volume of 8cc.

The samples were analysed on the basis of grain size and a knowledge of the amount of primary minerals (quartz and feldspar mainly) in the fine fraction was required. Only samples of particles less than 75µ diameter (passing a 200 mesh sieve) were used, those particles greater than this size were assumed to be mainly of quartz. Further subdivision of the samples was carried out by sedimentation through 500cc glass cylinders on the basis of Stoke's Law. The less than 10μ and less than 2μ fractions were obtained and from the < 2μ fraction a split into < 0.2μ and 0.2μ - 2.0μ was possible with some of the samples by using a MSE centrifuge. In several cases the < 0.2μ appeared to be comprised totally of colloidal material or of insufficient quantity for thermogravimetric analysis, where this occurred the 2u fraction only was used.

The Stoke's law principle is basically one of velocity of spherical particles settling through a vertical path in a still fluid. Not all the particles are spherical; because of this slower rates of settlement occur. However, for the purpose of separating the finer fractions it was assumed that all the larger particles were spherical and only the finer particles would remain in suspension. The rate of settlement of the particles was calculated from :-

$$r^2 = \frac{0.81h}{t}$$

where:-

r = the radius of the largest particles required to remain in suspension.

h = the height through which the particles fall.

t = time.

From the thermogravimetric curve the DTG curve was obtained for each sample. The five minute time periods proved to be useful for plotting the histograms, this represents a 23.5° temperature range each of which were plotted against the weight loss for that period. In accordance with the ICTA recommendations, outlined in

Chapter 8, the temperature is recorded on the abscissa increasing from left to right and the % weight loss per minute is recorded on the ordinate. In all cases only weight losses were recorded, these are presented as a weight decrease downwards. At the top of each DTG curve the sample name is given along with the size fraction and quantity used. In the bottom right hand corner of the graph the national grid reference is given, (except in the case of the New Zealand samples).

Results and Discussion

In the case of the grain size analysese reported in Chapter 6 the results from all the sites were compared with a Pegwell Bay standard, which, because of the prominence of this site in terms of British loess, was considered the one by which to compare the others. In the case of thermogravimetric studies it does not appear relevent to use one sample as a standard although strong similarities and differences between the Pegwell Bay and other deposits are worth recording. A comparison of the mineralogy of the separate fractions from the same site appears more appropriate because of the influence of the mineralogy on the engineering properties. The presence of non-lattice structured minerals in the fine fractions appears to be important in accounting for the low density, high porosity and high compressability of loess material that in many circumstances has presented foundation problems to engineers.

Several thermal events may be recognised on the DTG curve. Between 100° and 150° any loosely held water in the sample is driven off and in many cases this is the largest peak but is of little significance. Most of the samples were obtained free of organic matter as any preliminary treatment with hydrogen peroxide may have left a residue. If organic material was present a peak at 260° - 310° is indicated. The removal of the hydroxyl ion from the clay mineral gives a thermal event between 370° and 610° generally peaking at about 500°. Bidlo (1971 op cit) points out the problems of determining the amount of quartz in a sample where the clay content is high with the clay peaks superimposing on the polymorphous transformation of quartz at 575°C. From the X-Ray diffraction results the clay mineral in all the samples is believed to be illite, the amount present is calculated from the approximate known weight loss on heating. Kerr (1959), gives the following as the formula for illite:-

$$K\,Al_2(OH)_2\;\;AlSi_3(O,OH_{10})$$

A weight loss due to loss of water would represent approximately 20% of the weight of illite and therefore an approximation of the total weight of illite in a sample can be inferred.
Liptay (1971 - 74),records the Calcium Carbonate peaks on the DTG curve as occurring at 760°C and 920°C, however occasionally peaks as low as 650°C have been recorded for several samples and the calcium carbonate content is substantiated by Calcimetry (Table 9.2) and XRD analysis. Any small weight loss that may occur at the higher temperature may be masked by the disruption of illite (Deer, Howie and Zussman, 1966, p.262).

Calcium carbonate looses 44% of its weight as a result of the release of carbon dioxide.
A representative sample of the results obtained are shown in Figs: 9.2 - 9.12. Table 9.1 gives a brief summary of the histograms in terms of peaks present, the weight losses represented by water within the illite and carbon dioxide release along with calculated percentages of illite and calcium carbonate.

Most of the remaining material is represented by the inert primary minerals, mainly quartz but also the feldspars.

Figs: 9.2 and 9.3 compare the coarse and fine fractions of samples from two north Kent sites, Pegwell Bay and Denstead Wood. The illite is greatest in the< 2u analysis as expected but this represents less than 30% in each case, suggesting that the primary minerals constitute 70 - 80% of the ' clay fraction '. A similar comparison can be made with the loess deposits from New Zealand, Figs; 9.10 and 9.12 where the clay mineral is only 25% of the fine fractions. The Aokautere Ash, Fig.9.11 has a higher clay mineral content in both the <75u (12.6%) and the <2u (37.0%) fractions, in both cases approximately 50% more than in each of the loesses.

The effects of the leaching of calcium carbonate is shown by comparing the two histograms in each of the Figs: 9.4 - 9.6. Samples of similar particle size distribution from different depths at Allington and Cherry Orchard Lane are shown. In each size fraction the clay mineral contents are comparable for the different horizons but the lower horizon has a substantial carbonate content which is not measurable on the DTG histogram for the upper horizons. Fig.9.7 is from the lower horizon at Star Lane. In this layer the clay mineral percentage in the <2u fraction is twice that of the 2 - 10μ fraction but the carbonate is not as rich in the finer fraction. A similar feature is also displayed in Fig.9.8 from Hornhill Top, north western part of the section. The clay mineral content from this locality may be compared with that of other parts of the section, Figs:A.16 and A.17, but only here is there any recorded carbonate. This was also borne out by the XRD results in Chapter 7 and as suggested there may be the effect of the local drainage pattern on the

Chalk.

The involutions in the Hessle drift show a clay content of 15.5% (Fig.9.9a), which is much higher than similar features at Huggate (Fig.9.9b), Hornhill Top (Fig.A.16c and Eppleworth (Fig.A.18b).

The data given on Table 8.1 is similar to that given here, Table 9.1 referring to several of the DTG histograms given in Chapter 8 as illustrations of the problems occurring in thermogravimetry. The DTG results are completed in the Appendix with Table A.1 summarizing the thermal events for each histogram.

A close analysis of Tables 8.1, 9.1 and A.1 shows that the clay mineral content rarely exceeds 30% in the finest fractions and that the primary minerals are the most prominant. Calcium Carbonate may occur in any deposit although the effect of leaching restricts this at several sites to the lower horizons.

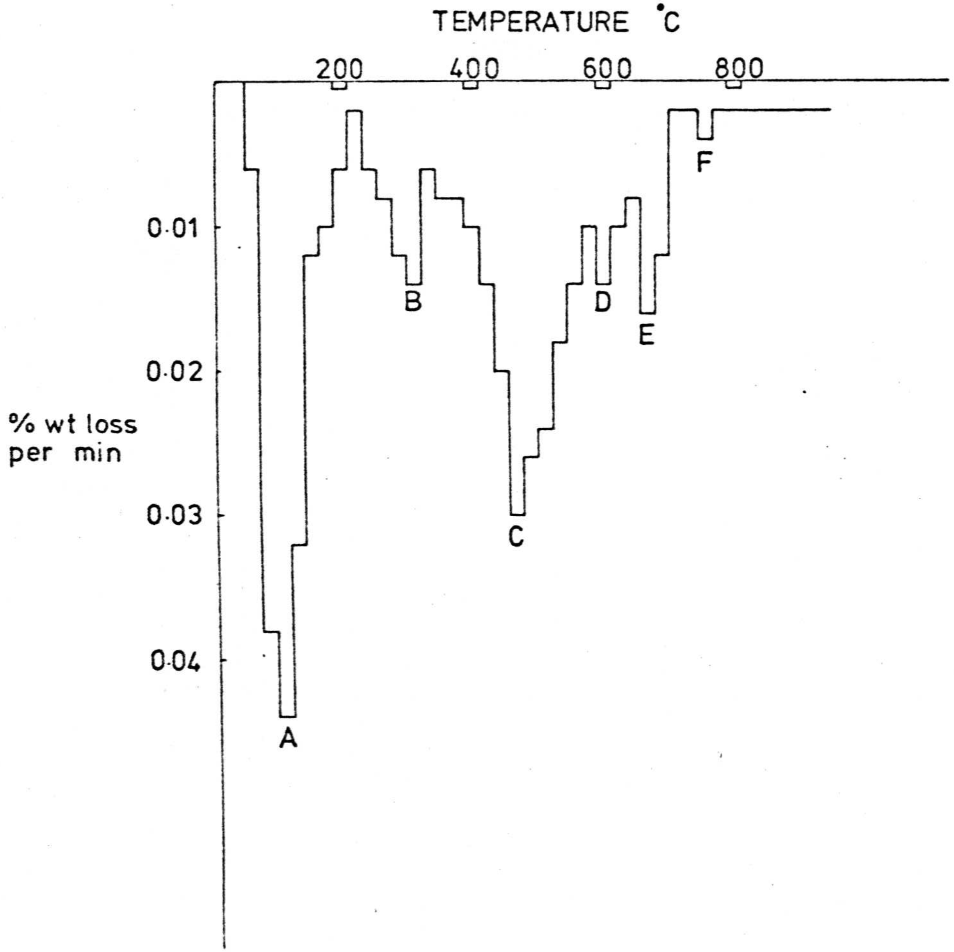
Table 9.2 compares the Calcium Carbonate values that have been obtained from thermogravimetry with that using a Collins Calcimeter, for several of the samples. Samples not producing any value by either method are not presented here. Most of the results are reasonable comparable although a few show a substantial discrepancy.

Figures 9.2 to 9.12

These are representative samples of several of the DTG histograms of deposits from various sites. An analysis of the peaks is given on Table 9.1.

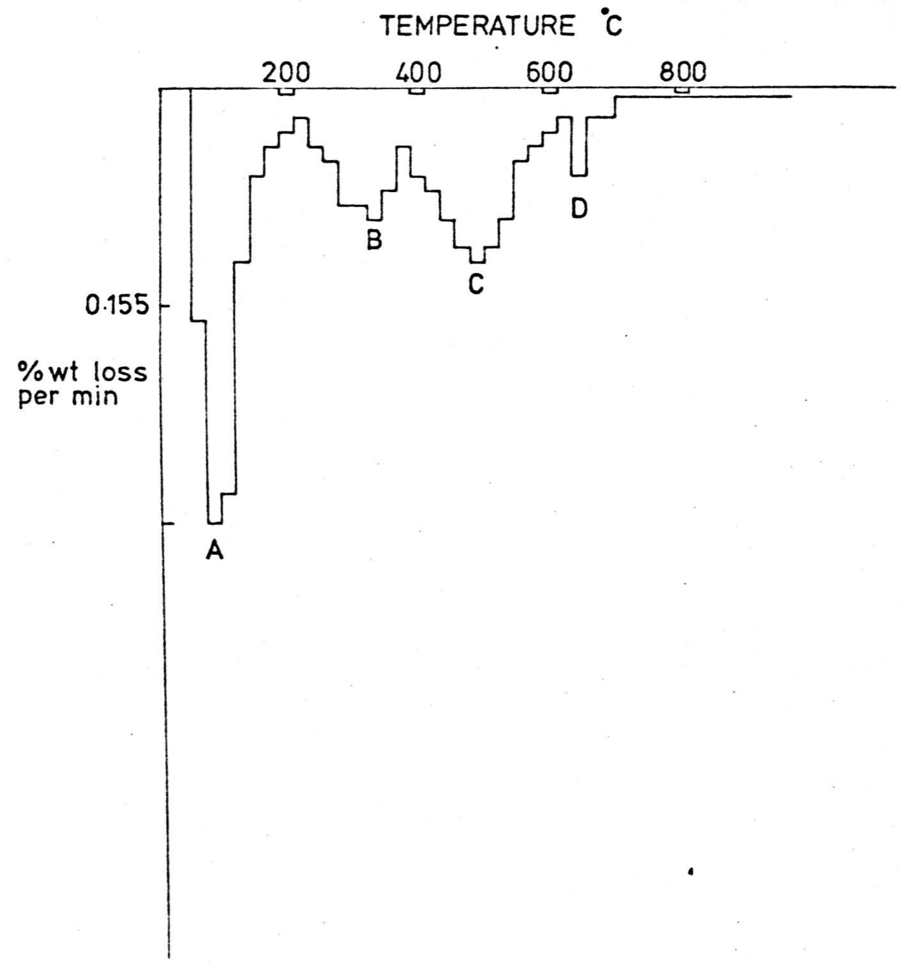
FIG 9.2

a: Pegwell Bay [1] <75μ 1.0g



TR 350642

b: Pegwell Bay [1] <2μ 0.193g

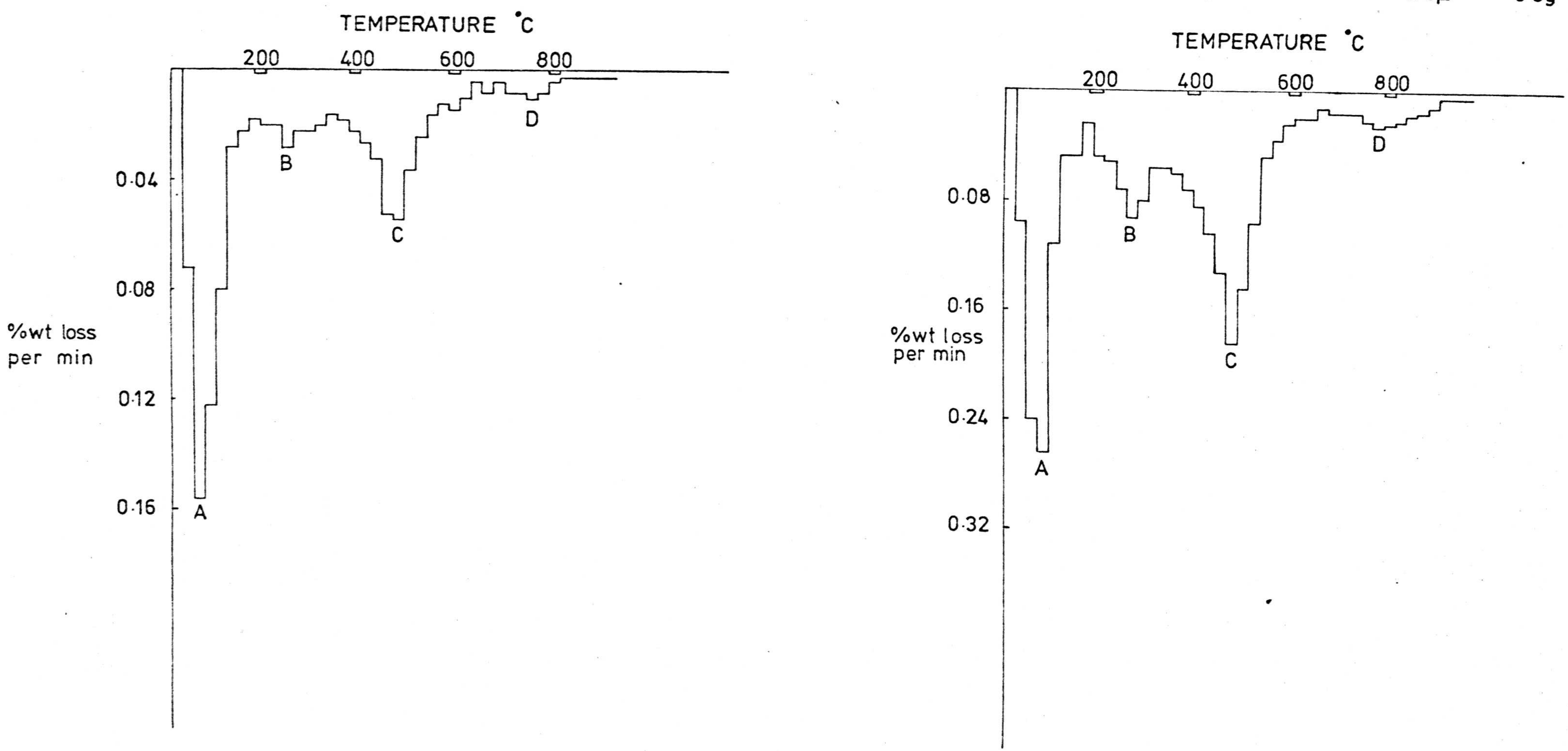


TR 350642

FIG 9·3

a: Denstead Wood [W] <75μ 1·0g

b: Denstead Wood [W] <2·0μ 0·5g



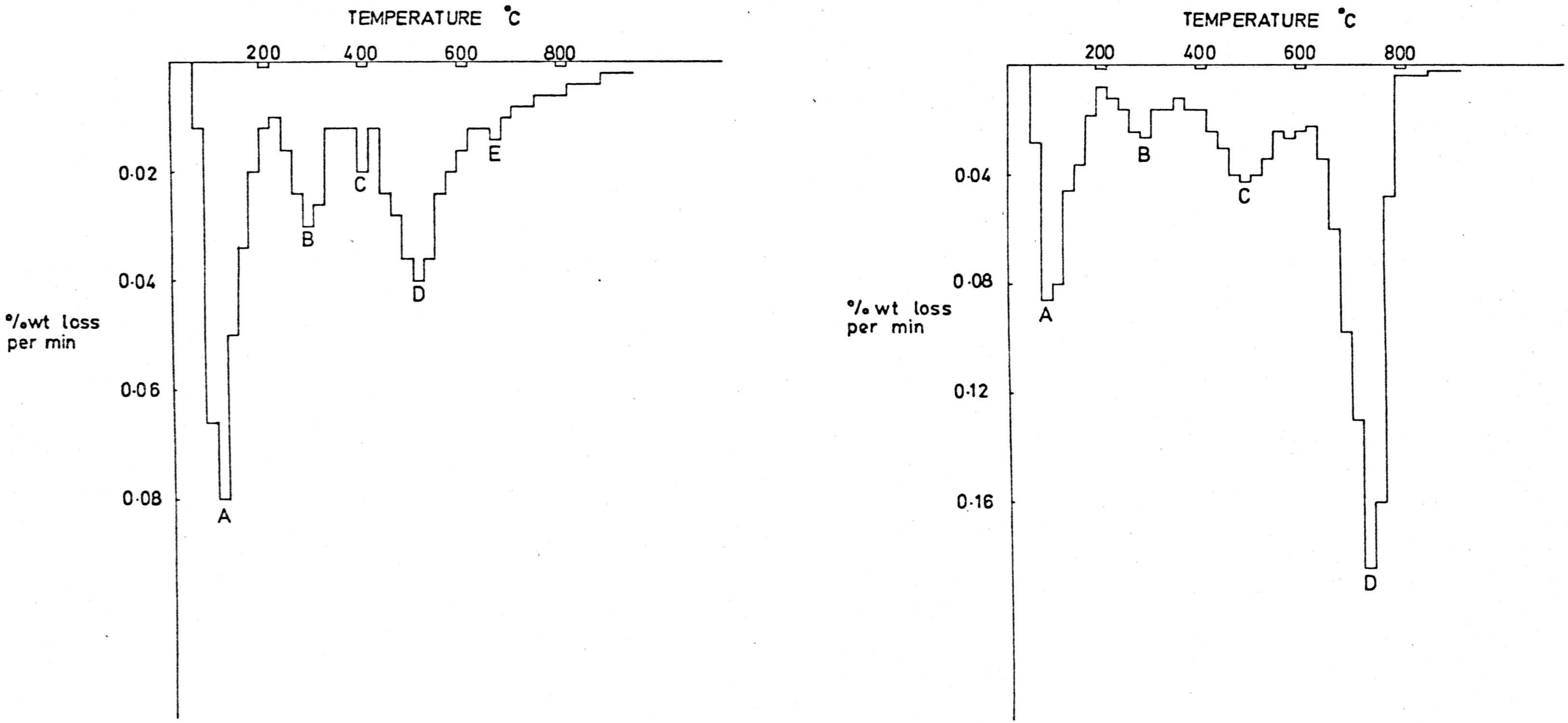
TR 090575

TR 090575

FIG 9.4

a: Allington [Quarry Gulls] 1·5m depth   < 75μ   1·0g

b: Allington [Quarry Gulls] 3·0m depth   < 75μ   1·0g

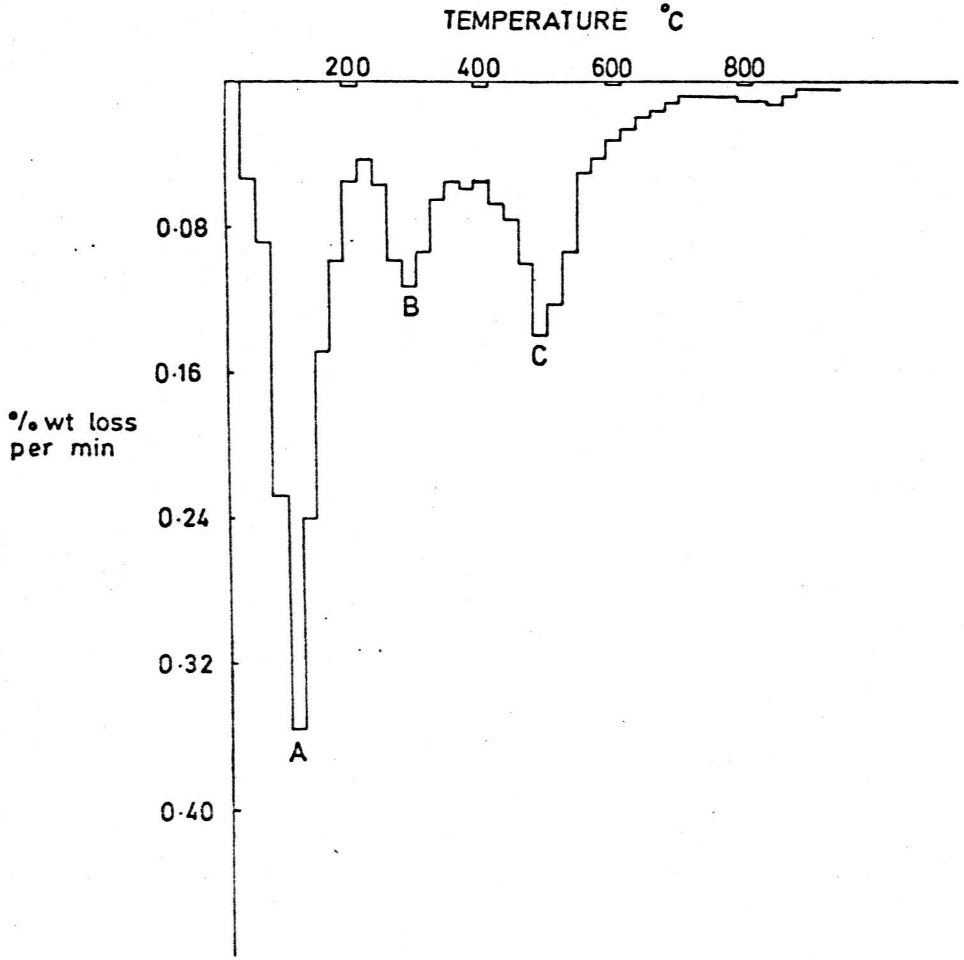


TQ 741577

TQ 741577

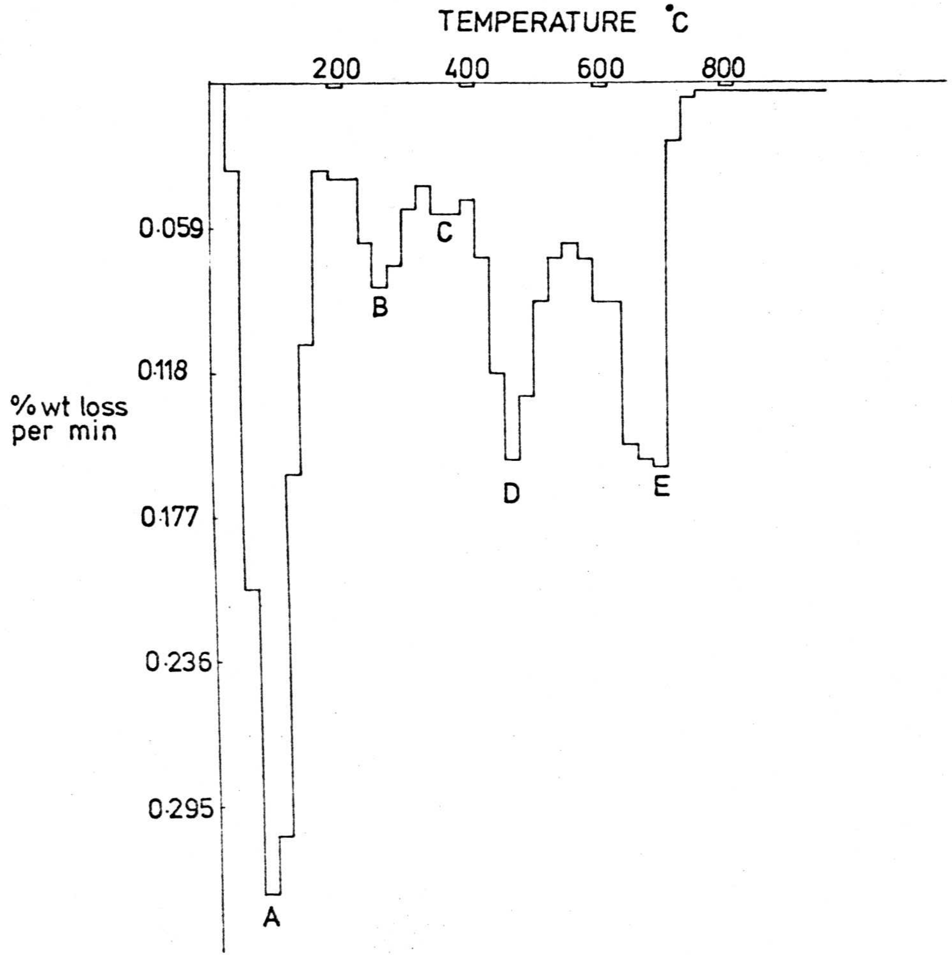
FIG 9.5

a: Allington [Quarry Gulls] 1.5m depth <2.0μ 0.985g



TQ 741577

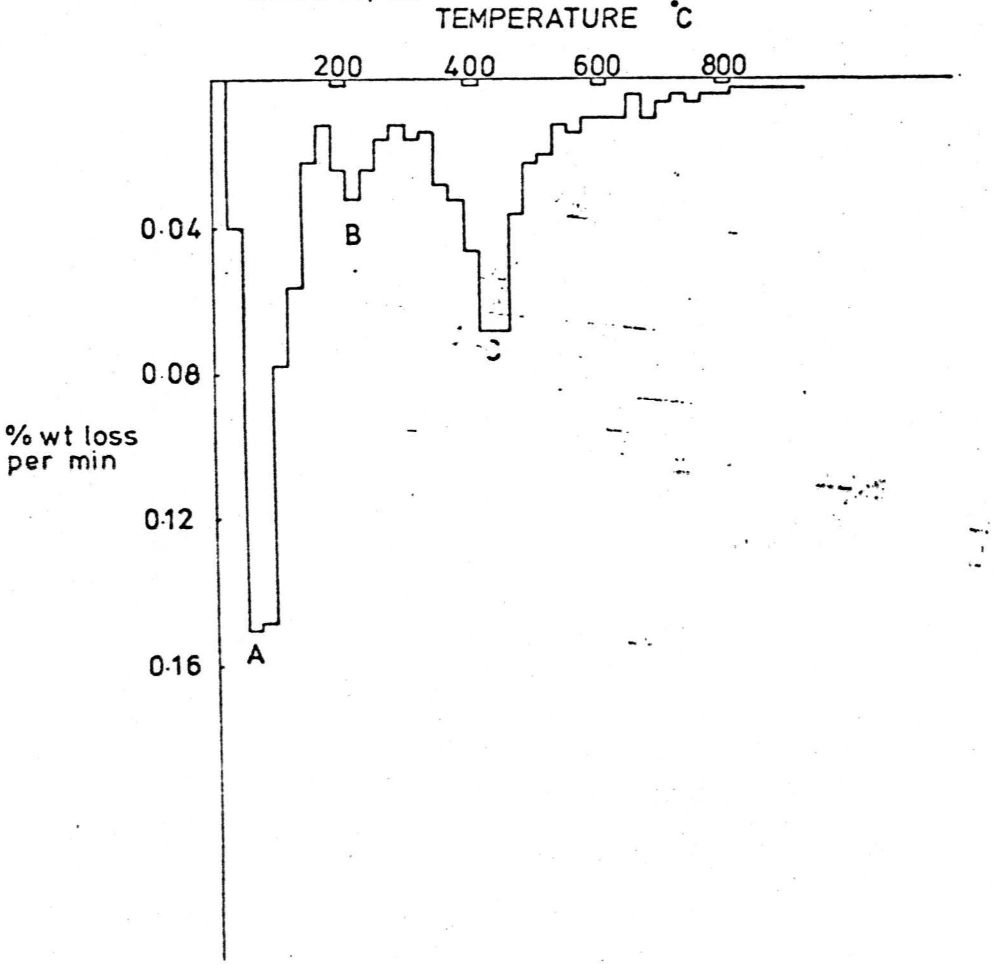
b: Allington [Quarry Gulls] 3.0m depth <2.0μ 0.685g



TQ 741577

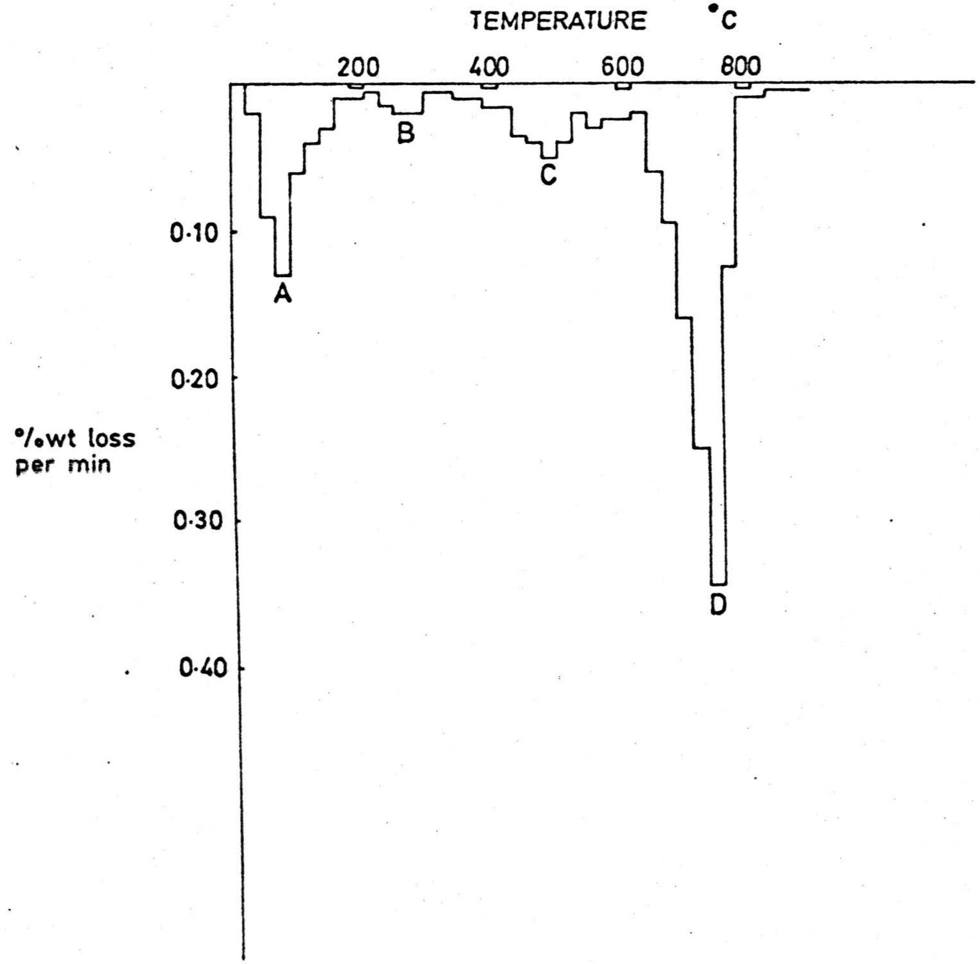
Fig 9.6

a: Cherry Orchard Lane Brickworks [0.5m depth] <75μ 1.0g



TQ 857898

b: Cherry Orchard Lane Brickworks [2.0m depth] <75μ 0.39g



TQ 857898

FIG 9.7

a: Star Lane Brickworks [1·55 m] 2–10µ 0·5g

b: Star Lane Brickworks [1·55 m] <2·0µ 0·5g

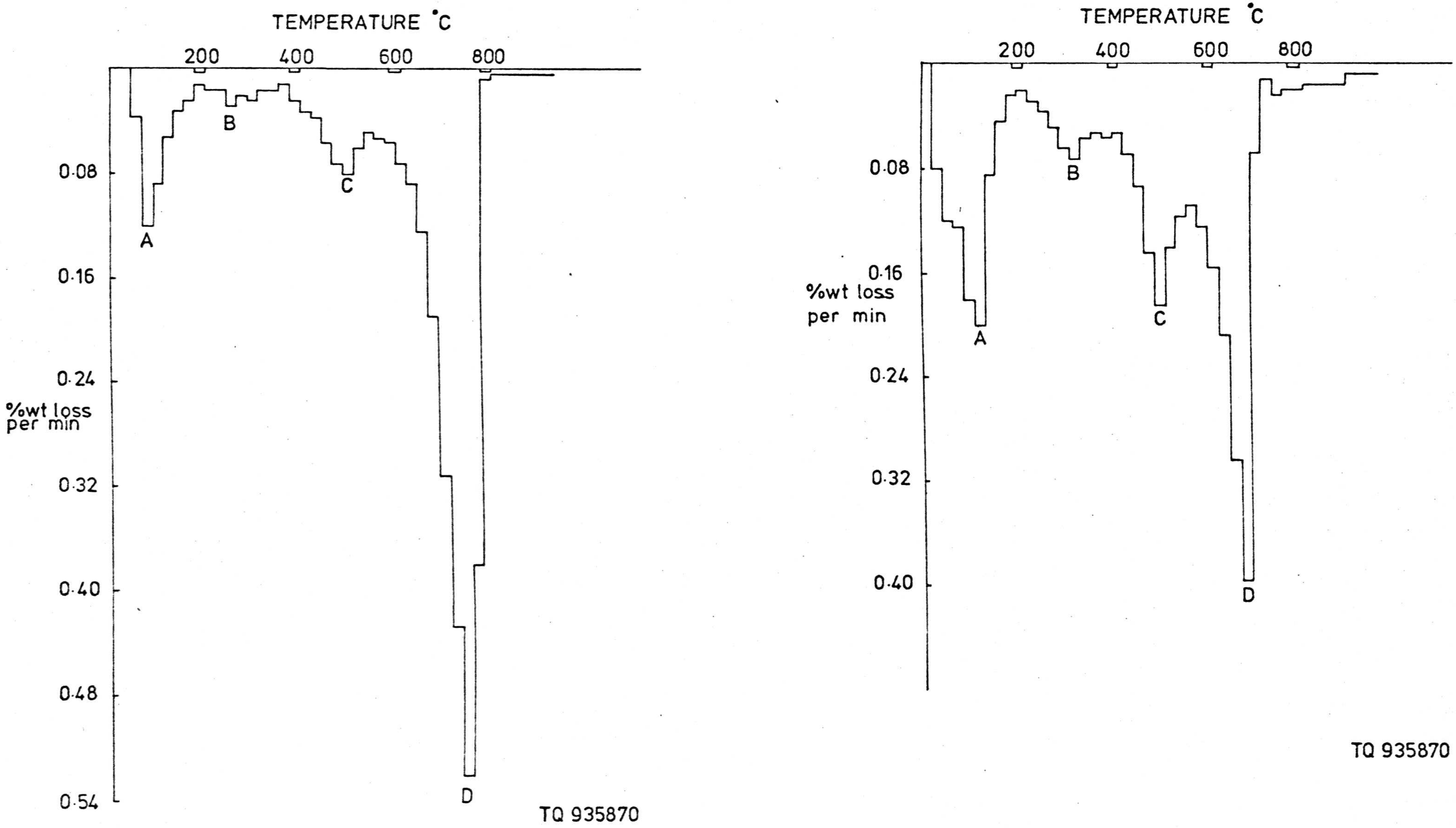


FIG 9.8

a: Hornhill Top [NW] 2–10µ 0.5g

b: Hornhill Top [NW] < 2.0µ 0.5g

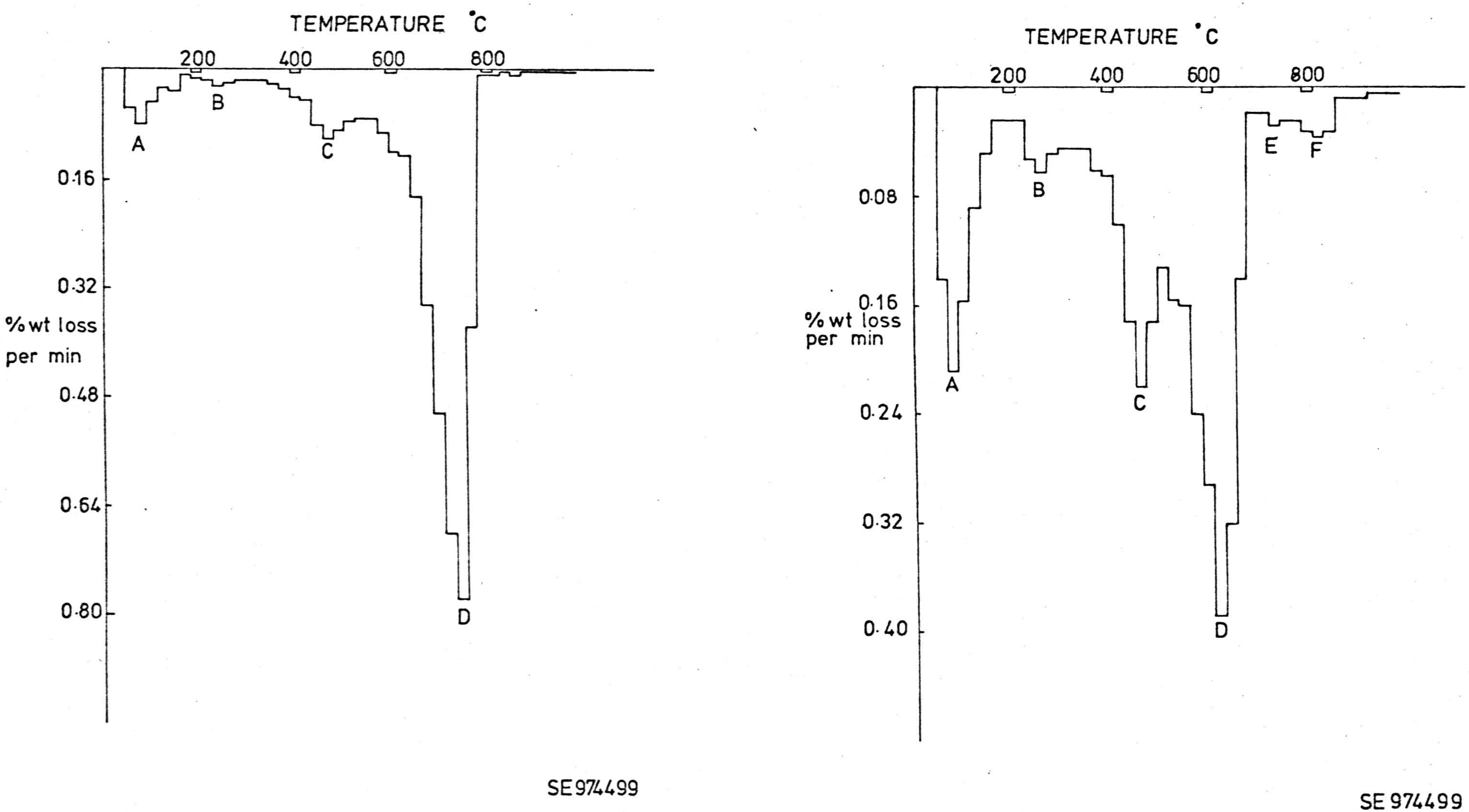
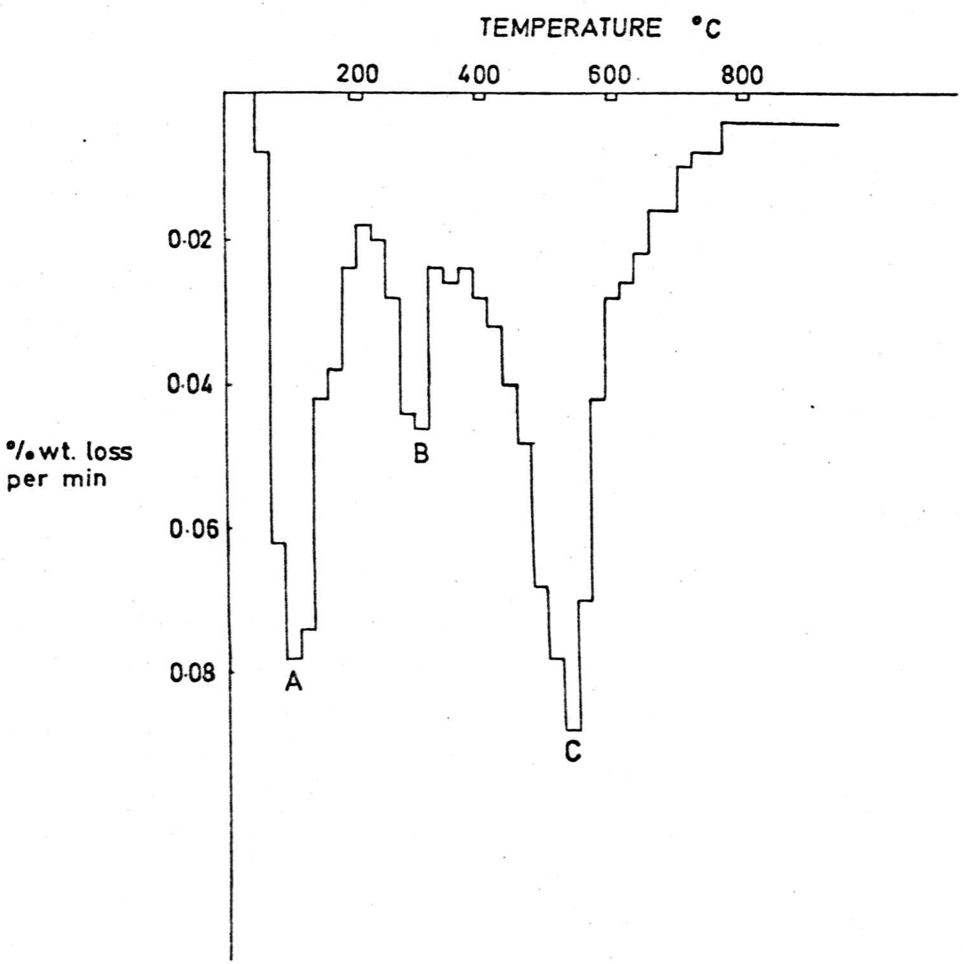


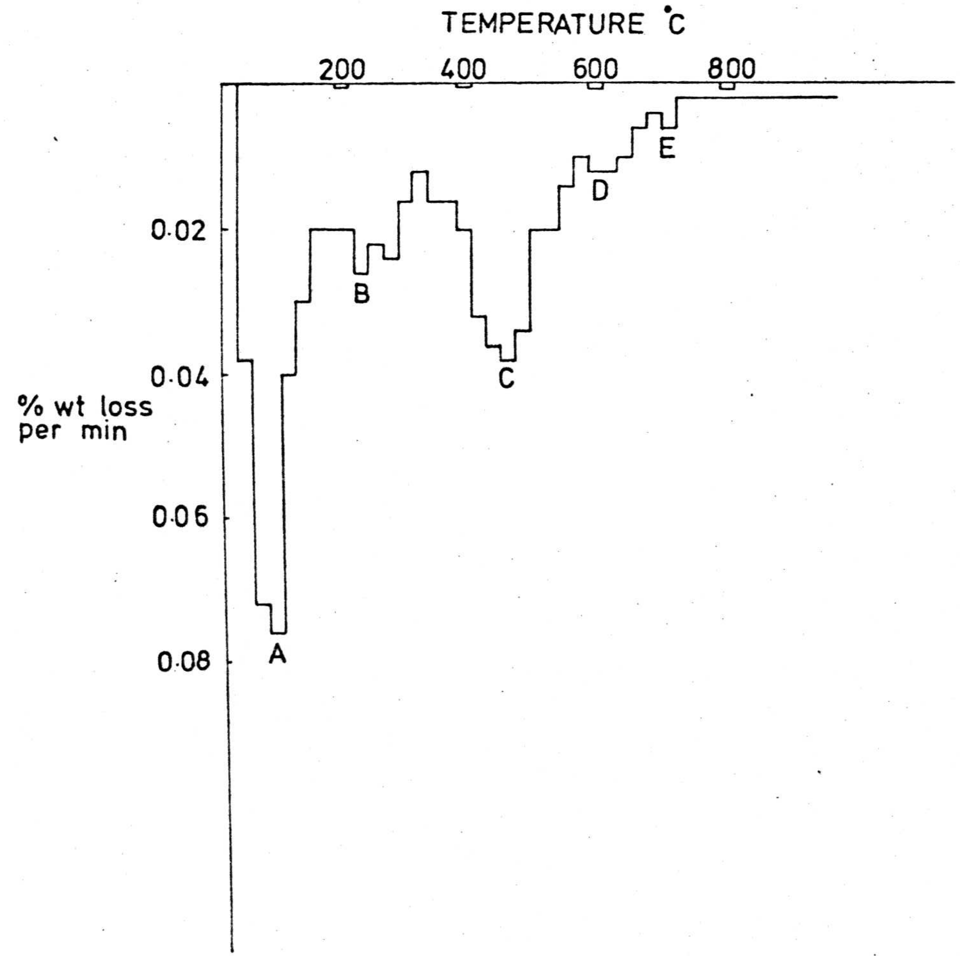
FIG 9.9

a: Drift at Hessle <75µ 1.0g



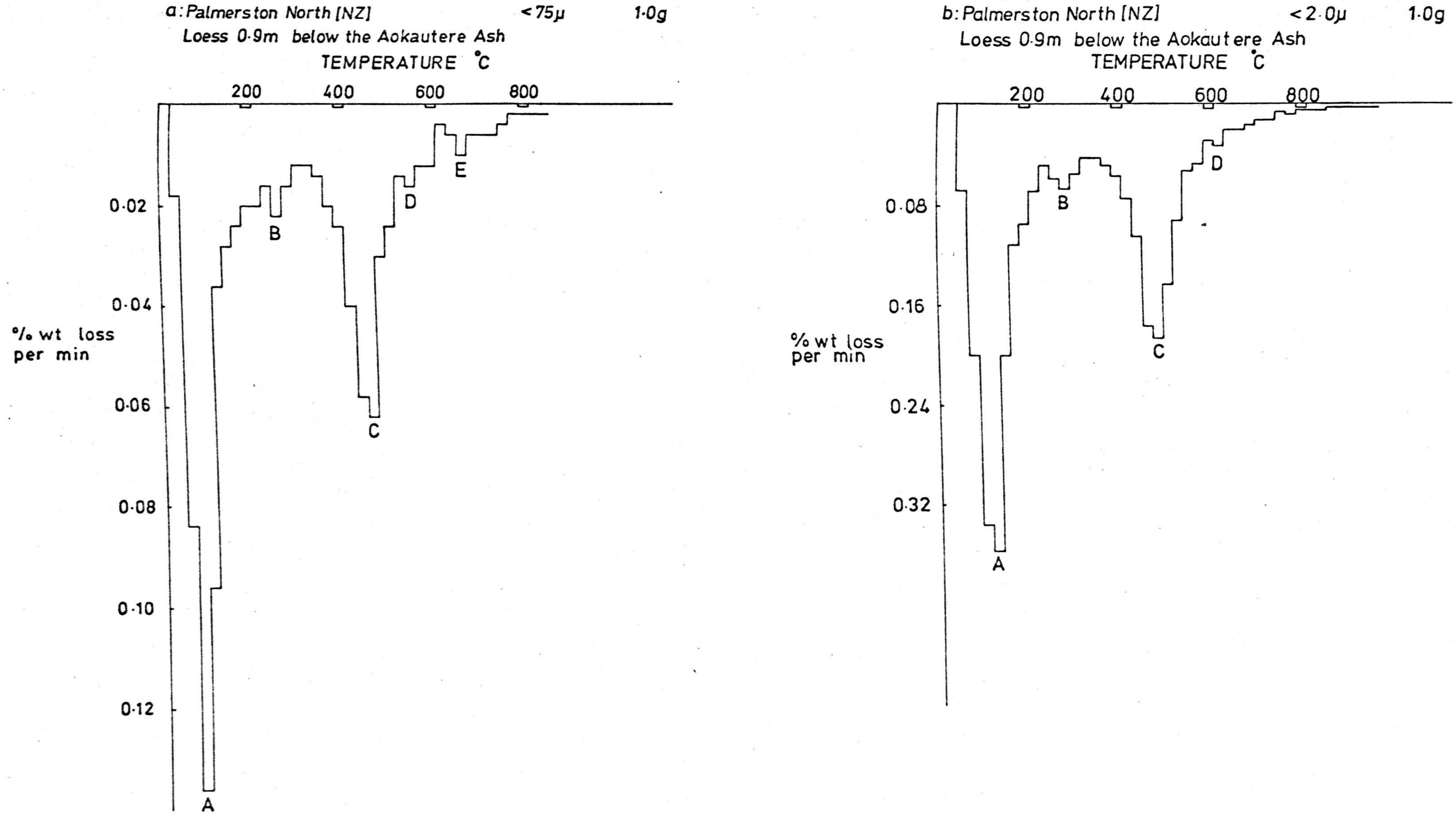
TA 013264

b: Huggate [A] <75µ 1.0g



SE 876548

FIG 9.10



a: Palmerston North [NZ] <75μ 1·0g
Loess 0·9m below the Aokautere Ash
TEMPERATURE °C
200
400
600
800
0·02
0·04
0·06
0·08
0·10
0·12
%wt loss per min
A
B
C
D
E
b: Palmerston North [NZ] <2·0μ 1·0g
Loess 0·9m below the Aokautere Ash
TEMPERATURE °C
200
400
600
800
0·08
0·16
0·24
0·32
% wt loss per min
A
B
C
D

FIG 9.11

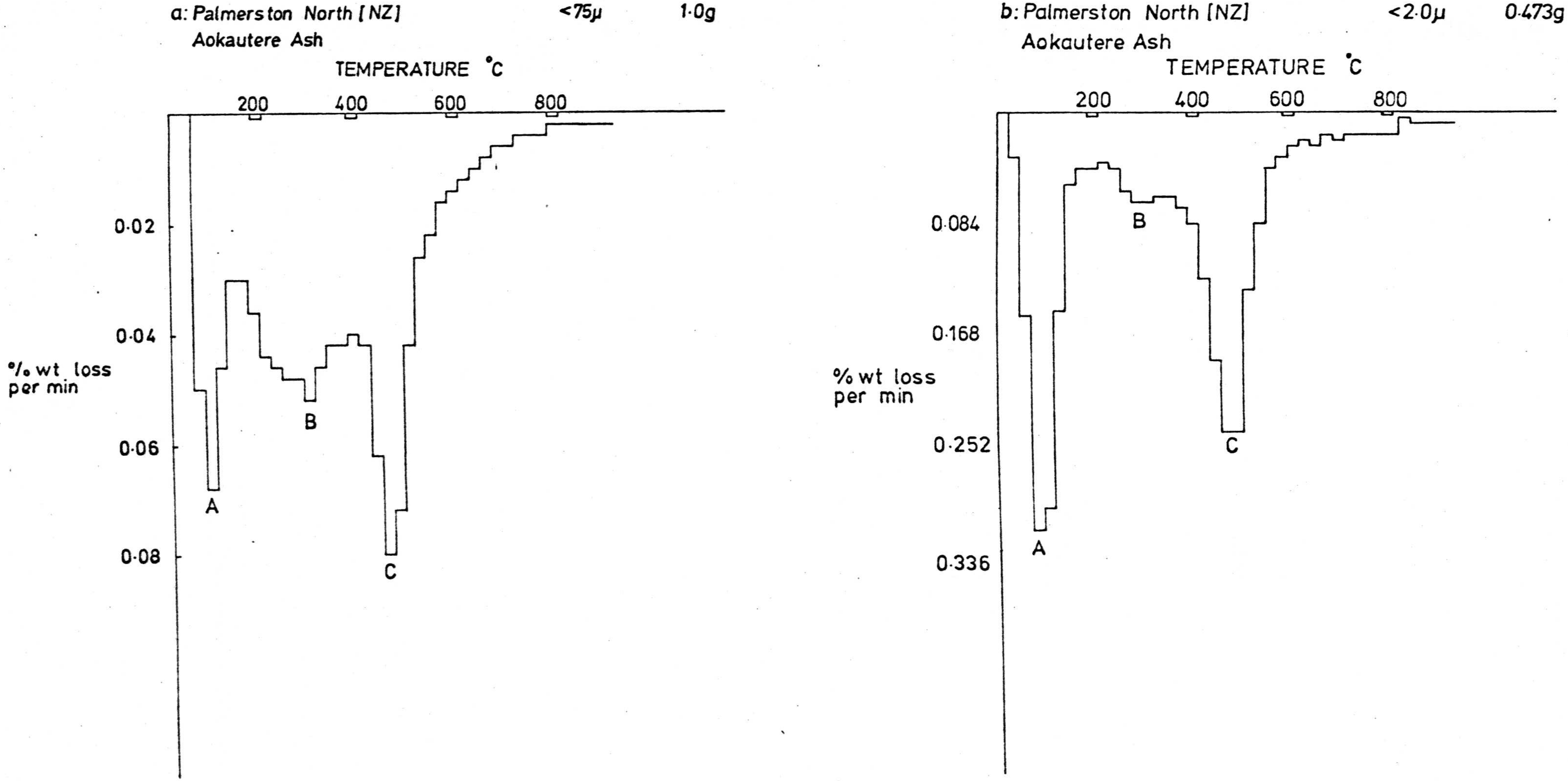

a: Palmerston North [NZ]
Aokautere Ash
<75µ
1·0g
TEMPERATURE °C
200
400
600
800
%wt loss per min
0·02
0·04
0·06
0·08
A
B
C
b: Palmerston North [NZ]
Aokautere Ash
<2·0µ
0·473g
TEMPERATURE °C
200
400
600
800
% wt loss per min
0·084
0·168
0·252
0·336
A
B
C

FIG 9.12

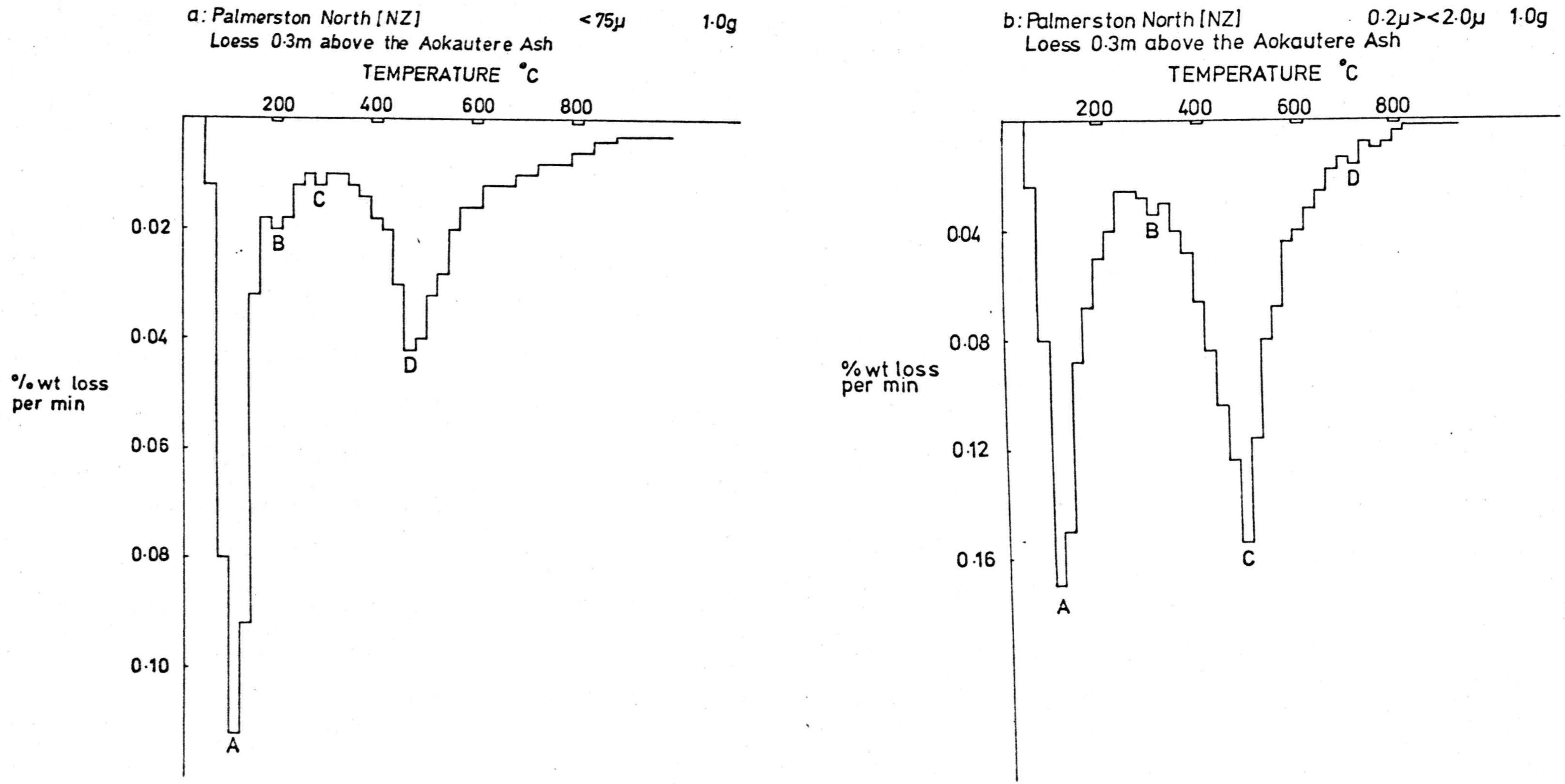

a: Palmerston North [NZ]
Loess 0.3m above the Aokautere Ash
<75μ
1.0g
TEMPERATURE °C
200
400
600
800
0.02
0.04
0.06
0.08
0.10
%wt loss per min
A
B
C
D
b: Palmerston North [NZ]
Loess 0.3m above the Aokautere Ash
0.2μ><2.0μ
1.0g
TEMPERATURE °C
200
400
600
800
0.04
0.08
0.12
0.16
%wt loss per min
A
B
C
D

TABLE 9. 1

ANALYSIS OF DTG HISTOGRAMS 9.2 – 9.12

FIG. No.	SAMPLE		100–150°C	260–310°C		ILLITE 370 – 610°C %wt loss	wt of illite in mg.	% of illite		CALCIUM CARBONATE 690 – 800°C %wt loss	wt of $CaCO_3$ in mg.	% of $CaCO_3$
9.2a	Pegwell Bay 1	(<75u)	A	–	C,D&E	1.25	62.75	6.275	F	0.06	1.36	0.136
9.2b	Pegwell Bay 1	(<2u)	A	–	C&D	4.14	40.0	20.72				
9.3a	Denstead West	(<75u)	A	B	C	1.63	81.5	8.15	D	0.22	4.99	0.499
9.3b	Denstead West	(<2u)	A	B	C	5.44	136.0	27.2	D	0.92	10.44	2.09
9.4a	Allington 1.5m	(<75u)	A	B	C,D&E	1.68	84.0	8.4				
9.4b	Allington 3.0m	(<75u)	A	B	C	1.66	83.0	8.3	D	3.66	83.08	8.3
9.5a	Allington 1.5m	(<2u)	A	B	C	4.4	220.0	22.33				
9.5b	Allington 3.0m	(<2u)	A	B	C&D	5.3	181.0	26.5	E	3.17	49.27	7.19
9.6a	Ch.Orch.Ln 0.5m	(<75u)	A	–	C	1.94	97.0	9.7				
9.6b	Ch.Orch.Ln 2.0m	(<75u)	A	B	C	1.74	33.99	8.72	D	5.54	49.03	12.57
9.7a	Star Lane 1.55m	(2–10u)	A	B	C	2.52	63.0	12.6	D	10.88	123.48	24.7
9.7b	Star Lane 1.55m	(<2u)	A	B	C	5.36	134.0	26.8	D	6.4	72.64	14.53
9.8a	Hornhill Top NW	(2–10u)	A	B	C	3.0	75.0	15.0	D	15.58	176.83	35.37
9.8b	Hornhill Top NW	(<2u)	A	B	C	6.94	173.0	34.7	D,E&F	7.5	85.81	17.16

Letters refer to peaks on the relevant figures.

TABLE 9. 1 Cont.

FIG. No.	SAMPLE		100–150°C	260–310°C	ILLITE 370 – 610°C	%wt loss	wt of illite in mg	% of illite	CALCIUM CARBONATE 690 – 800°C	%wt loss	wt of $CaCO_3$ in mg	% of $CaCO_3$
9.9a	Hessle	(<75u)	A	B	C	3.1	155.0	15.5				
9.9b	Huggate A	(<75u)	A	–	C&D	1.36	68.0	6.8	E	0.2	4.54	0.45
9.10a	New Zealand Loess Lower	(<75u)	A	B	C&D	1.64	82.0	8.2	E	0.24	5.45	0.54
9.10b	New Zealand Loess Lower	(<2u)	A	B	C&D	5.28	264.0	26.4				
9.11a	New Zealand Aokautere Ash	(<75u)	A	B	C	2.52	126.0	12.6				
9.11b	New Zealand Aokautere Ash	(<2u)	A	B	C	7.4	175.0	37.0				
9.12a	New Zealand Loess Upper	(<75u)	A	C	D	1.6	80.0	8.0				
9.12b	New Zealand Loess Upper	(0.2–2.0u)	A	B	C	5.2	260.0	26.0	D	0.4	9.1	0.91

TABLE 9.2

COMPARISON OF $CaCO_3$ CONTENT OBTAINED BY TWO METHODS

SAMPLE	CALCIMETRY %	THERMOGRAVIMETRY %
Monkton (2-10u)	41.31	39.0
Allington 3.0m (2-10u)	5.85	5.81
Allington 3.0m (2u)	7.69	7.19
Allington Q.G. (75u)	8.82	9.85
Beacon Hill (2-10u)	8.12	8.17
Ch Orch Ln DT (2u)	3.08	3.26
Star Lane 1.55m (75u)	14.17	16.8
Star Lane 1.55m (2-10u)	23.77	24.7
Star Lane 1.55m (2u)	18.41	14.53
Marks Tey U. (75u)	14.14	16.77
Marks Tey L. (75u)	13.72	18.73
Etton (2u)	0.62	-
Hornhill Top NW (2-10u)	39.03	35.37

CHAPTER TEN

CALCAREOUS CONCRETIONS

CHAPTER TEN

CALCAREOUS CONCRETIONS

The aggradation of a large number of minute calcite particles and their cementation around a nucleus or nuclei or quatrz grains in an apparantly random manner throughout loess deposits in Europe and the south east of England, resulting in the formation of calcareous concretions or nodules, has led to several investigations as to their nature, origin and general significance to the deposits in which they occur.

It appears that de la Beche was one of the earliest geologists to record concretions when he noted them in his text book of 'Researches in theoretical geology', (1834). Calcareous nodules in general have since been extensively described, with those occurring in loess receiving more prominence in the last ten to fifteen years. The description by Gibb in 1857 of calcareous concretions in a Buckingham brickclay from Tingewick is possibly the first recording of a loess nodule although at the time the relationship of the Pliestocene brickearths of southern England to the deposits of continental Europe had not been recognised. Similar forms were described some twenty years later by Woodward (1878), when recording a 'race' bearing brickclay at Mildenhall in Suffolk. The 'race' is later revealed by Blake (1878) to be the nodule of calcium carbonate, this term is common in many of the older reports of brickworkings referring to this particular non-beneficial content of the deposit. The presence of concretions within the brickmaking material increases the lime content of the bricks resulting in a loss of strength and the 'blowing' of the bricks. Although 'race' refers to concretions found within the loess in this particular case, it is not completely synonymous with other terms that describe only those forms occurring in loess, i.e. lösskindeln, lösspüppen, lössmänchen and lössdoll.

Lössdolls were later found and described by Trechmann (1919), who noticed them on the Durham coast within a deposit he claimed to be interglacial loess, (see Chapter 2). These forms were of a spherical nature, measuring 3" - 4" in diameter, having a calcium carbonate content of 44% and a quartz content of 41%. All the work carried out on loess since Trechmann's report has confined itself to the deposit and only passing reference has been made to the presence of concretions.

The great amount of interest created by concretions during the nineteenth century preoccupied many researchers into deducing their origin and left a substantial gap in the recording of shape, size and relationship to the deposit within which they were found. Dobrowoski (1858), in Russia, made probably the first classification of calcareous concretions based on form, it was from this that Chmielowiec in 1960 compared those he collected on the Lublin Plateau in Poland. Chmielowiec studied 1,440 concretions which he divided into a ten fold classification giving the percentages as they occurred within his area of study. This classification is shown in Table 10.1 but in order to put it in perspective Chmielowiec regarded it as by no means complete and would increase with the number of concretions examined. If this is the case, as it appears from those concretions that have been obtained from British deposits, the purpose of grouping such a varied form is unjustifiable.

TABLE 10.1.

TABLE OF GROUPS OF CONCRETIONS AS IDENTIFIED BY CHMIELOWIEC ON THE BASIS OF SHAPE

	TYPE	DESCRIPTION
1	SPHERICAL (3.49%)	HAVING CIRCULAR SECTIONS AND ALMOST EQUAL DIMENSIONS IN ALL DIRECTIONS
2	OVAL (18.33%)	OVAL IN SECTION WITHOUT DISTINCT EDGES
3	PIPE-LIKE (0.65%)	APPEARING IN THE ROCKS IN A PERPENDICULAR POSITION, HAVING A CIRCULAR CROSS-SECTION WITH HOLLOW INTERIOR
4	DROP SHAPED (12.98%)	
5	TRIANGULAR (1.43%)	USUALLY FLAT WITH A TRIANGULAR SECTION
6	CONCHOIDAL (0.45%)	FLATTENED OVAL SHAPE WITH ONE DISTINCT EDGE
7	KIDNEY SHAPED (3.05%	
8	DOUBLE CONCRETIONS (3.92%)	HAVING THE CHARACTERISTIC NARROWING HALFWAY THROUGH THEIR LENGTH
9	IRREGULAR (18.04%)	A LARGE GROUP SUB-DIVIDED INTO: i IRREGULAR - ELONGATE ii IRREGULAR - RAMIFIED iii IRREGULAR - WITH ODD SHAPES
10	CONGLOMERATE CONCRETIONS (37.64%)	EACH CONCRETION BEING A CONGLOMERATE OF SEVERAL CONCRETIONS

In comparison to the classification laid down by Chmielowiec many of the forms are identifiable particularly those of group 10 which generally appear as the largest concretions. This is not surprising as they owe their size to the ammalgamation with adjacent growths. A slightly different approach to the classification was that taken by Siuta and Florkiewicz, (1965), who whilst investigating the genesis of calcareous concretions, recognised twelve groups on their associated deposits as well as their form. These groups are listed in Table 10.2 below.

TABLE 10.2

TABLE SHOWING THE DIVISIONS OF CONCRETIONS INTO THEIR SHAPES AND ASSOCIATED DEPOSITS

1 RATTLERS OCCURRING IN BOULDER LOAM COVERED WITH LOESS, EMPTY INSIDE AND HAVING MANY SPLITS

2 RATTLERS AS IN GROUP 1 BUT WITH SMALLER HOLLOW SPACES i.e. HALF SOLID

3 SOLID CONCRETIONS WITH LARGE FISSURES, OCCURRING IN BOULDER LOAM COVERED WITH LOESS

4 CONCRETIONS ORIGINATING FROM THE ILLUVIAL CALCAREOUS HORIZON OF CONTEMPORARY SOILS, DEVELOPED OUT OF BOULDER LOAM

5 CONCRETIONS ORIGINATING FROM THE ILLUVIAL CALCAREOUS HORIZON OF FOSSIL SOILS DEVELOPED OUT OF LOAMY LOESS AND HAVING THE MECHANCIAL COMPOSITION OF CLAY

6 HALF-SOLID RATTLERS OCCURRING IN HIGHLY GLEYED ALLUVIAL LOESS

7 SOLID CONCRETIONS WITH SMALL FISSURES INSIDE OCCURRING IN A HIGHLY GLEYED ALLUVIAL LOESS

8 EXTERNAL PART OF A SLIGHTLY POLISHED CONCRETION OF A SOLID NATURE WITH SMALL FISSURES INSIDE

9 SOLID CONCRETIONS WITH SMALL FISSURES OCCURRING IN LOESS DEPOSITS

10 CONCRETIONS ORIGINATING FROM THE ILLUVIAL CALCAREOUS HORIZON OF CONTEMPORARY CHERNOZEMS, A PERIODICALLY MOISTENED SOIL

11 SOLID CONCRETIONS - CEMENTED TYPE IN BOG SOILS OF A DESERT CLIMATE

12 SOLID CEMENTED CONCRETIONS FORMED IN LOAM POTS FROM AN ARCHAEOLOGICAL DISCOVERY OF 4,000 B.P. SUB DIVIDED INTO:

- i WHOLE MASS OF CONCRETIONS
- ii MIDDLE PART OF CONCRETIONS

Sorby (1908), considered the shape and size of concretions to be of secondary importance, noting that the most important division to be a concretions relation to the depositional history of the surrounding material, i.e. whether it formed prior to sediment deposition, subsequent to it or was contemporaneous with deposition. Sorby does, however, attempt to relate the relative lengths of the three major axes of the concretions to those of the original nucleus although he does recognise that the larger the concretions then the less is the influence of the nucleus.

Internal Structure:

The internal structure may be concentrically laminated or have a radial form or may be amorphous. The interior may also be hollow or fissured as described by Siuta et al, these types being referred to as septarian, i.e. concretions having cracks or veins, either open or filled, usually widening towards the centre. Much of the literature of the early twentieth century was concerned with the origin of this particular type of structure.

It appears that until Todd (1903), wrote on 'concretions and their geological effects' the only theory explaining setparian forms was that of dessication and contraction, a theory briefly outlined by Buckland in 1846 when describing calcareous nodules in the shores of Lough Neagh in Ireland. Todd regarded expansion to be the cause of this internal structure, an explanation later supported in Britain by Morley Davies in 1913.

The means by which the expansion took place was envisaged by Todd to be of a molecular nature, i.e. a collection of molecules of a similar type being deposited between particles and wedging them apart. The magnitude of the force that is required to cause this molecular expansion becomes a realistic possibility when the force created by freezing water in the pore spaces of rocks is considered. This process of septarian formation is labelled as intercretion, the evidence for which was derived from concretions found in the loess deposits of eastern Nebraska by Todd. Three further classes of concretions were recognised based on their method of growth:

i. ACCRETIONS: ones that grow from the centre outwards in a regular manner

ii. EXCRETIONS: those growing from the exterior inwards

iii. INCRETIONS: those of cylindrical form with a hollow core.

Todds intercretion ideas were vigorously attached by Crook (1913), a protagonist of the contraction theory, the basis of which was the presence of a core relatively rich in clay in comparison to the outer layers thus resulting in shrinkage taking place once the concretion dried out. The presence of a clay enriched core was not substantiated by Todd (1913), who also further objected to this differential contraction theory by recording the presence of water in the centre of many of his concretions, this prevented shrinkage of the clay and therefore contraction from taking place.

Richardson (1919), was neither convinced by the expansionists or the contractionists, having carried out various experiments with clay balls and pats and noting the type of cracks that formed. From the results a chemical dessication theory was postulated, this involving the cracking of the nodule as a result of dessication of a colloidal centre, by chemical means.

Rosauer and Frechen (1960), when describing concretions found in the loess at Kärlich, West Germany, attributed the septarian structure to that of percolating waters containing dissolved carbonate and colloidal clay which upon drying shrinks together.

Of the concretions that show concentric zoning the major problem is deciding whether the zoning is a result of successive layering of material around the centre or produced by a separation of the material once they have formed. An investigation by Galimov and Girin (1968), into the isotopic composition of carbon in carbonate concretions showed that layering took place from the centre to result in their formation. The increase of dC^{13} from the centre to the perifery was shown to occur, indicating that this was the means of formation. The carbon of the central carbonate is derived from organic matter which is poor in the heavier carbon isotope where the value was found to be -2.27 per mil. The outer parts are composed of precipitated calcium carbonate and thus have a higher dC^{13} value of -0.86 per mil.

Although Sorby (op cit) related concretion shape to that of the original nucleus , it was realised by Bouve (1857), that a nucleus was not essential for the growth of concretions, when he described calcareous concretions occurring in a clay slide deposit at Presumpscot river, near Portland, Maine. Bouve recorded that " The carbonate of lime in the clay acted upon by elective affinity was led to draw itself more or less concentrically about a centre where might be or not a nucleus of some foreign body."

With many of the concretions that are found within loess a central growth point is not observable but one group of nodules of a calcareous nature possessing distinct nuclei are the Imatra Stones found in the glacial clay of Vualenkoski in Finland, Salmi (1960). When sectioned these concretions were found to contain a nucleous of a small angular pebble of a similar nature to the pebbles occurring in the surrounding clay. Varved clays are also seen here containing concretions but only in the summer bands. An earlier theory proposed by Tarr (1935), was suggested by Salmi as the cause of concretion growth within these summer bands. The summer silt layers are considered to contain particles of limestone which had been loosened and ground fine by the ice and then dissolved in the cold meltwater. A large amount of calcium carbonate was dissolved and was converted to the bicarbonate of lime. The cold meltwater enriched in carbon dioxide which, when warmed in summer, was released and resulted in the bicarbonate precipitating tiny particles which settled to form layers on top of the summer silt bands. Grains of calcium carbonate formed, possibly due to local supersaturation, these becoming the inital points for the development of calcareous concretions in different parts of the silt layer.

During the winter period of the year clay covered the silt layer with pores between the silt particles containing bicarbonate rich water. Exposure of the formation on dry land as a result of isostatic adjustment in the post glacial period allowed heat to penetrate the deeper layers and thus the precipitation of the calcium carbonate continued. The resulting flow of ground water that took place in the post glacial was also considered beneficial to the growth of concretions, a point that had been noted by Abbot in 1899 when discussing the role of water zones in influencing the situation and growth of concretions. Once percolation of rain water ceases the water breaks up into ' horizontal lines ' or water zones, these being subsequently broken up into moist patches. From this Abbot suggested that at these points soluble substances in the deposits such as lime, iron and silica would be taken into solution and transported eventually into positions favourable for growth into crystalline and amorphous masses. The distance which these substances were transported in solution prior to crystallization was considered by Abbot not to exceed two feet.

Siuta and Florkiewicz (op cit) show both in the field and experimentally that calcareous concretions have arisen in environments with superfluous moisture contents containing a certain amount of organic matter. The anaerobic decompostion of this organic matter provides a large amount of carbon dioxide and organic acids and as a result increases the solubility of calcium carbonate. They state that most calcareous concretions form on the surface of channels and vacant spaces of different shapes which have formed by the accumulation of gases from the anaerobic fermentation. The spaces are often connected with the atmosphere which facilitates the mineralization of the salts of organic acids and the accumulation of calcium carbonate sediments inside the spaces.

The anaerobic environment theory received support from Sass and Kolodny (1972), working on the carbonate concretions found in the Mishash formation of Isreal. The evidence of these workers is based on the isotopic determinations of C^{12} and C^{13} in the calcite of the concretions, Berner (1968), had earlier suggested that the derivation of calcium carbonate from organic matter would be the finding of low C^{13}/C^{12} ratios as carbon derived from organic matter is rich in the light carbon isotope. The concretions of the Mishash formation had a low C^{13}/C^{12} ratio whilst the surrounding rocks were not as enriched in C^{12}.

Sass and Kolodny realised that the concretions were formed in a microenvironment within the main environment. A situation was proposed by these authors as shown in Fig.10.1 whereby in a diagenetic environment the organic matter derived calcium carbonate is precipitated at some locations in which the pH is high whereas in laterally equivalent sediments it is low and the calcium carbonate is solubulized.
Other isotope studies of comparing the enrichment of C^{12} in the concretions with that of the enclosing rock have been carried out by other workers including Weber, Williams and Keith (1964), who, working on siderite nodules, used their results to obtain paleoenvironmental information, and Degens, Pierce and Chillinger (1962), on petroleum bearing fresh water concretions of the Calico Mountains in San Barnardino County, California, where it was discovered that a regular variation existed in the oxygen isotopes distribution as shown in Table 10.3. The rim of the concretion studied was relatively enriched in O^{18} with values decreasing towards the centre of the nodule. The difference between the dO^{13} in the calcites of the sediments and those of the nodules is more pronounced, being approximately 12 mil. the sediment being enriched in the lighter O^{16}.

TABLE 10.3

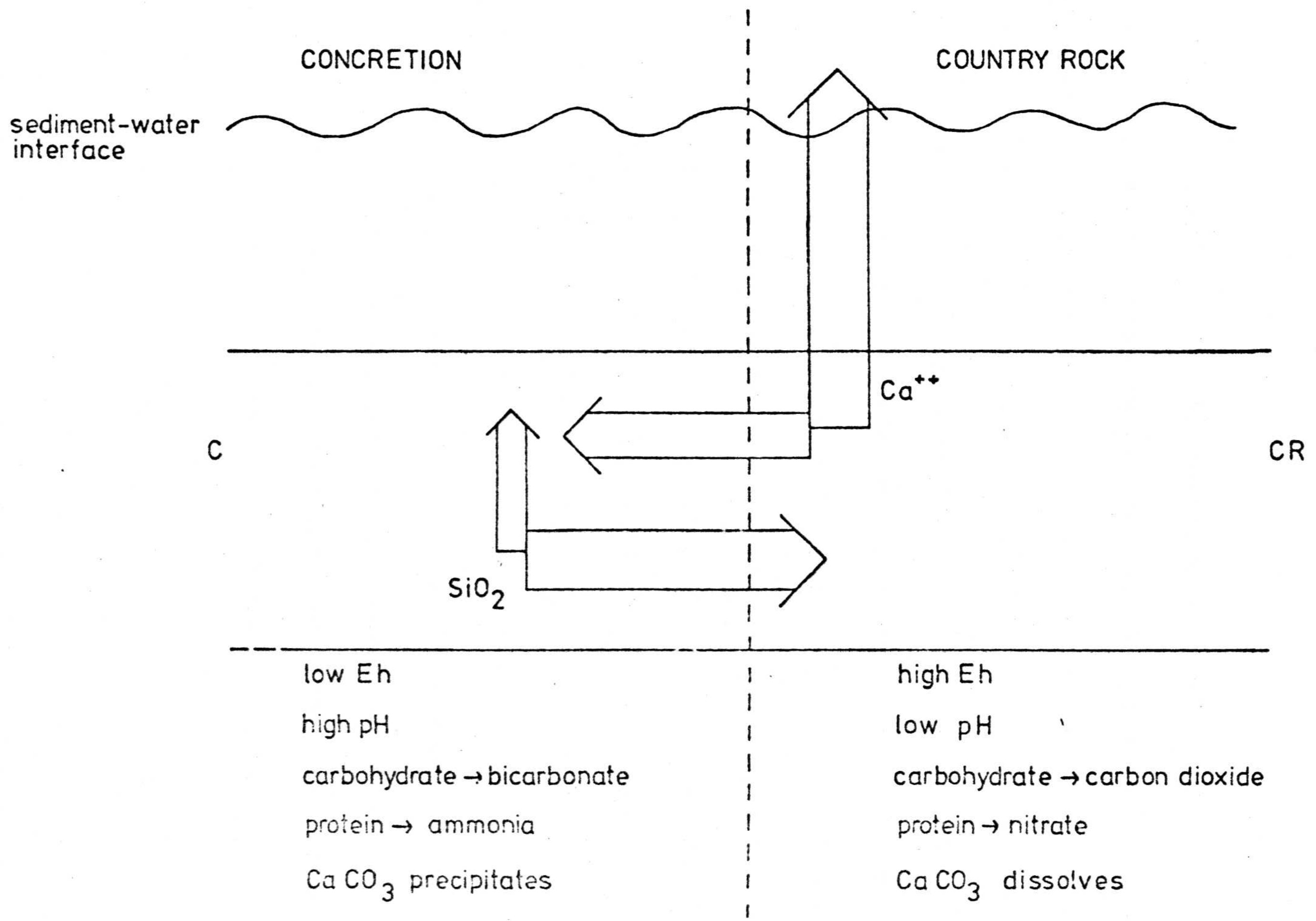
OXYGEN AND CARBON ISOTOPE ANALYSIS OF DARK GREY NODULE AND SURROUNDING SEDIMENT. (Data are reported as per mil deviation relative to Chicago Belemnite Standard)

Description	O^{18}	C^{13}
Centre of nodule	-7.26	-11.42
0.5 cm from centre	-3.27	-13.63
1.0 cm from centre	-1.53	-12.43
1.5 cm from centre	-0.28	-12.13
Syngenetic calcite in sediments (0.5 cm from rim of nodule)	-12.58	-7.93

(after Degens, Pierce and Chilinger 1962)

FIG 10·1

A SCHEMATIC MODEL OF DIAGENETIC CONDITIONS AT CONCRETION SITES AND SURROUNDING SEDIMENTS.



ARROWS INDICATE DIRECTION AND AMOUNT OF TRANSPORT OF DISSOLVED SPECIES.

After Sass & Kolodny 1972

Epstein and Meyeda (1953), showed that freshwater was depleted in O^{18} in comparison to ocean water due to the greater volatility of H_2O^{16} to that of H_2O^{18} indicating that fresh water carbonates should be relatively low in O^{18}. The dO^{18} in the calcite of these sediments comes within the range of normal fresh water limestones as shown by Clayton and Degens (1959). Degens et al (1962), used this isotope data to indicate that the concretions grew from the centre outwards with a time gap between the deposition of the sediment and the beginning of the concretion growth. Evaporation was shown to be taking place and as a result the environment was becoming more saline, this being indicated by the increase of the O^{18} isotope. The -7.93 value of the dC^{13} of the sediment falls within the normal range of fresh water carbonates. A 4 - 5 per mil. difference between the sediment calcite and the nodule calcite was considered by Degens et al to be probably due to the biogenic contribution of light carbon generated in the form of carbon dioxide during the decay of the organic matter at the centre of the nodules. Other organic matter decomposing simultaneously supplied ammonia to the reacting system and resulted in the creation of an alkaline environment, this being favourable for carbonate precipitation and nodule formation. Chilinger (1956) suggested that where the nodules have a higher magnesium carbonate content than the surrounding sediments then a higher pH exists in the nodule forming environment.

CONCRETIONS FOUND IN LOESS:

The preceeding part of this chapter has dealt with calcareous concretions in general with a few occasional specific references being made concerning concretions found in loess. The latter part of this chapter deals with individual loess nodules, several of these have been collected from the Essex Brickearths whilst the remainder have been extracted from various east European loess deposits.

The Essex concretions were obtained from one of the few remaining loess containing brickworks, Cherry Orchard Lane (TQ859899), near Southend. Two working faces at this site revealed calcareous nodules at a depth of approximately two metres, these are readily available as the upper layer, without the concretions, is extracted for brickmaking, this extraction ceases once the concretionary zone is reached. The nodules are comparatively small, very rarely exceeding 40mm across their longest axis, mostly of a uniform size. The shape is not as uniform as the size with as many variables present as described by Chmielowiec, (1960 op cit). The various irregular forms are shown in Plate 10.1 and are contrasted with the regular 'root' type (Plate 10.2).

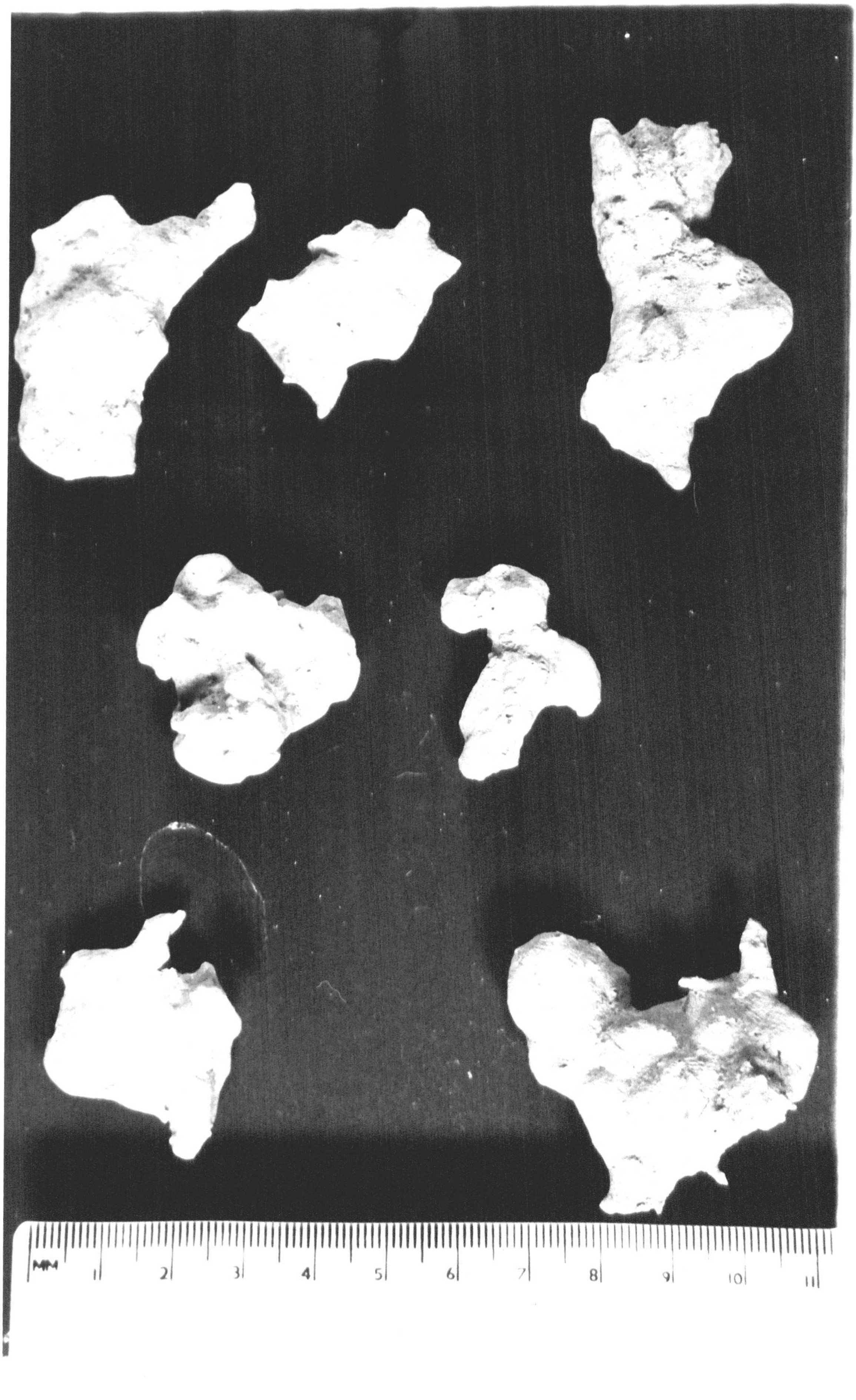
The east European concretions have been obtained from the Silesia-Saxony region of the German Democratic Republic and from the Danube valley-Pannonian basin of Hungary. The former area belongs to the same northern belt of loess deposits as those of Essex, the latter region being the southern group. The east German concretions, like the British, are generally small with the occasional larger forms present. The shapes are also as various as the individual nodules.

The Hungarian concretions were obtained from the classic loess sections of Paks and Mende, as described by Pecsi (1972 see Chapter 3), mainly from the former site.

In comparison to the other areas, the concretions from the

PLATE 10. 1.

Photograph showing a selection of small irregular concretions.


MM
1
2
3
4
5
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7
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10
11

PLATE 10. 2.

Photograph of a ' root ' type concretion.

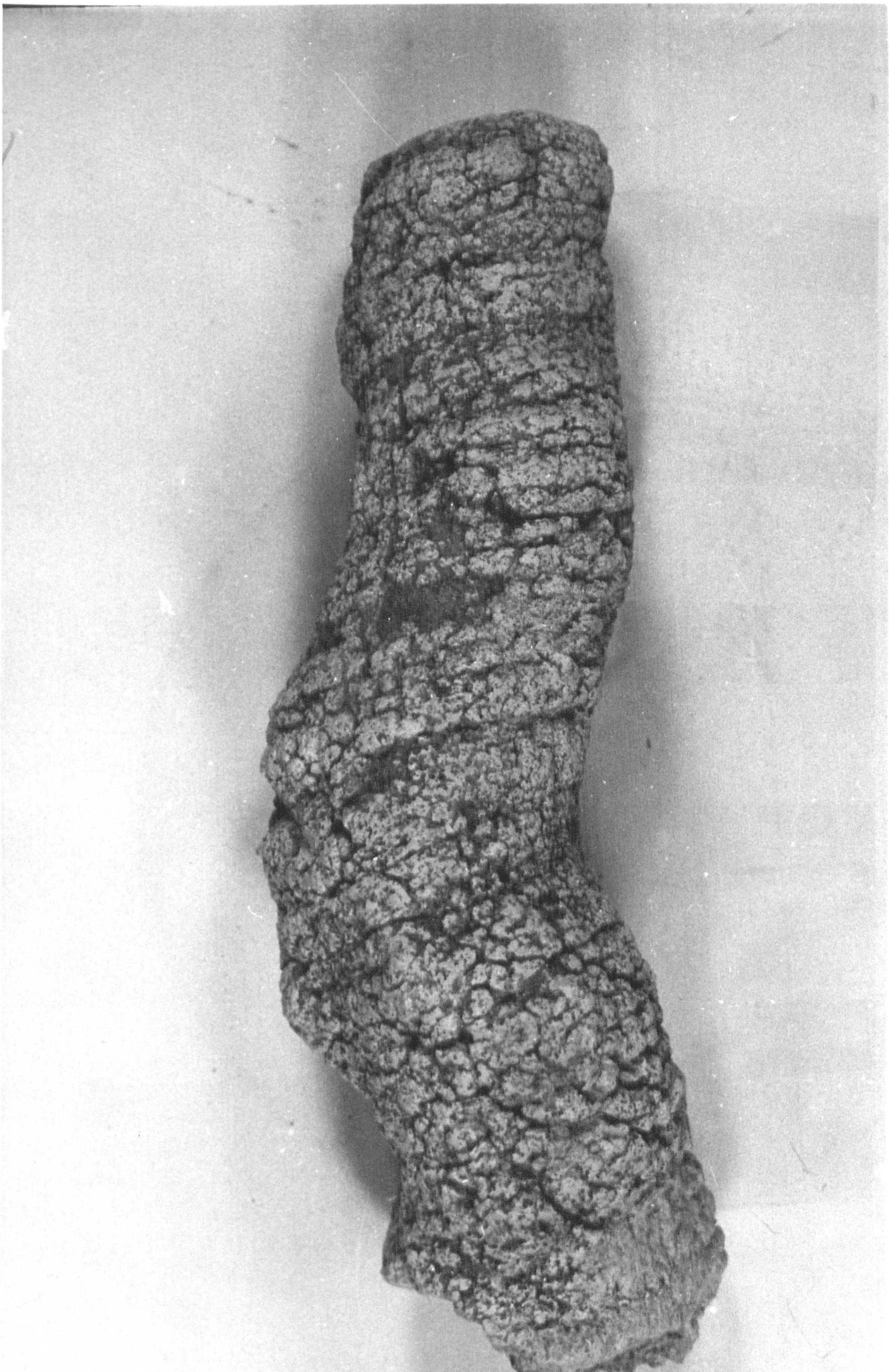


PLATE 10. 3.

Photograph of a large concretion from Paks, Hungary.

Hungarian loess are large, (Plate 10.3), those from Paks being derived from the ' concretion concentrated ' Lower Pleistocene loess. At Mende the concretions are not as abundant, occurring 27 metres below the surface, this being 2 metres below the Mende Basal soil which marks the bottom of the Upper Pleistocene and from crude estimates of rates of deposition has been dated at about 50 to 70,000 years B.P.

The shapes of the Hungarian concretions are also varied with the most perfectly spherical concretion yet observed being derived from Paks. Unfortunately this was not found insitu in the loess but among the piles of ' byproduct' concretions that are sorted from the loess before the brickmaking process begins. However, it appears safe to assume that it, like the other concretions from Paks, is a Lower Pleistocene concretion, or rather comes from a Lower Pleistocene position in the profile. Whether or not it formed at a time close to that of the deposition of the loess matrix is open for discussion. The spherical concretion has a diameter which varies between 58mm and 63 mm. A value of 60mm will be used in the Berner equation as described below.

Berner (1968), derived a mathematical description of concretion formation by diffusion from supersaturated ground water followed by simple precipitation. The results apply to post depositional concretions and therefore must include lösskindl. Two models were proposed (a) growth of a spherical concretion by ionic diffusion and precipitation from a non-flowing or stagnant ground water as may occur in impervious muds and shales and (b) slow ground water flow along with diffusion are considered as the two processes contributing precipitating matter to the spherical concretion surface, a situation which Berner suggested is better suited to porous sands and sandstones, and appears at first sight to be applicable to loess.

If the rate limiting step in concretion growth is not diffusion (plus convection) but instead some other process such as crystal nucleation at the concretion surface, then the results of Berners study give only minimum times of growth.

The simplest model for post-depositional concretion growth is precipitation in ionic diffusion from a supersaturated non-flowing ground water. The general expression for the growth of a spherical concretion by diffusion is:-

$$v(C_{\infty} - C_R) = \frac{S^3}{2} \exp \frac{S^2}{4} \left[\frac{1}{S} \exp \left(\frac{-S^2}{4} \right) - \frac{\sqrt{\pi}}{2} \left(1 - \operatorname{erf} \left(\frac{S}{2} \right) \right) \right] \quad (1)$$

where v = molar volume of cementing mineral in the concretion (considered as $CaCO_3$ for the loess concretions);

C_{∞} = concentration at a great distance from the concretion;

C_R = concentration at the surface of the concretion assumed to represent the saturation concentration or 'solubility';

$S \equiv \frac{R}{\sqrt{Dt}}$ where R = radius of concretion

D = diffusion coefficient (including sediment tortuosity factor);

t = time of growth.

In order to calculate the time necessary to form a concretion of radius R, it is necessary to know values for the molar volume and degree of supersaturation ($C - C_R$) of the ground water. Substitution of these values in e.q. 1 enables the calculation of S to be made which in turn allows R to be related to t via the definition of S. This rigorous approach can be simplified and e.q. 1 reduced to:

$$v(C_\infty - C_R) = \frac{S^2}{2} = \frac{R^2}{2Dt} \qquad (2)$$

Solving for t:

$$t = \frac{R^2}{2vD(C_\infty - C_R)} \qquad (3)$$

Thus a very simple expression is obtained for the time of concretion formation which is applicable to ground water with supersaturations, $C - C_R$ up to about 0.05 moles per litre (e.g. 5000 ppm $CaCO_3$), a value far in excess of any expected for most ground waters. This method is taken directly from Berners (1968), paper and for the steps from e.q. 1 to e.q. 2 and the derivation of e.q. 2 this work should be consulted.

Berner developed his approach to the problem of diffusion growth in moving ground water from the work of Nielson (1961). From the simplified expression $\bar{V} = \frac{4}{3} R^3$ the following equation for growth at zero rate of flow (stagnant water) can be derived:

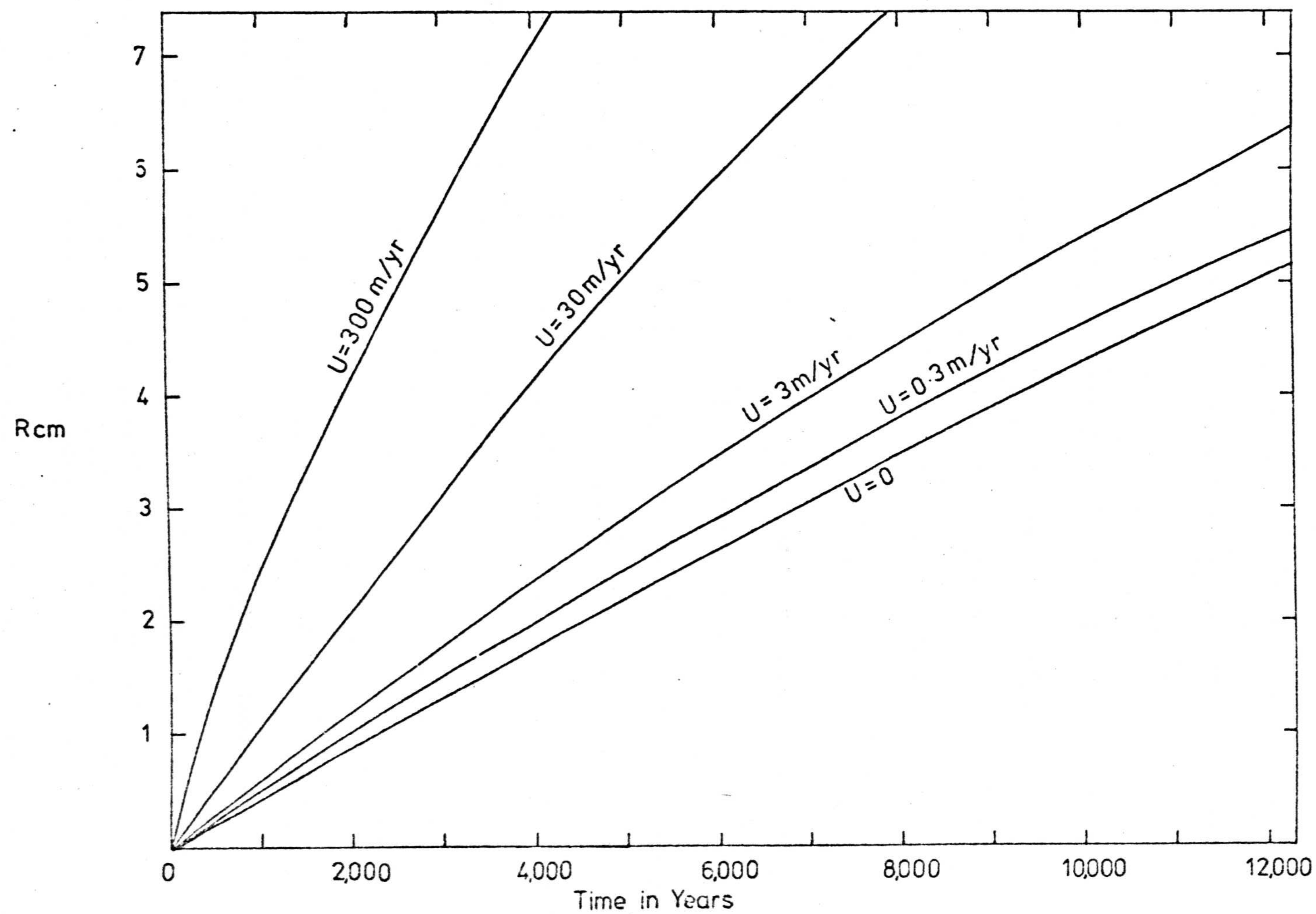
$$\frac{dV}{dt}_{\text{Diffusion}} = 4 \pi RDv(C_\infty - C_R) \qquad (4)$$

A flow factor can be introduced, and determined by Nielson's method, and the following moving water equation derived:

$$t = \frac{\left| R - \frac{D}{0.715U} \right| \left| 1 + \frac{RU}{D} \right|^{0.715} + \frac{D}{0.715U}}{1.715Uv(C_\infty - C_R)} \qquad (5)$$

FIG 10·2

GROWTH CURVES FOR $CaCO_3$ CONCRETIONS



After Berner 1968

U = ground water flow velocity   R = radius of spherical concretions

From equations 3 and 5 it should be possible to determine growth time for concretions, where the boundary conditions of the actual growth process falls within Berners assumptions. The use of the equations can be illustrated by the graph shown in Fig.10.2. This relates time of growth for $CaCO_3$ concretions to the radius and the ground water velocity U. The degree of supersaturation $C - C_R$ is assumed to be 10ppm dissolved $CaCO_3$ which Berner suggested to be not an unreasonable value for slightly supersaturated fresh ground waters, and appears to be applicable to the loess situation. Other values assumed are: $D = 10^{-5} cm^2/sec$ and $v = 35 cm^3/$ mole. The range of flow rates shown (0-300 metres per year)should include most normal ground waters.

From Fig.10.2 a flow rate of between 0 and 3 m per year would indicate that the 60mm diameter spherical concretion that was obtained from Paks would have taken about 4,000 years to form. There is no reason to assume high flow rates for the ground water; in fact the opposite assumption has been made because of the high overall clay content of the profile which will tend to impede ground water flow. The stratum is in excess of 70,000 years old so the question naturally arises as to which part of this time was occupied in concretion growth. Berner considers that concretion growth is a relatively rapid process, in geological time terms, and proposed that many concretions may be early diagenetic formations. This leads to another question concerning the reason for the cessation of growth. Various possibilities exist:

(a) the requisite carbonate concentration in the ground water has only existed over a limited period of time. This does not appear unreasonable although there is no agreement about the actual source of the carbonate.

(b) the concretion growth was so dense that the separate units interferred with each other and obstructed growth. The morphology of concretions suggests that in many cases they have started from separate growth initiation points and subsequently grown together as in the case of a lössdoll so this argument should not apply to an isolated spherical concretion.

(c) the supply of calcium carbonate failed or the moisture content of the loess dropped below a critical level. Some observations by Chmielowiec (1960), support this view. He has shown that in the vicinity of a concretion there is a lack of carbonate in the loess (see Fig.10.5); even though the loess at large may have quite a high carbonate content.

The early part of this chapter indicated the substantial amount of work that had been published in describing the size and shape of the concretions and the attempts that had been made to classify them. The internal structure, the cracks and fissures have also been studied, all this on a macroscopic scale. It is only recently that the microscopic approach to concretionary investigations has been adopted, by Leach (1974), and Wieder and Yaalon (1974).

Weider and Yaalon by means of photomicrographs distinguished three types of carbonate nodules.

1. Orthic nodules - here the skeleton grains are similar to those of the surrounding soil and show a gradual transition to the soil matrix, these they infer have been formed in situ.
2. Disorthic nodules - these have sharp bounderies and have been thought to have been subjected to some pedoturbation although their fabric resembles that of the surrounding matrix.
3. Allothic nodules - here the fabric differs from that of the soil in which they are incorporated, from which they

PLATE 10. 4.

Photograph showing the fine and coarse grained boundary within a concretion. This appears as concentric zoning at a lower magnification.

X 70

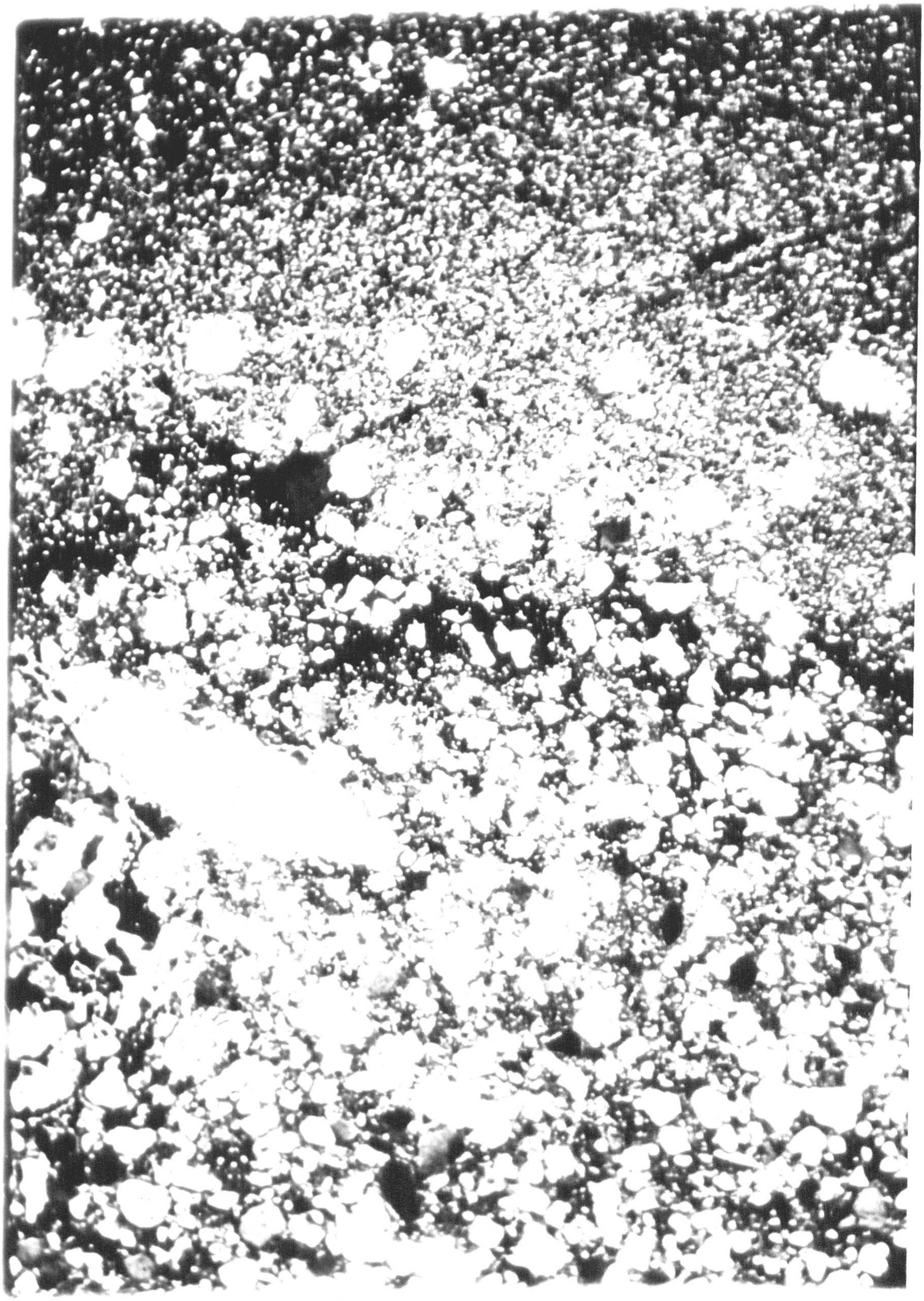
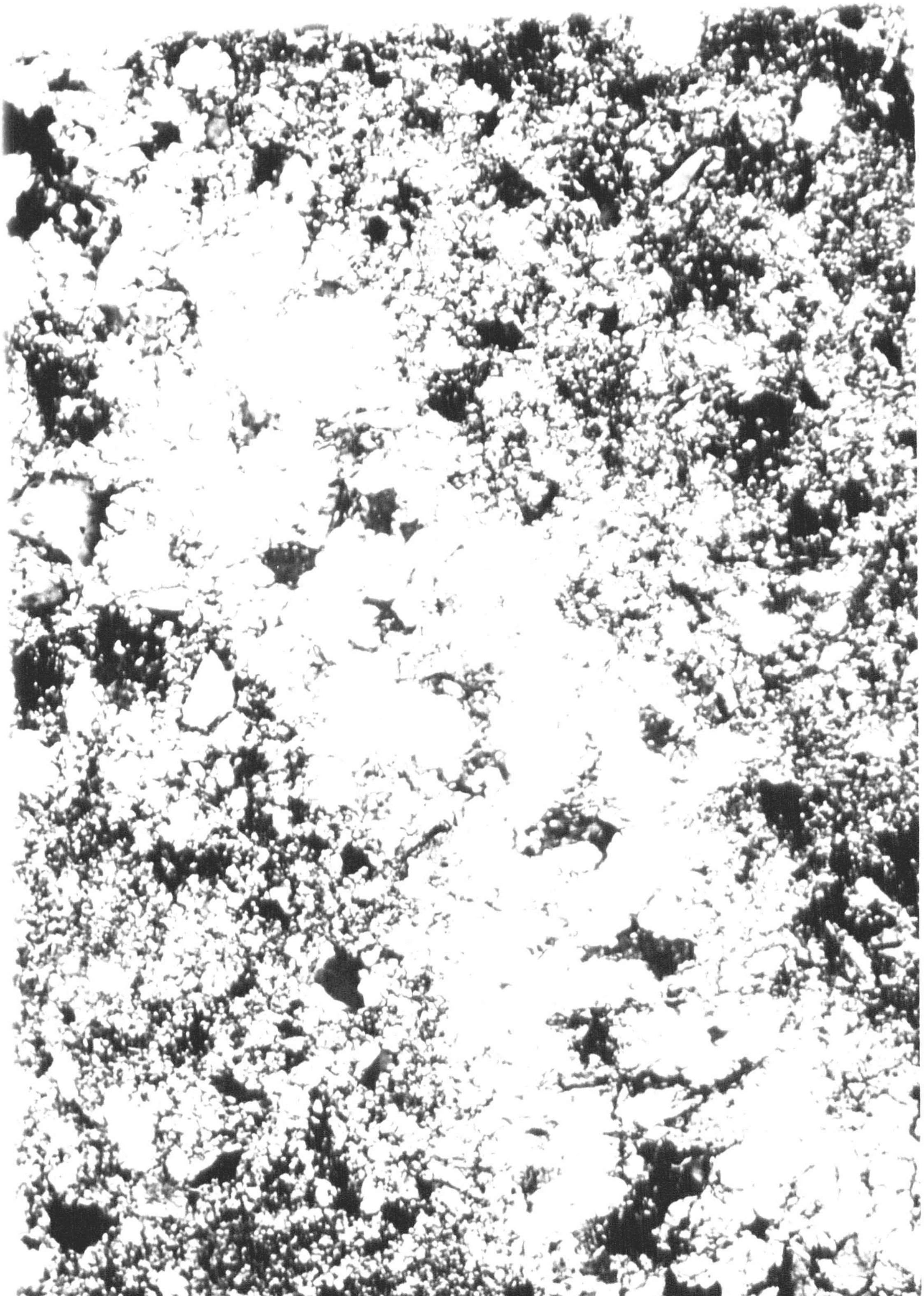


PLATE 10. 5.

View showing the infilling of a fissure within a concretion with calcite.

X 280



are said to have been transported, into the soil.

The orthic nodules are shown to have formed by the gradual precipitation of carbonate in the microvoids of the matrix resulting in greater density and a partial expulsion of the non-carbonate clay to the edges is not observed.

They conclude that the size and growth of calcite crystals in the nodules is determined by the matrix composition, in particular the presence of clay minerals which, they believe retards and possibly prevents a subsequent growth and recrystallization of the calcite crystallites. This theory was also put forward by Bouve, (op cit) .... " Why the carbonate of lime did not in such cases crystallize is more than is clearly understood. Probably it might have something to do with the mechanical action of the clay as a disturbing element."

Thin sections for microscopic study were prepared of concretions from the three regions. Variation in grain size is displayed in each of them and occasionally concentric zoning is present, Plate 10.4. This latter feature is seen clearer at lower magnifications. The calcite crystals are seen as the main cementing material as small discreet grains. Where fissures are present in the concretions the calcite is seen growing towards the centre of this fracture in the form of much larger grains than those acting as cement, (Plate 10.5). Most of the granular material that makes up the rest of the concretion is quartz which in several of the concretions has a relationship with the calcite which is the most striking of any of the features observed. The photomicrographs of Plate 10.6 to 10.8 show how the calcite appears to be replacing the quartz particles, attacking them at the edges and gradually working their way to the centre

PLATE 10. 6.

Photograph of a large quartz particle being attacked by calcite.

X 280

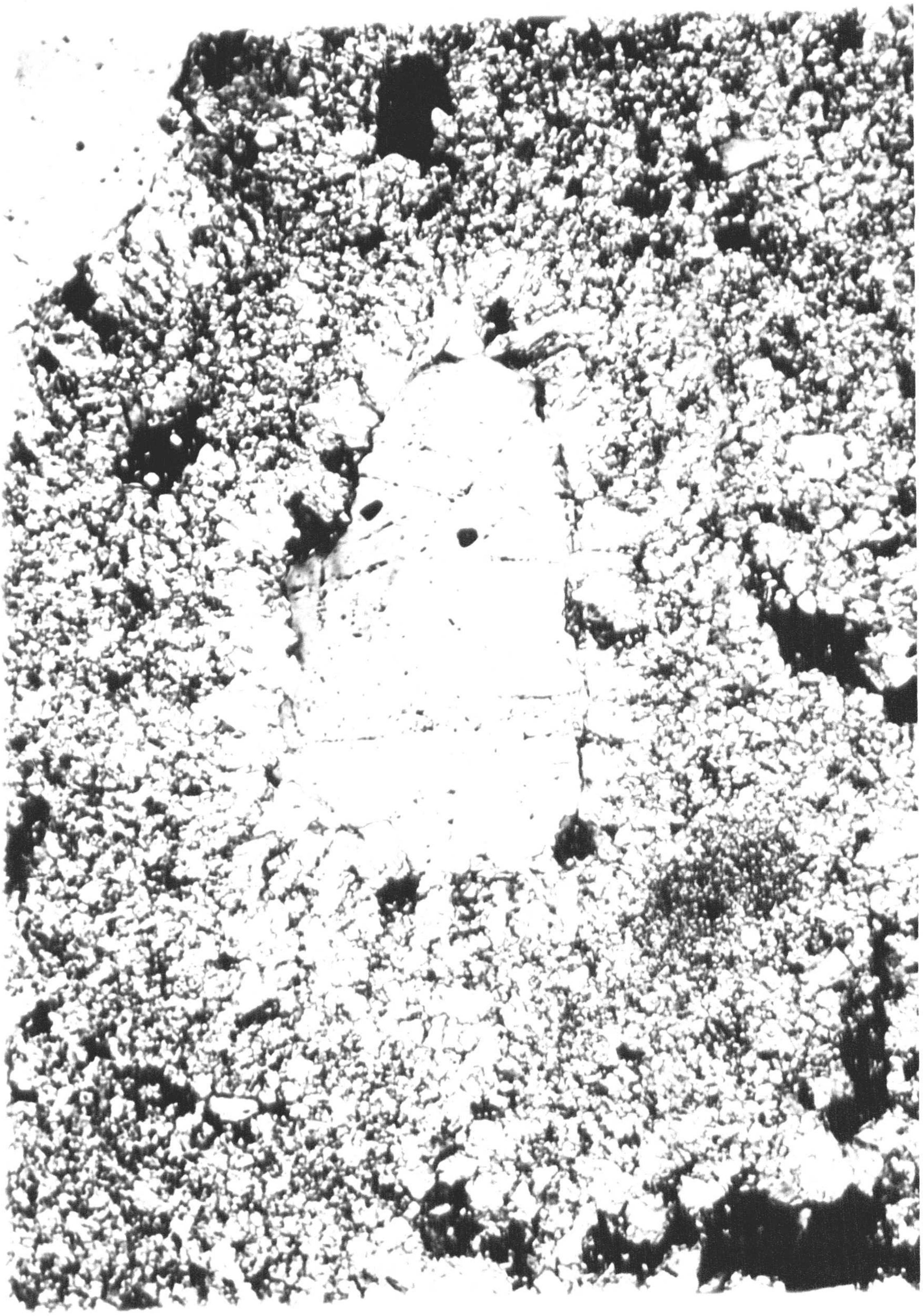


PLATE 10. 7.

View of several large quartz particles having been partially replaced by calcite. The large grain in the central - lower part has had a large portion removed.

X 280

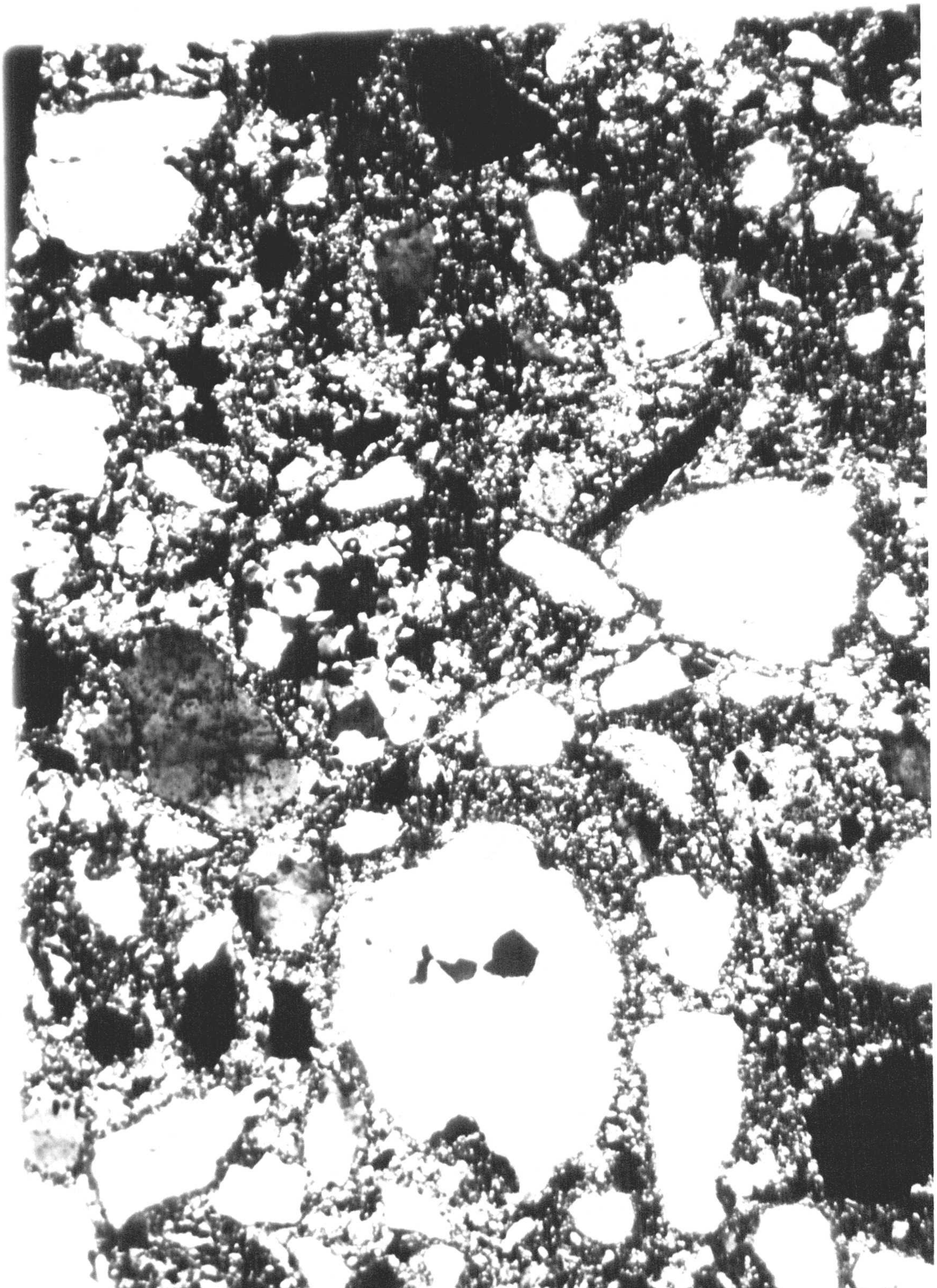


PLATE 10. 8.

Photograph of calcite replacement of quartz. In the lower right hand corner a ghost feature of part of a quartz grain can be seen.

X 280

in some cases leaving a ghost structure of the quartz. This replacement is regarded by Dapples, (1971) as being of commonplace particularly in carbonate concretions in loess. Dapples suggests the mechanism as being one that involves the solution of certain unstable silicate mineral grains, particularly quartz and feldspar, replacing them with calcite and, as a part of the carbonate crystal growth, expansion of the remaining detrital framework. This is said to be accomplished principally without pseudomorphic development although the present work indicates otherwise.

Whilst it is recognised that feldspar is an unstable silicate mineral that breaks down readily to form clay minerals, quartz cannot be regarded as such under normal physical or normal chemical conditions.

Replacement of quartz does, however, appear to have been recognised for a long time. Jackson (1857), stated ....

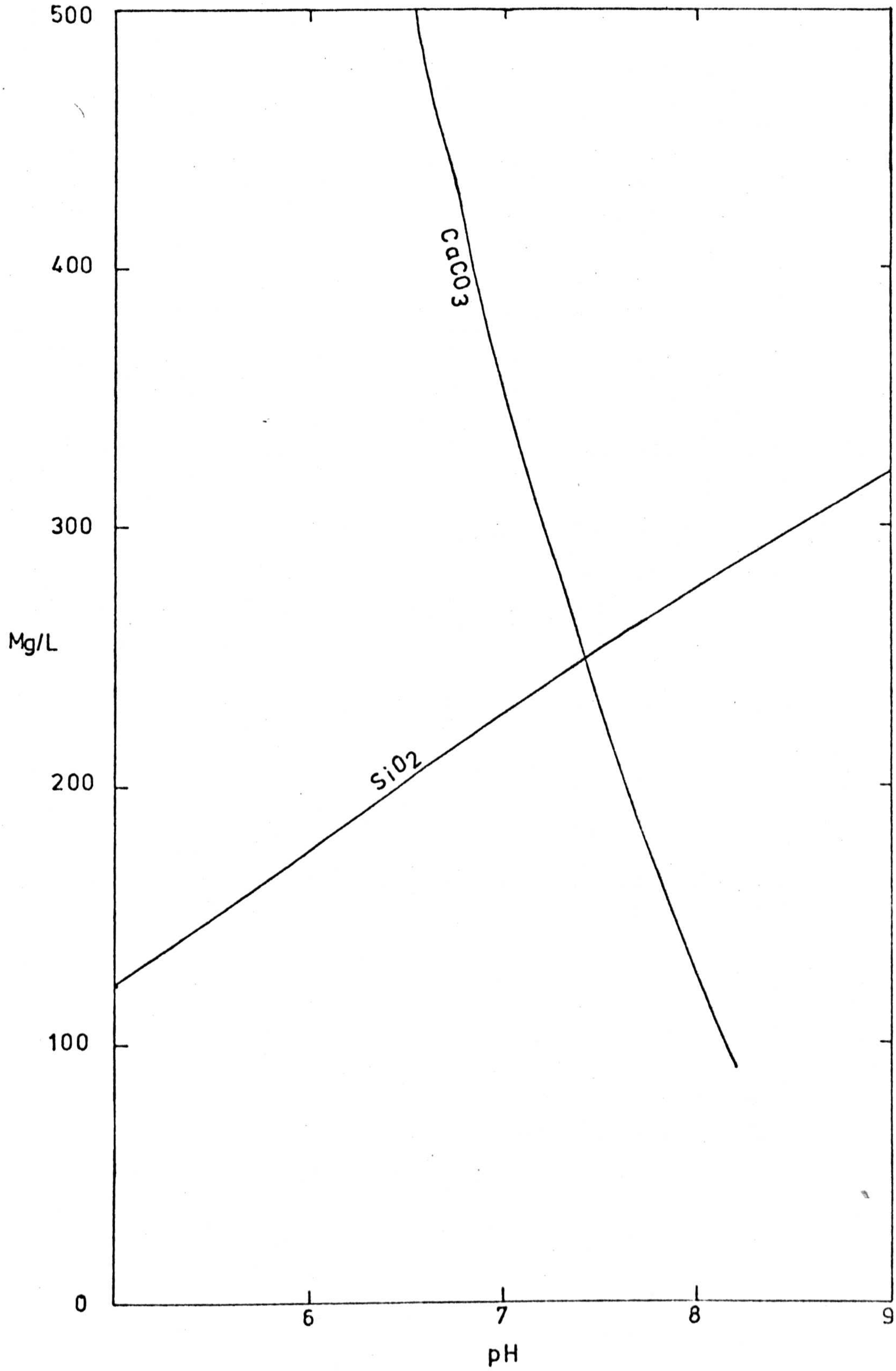
" In case there were a larger proportion of carbonate of lime in solution as a bicarbonate, the crystalline forms would become more perfect, as in the well known crystalline sandstones of Fontainbleu, in which grains of siliceous sand are forced into the form of calcareous spar by the energetic segretation of the crystalline carbonate of lime; the sand being inert matter which was forced by the calcareous salt to enter into the crystalline form of the spar."

The means by which this process takes place has been under discussion for many years.

Correns (1950), published data which indicated that amorphous silica increases in solubility with increase in pH between values of 5 and 9, these being important in geological environments. Fig.10.3. illustrates Correns results and as can be seen this is a pH situation which favours the precipitation of

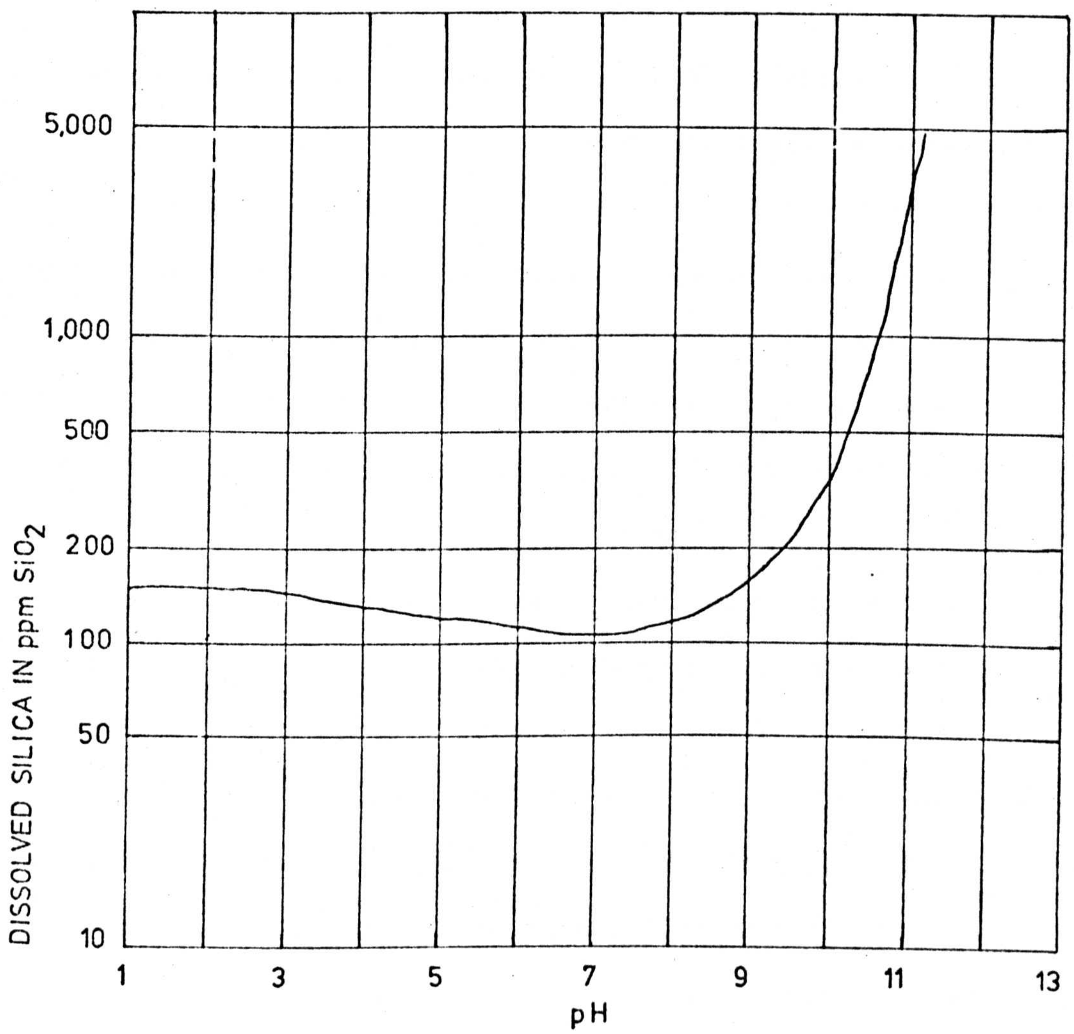
FIG 10·3

SOLUBILITY OF AMORPHOUS SILICA AND CALCIUM CARBONATE IN WATERS OF VARYING pH



After Correns 1950

FIG 10·4



SOLUBILITY OF AMORPHOUS SILICA IN WATERS OF VARYING pH

After Alexander, Heston & Iler, 1954

$CaCO_3$. From this Correns suggests that interstitial water saturated with calcium carbonate and silica at a particular pH would tend to precipitate $CaCO_3$ and dissolve more SiO_2 upon migration to a higher pH enviroment.

These results were not, however, confirmed by later authors. Alexander et al (1954), Krauskopf (1956), Okamoto et al (1957), indicate that the solubility of amorphous silica increases rapidly above pH 9 and below 9, where such environments are common the solubility is constant, (Fig.10.4).

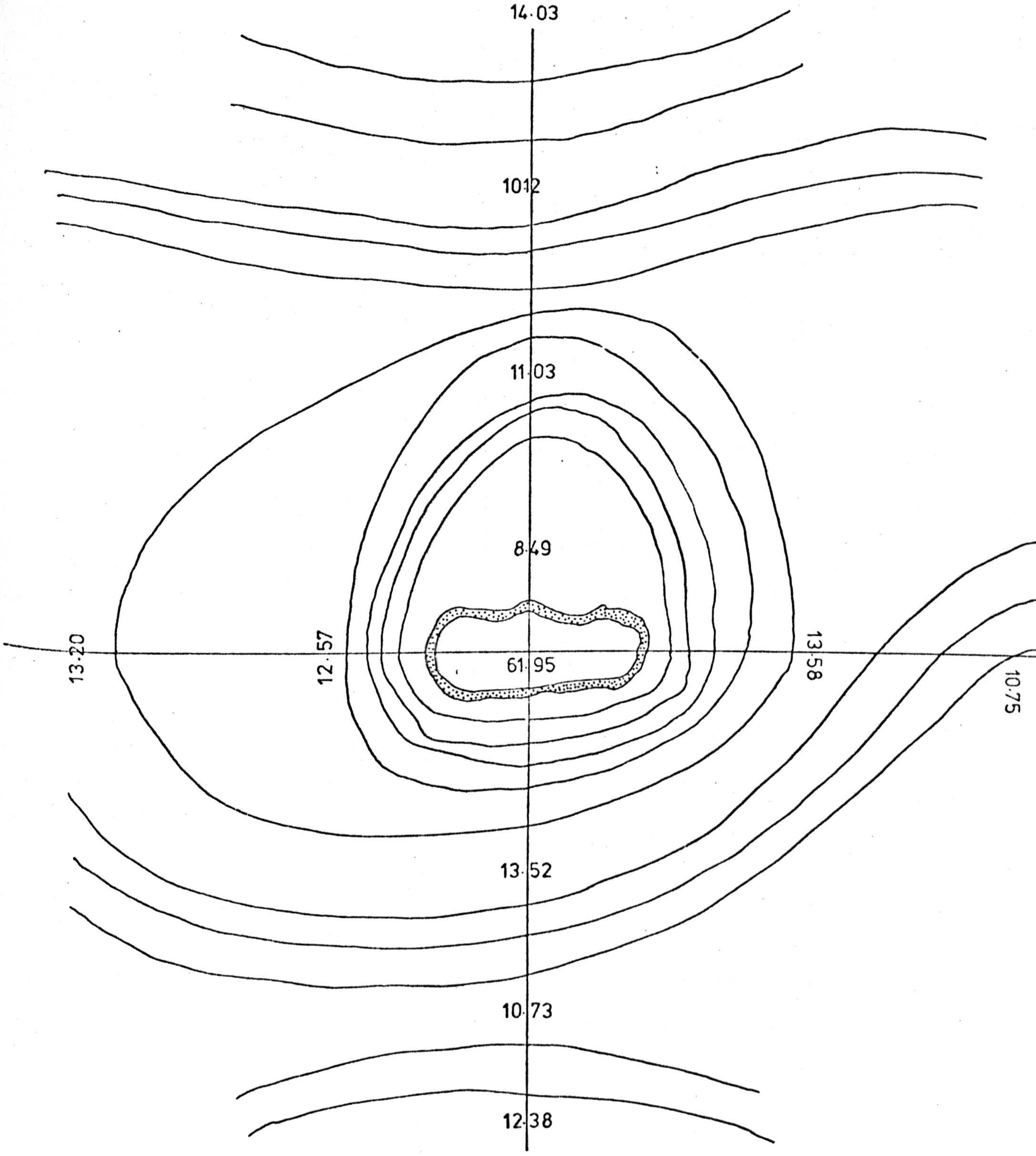
As pH values above 9 are not usual even in local environments this data would indicate that there are other causes than pH conditions which result in calcite replacement of silica. These factors appear to be unknown;high temperature and pressure is not a factor as loess concretions are found in zones of low temperature and pressure. The replacement of silica draws attention to two other problems,

(a) the source from which the carbonate of lime is derived, and

(b) the location to which the quartz is transported.

The carbonate content of the concretions amounts to over 50% whilst that of the surrounding loess rarely exceeds 12%. The distribution of $CaCO_3$ within the loess around the concretions was shown by Chmielowiec (1960 op cit), by means of a contour diagram (Fig.10.5), the maximum $CaCO_3$ content in the loess was shown to be 14%, the maximum $CaCO_3$ content of 60%.

A similar study has been attempted here, on British concretions and their surrounding deposits. The large number of concretions thatwere found at Cherry Orchard Lane in close proximity to one another made this part of the work very difficult. On a freshly prepared face of the brickearth one of the larger nodules was chosen as the reference point from which to take samples of the



THE DISTRIBUTION OF $CaCO_3$ IN THE CLOSE NEIGHBOURHOOD OF THE CONCRETIONS.

The value in %

After Chmielowiec 1960

FIG 10·5

surrounding material at measured distances from the periphery of the nodule. The field sketch of the position of the samples and the values that were later obtained in the laboratory for calcium carbonate, using a Collins calcimeter are shown in Fig.10.6. From this diagram it can be seen that reference nodule B was only 70mm from its nearest nodule A, because of this only small quantities of brickearth could be extracted at any given distance from B which only allowed analysis on fractions of a gramme. The outer skin of concretion B gave a value of 54% $CaCO_3$ whilst the outer skin of A gave a value of 72% with 90% being recorded in the core of this particular nodule. Samples of brickearth that were attached to the outer skin of the nodules were also analysed, these showed 25% in the case of the material attached to B and only 16% in the material attached to A. Values of approximately 10% and 13.5% were found at distances between the two nodules. The close proximity of the nodules and the small quantities of material that had to be dealt with means that the results obtained do not give any conclusive data as to the distribution of calcium carbonate in loess, particularly around the concretions. The source of the $CaCO_3$ was indicated to be from surface melt water by Salmi (1959 op cit), when discussing the Imatra Stones. In the case of these Brickearths, where they rest on London Clay, the lime has probably been derived from the depositional waters.

The problem of the origin of the quartz was discussed by Walker (1960), who believed it only to migrate a small distance. In the case of the Essex Brickearth there appears to be little evidence as to where the quartz has gone, it may be that it recrystallized again at another point within the sediment.

DISTRIBUTION OF $CaCO_3$ AROUND CONCRETIONS OCCURING IN THE BRICKEARTH AT CHERRY ORCHARD LANE, ESSEX.

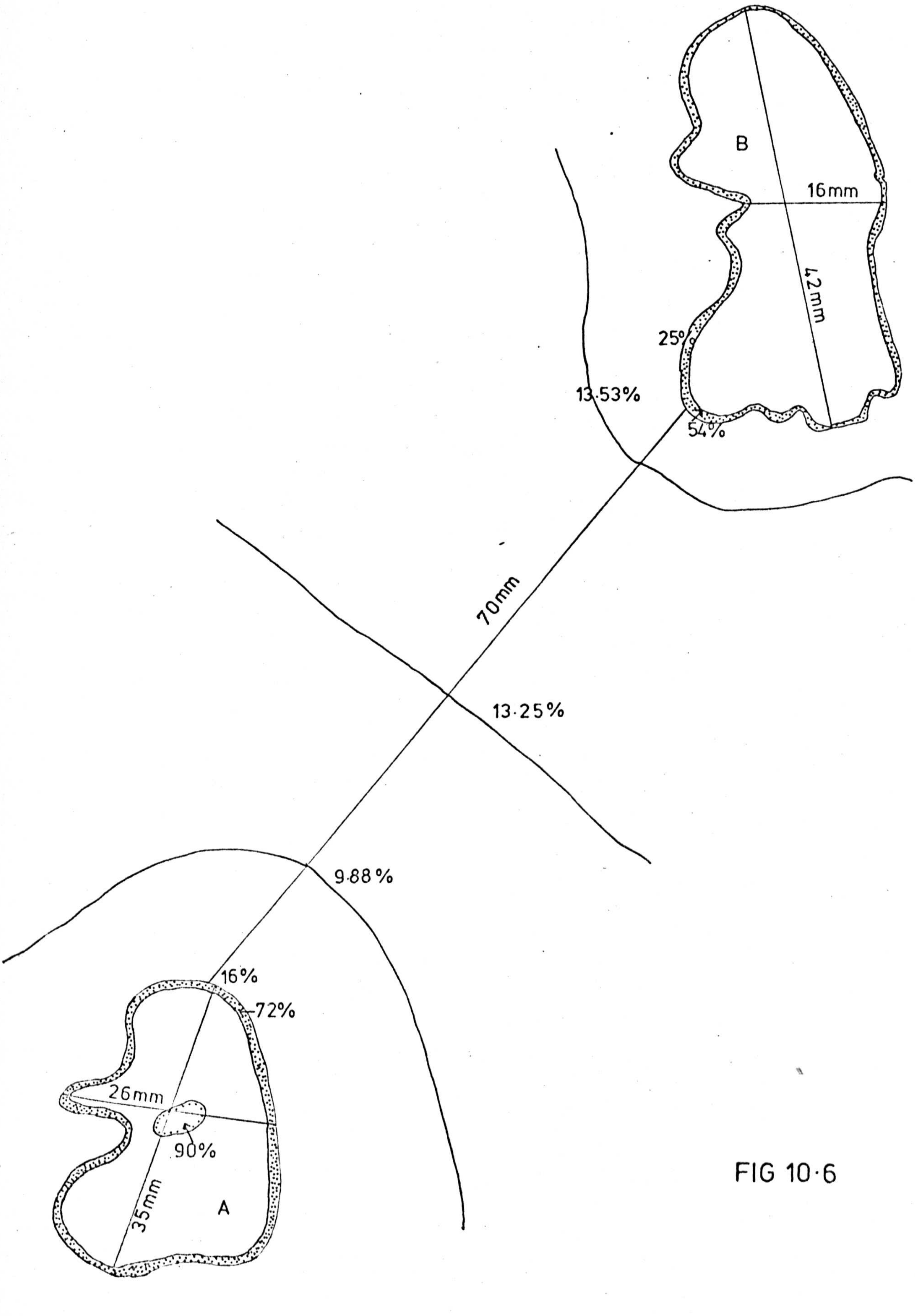


FIG 10·6

CHAPTER ELEVEN

MICROSCOPIC STUDIES

CHAPTER ELEVEN

MICROSCOPIC STUDIES

The previous four chapters have concerned the mineralogy of the loess deposits and the concretions that are contained within many of them. The microscopical nature of the concretions was also investigated in the last chapter but not that of the actual loess. This chapter looks at the British loess deposits microscopically with photomicrographs illustrating the undisturbed nature of the material and also highly magnified examples of loess grains produced by Scanning Electron Microscopy.

i) Optical Microscopy

From several of the sites undisturbed samples were obtained in small light weight open ended tins having a cutting edge in order to prevent disturbance of the material. These were sealed to hold the natural moisture content during transport to the laboratory.

Impregnation of the samples using Carbowax 6000 was carried out in accordance with the procedure suggested by Bascomb and Bullock (1974); Carbowax is water soluble and as such could be greatly diluted initially to enable the gradual removal of the natural water without disturbing the structure and causing a collapse of the pores. By gradually increasing the strength of the solution the sample eventually became rock hard. The main disadvantage of this method is that the carbowax melts on heating and dissolves in water. When cutting and grinding the thin sections, it was found necessary to cool the diamond blade with oil and to lubricate the carborundum paper and lapping cloths with paraffin. This was eventually washed away with 1,1,1,trichloroethane. The sections were mounted using fast setting epoxy resin.

On Fig.5.1 the position of the Pegwell Bay sample is shown; a thin section is shown in Plate 11.1. Most of the grains appear to be of a similar size, 30 - 70μ in diameter with the occasional larger grains, such as that in the top left hand corner which is approximately 700μ across its greatest length. The grains give the general appearance of having once being angular and have subsequently had their edges rounded off. This would indicate a possible original transportation by aeolian means and a further fluvial transportation after the first deposition. Because the grains are not totally rounded it may be inferred that the second stage of transportation and deposition was a rapid process. The equality of grain size is also an indication of aeolian transportation as the wind tends to sort and carry a limited particle distribution.

At Allington, near Maidstone a sample also revealed a distribution of silt grade particles with the occasional sand grains. The particles in Plate 11.2 have also been partially rounded probably as a result of fluvial transportation prior to deposition and the filling in of quarry gulls.

Plates 11.3 to 11.6 are from samples obtained at Star Lane Brickworks, near Southend.

The section at this site was described in Chapter 5 as having a silty upper horizon and a finer grained lower horizon below a depth of 1.4 metres. The upper horizon was also shown in Chapters 7 and 9 to be lime free with the lower bed being rich in calcium carbonate. Plate 11.3 is from the upper horizon from a sample obtained at 72cm from the surface. The grains are generally of an even size possessing sharp edges. Although the calcium carbonate content is low the large quartz grain in the

PLATE 11. 1.

Photomicrograph of a soil from Pegwell Bay. Quartz grains are seen to be generally equidimensional with sharp of slightly rounded edges.

X 70

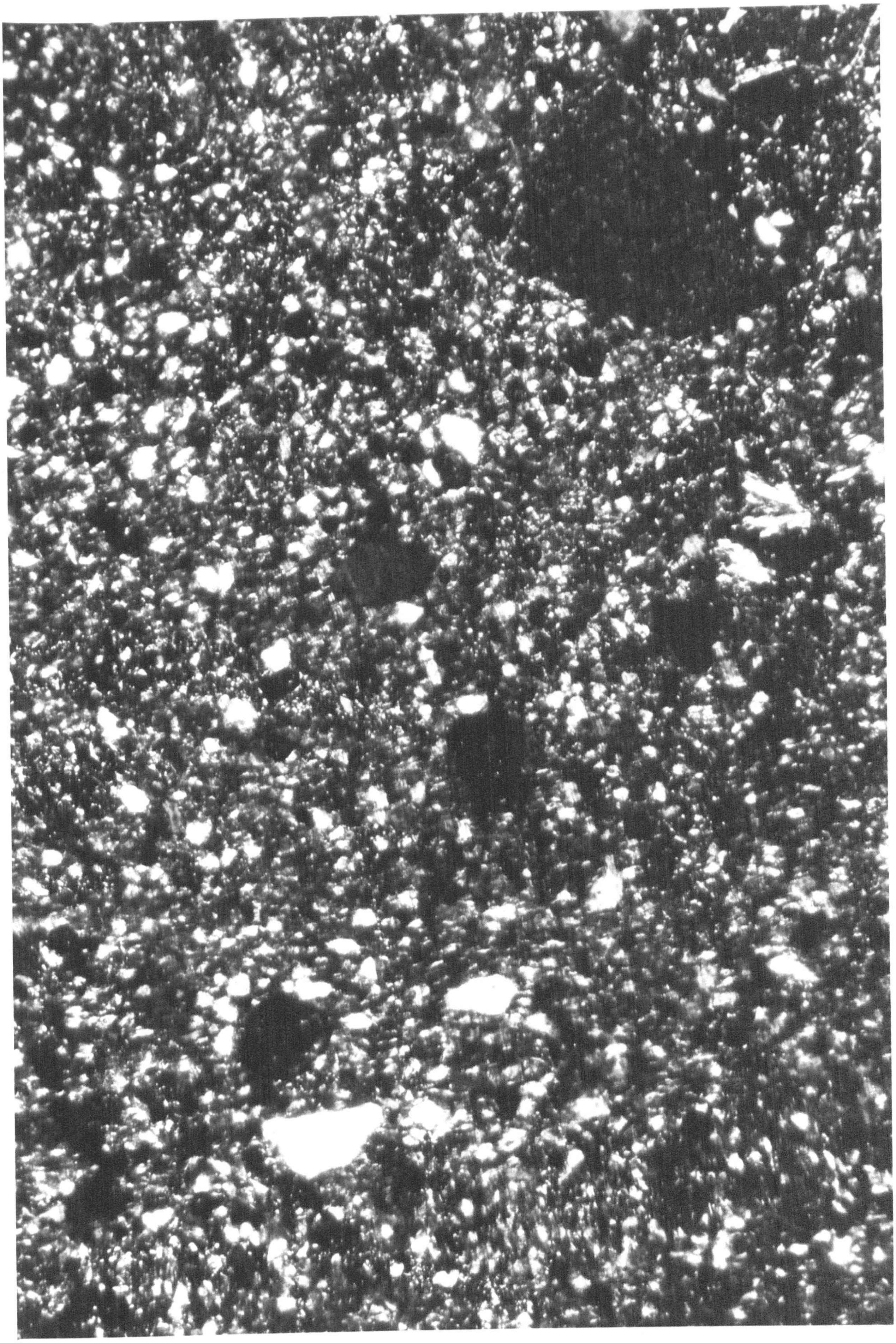


PLATE 11. 2.

Photomicrograph of a soil sample from Allington.

X 70

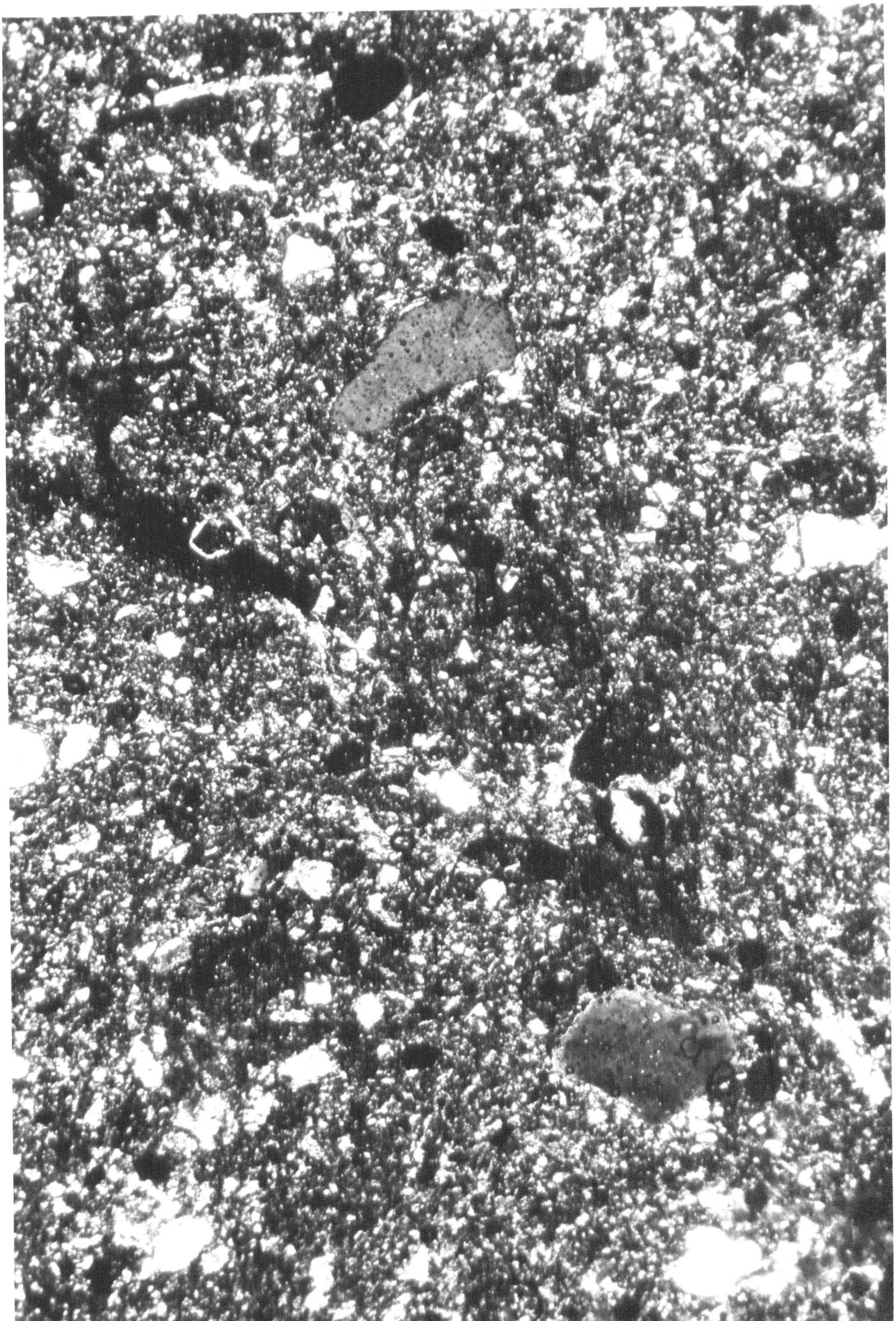


PLATE 11. 3.

Photomicrograph of a soil sample obtained at a depth of 72cm from the section at Star Lane Brickworks. Although this is in the lime free horizon the large quartz grain in the centre of the photograph appears to have been partially replaced by calcite.

X 175

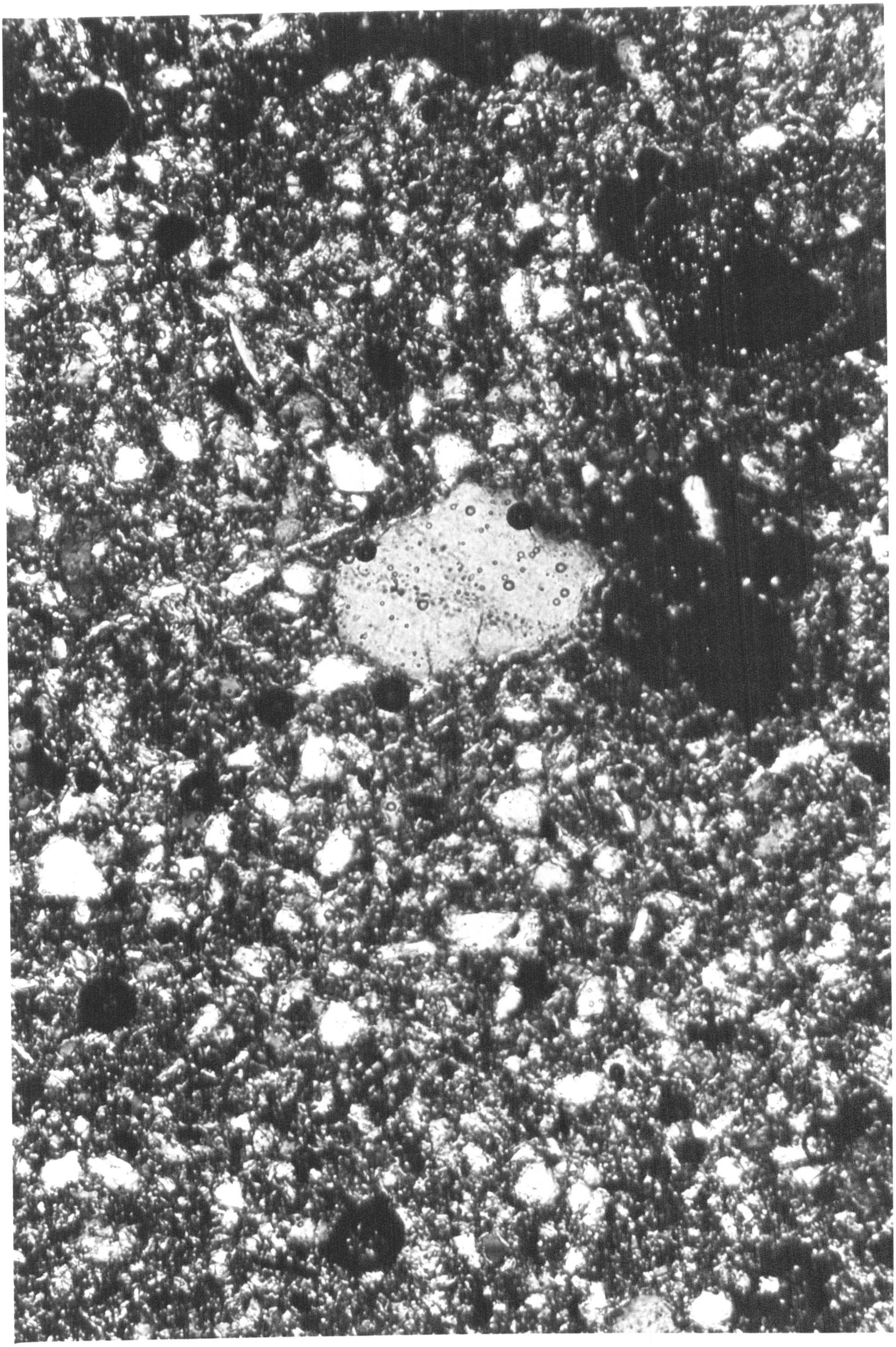


PLATE 11. 4.

Photomicrograph of a soil sample obtained from Star Lane Brickworks at a depth of 1.5 metres showing parallel channels running through the deposit.

X 28

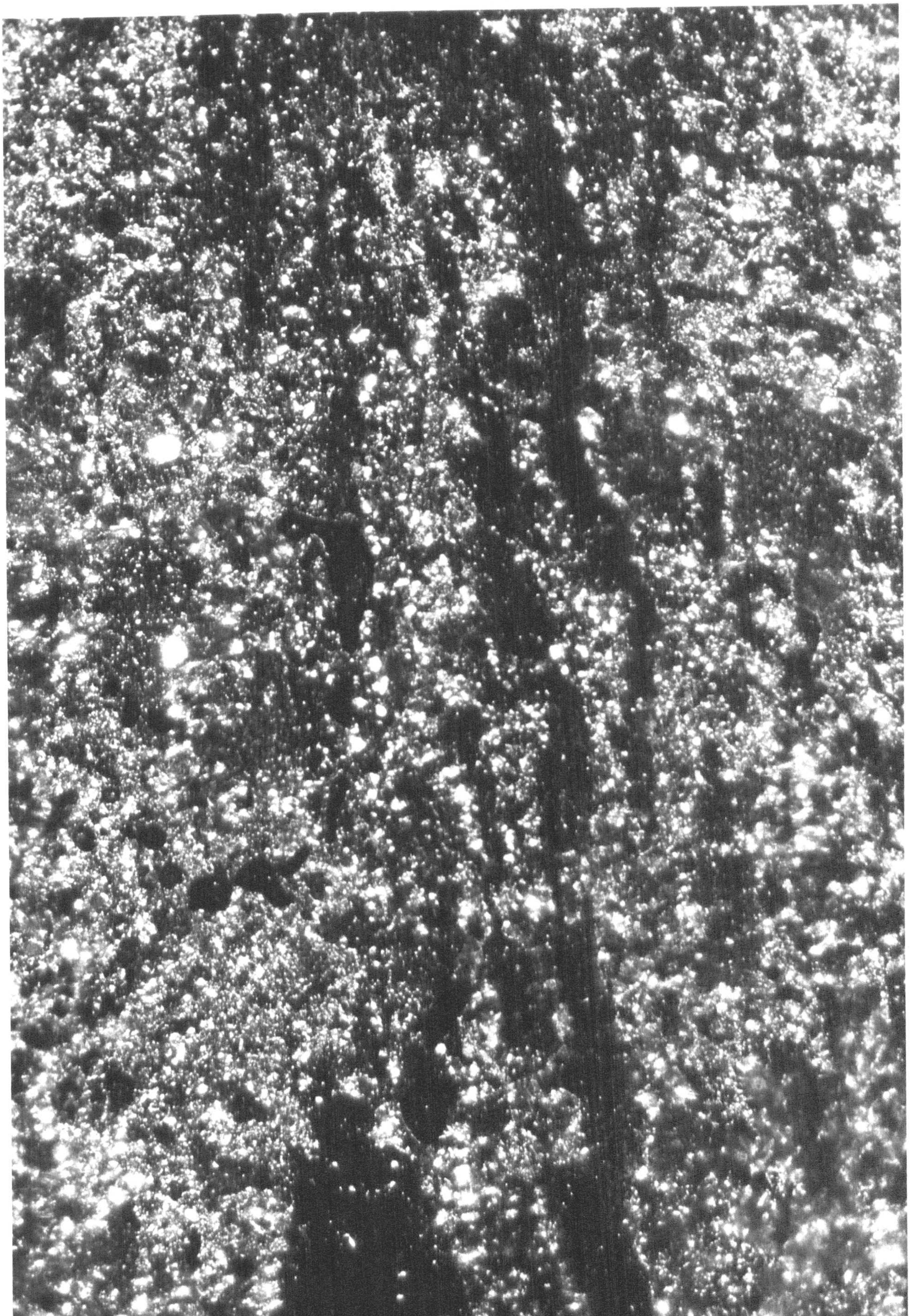


PLATE 11. 5.

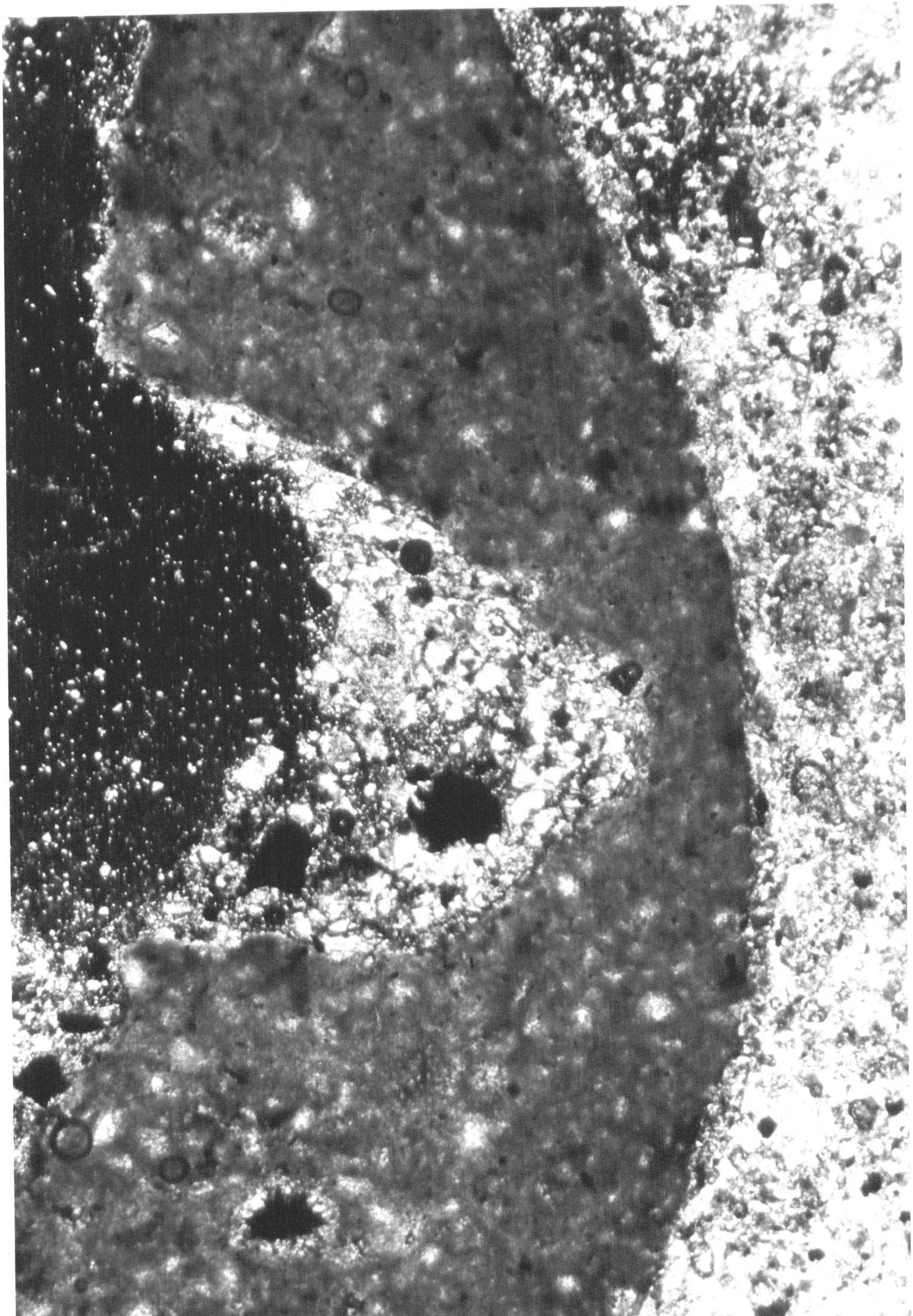
Photomicrograph showing a small concretion preserved at a depth of 1.5 metres, Star Lane Brickworks.

X 28

PLATE 11. 6.

Photomicrograph of a small part of the concretion shown in Plate 11. 5. giving a view of the boundary with the brickearth. The infilling of part of the fissure with secondary calcium carbonate can be seen.

X 70



centre of the micrograph appears to have been etched in a similar way to those shown in Chapter 10 within the concretions. This may be indicative of the presence of lime in the past which has gradually been leached towards the lower horizon.

Plate 11.4 is from a depth of 1.5 metres showing the parallel running channels through the deposit. Although this is generally a finer grained sediment the quartz grains appear in substantial quantities showing rounded off edges in a similar way to the north Kent deposits.

The calcium carbonate appears as concretions in some cases, Plate 11.5 shows a thin section of one occurring within the lower horizon at 1.5 metres depth. The centre of the concretion reveals a well developed contraction crack,part of which is shown in Plate 11.6 to be filled with calcite as a result of secondary deposition.

ii) Scanning Electron Microscopy

Higher magnifications of disturbed samples in three dimensions have been made possible by use of a Cambridge S600 scanning electron microscope. Previous studies of loess particles using this technique include reports by Smalley et al (1970), Cegla et al (1971), and Smalley et al (1973), all on European deposits. A few examples of the features displayed by the particles of British loess are given in this section. The magnification is given on each plate by the dark band on the scale line. Plate 11.7 is from sample 6 on the western side of Pegwell Bay. Several particles 30 - 40μ across are seen with sharp angular edges and corners. Small quantities of fine clay particles adhering to the silt grain can also be seen. Plate 11.8 is a large silt grain with three prominant sharp faces; this is from sample 7 on the east side of Pegwell Bay.

The south east Essex samples have less angular particles with some of the edges having the appearance of being rounded off. Plate 11.9 is from the original section at Cherry Orchard Lane from a 2 metre depth. The silt grade particles have small carbonate and clay grains adhering to them.

The regular size of coarse silt grains is shown in Plate 11.10 from Costessey near Norwich. The grains are sharp with angular corners and edges, and lack considerable attachment of fine grained particles.

Plates 11.11 and 11.12 contrast the glacial originated quartz grains of east Yorkshire with the desert originated dolomite particles of the Permian of Tadcaster. The angular fine sand fragment from involutions at Hornhill Top is shown in Plate 11.11 and the dolomite rhombs from Windmill Quarry with their almost perfect faces are shown in Fig.11.12. Here the rhombs show the equality of size that presents the steep particle size distribution curve of Fig.6.12.

PLATE 11. 7.

Scanning Electron Micrograph of sample 6, from Pegwell Bay showing several silt sized quartz particles.

PLATE 11. 8.

Scanning Electron Micrograph of sample 7, from Pegwell Bay, showing sharp angular faces to the silt sized particles.

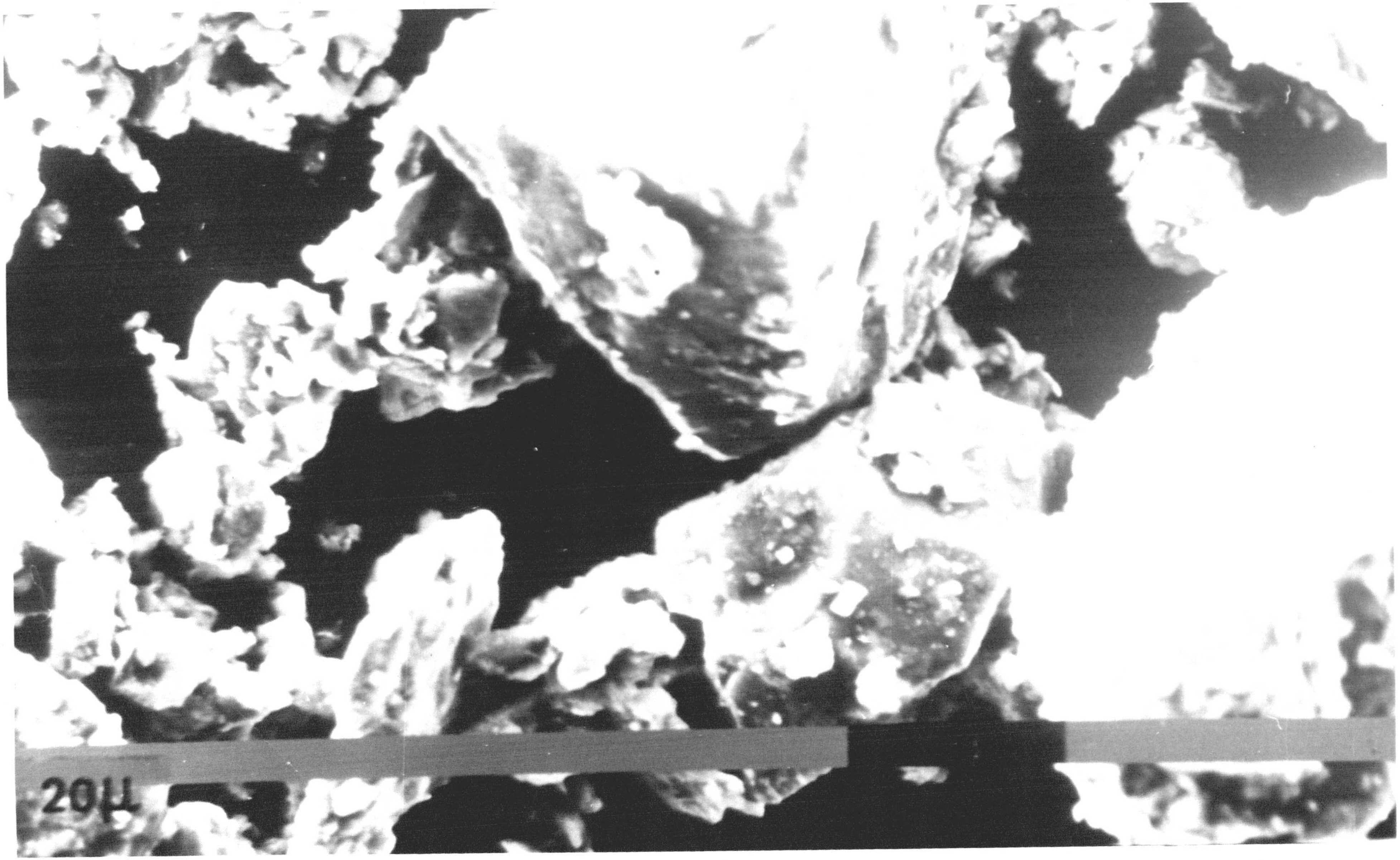

20µ

PLATE 11. 9.

Scanning Electron Micrograph from Cherry Orchard Lane Brickearth. The quartz particles are clustered with clay plates.

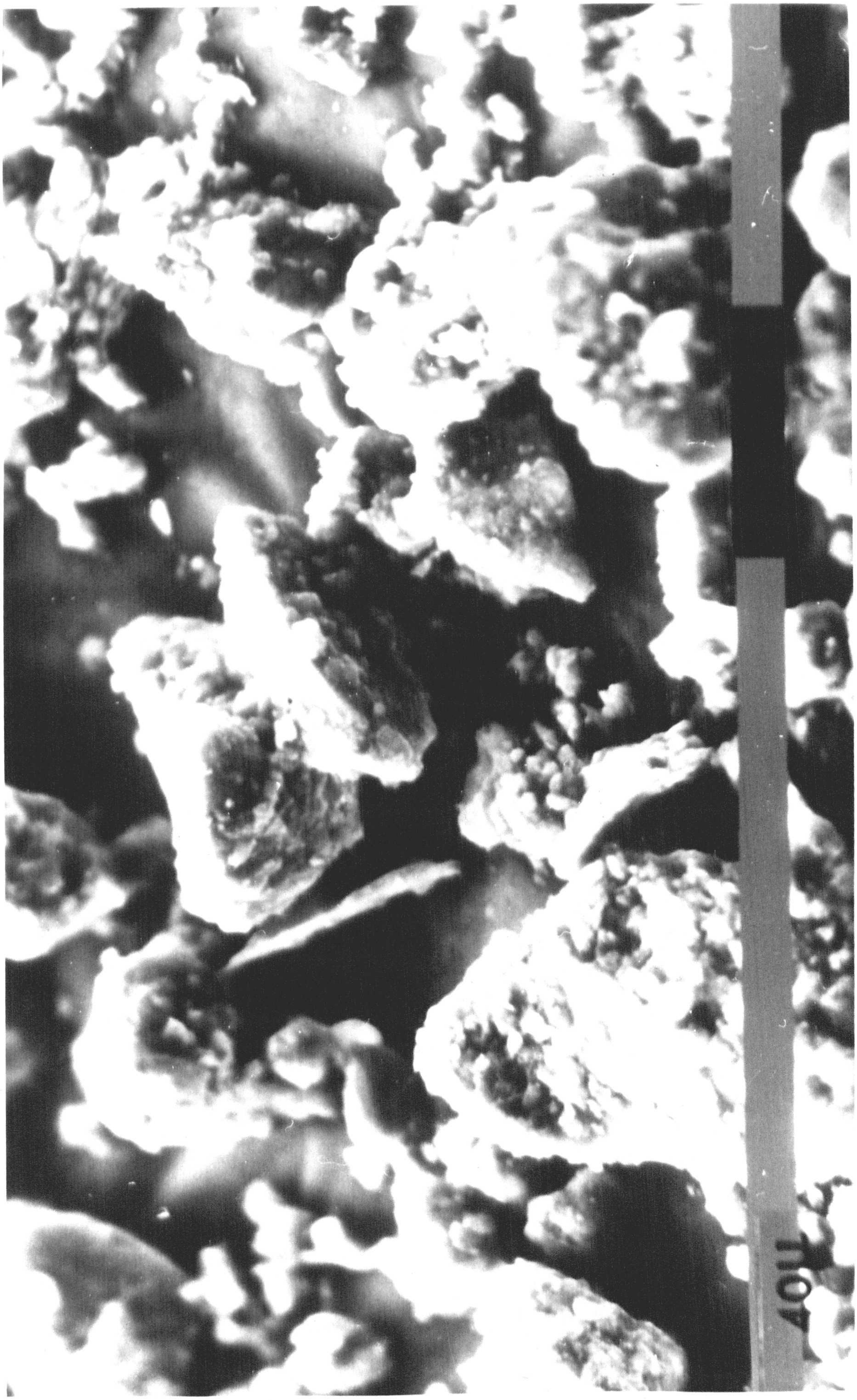

40U

PLATE 11. 10.

Scanning Electron Micrograph showing numerous coarse silt grains without any clay attachments from Costessey.

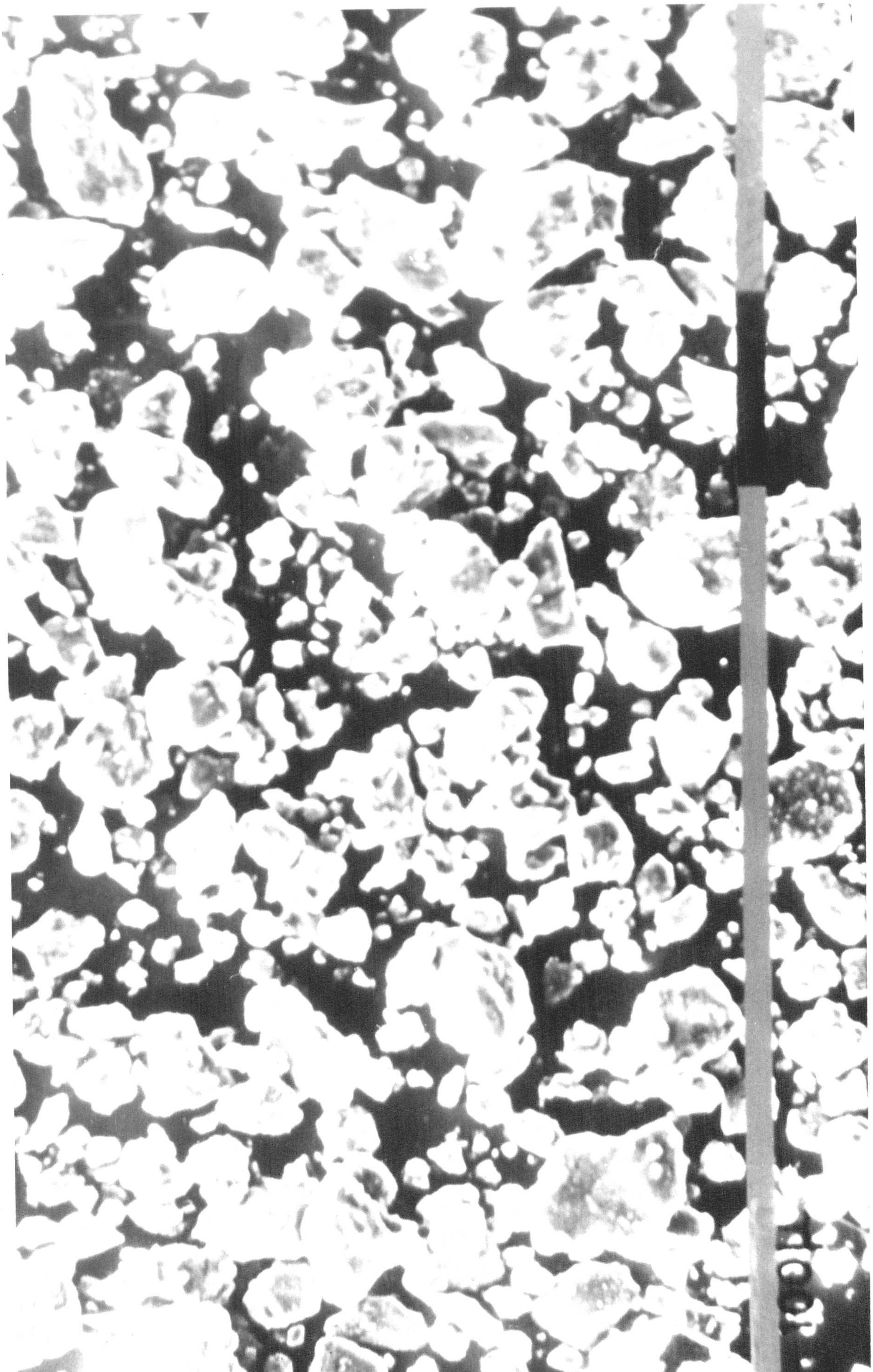


PLATE 11. 11.

Scanning Electron Micrograph of a large angular quartz grain contained within the involution deposits at Hornhill Top.

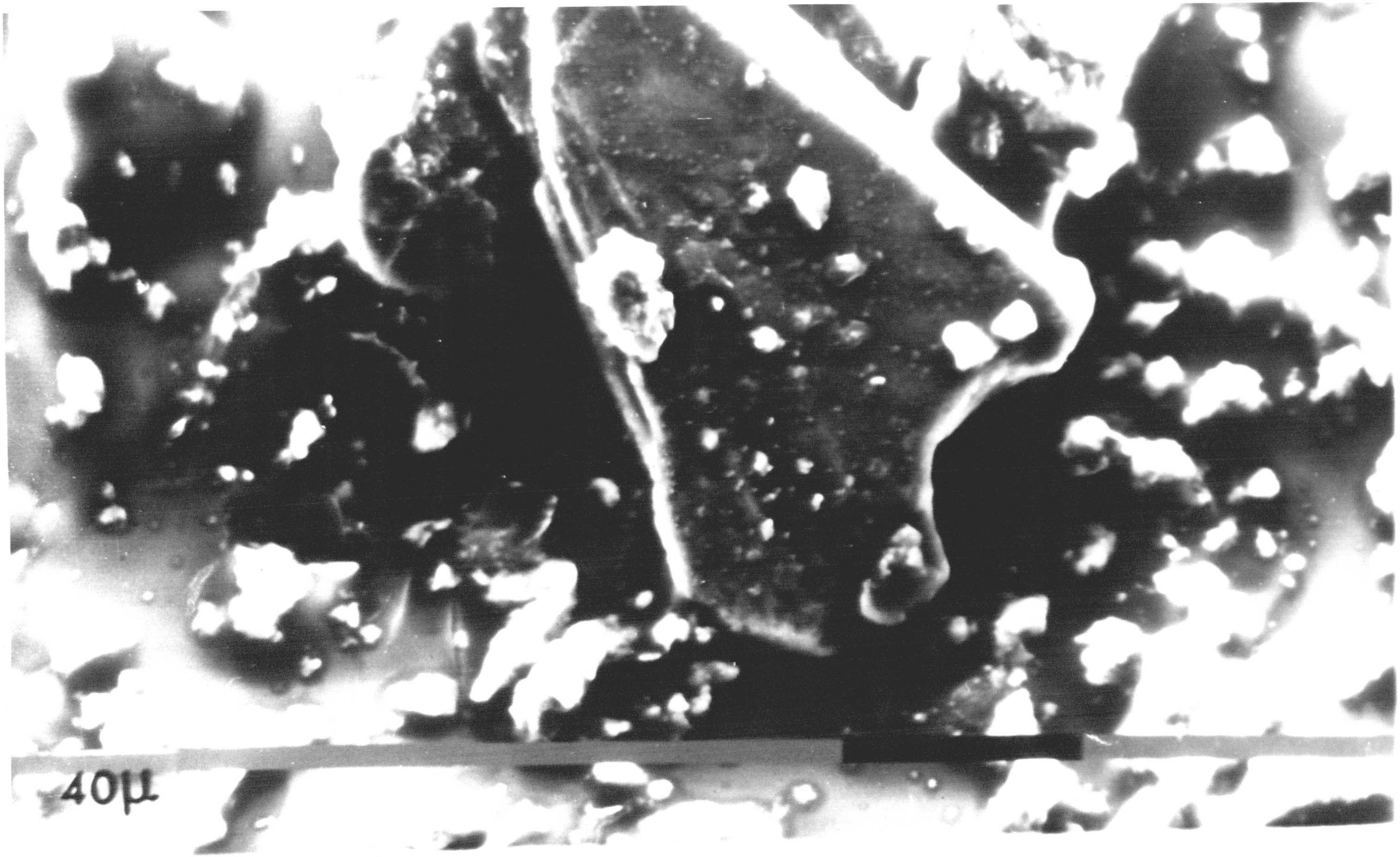

40μ

PLATE 11. 12.

Scanning Electron Micrograph of fresh dolomite silt particles from Windmill Quarry, near Tadcaster. These particles do not appear to show any effects of either physical or chemical weathering.


20µ

CHAPTER TWELVE

DISCUSSION

CHAPTER TWELVE

DISCUSSION

Throughout the course of this research it became apparant that very little was known regarding both the nature of the British loess deposits and of their distribution, particularly in areas outside the south-eastern part of England. The investigations that had been undertaken by Victorian geologists had been with the primary aims of establishing lists of fauna and collecting fossil and palaeolithic material from the brickearths. A few workers had attempted to date the brickearths of the lower Thames valley and to relate them to the glacial deposits of eastern England. The controversy concerning the age of the brickearths has still to be settled with several present day workers observing the problem with the help of non-compatible techniques. The archaeologists using the data provided by palaeolithic man and the palaeobotanists with their pollen analysis appear to be as far from solving the dating problem as were the geologists of one hundred years ago (Chapter 2.)

During the last twenty years a limited amount of progress has been made in establishing a distribution pattern of the British loess with several of the south eastern sites being described, along with other localities in northern, eastern and south west England receiving attention. A review of the literature pertaining to these sites was undertaken in Chapter 2 giving an overall view of the situation regarding distribution. Several places were visited, which enabled an assessment of the nature of the field relationships to be made and for an analysis of the mineralogical and physical properties to be obtained (Chapters 5 to 9).

Observations of a typical loess deposit were found to be rare with the only locality that appeared to show any similarity to those deposits described from eastern Europe, being the western part of Pegwell Bay. The thickness of the deposits, without any visible stratification, resting with a slight unconformity directly on the Thanet Sands suggested these to be almost typical loess sediments. By using these deposits as a means by which others may be compared in terms of field relationships, mineralogy and geotechnical properties it has been possible to establish a general picture of where the British loess is to be found and the individual characteristics of the deposits. The eastern section of Pegwell Bay contrasted significantly with that of the west. The unstratified, homogeneous material behind the hoverport gave way to highly contorted brickearths, with flint pebble bands ' picking out ' the disturbed features of the deposits. On top of the section and further east the contorted brickearth gave way to solifluction features with involution being prominent. The significance of these two distinct types of deposits at one locality appears to suggest that two separate phases of deposition have been active with the deposits of the eastern section deposited first and later affected by post-depositional periglacial activity. The deposits of the western section are of late glacial or post glacial age having not been influenced by any cold phase. An alternative to this view rests with the solid geology. The brickearths of the western section rest upon the Chalk and not the Thanet Sands. It is possible that the Chalk reacted in a different way as a result of freeze-thaw conditions opening up joints and cracks in the rock, causing a general degree of physical and possibly chemical disruption. The Thanet Sands may have been able to withstand the influence of the periglacial conditions and as a result prevented disturbance of the overlying loess.

At Monkton a few miles from Pegwell Bay, a thin cover of brickearth was found overlying the Chalk; this also showed involutions suggesting that these are of a similar age to those in the eastern section at

Pegwell Bay. The most noticable feature of the deposits at all the other sites studied was their lack of similarity to those of Pegwell Bay. This may be partly a function of the predepositional topography and also of the depositional history of the deposits. At Denstead Wood, an old quarry face, located at the site of the Local Authority refuse disposal tip, revealed a brickearth of an unstratified nature banked against a ' rise ' in the Woolwich Beds. The Tertiary deposit had a steeper eastern face which resulted in a greater thickness of brickearth at this part of the section. The topsoil formed on the brickearth had developed through to the Woolwich Beds at the top of the rise but it was still possible to note that the brickearth had originally covered the whole of the older deposits at this point. The field relationship of the brickearth appeared to suggest that it had filled a stream channel in the Woolwich Beds and that deposition had been rapid without allowing any sedimentary structure to form.
At Allington near Maidstone, the brickearth was found filling solution pipes in the Kentish Ragstone. This post-depositional activity appears to be a result of periglacial activity suggesting that the brickearth at least ante-dates the last galcial phase affecting eastern England.

The brick pits at Funton, Cherry Orchard Lane and Star Lane show several similarities. The buff coloured silt extracted for brickmaking is generally 1.5 to 2.0 metres in thickness, unstratified and overlies similar material with a higher calcareous content. The widespread distribution of these deposits suggest that deposition has occurred by a similar process. Their close proximity to the Thames indicates that the river has been instrumental in their deposition, possibly depositing the material in periods of flood and leaving it undisturbed. The gradual shifting course of the river, depositing flood loams at different localities during times of excessive flow, eventually gave the appearance of a blanket cover over the Thames estuary region.

Turner (1970), described the deposits at the Marks Tay brickpit, as lacustrine. The laminated nature of these deposits suggests this interpretation to be correct. A floodloam mechanism of deposition would have resulted in non-stratified homogenous deposits, similar to those recorded in the vicinity of Southend.

Investigations in the area around Norwich revealed little conclusive evidence regarding the distribution of loess. The coverloam of this region has been described as containing a silt fraction which respresents the loess content, (Catt et al 1971). The widespread distribution of sands and gravels, which have been derived from melt water of retreating glaciers, tend to mask much of the remaining superficial material. The presence of any silt rich deposits appears to be a coincidental feature of the sorting action of fluvial agencies dominating the margin of the ice.

The homogeneity seen in the Pegwell Bay loess, both on the western side and in the involutions of the eastern section is not repeated in the deposits of east Yorkshire. The dark brown deposit at Hornhill Top was found to contain numerous small stones both rounded and angular. The north western and south eastern parts of this section appear to be undisturbed but the deposit in the central part of the section has been affected by periglacial action with well developed involution having formed. Similar features are seen at Etton, Eppleworth, Huggate and Hessle. The general appearance of the east Yorkshire deposits suggest that these have originally formed as glacial drift, in some cases the silt fraction is high suggesting that an aeolian content is present. Post-depositional periglacial activity has affected these deposits at all the sites, to a variable degree. The common factor linking the Yorkshire sites with other localities where involutions, or the influence of solifluction may be observed is the presence of calcareous bedrock. Conversly solifluction does not appear where the deposits are underlain by non-calcareous bedrock. The effect of the ice on the Chalk or Kentish Ragstone, (as at Allington), must bear a substantial degree of responsibility for the features that are observable in the overlying superficial cover.

Mechanical analysis of all the samples obtained has shown in almost every case that the Pegwell Bay deposits, on the western section, are finer, with a high silt and clay content and a lower sand fraction. The significance of this feature is not totally clear; it may be a function of the source or a result of postformation transportation of the particles. In the case of the east Yorkshire drift deposits a general sandy composition was recorded with a lower silt content than that suggested by Catt et al (1974).

The floodloam deposits of the Thames estuary appear to show the greatest similarity, in terms of particle size distribution, to the Pegwell Bay standard.

The mineralogical analysis of all the Pleistocene samples has emphasised the high content of primary minerals as expected. The concentration of clay minerals in the $< 2u$ fraction was not surprising but the high proportion of primary minerals found in the ' clay fraction' is significant to the geotechnical behaviour of these soils. The strength of any soil depends upon the strength of the individual particles and the bonds which link these particles to each other. Quartz particles are generally strong both physically and chemically but by themselves do not possess sufficient strength to maintain a stable soil structure. Thepresence of clay minerals usually provides the necessary ' adhesion ', between these primary particles, but in soils where the clay forms only a small percentage, the strength of the material is reduced and as such is unable to retain any stability under load. The presence of calcium carbonate was shown in Chapter 6 to contribute a temporary degree of strength to the Star Lane deposit, with the lining formed in the pore walls able to act as a structure.

The wetting of the soil breaks or weakens the bond between the clay and the primary minerals causing deformation and eventually collapse of the soil to take place. The nature and the distribution of the deposits described are all a function of their history in terms of particle formation, transportation, deposition and post-depositional activity. Samlley's model (1976), of events in the formation of a loess deposit can be simplified as shown here:

material formed	→	transported	→	deposited	→	subsequent activity

Loess deposits throughout the world have presented problems to investigators of numerous disiplines. The British deposits are not an exception to these problems and in order to understand the British deposits it is necessary to consider those from other regions particularly European deposits.

The controversies surrounding the various loess formation theories have probably contributed to the greater part of the discussions which this particular type of deposit has attracted, this in part may have been caused by insufficient knowledge of the loess material or general speculation as in the early days of investigations when many of the known facts were ignored.

The production and accummulation of large quantities of silt grade quartz particles appears to require the actions of distinctive processes to have predominated at certain periods during the Pleistocene. The problems arising from the relative dating of these processes primarily as they affected the formation of British deposits but also in a wider context are the major concern of this discussion.

The problems attached to particle formation are not confined to British or European loess deposits but are a feature of loess deposits throughout the world. Most of the land area of Britain and northern and central Europe was directly influenced by the cooling of the earth's atmosphere during the Pleistocene with glacial or periglacial activity predominating for much of the period. The production of large quantities of material by the crushing action of the ice as rock fragments are ground against each other is one of the possible primary methods for the intial production of ' loess ' particles.

The major alternative to this proposal is that of wind abrasion in arid regions with sand grade particles blasting together resulting in the formation of small silt sized grains. It appears doubtful that this method could have produced sufficient quantity of material in the time available to account for the thick accumulations of loess found stretching across the continental areas of Europe, Asia and North America. The protagonists of this desert theory do not account for the one direction transport this material takes to substantiate this process. The particle forming regions are the deserts of northern Africa, eastwards through the Gulf States of the Middle East, the depositional areas are northwards from these regions. If these are the regions for the production of large quantities of silt grade particles, where are the loess deposits to the south towards the central regions of Africa? For this reason it appears that although wind abrasion in the hot desert areas may produce a significant quantity of silt particles in localised regions the process is not sufficiently extensive or intensive to produce material for the major loess deposits.

The actions of the glaciers were widespread and possessed the continuous force to produce the correct grade of particle for loess deposits to attain basic similarities throughout the world.

The means of transportation and deposition of ' loess' particles in such a way that they accumulate without a sedimentary structure, found common to most deposits, has intrigued geologists for over a century and a half. The association of large loess deposits with the major rivers of North America, Europe and China has influenced the fluvialists in regarding this to be the major means of loess movement and deposition. The problems arising from material being ' tipped ' onto the watershed by a glacier for the river to proceed with a sorting process does not appear to have been considered. There is little doubt that the major river systems have played a part in the essential formation of loess deposits but cannot be considered totally responsible for all the processes occuring at the moment the material is released from the mouth of the glacier.

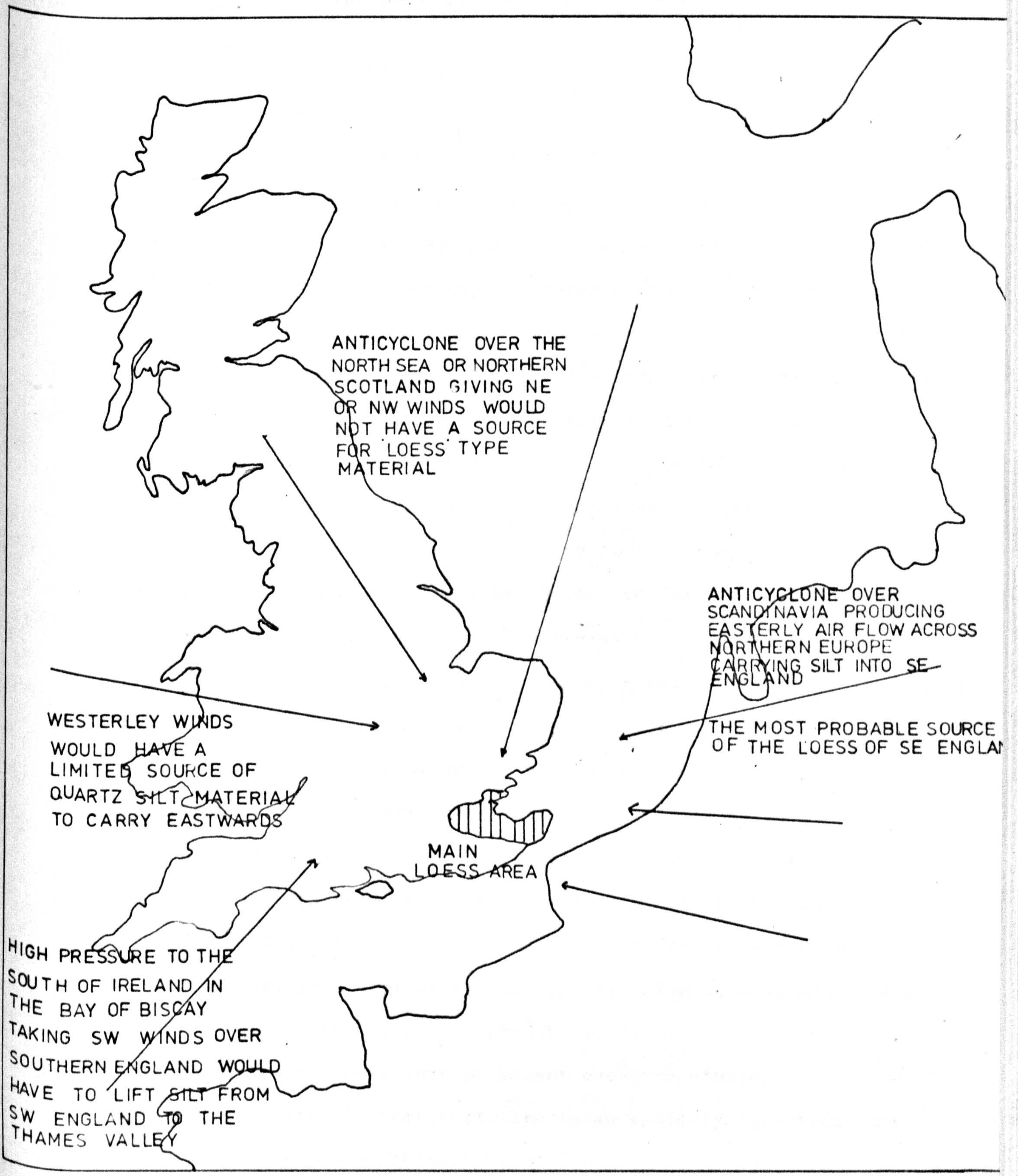
Howarth (1882), proposed a marine transportation or flood to account for the Chinese deposits, a theory quickly opposed by Richtofen (1882), who suggested that loess at 8,000 feet above sea level could not have resulted from such a process.

Richtofen's (op cit) alternative proposal in terms of aeolian processes appears to be the basis upon which many of the loess problems have been solved. The action of the wind with its ability to sort and grade particles and to be independent of location or altitude appears to give this process a major advantage over others that have been proposed.

The proposals suggested here as appropriate to the formation of British loess deposits attempts to incorporated various processes through several stages of development. These processes may be mirrored in part or as a whole in Europe, America and Asia.

As far as the British deposits are concerned it is critical to ascertain the source of the silt particles as well as their mode of formation and from study of these deposits it has been possible to suggest where and the means by which the material has formed.

The influence of glaciation is undoubted in the formation of the particles, the location of the glacier prodcuing these particles has not been extensively discussed. Williams (1975), implied that the wind blown deposits of England originated from the west, an assumption



MAP 12.1 INDICATING THE POSSIBLE AND MOST PROBABLE SOURCE OF LOESS MATERIAL IN TERMS OF SOUTHERN ENGLAND DEPOSITS AND WIND DIRECTIONS AROUND BRITAIN

based on the present predominence of westerly winds. This proposal is unable to account for a source of the quantity of material required. It is doubtful if the glaciation of western Britain could have produced enough silt grade quartz material to form the brickearths of south-eastern England; the Chalk and limestones of central England could not provide quartz particles.

The alternative to a westerly source is an easterly one, with material being derived from the Northern European Plain and eastern Europe. The Scandinavian glaciers would have been able to grind and move vast quantities of quartzitic particles, depositing them at the ice margins for the wind to lift and sort. Deposition of a loess belt across Europe from the Russian border through to France and south east England took place gradually as the wind lost its carrying power at various stages. In Chapter 4 the anticyclonic theory of Hobbs was suggested to account for the distribution of loess across northern Europe into south eastern England. Several of the loess sites of Kent from which material was analysed were described in Chapter 5 along with possible pre-depositional histories of the deposits.

Anticyclonic conditions appear to be the most suitable for the distribution of silt particles produced by glacial actions. High pressure armospheric systems dominate the polar regions of the earth today; during the cold phases of the Pleistocene this domination extended with the ice towards the lower latitudes giving many parts of western Europe a dominating easterly air flow in contrast to the westerly type of the temperate phases.

Such a feature may have been prominent over the Himalayas with the anticyclones carrying silt particles in an easterly direction into the Hwang Ho valley of China.

The suitability of anticyclonic systems over Scandinavia and the non-suitability of other systems are shown in Map.12.1. The processes of re-working freshly deposited loosely consolidated quartz rich, silt grade material were rapid and intensive particularly in the fringe areas of deposition where deposits are thin and the fluvial action of the freely flowing water courses are more extensive. The Wealden area of south east England appears to have acted as a natural loess trap as the effect of the easterly winds diminished resulting in deposition. Material was quickly removed from the higher parts and the valley sides and carried towards the bottom of the deeply dissected drainage lines flowing northwards towards the Thames and eastwards towards the English Channel (Map 12.2). In many cases the deposits were affected by periglacial activity with solifluction and involution formation being prominent.

The original source of the clay particles presents a very interesting problem. The separation of quartz particles from one another allowing the wind to sort and separate the size fractions it is able to lift from those it cannot is a relatively straight forward procedure. The bonding of the individual clay plates to each other, results in clusters of particles of a substantial size, ofter greater than the silt fraction. The power of the wind is unable to separate the clusters into individual plates and cannot transport the clay over large distances. It is this feature that accounts for the large percentage of primary minerals within the loess deposits and also indicates that much of the clay mineral present has been introduced subsequent to the initial stage of deposition.

Small quantities of clay minerals may be transported attatched to primary quartz particles but the majority of the clay particles have been introduced by one of two main processes; firstly by mixing with existing deposits upon which the silt has been deposited, this may take place by pedological processes or during fluvial or solifluctual movement and redeposition. The second method of clay mineral introduction is by the breakdown of feldspars or the breakdown of amphiboles such as hornblende to feldspars which inturn are broken down by weathering processes to illites and kaolinites, the latter in cases where a substantial amount of potassium is present, generally contained within orthoclase. The source of the feldspars and amphiboles may be the same as that of the silt grade quartz - the glacially crushed debris, or may be introduced by the fluvial or periglacial mixing before being broken down. From this it is possible to infer that a combination of the two processes may have caused the introduction of the clay minerals, particularly at such sites as Denstead Wood where fluvial processes appear to have existed and Allington where periglacial activity has succeeded the deposits of the brickearth.

At several of the sites in the south east of England that were discussed in Chapter 5 it was suggested that the rivers draining the higher parts of Kent were responsible for the transportation and deposition of the brickearths. A look at Map 1 (Back folder) quickly shows how the brickearths are concentrated almost totally in the valleys of the northward draining rivers rather than those flowing southwards. It would appear unlikely that any brickearth that did exist in any of the latter streams would have been carried into the English Channel with the result that all traces have disappeared. Deposition as a result of the loss of force of easterly dominating winds on the ' lee ' side of the Wealden axis may account for this particular form of distribution.

The deposits of the low lying regions alongside the Thames may be regarded as fluvially deposited silts as the river flooded, possibly caused by ponding of the estuary by ice surges as Hollins (1964) suggested, or may be considered as primary deposits with the silt having been ' dumped ' on wet marsh area around the Lower Thames and being ' trapped ' permanently in its present position.

The activity caused by periglacial processes has succeeded fluvial deposition at some of the localities which adds to the interpretive problems that already exist with this type of deposit.

Not all loess investigations have considered transport or deposition a major problem to their ideas of formation. The in-situ theorists regard loess to have formed by the normal pedological processes resulting in the breakdown of the rock upon which they rest with localised movements taking place in localised situations. To account for such a widespread distribtuion of material by this process where different rock types and climates are involved presents numerous objections.

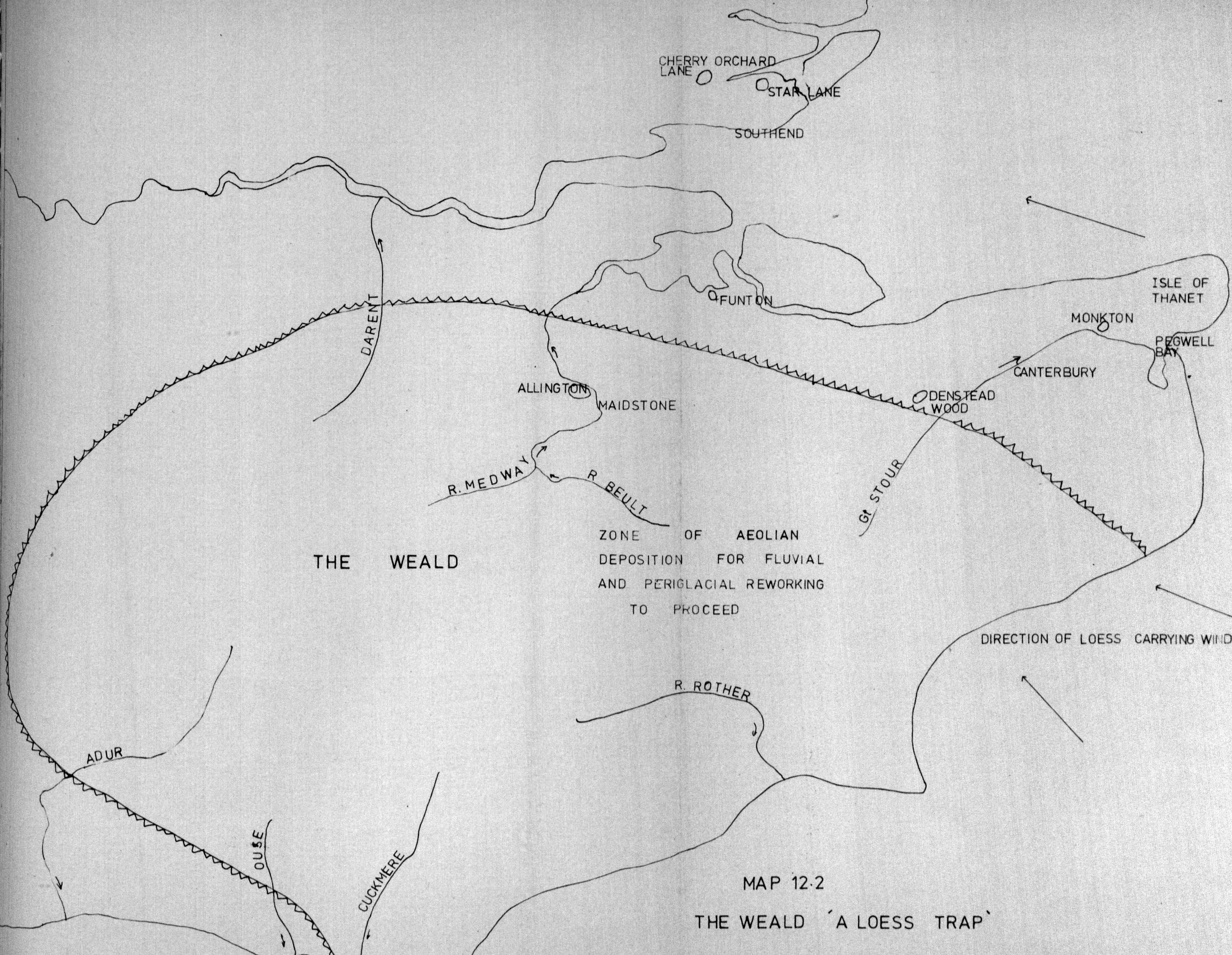
The presence of terrestrial forms in abundance in many loess deposits have to a limited extent influenced the thinking of the insitu theorists but numerous freshwater species, some of which appear in the position of life, suggests that fluvial activity has affected the transportation and deposition of loessial material.

The significance of calcium carbonate during the post-depositional period varies with the deposit. At Funton, Cherry Orchard Lane and to a lesser extent at Star Lane the calcareous nature is expressed in the lower horizons as small nodules;at Allington small calcareous fibres are visible in the brickearth approximately 3.0 metres below the surface. The importance of the concretions is not sufficiently understood. They may preserve a previous soil structure, a feature that is difficult to obtain conclusive evidence from. The generally higher calcareous content in the lower horizon appears to be a result of leaching from above. The absence of calcareous bedrock indicates that the source of the lime is not from below and has been introduced during the second stage of deposition.

In comparison to the European nodules, the British type are generally much smaller and do not have such an extensive variety of shape but internally their microscopic nature is similar with many of the quartz particles having irregular angular and sub-rounded faces where they have been replaced by calcium carbonate. From these observations it appears that similar processes are occurring in all the nodules once they have formed and created a mirco environment of high alkalinity in order to replace such a resistant mineral as quartz.

The Yorkshire deposits have been deposited as drift from the Devensian glaciation. The mixing of silt grade quartz particles during the post-depositional period to present the deposit with a ' loess fraction ' is possible but has not been substantiated by this research.

Future research regarding the British loess requires extensive detailed mapping of the deposits in terms of their mechancial properties and mineralogical composition. The post-depositional history of each deposit is also required to establish the general nature during both the interglacial and post glacial phases. The significance of the calcareous nodules requires further exploration as they may supply information concerning the history of the structure of the deposit. Undisturbed samples of loess are difficult to obtain in the most ideal conditions; retaining the structure during impregnation is also difficult. The perfection of these techniques may also assist with further microscopical studies of the soil.



MAP 12.2

THE WEALD 'A LOESS TRAP'

CHAPTER THIRTEEN

CONCLUSIONS

CHAPTER THIRTEEN

CONCLUSIONS

The major aim of this work has been to establish the distribution of loess in Britain, mainly on the basis of reports of previous investigators, and also to examine the nature of the loess. The means by which the British loess attained its present position has also been considered.

In Chapter 1 a list of the accepted definitions of loess was presented (Fig.1.2) outlining the synonyms used for the various types of loess deposits. Using this as a basis, it appears that few of the British deposits can be considered as typical loess. The Pegwell Bay loess on the western section may display the greatest similarities to a typical loess but the solifluction features that are seen on the eastern section suggests that other processes have been effective subsequent to deposition.

Solifluction and cryoturbation activity has also been prominant at other localities, particularly those in east Yorkshire. The well developed involutions at Hornhill Top and Eppleworth along with the lesser developed ones at Hessle, Etton and Huggate suggest that these deposits have been altered to a considerable degree since their intial deposition.

The question as to whether the Yorkshire and Norfolk deposits are actually loess is still undecided. They were originally suggested as loess because of their silt fraction, which having been blown from the edge of the retreating ice margin, was mixed with the drift.

The field relationships of the Norfolk deposits did not suggest that a loess ' tag ' should be placed upon them; it appeared that many of them constituted the finer parts of sand and gravel deposits. The scanning electron micrographs (Chapter 11), showed one of the Norfolk samples, Costessey, to be evenly graded in the less than 75µ fraction with coarse silty, angular particles; this appears to be the only positive evidence and by itself is not conclusive. If these are considered to be loess they would fall into the sandy loess catagory whilst those of east Yorkshire may be referred to as sandy solifluction loess.

In north Kent, the deposits at Allington have the appearance of a brickearth let into solution pipes in the Ragstone, a feature of the periglacial environment affecting this region. These may be referred to as solifluction loesses.

Other brickearth deposits at Funton, Cherry Orchard Lane and Star Lane have the appearance of a river laid loam and as such may be equivalent, sedimentologically, to the German schwemmlöss or subaquatischer löss.

At Denstead Wood the brickearth is banked up either side of a ridge of Woolwich Beds. The appearance is one of an infilled channel suggesting that fluvial forces have been operative in the deposition of this material and may therefore be considered as a schwemmlöss.

The processes resulting in the final formation and deposition of these sediments are probably relatively simple to interpret. The problems arise in attempting to ascertain the source of the material and the means by which it has been brought to its place of deposition.

A nine stage process is proposed on the basis of those suggested by Smalley 1966.

P1 Silt grade quartz particles are produced in the boulder clay by glacial grinding as it passes over northern Europe.

T1 This material is transported by the glacier over the northern and eastern part of Europe

D1 Deposition by the glacier and by melt water as the glacier retreats.

T2 Anticyclonic conditions over the retreating glacier produce a dry easterly air flow across northern and eastern Europe. The wind sorts and selects sand and silt size particles lifting them into the atmosphere. The heavier sand particles are only carried relatively short distances, whereas the silt can be carried higher in the atmosphere over long distances.

D2 The dry easterly wind looses its strength over western Europe where the anticyclonic influence gradually gives way to cyclonic conditions and to the effect of an oceanic climate. The silt grade particles are ' dumped ' over northern France and south-east England. The Weald becomes a ' loess trap '. The central part of southern England and the middle Thames valley also receives a substantial amount of material.

T3 The Thames along with other rivers draining the Weald pick up these loose, easily eroded deposits carrying them towards the Thames estuary and to the English Channel. The sharp angular fragments produced by the glacial grinding are rounded off by the fluvial rolling but this is only partially achieved because of the short distance of transport.

D3 Deposition in the lower Thames valley of the brickearths, and in ' pockets' of the tributaries of the Thames and those rivers draining the Weald southwards towards the English Channel.

T4 In some cases the effect of the periglacial activity causes further short distance movement as a result of solifluction.

D4 Deposition of soliflucted material.

The deposits of Yorkshire and Norfolk have not originated from the same source as those of the south east. Here a local origin is suggested with the retreating glaciers leaving drift deposits along with melt water sands and gravels. Stages F1 and D1 are similar but the sorting and redeposition stages T2 - D3 do not occur. In some cases the equivalent to T4 and D4 are observed with solifluction effects being observed.

The mineralogy of the loess produced interesting results, Chapters 7 - 9. The use of thermogravimetric techniques in determining the quantitive nature of loessial materials has only been used to a limited extent by a few investigators. This technique has been adopted here and been shown useful in determining how much clay mineral is present in the separate grain size fractions and how much of the fraction is of primary minerals, mainly quartz but also feldspars.

Quartz was found to be the most predominant mineral in the finer than 75μ fraction as expected, but its presence in large quantities, up to 80%, in the ' clay fraction ' is probably the cause of its instability as a foundation material. The low proportion of clay mineral prevents an adequate bondage of the primary minerals. Wetting and loading of the loess quickly breaks the clay bonds resulting in either a partial or total collapse of the soil structure.

The presence of calcium carbonate is not considered important to the definition of the deposits studied. In Chapter 6 it was shown that the presence of lime may give a certain degree of temporary strength to a deposit (Figs: 6.19 and 6.20) by forming a ' skin ' around the inside of the pores, adding to the soil framework. Where calcium carbonate is present, it is generally in the lower horizon of a deposit as a result of post D3 or D4 leaching. The influence of the Chalk or other calcareous rocks, forming the solid geology, below the deposits does not appear significant. In east Yorkshire most of the deposits are lime free although they rest directly on the Chalk. The south east Essex and Funton deposits rest on non-calcareous Tertiary Beds and have a high lime content in their lower horizons. The drainage of the Chalk scarpland areas of the upper and middle Thames valley suggests that the lime was introduced by the river when redepositing these sediments during stages T3 and D3. At Windmill Quarry near Tadcaster a Permian, pure dolomite silt has been described. The particle size distribution, 83% in the 20μ - 60μ range, suggests that either a great deal of sorting has taken place or that the silt has weathered from the underlying rock. The grains shown in Plate 11.12 display fresh faces which would exclude chemical weathering but may not exclude physical weathering. If transportation has contributed to the position of these deposits, the degree of sorting has been achieved rapidly because of the local origin of the material. It appears that the most suitable method of transport is that of a localised flood, this would account for the lack of mixing of the deposits that an aeolian method would have to account for, it would preserve the freshness of the grain, and would indicate this to be the last phase of the flood with the streams gradually drying and only carrying one grade of material.

The distribution of Schwemmlöss appears to be totally confined to the south and south east of England. Solifluction loess is present at Allington and on the east side of Pegwell Bay. The Yorkshire and Norfolk deposits are essentially dissimilar to those of the south east of England and if they are to be referred to as loess they fall into the sandy solifluction and the sandy loess catagories.

All the south east deposits are generally unstratified and have a mineralogy consistant with a loess definition that places an emphasis on the presence of quartz with the primary minerals present in all the size fractions including the 0 - 2μ distribution.

APPENDIX

PROGRAMME FOR PARTICLE SIZE DISTRIBUTION

```
10 SELECT PRINT 005
20 DIM A(19,12),B(19,2),C(5),A$(5)
30 INPUT "NO.OF READINGS",N
40 FOR I=1TO N:PRINT HEX(03):INPUT "A=",A:INPUT "B=",B
50 B(I,1)=A:B(I,2)=B:NEXT I
60 A$(1)=">500":A$(2)=">250"
70 A$(3)="125":A$(4)="75":A$(5)="<75"
80 FOR I=1TO 5:PRINT HEX(03):PRINT "WEIGHT RETAINED ";A$(I);:INPUT C(I)
90 C=C+C(I):NEXT I:L=C(5)*100/C
100 A(1,1)=.5:A(2,1)=1:A(3,1)=2:A(4,1)=3:A(5,1)=4
110 A(6,1)=6:A(6,4)=8:A(6,5)=4:A(1,4)=.75:A(2,4)=1.5:A(3,4)=2.5:A(4,4)=[illegible]
120 A(1,5)=.5:A(2,5),A(3,5),A(4,5)=1:A(5,5)=2
130 FOR I=7TO 19:A(I,1)=A(I-1,1)+4
140 A(I,4)=A(I-1,4)+4:A(I,5)=4:NEXT I
150 FOR I=1TO 19:J=0
160 J=J+1
170 IF A(I,1)<B(J,1)THEN 160
180 IF A(I,1)=B(J,1)THEN 190:GOTO 200
190 A(I,2)=B(J,2):GOTO 230
200 E=B(J-1,1)-B(J,1):F=B(J-1,2)-B(J,2)
210 G=F/E:A(I,2)=B(J,2)+(A(I,1)-B(J,1))*G
220 A(I,2)=INT(A(I,2)*10+.5)*.1
230 NEXT I
240 FOR I=1TO 18:A(I,3)=A(I+1,2)-A(I,2):NEXT I
250 A(1,6)=1.9:A(2,6)=2.5:A(3,6)=2.78:A(4,6)=2.97:A(5,6)=2.44
260 A(6,6)=2.05:A(7,6)=1.97:A(8,6)=1.9:A(9,6)=1.75:A(10,6)=1.6
270 A(11,6)=1.5:A(12,6)=1.4:A(13,6)=1.35:A(14,6)=1.3
280 A(15,6)=1.25:A(16,6)=1.225:A(17,6)=1.2:A(18,6)=1.15:N=0
290 FOR I=1TO 18:A(I,7)=A(I,4)*A(I,3)/A(I,6)
300 A(I,7)=INT(A(I,7)*100+.5)*.01:N=N+A(I,7):NEXT I
310 FOR I=1TO 18:A(I,8)=A(I,7)*100/N:A(I,7)=INT(A(I,7)*100+.5)*.01:NEXTI
320 FOR I=1TO 18:A(I,11)=C(5)*A(I,8)/100
330 A(I,11)=INT(A(I,11)*1E4+.5)*1E-4:NEXT I
340 FOR I=1TO 18:A(I,12)=A(I,11)*100/C
350 A(I,12)=INT(A(I,12)*100+.5)*.01:NEXT I
360 A(19,10)=INT(L*100+.5)*.01
370 FOR I=18TO 1STEP -1
380 A(I,10)=A(I+1,10)-A(I,12):A(I,9)=100-A(I,10):NEXT I
390 SELECT PRINT 01D(72):PRINT :PRINT :PRINT
400 FOR I=1TO 18:PRINTUSING 410,A(I,1),A(I,2):PRINTUSING 420,A(I,3),A(I
410 %##.# ##.#
420 %        #.#   ##.##   #.#   #.###   ##.##  ##.##  ###.##  ##.##  #.####  ##
430 PRINTUSING 410,A(I+1,1),A(I+1,2):END
```

TABLE A.1 ANALYSIS OF DTG HISTOGRAMS A1 – A19

FIG. No.	SAMPLE		100–150°C	260–310°C	ILLITE 370 – 610°C	%wt loss	wt of illite in mg	% of illite	CALCIUM CARBONATE 690 – 800°C	%wt loss	wt of $CaCO_3$ in mg	% of $CaCO_3$
A1a	Pegwell Bay 2	(≤ 2u)	A	B	C&D	5.0	127.0	25.0				
A1b	Pegwell Bay 2	(≤ 75u)	A	B	C&D	1.3	64.75	6.47	E	0.05	1.135	0.1135
A1c	Pegwell Bay 6	(0.2–2.0u)	A	B	C	3.35	82.0	16.77	D	4.45	48.48	10.12
A2a	Pegwell Bay 7	(0.2–2.0u)	A	B	C	8.2	314.0	41.05				
A2b	Pegwell Bay 7	(≤ 75u)	A	B	C&D	1.37	34.25	6.85	E	0.12	1.36	0.27
A3a	Monkton	(≤ 2u)	A	B	C	4.5	56.5	22.6	D	14.4	81.72	32.6
A3b	Monkton	(2–10u)	A	B	C	2.92	73.0	14.6	D	17.2	195.2	39.0
A4a	Denstead East	(≤ 2u)	A	B	C&D	4.93	35.0	24.65	E	1.06	3.4	2.4
A4b	Denstead East	(2–10u)	A	B	C&D	3.08	77.0	15.4	E	0.2	2.27	0.45
A4c	Denstead East	(≤ 75u)	A	B	C&D	0.96	48.0	4.8	E	0.14	3.18	0.318
A5a	Allington 1.5m	(≤ 0.2u)	A	B	C	12.04	118.0	60.2				
A5b	Allington 1.5m	(0.2–2.0u)	A	B	C&D	4.48	112.0	22.4				
A5c	Allington 3.0m	(2–10u)	A	B	C	2.98	74.5	14.9	D	2.56	29.06	5.81
A6a	Allington Weathered Rock	(≤ 75u)	A	B	C&D	2.3	115.0	11.5				
A6b	Allington Quarry Gull	(≤ 75u)	A	B	C	1.56	78.0	7.8	D	4.34	98.5	9.85
A7a	Funton 1.0m	(≤ 2u)	A	B	C&D	6.4	160.0	32.0				

Letters refer to peaks on the relevant figures.

TABLE A1 Cont.

FIG. No.	SAMPLE		100–150°C	260–310°C		ILLITE 370 – 610°C % wt loss	wt of illite in mg	% of illite		CALCIUM CARBONATE 690 – 800°C %wt loss	wt of $CaCO_3$ in mg	% of $CaCO_3$
A7b	Funton 1.0m	(2–10u)	A	B	C	3.44	86.0	17.2				
A7c	Funton 1.5m	(<75u)	A	B	C	1.7	85.0	8.5	D	5.82	132.11	13.21
A8a	Beacon Hill	(<2u)	A	B	C	5.48	137.0	27.42	D	3.2	36.32	7.26
A8b	Beacon Hill	(2–10u)	A	B	C	4.0	100.0	20.0	D	3.6	40.86	8.17
A8c	Beacon Hill	(<75u)	A	B	C	1.7	85.0	8.5	D	4.4	99.88	9.98
A9a	Ch.Orch.Ln 2m	(<0.2u)	A	–	C&D	7.0	35.0	29.16	E	0.67	1.82	1.5
A9b	Ch.Orch.Ln 2m	(<2u)	A	B	C	4.0	50.0	20.0	D	2.4	13.62	5.45
A9c	Ch.Orch.Ln 2m	(0.2–2.0u)	A	B	C	4.13	73.9	20.67	D	1.84	14.98	4.47
A10a	Ch.Orch.Ln DT	(<2u)	A	B	C	4.68	117.0	23.4	D	1.44	16.34	3.26
A10b	Ch.Orch.Ln DT	(<75u)	A	B	C	1.66	83.0	8.3	D&E	0.58	13.2	1.32
A11a	Star Lane 0.33m	(<2u)	A	B	D	6.4	75.0	32.0	E	0.51	2.72	1.16
A11b	Star Lane 0.33m	(<75u)	A	B	C	1.36	34.0	6.8				
A11c	Star Lane 1.55m	(<75u)	A	B	C	1.56	39.0	7.8	D	7.4	84.0	16.8
A12a	Marks Tey Lower	(0.2–2.0u)	A	B	C	4.55	227.5	22.75	D	3.83	86.9	8.69
A12b	Marks Tey Lower	(<75u)	A	B	C	1.49	74.5	7.45	D	8.25	187.27	18.73
A12c	Marks Tey Lower	(75u>)	A	B	C	2.2	110.0	11.0	D	7.7	174.8	17.48

TABLE A. 1 Cont.

FIG. No.	SAMPLE		100–150°C	260–310°C		ILLITE 370 – 610°C %wt loss	wt of illite in mg	% of illite		CALCIUM CARBONATE 690 – 800°C %wt loss	wt of $CaCO_3$ in mg	% of $CaCO_3$
A13a	Marks Tey Middle	(0.2–2.0u)	A	B	C	4.8	120.0	24.0	D	3.64	41.31	8.26
A13b	Marks Tey Middle	(<75u)	A	B	C	1.3	65.0	6.5	D	7.8	177.1	17.71
A13c	Marks Tey Middle	(75u >)	A	B	C	1.37	68.5	6.85	D	8.36	190.0	19.0
A14a	Marks Tey Upper	(<75u)	A	B	C	1.83	91.5	9.15	D	7.39	167.75	16.77
A14b	Marks Tey Upper	(75u >)	A	B	C	2.03	101.4	10.14	D	10.35	235.0	23.5
A15a	Aylmerton	(2–10u)	A	B	C	2.08	19.0	10.4				
A15b	Aylmerton	(<75u)	A	B	D&E	0.72	18.0	3.60				
A15c	Burlingham	(<75u)	A	B	C&D	1.3	65.0	6.5	E	0.18	4.1	0.41
A16a	Hornhill Top INV	(<2.0u)	A	B	C	5.64	141.0	28.2				
A16b	Hornhill Top INV	(2–10u)	A	B	C	4.2	105.0	21.0				
A16c	Hornhill Top INV	(<75u)	A	B	C&D	2.06	103.0	10.3				
A17a	Hornhill Top SE	(<2u)	A	B	C,D,E&F	5.94	30.0	29.7				
A17b	Hornhill Top SE	(2–10u)	A	B	C&D	2.92	31.5	14.58				
A18a	Eppleworth CBT	(0.2–2.0u)	A	B	C&D	5.57	76.0	27.84				
A18b	Eppleworth CBT	(<75u)	A	C	D&E	2.04	51.0	10.2				
A19a	Etton	(2–10u)	A	B	C	4.4	110.0	22.0				
A19b	Callis Wold	(<75u)	A	–	D,E,F&G	1.74	43.5	8.7				

FIG A1

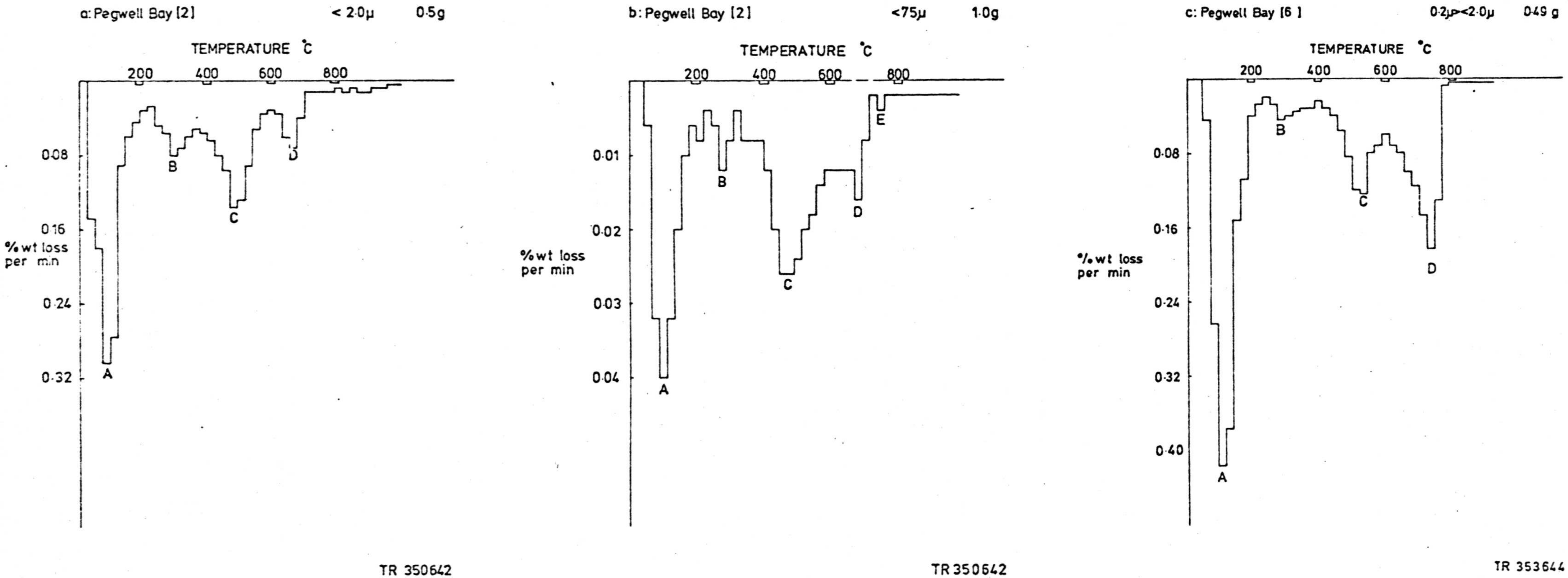
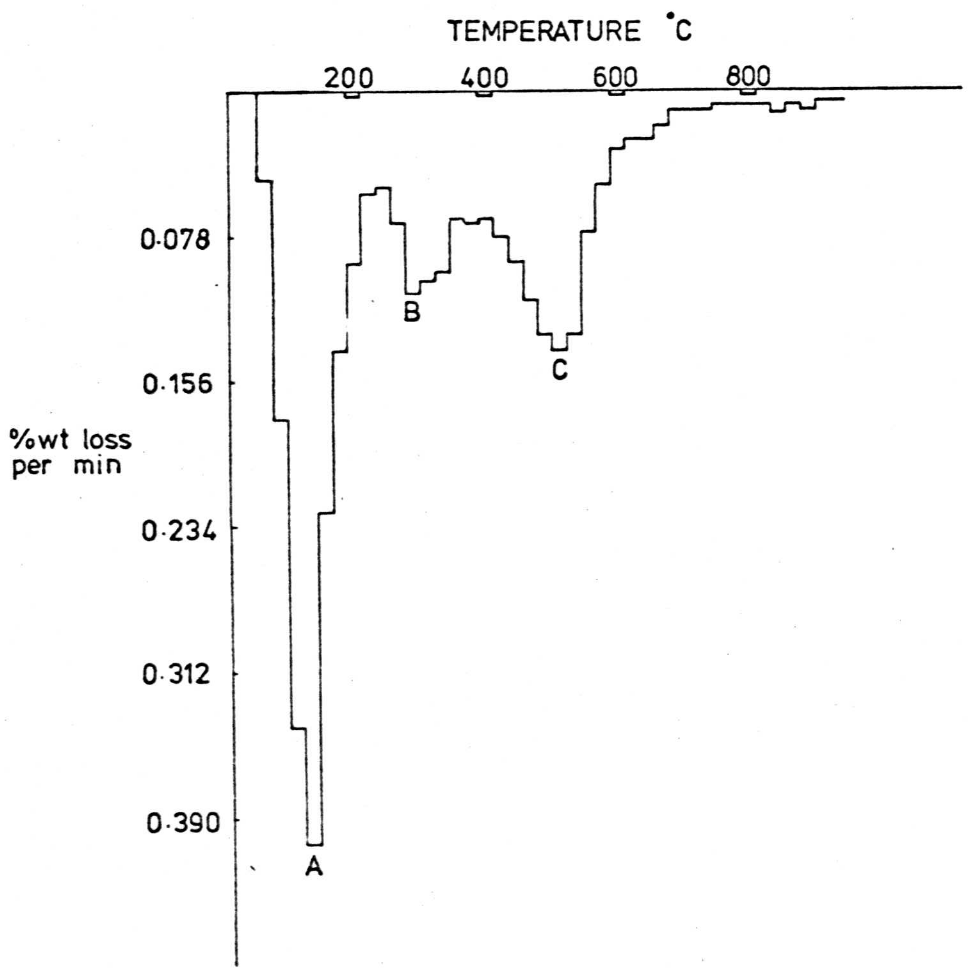

a: Pegwell Bay [2]
< 2·0μ
0·5g
TEMPERATURE °C
200
400
600
800
0·08
0·16
0·24
0·32
%wt loss per min
A
B
C
D
TR 350642
b: Pegwell Bay [2]
<75μ
1·0g
TEMPERATURE °C
200
400
600
800
0·01
0·02
0·03
0·04
%wt loss per min
A
B
C
D
E
TR 350642
c: Pegwell Bay [6]
0·2μ-<2·0μ
0·49 g
TEMPERATURE °C
200
400
600
800
0·08
0·16
0·24
0·32
0·40
%wt loss per min
A
B
C
D
TR 353644

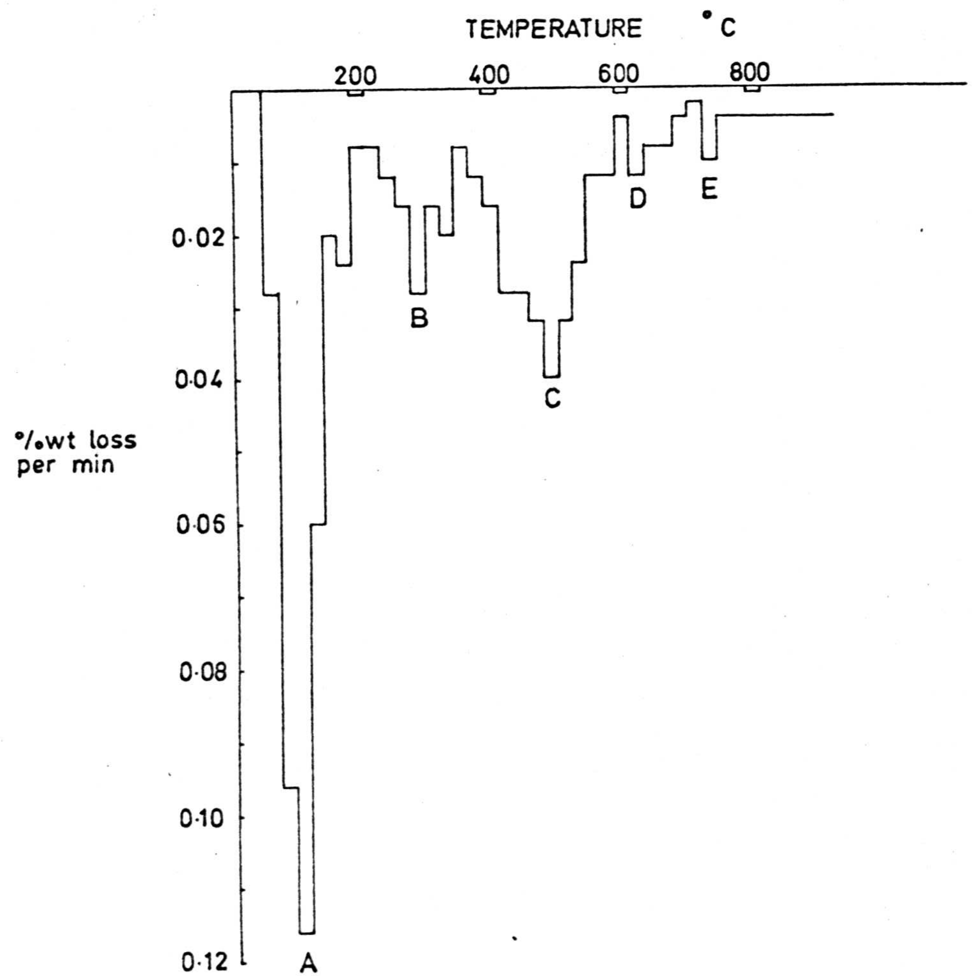
FIG A2

a: Pegwell Bay [7]　0·2μ><2·0μ　0766g



TR 354643

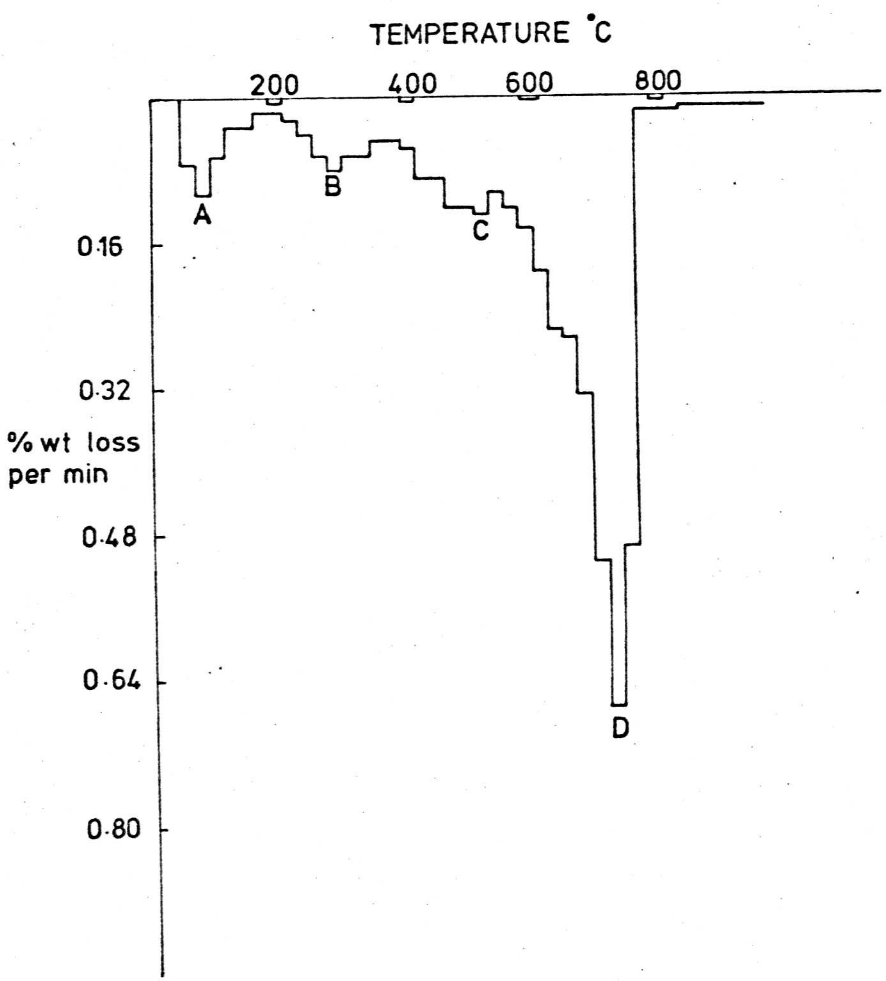
b: Pegwell Bay [7]　<75μ　0·5g



TR 354643

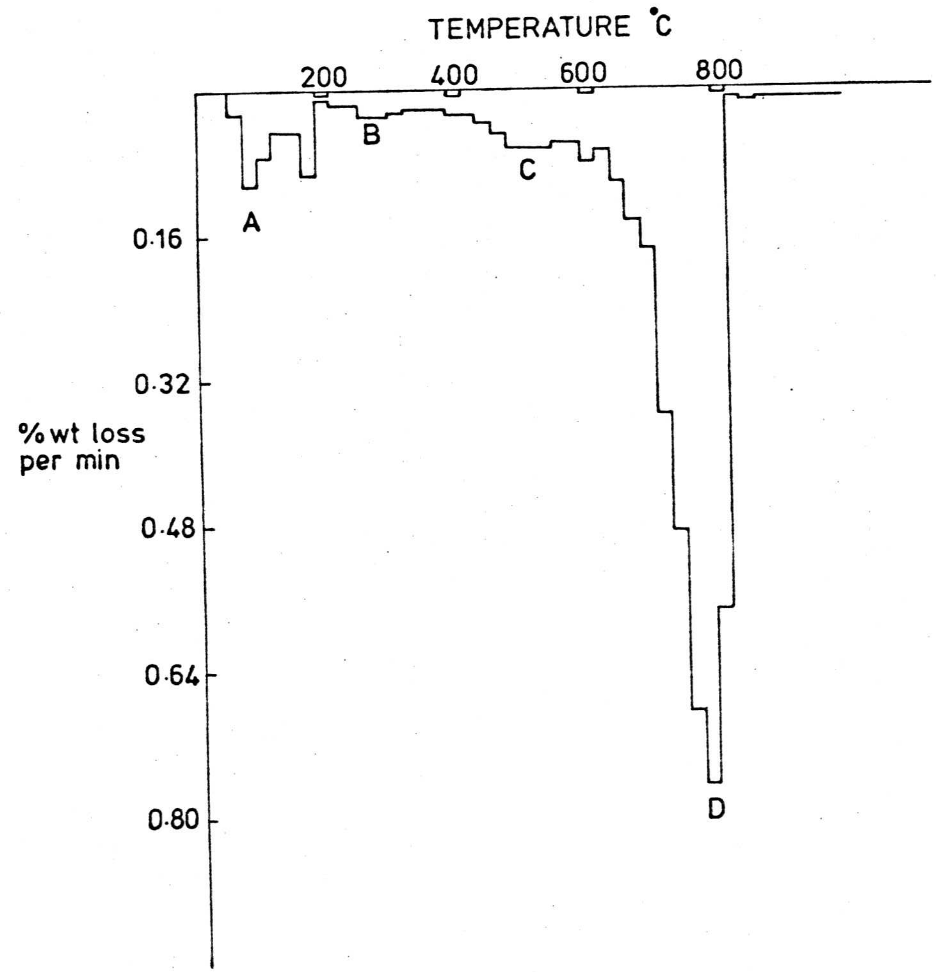
FIG A3

a: Monkton < 2·0μ 0·25g



TR 285656

b: MONKTON 2-10μ 0·5g



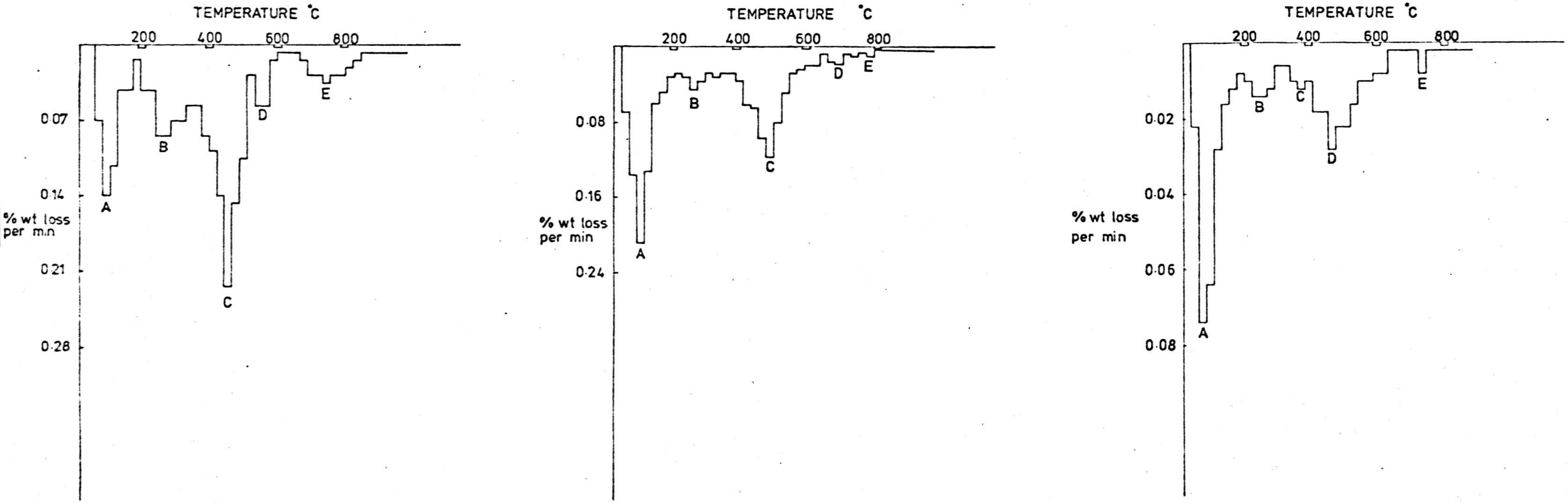
TR 285656

FIG A4

a: Denstead Wood [E] <2·0µ 0·142g

b: Denstead Wood [E] 2-10µ 0·5g

c: Denstead Wood [E] <75µ 1·0g



TR 090575 TR 090575 TR 090575

FIG A5

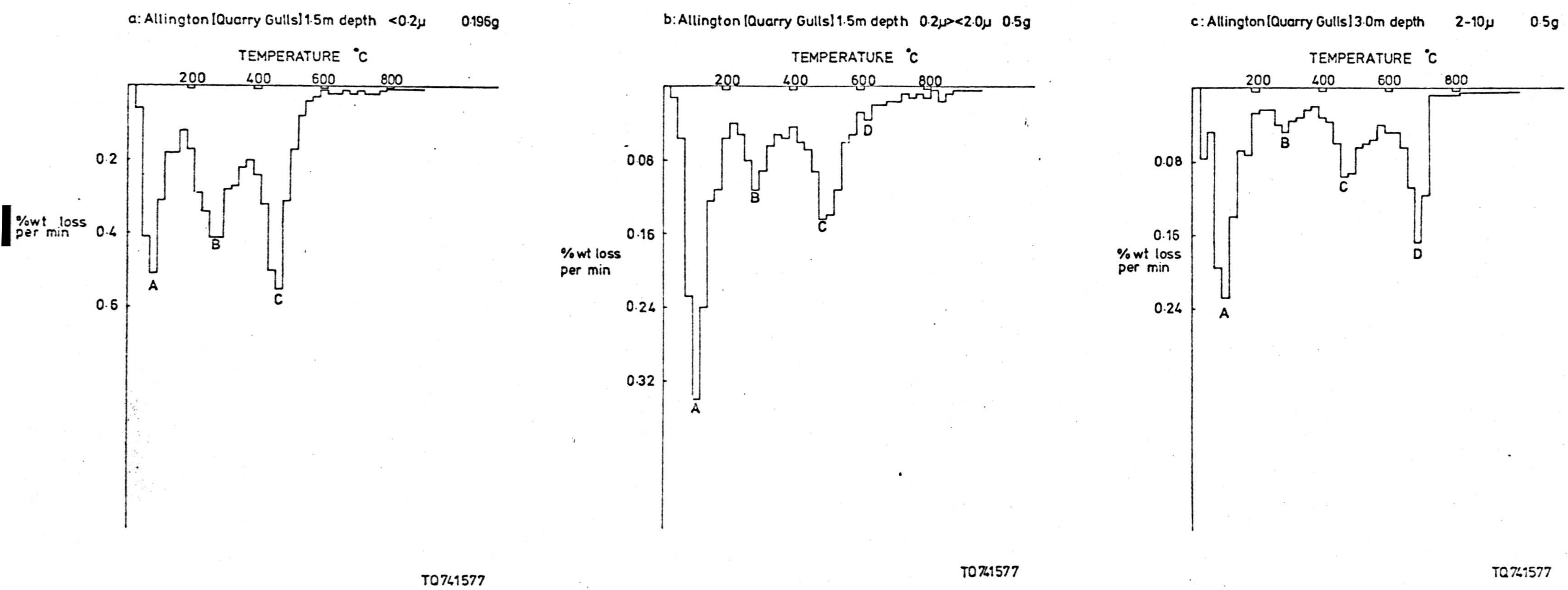
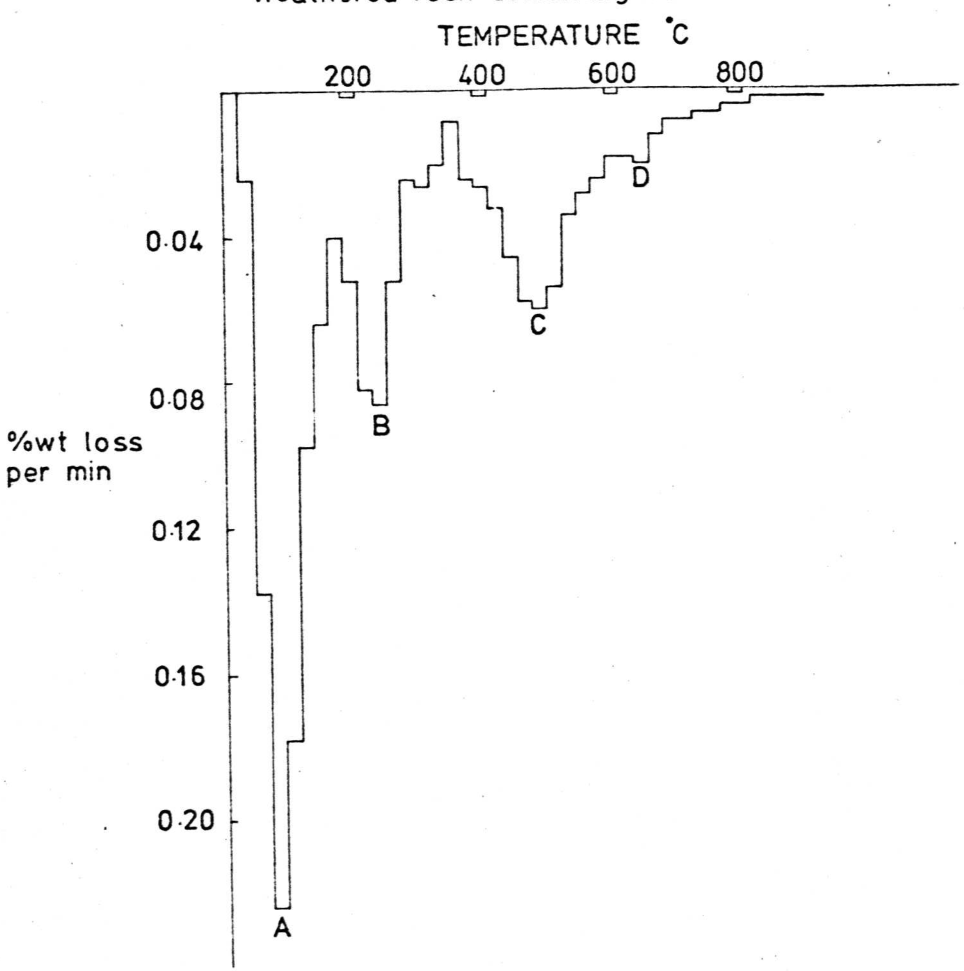

a: Allington [Quarry Gulls] 1·5m depth <0·2μ 0·196g
TEMPERATURE °C
200
400
600
800
%wt loss per min
0·2
0·4
0·6
A
B
C
TQ741577
b: Allington [Quarry Gulls] 1·5m depth 0·2μ><2·0μ 0·5g
TEMPERATURE °C
200
400
600
800
%wt loss per min
0·08
0·16
0·24
0·32
A
B
C
D
TQ741577
c: Allington [Quarry Gulls] 3·0m depth 2-10μ 0·5g
TEMPERATURE °C
200
400
600
800
%wt loss per min
0·08
0·16
0·24
A
B
C
D
TQ741577

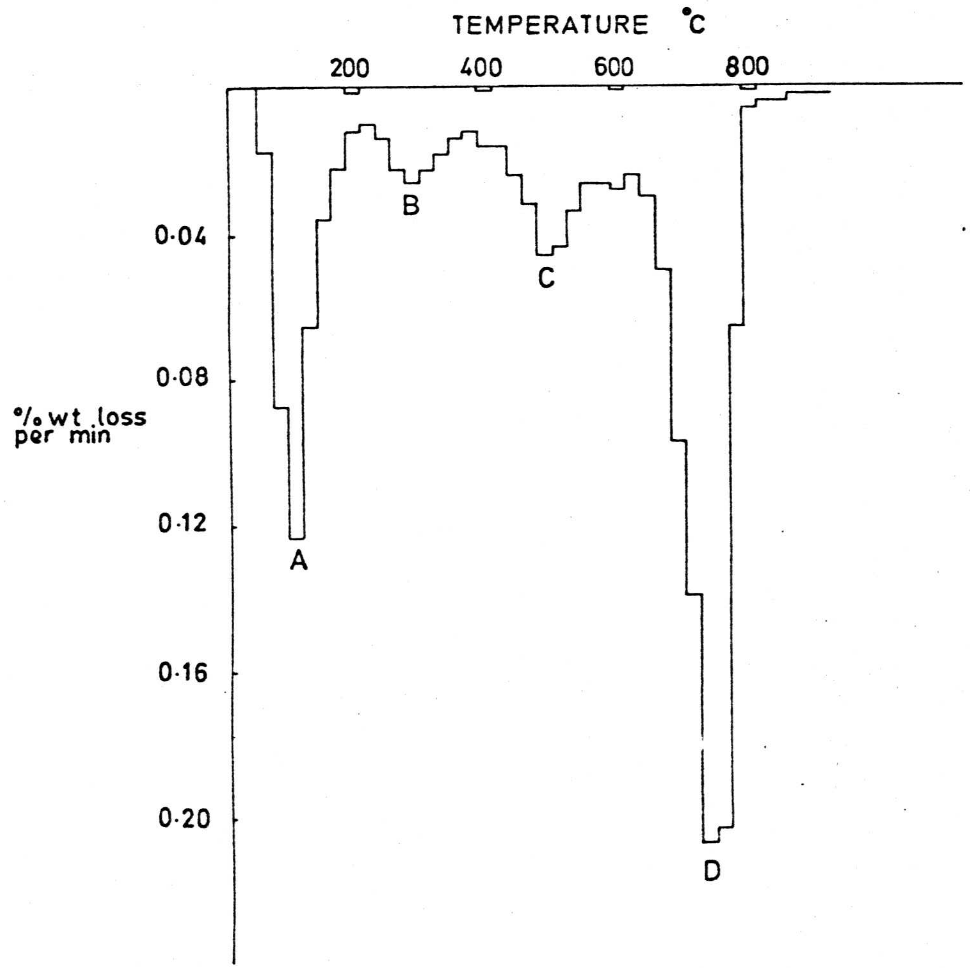
FIG A6

a: Allington [Quarry Gull] <75μ 1·0g
Weathered rock containing material



TQ 741577

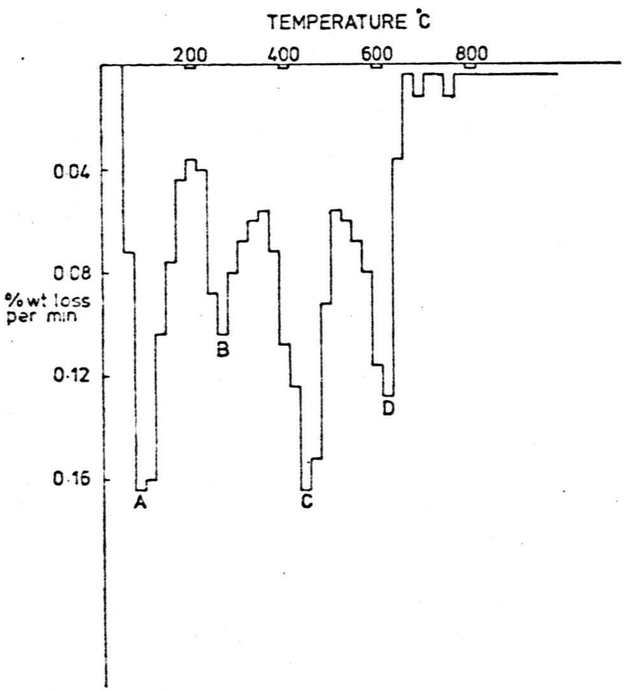
b: Allington [Quarry Gull on Southern Face] <75μ 1·0g



TQ 739577

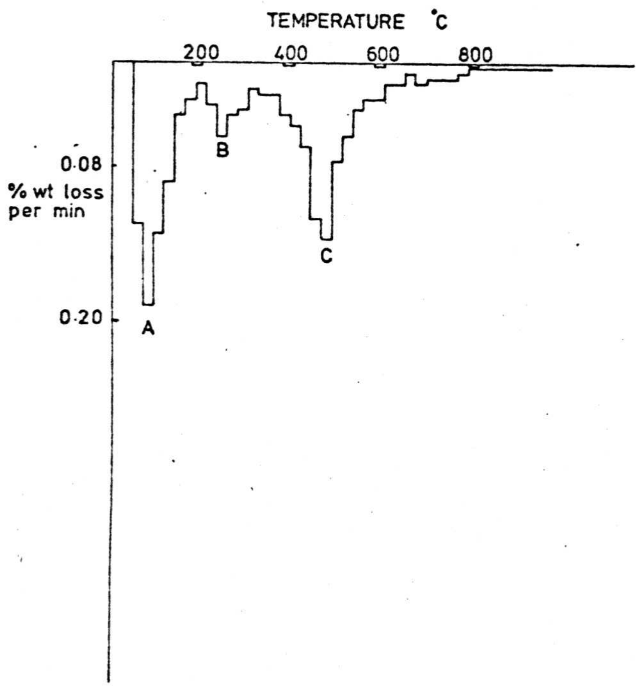
FIG A7

a: Funton Brickworks [1·0m] <2·0μ 0·5g



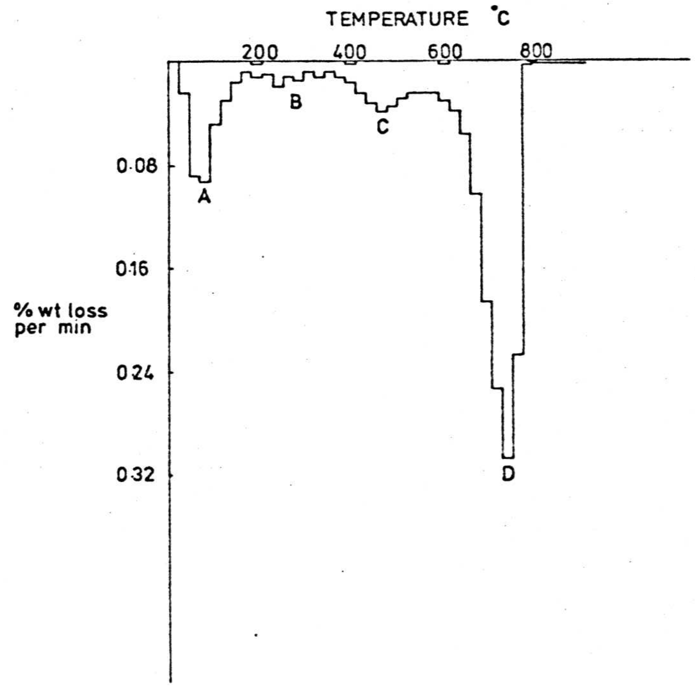
TQ880670

b: Funton Brickworks [1·0m] 2-10μ 0·5g



TQ 880670

c: Funton Brickworks [1·5m] <75μ 1·0g



TQ880670

FIG A8

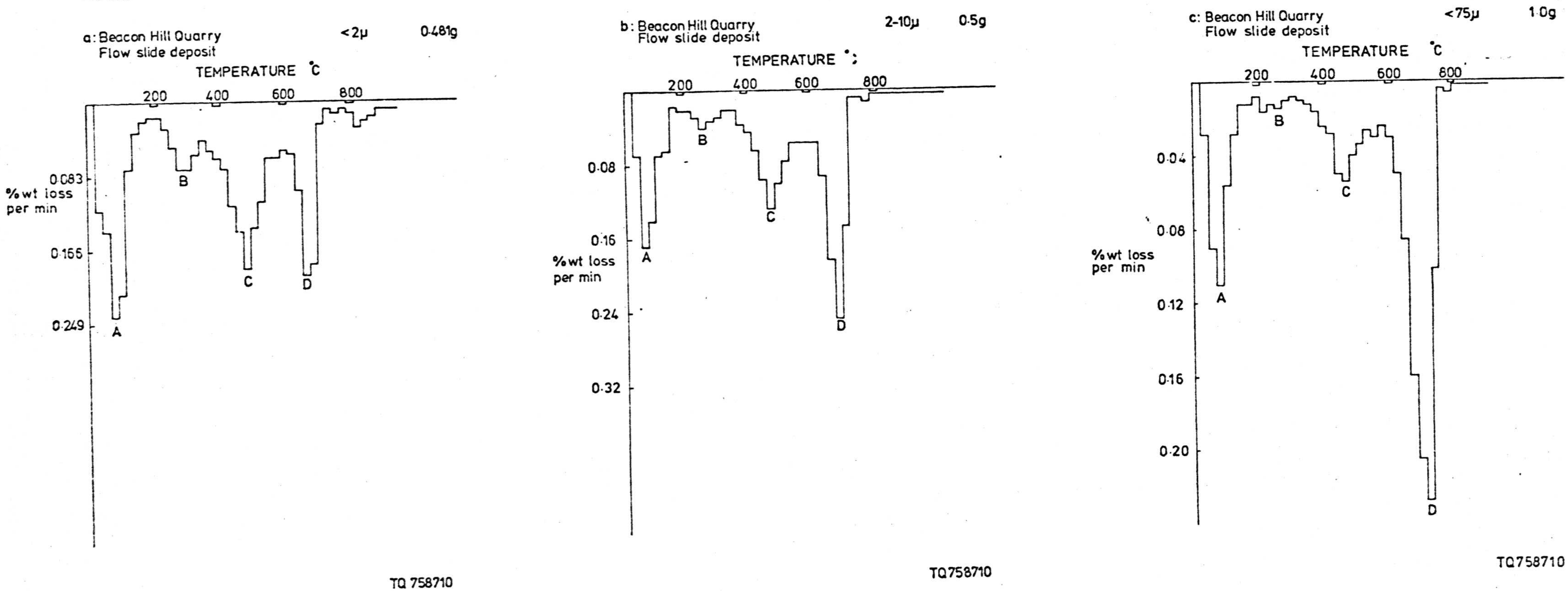

a: Beacon Hill Quarry
Flow slide deposit
<2µ
0.481g
TEMPERATURE °C
200
400
600
800
0.083
0.165
0.249
%wt loss per min
A
B
C
D
TQ 758710
b: Beacon Hill Quarry
Flow slide deposit
2-10µ
0.5g
TEMPERATURE °C
200
400
600
800
0.08
0.16
0.24
0.32
%wt loss per min
A
B
C
D
TQ758710
c: Beacon Hill Quarry
Flow slide deposit
<75µ
1.0g
TEMPERATURE °C
200
400
600
800
0.04
0.08
0.12
0.16
0.20
%wt loss per min
A
B
C
D
TQ758710

FIG A9

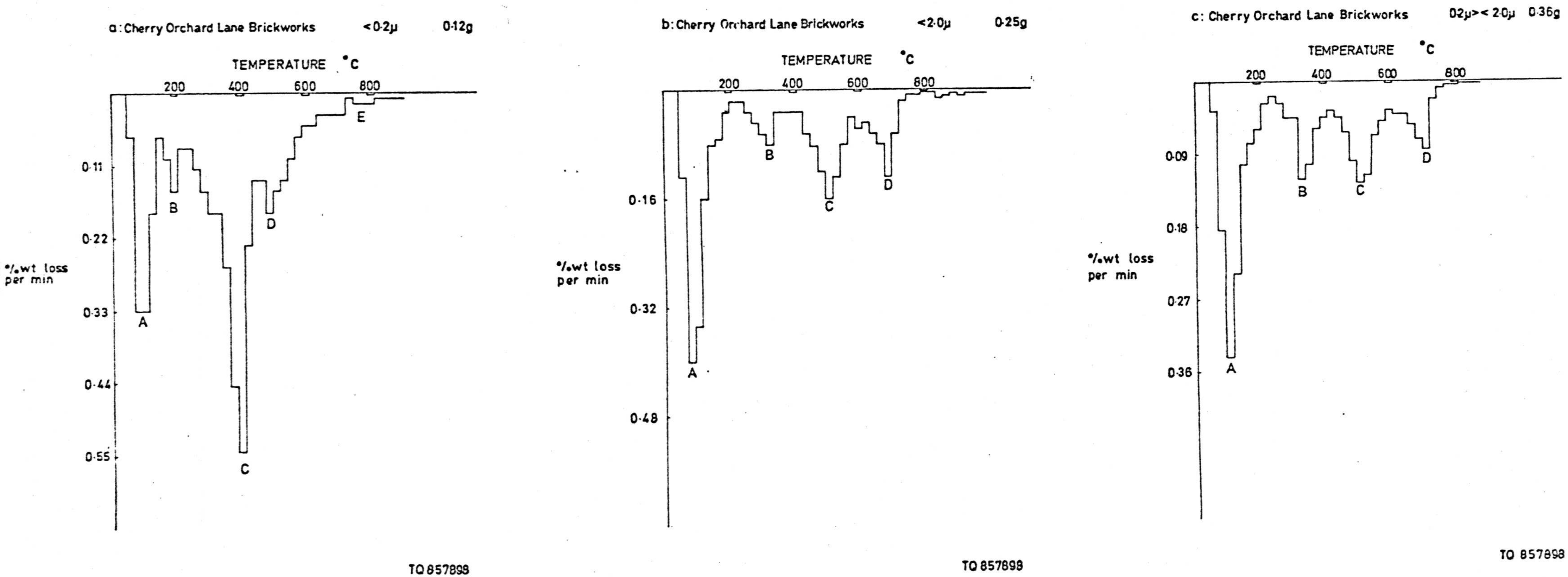
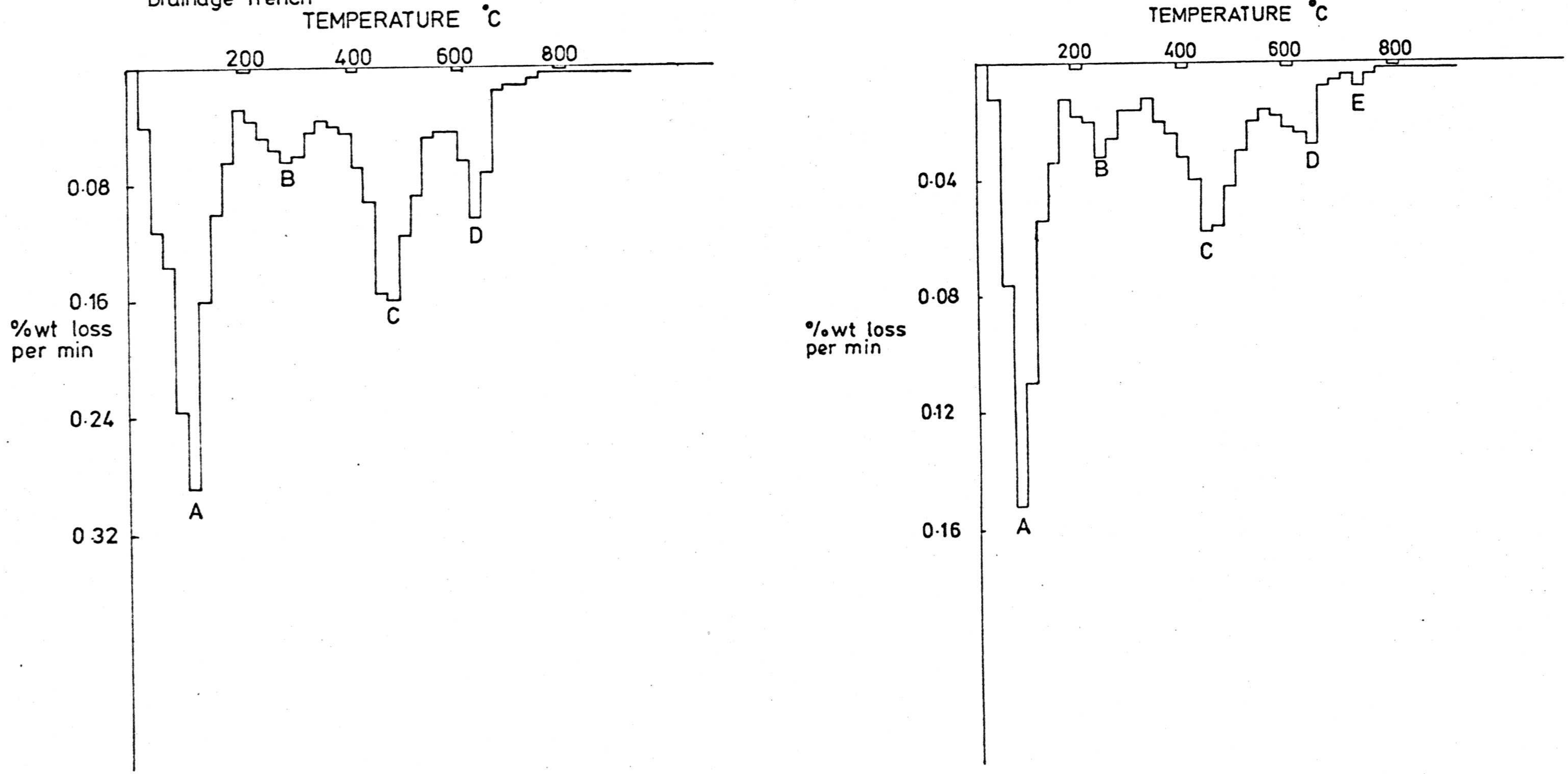

a: Cherry Orchard Lane Brickworks
<0·2μ
0·12g
TEMPERATURE °C
200
400
600
800
A
B
C
D
E
0·11
0·22
0·33
0·44
0·55
°/o wt loss per min
TQ 857898
b: Cherry Orchard Lane Brickworks
<2·0μ
0·25g
TEMPERATURE °C
200
400
600
800
A
B
C
D
0·16
0·32
0·48
°/o wt loss per min
TQ 857898
c: Cherry Orchard Lane Brickworks
0·2μ>< 2·0μ
0·36g
TEMPERATURE °C
200
400
600
800
A
B
C
D
0·09
0·18
0·27
0·36
°/o wt loss per min
TQ 857898

FIG A10

a: Cherry Orchard Lane Brickworks <2·0µ 0·5g
Drainage Trench

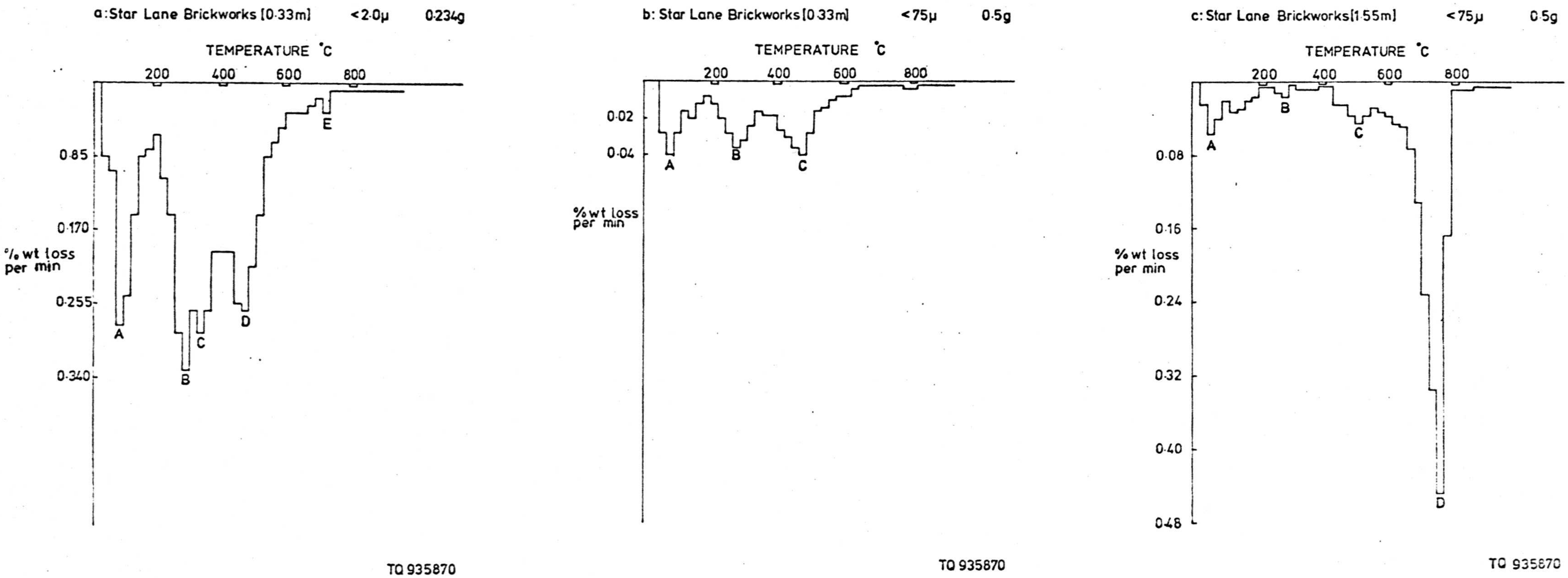
b: Cherry Orchard Lane Brickworks <75µ 1·0g
Drainage Trench



TQ 860897

TQ 860897

FIG A11



a: Star Lane Brickworks [0·33m] <2·0μ 0·234g
TEMPERATURE °C
200 400 600 800
0·85
0·170
0·255
0·340
%wt loss per min
A B C D E
TQ 935870
b: Star Lane Brickworks [0·33m] <75μ 0·5g
TEMPERATURE °C
200 400 600 800
0·02
0·04
%wt loss per min
A B C
TQ 935870
c: Star Lane Brickworks [1·55m] <75μ 0·5g
TEMPERATURE °C
200 400 600 800
0·08
0·16
0·24
0·32
0·40
0·48
%wt loss per min
A B C D
TQ 935870

FIG A12

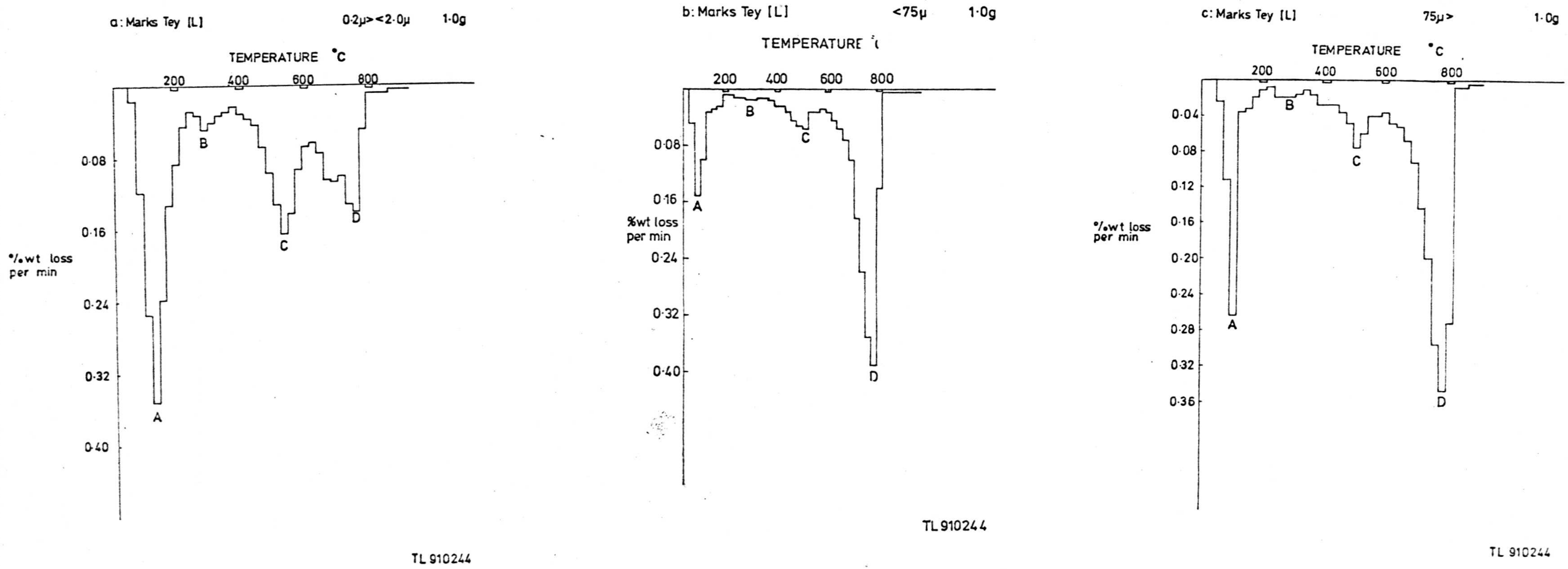

a: Marks Tey [L]
0·2μ><2·0μ
1·0g
TEMPERATURE °C
200
400
600
800
0·08
0·16
0·24
0·32
0·40
°/o wt loss per min
A
B
C
D
TL 910244
b: Marks Tey [L]
<75μ
1·0g
TEMPERATURE °C
200
400
600
800
0·08
0·16
0·24
0·32
0·40
%wt loss per min
A
B
C
D
TL 910244
c: Marks Tey [L]
75μ>
1·0g
TEMPERATURE °C
200
400
600
800
0·04
0·08
0·12
0·16
0·20
0·24
0·28
0·32
0·36
°/o wt loss per min
A
B
C
D
TL 910244

FIG A13

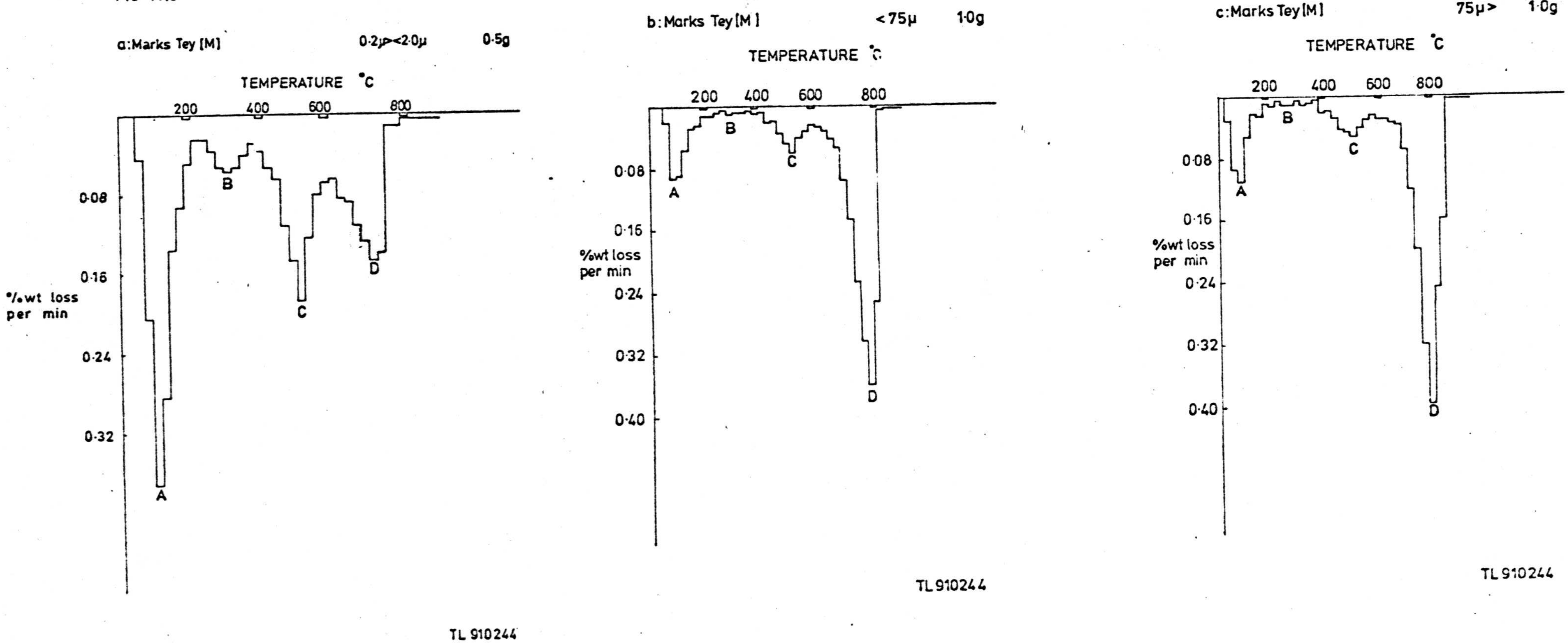

a:Marks Tey [M]
0·2μ><2·0μ
0·5g
TEMPERATURE °C
200
400
600
800
0·08
0·16
0·24
0·32
%wt loss
per min
A
B
C
D
TL 910244
b:Marks Tey [M]
<75μ
1·0g
TEMPERATURE °C
200
400
600
800
0·08
0·16
0·24
0·32
0·40
%wt loss
per min
A
B
C
D
TL 910244
c:Marks Tey [M]
75μ>
1·0g
TEMPERATURE °C
200
400
600
800
0·08
0·16
0·24
0·32
0·40
%wt loss
per min
A
B
C
D
TL 910244

FIG A14

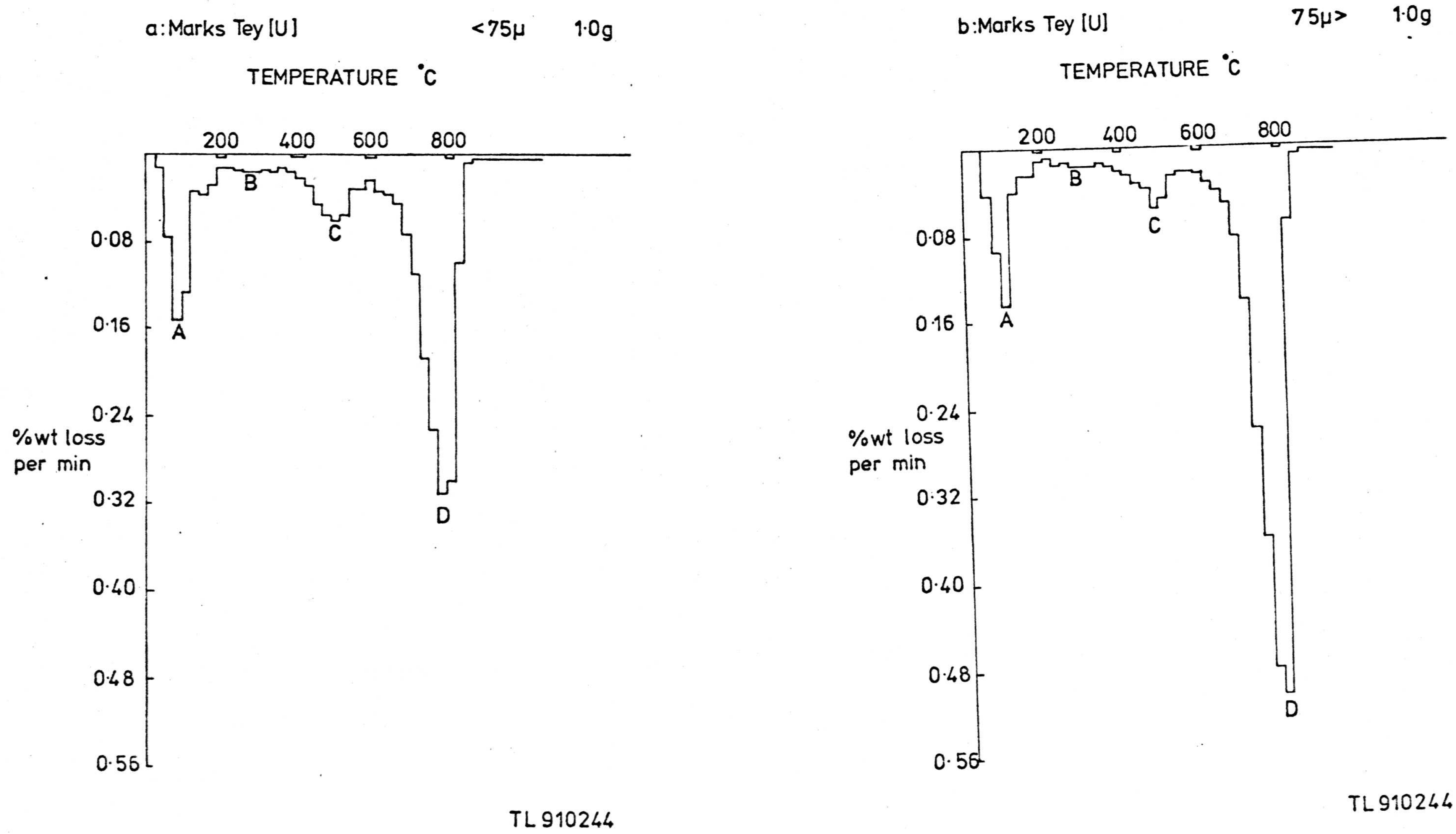

a:Marks Tey [U]
<75μ
1·0g
TEMPERATURE °C
200
400
600
800
0·08
0·16
0·24
0·32
0·40
0·48
0·56
%wt loss per min
A
B
C
D
TL 910244
b:Marks Tey [U]
75μ>
1·0g
TEMPERATURE °C
200
400
600
800
0·08
0·16
0·24
0·32
0·40
0·48
0·56
%wt loss per min
A
B
C
D
TL 910244

FIG A15

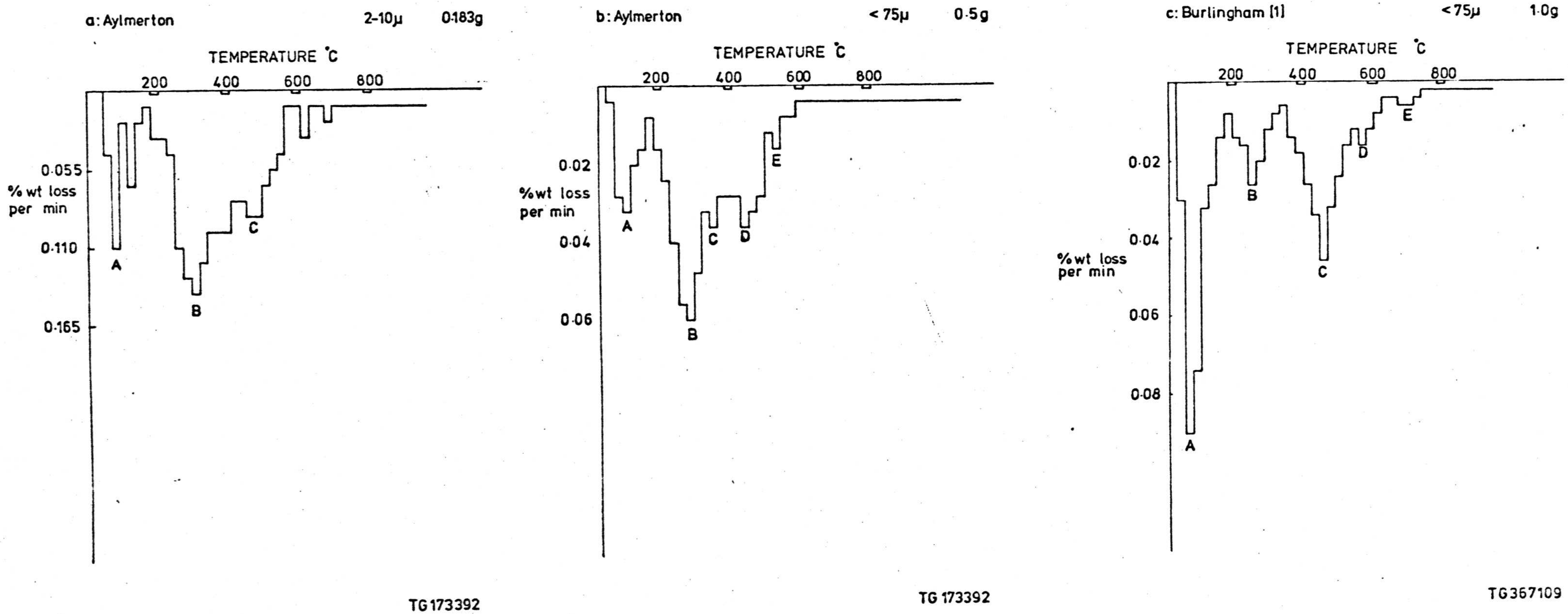

a: Aylmerton
2-10μ
0.183g
TEMPERATURE °C
200
400
600
800
0.055
% wt loss per min
0.110
0.165
A
B
C
TG173392
b: Aylmerton
< 75μ
0.5g
TEMPERATURE °C
200
400
600
800
0.02
% wt loss per min
0.04
0.06
A
B
C
D
E
TG 173392
c: Burlingham [1]
< 75μ
1.0g
TEMPERATURE °C
200
400
600
800
0.02
0.04
% wt loss per min
0.06
0.08
A
B
C
D
E
TG367109

FIG A16

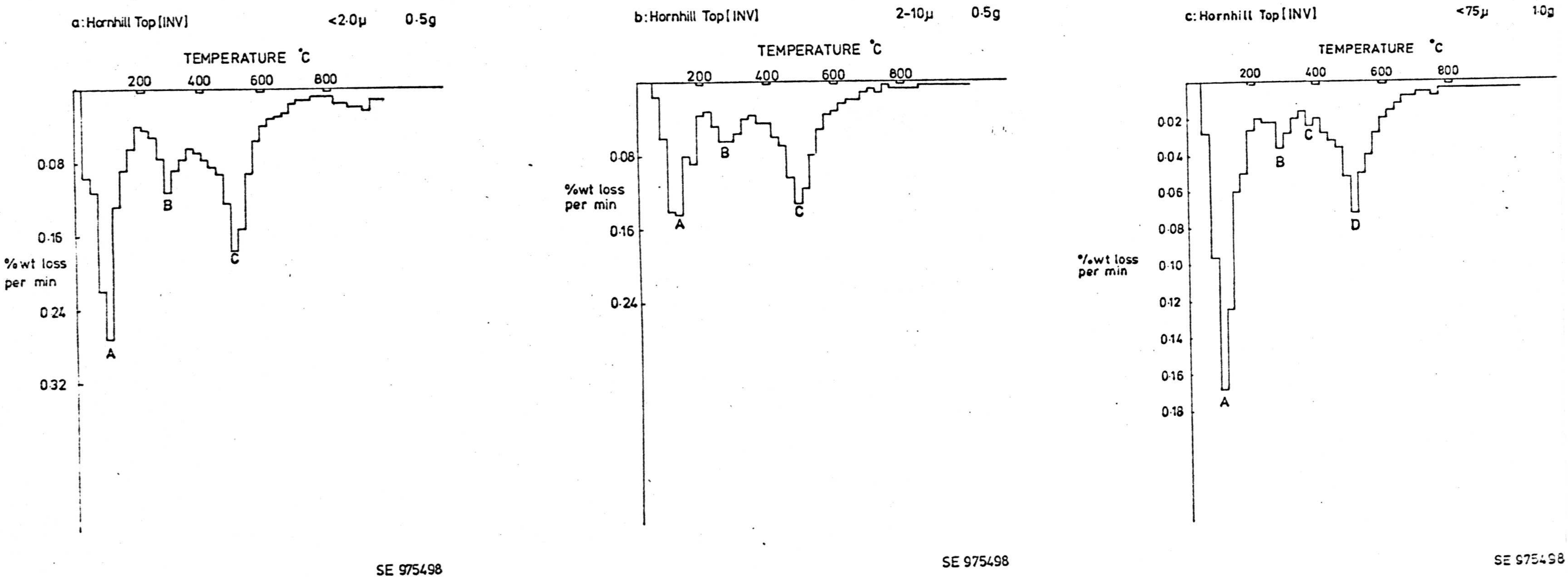
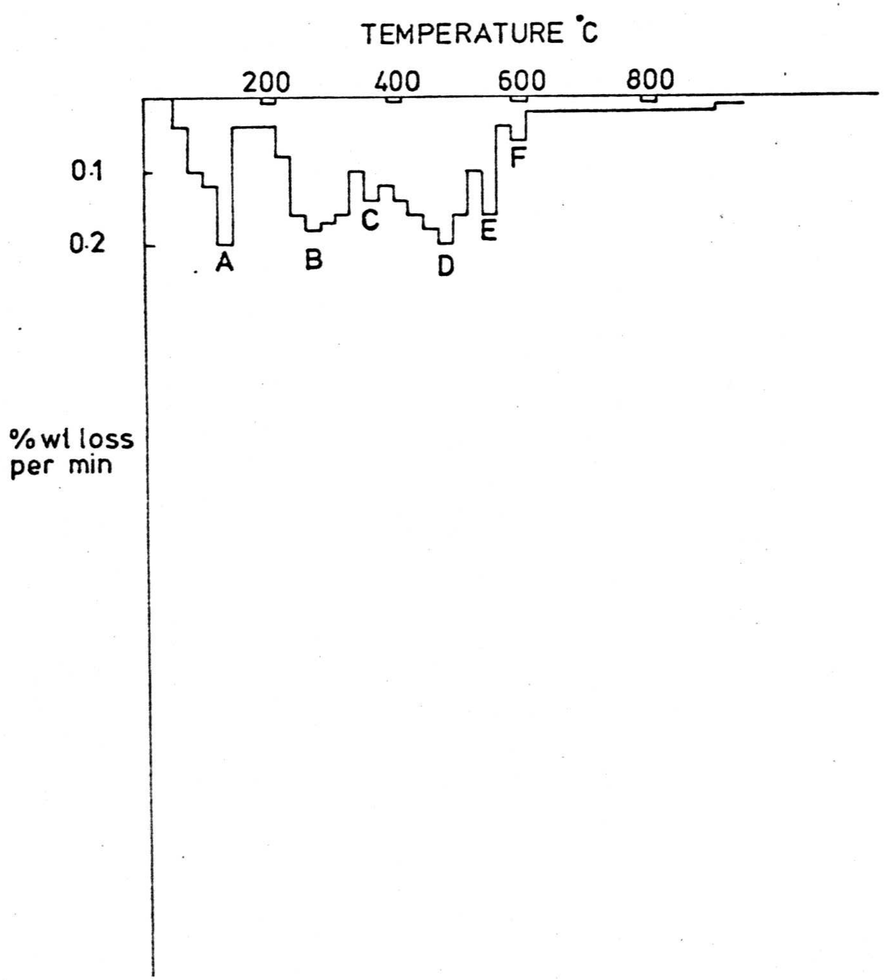

a: Hornhill Top [INV]
<2·0μ
0·5g
TEMPERATURE °C
200
400
600
800
0·08
0·16
%wt loss
per min
0·24
0·32
A
B
C
SE 975498
b: Hornhill Top [INV]
2-10μ
0·5g
TEMPERATURE °C
200
400
600
800
0·08
%wt loss
per min
0·16
0·24
A
B
C
SE 975498
c: Hornhill Top [INV]
<75μ
1·0g
TEMPERATURE °C
200
400
600
800
0·02
0·04
0·06
0·08
%wt loss
per min
0·10
0·12
0·14
0·16
0·18
A
B
C
D
SE 975498

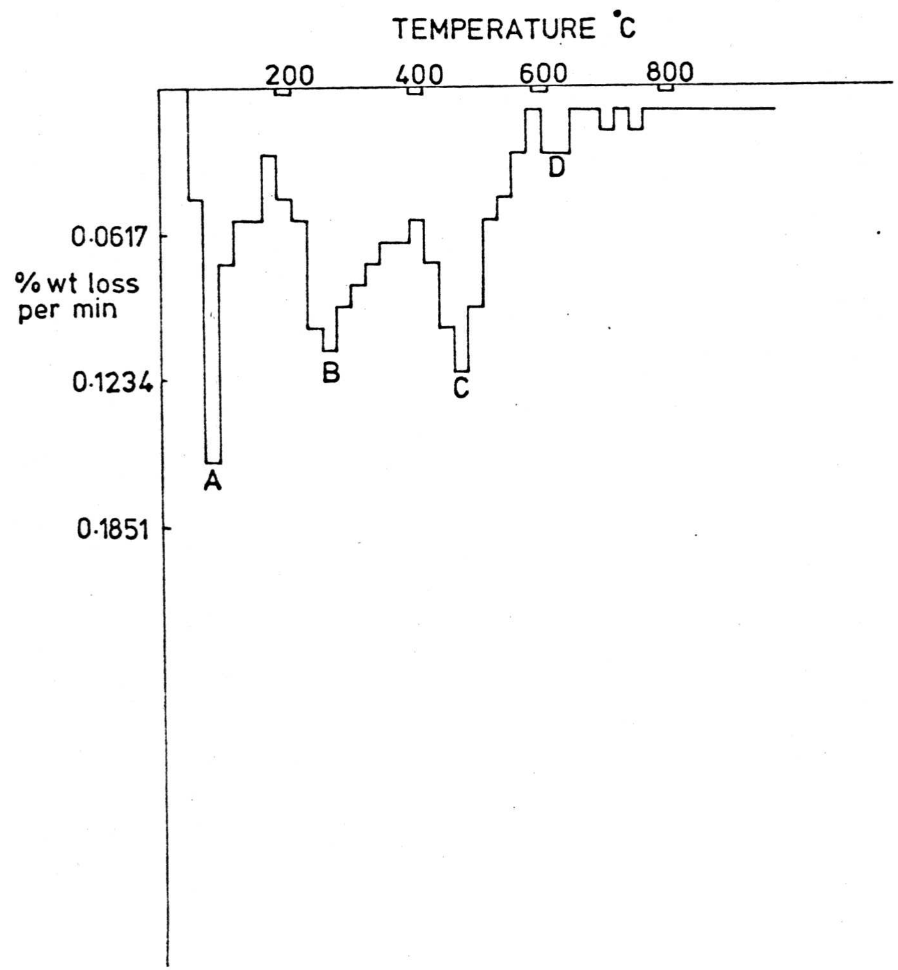
FIG A17

a: Hornhill Top [SE] <2·0μ 0·1 g



SE 976497

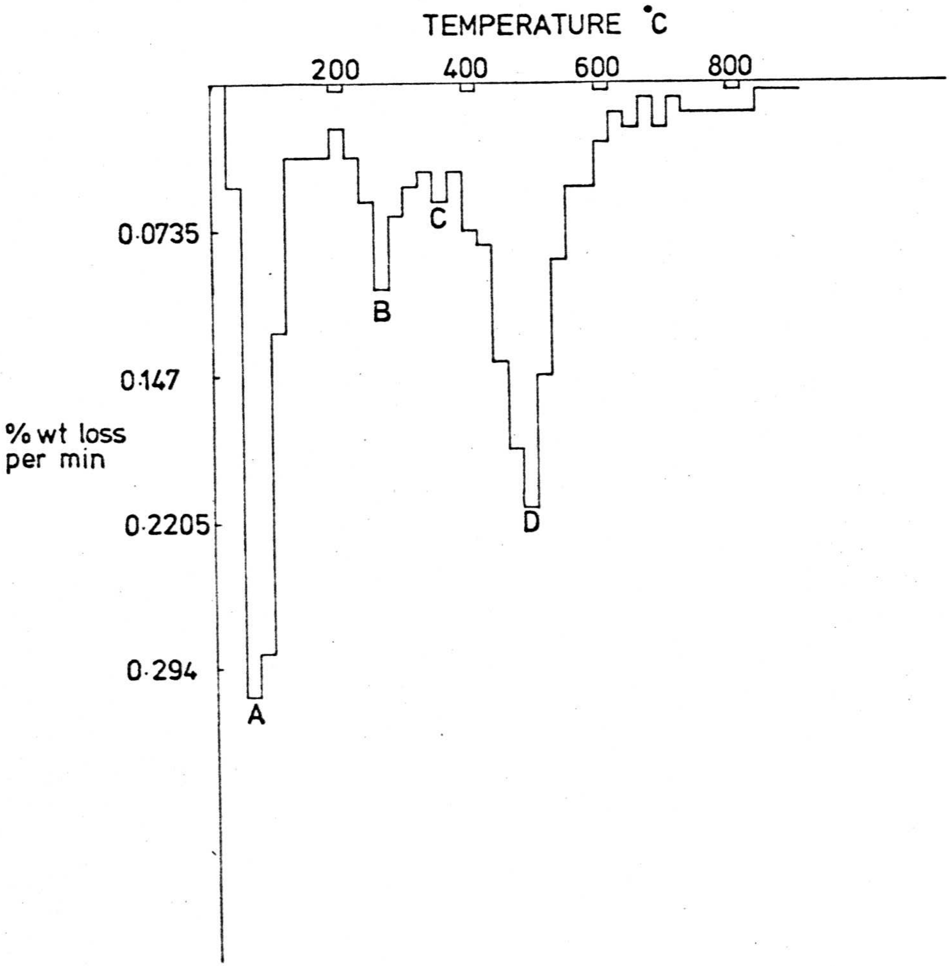
b: Hornhill Top [SE] 2–10μ 0·216g



SE 976497

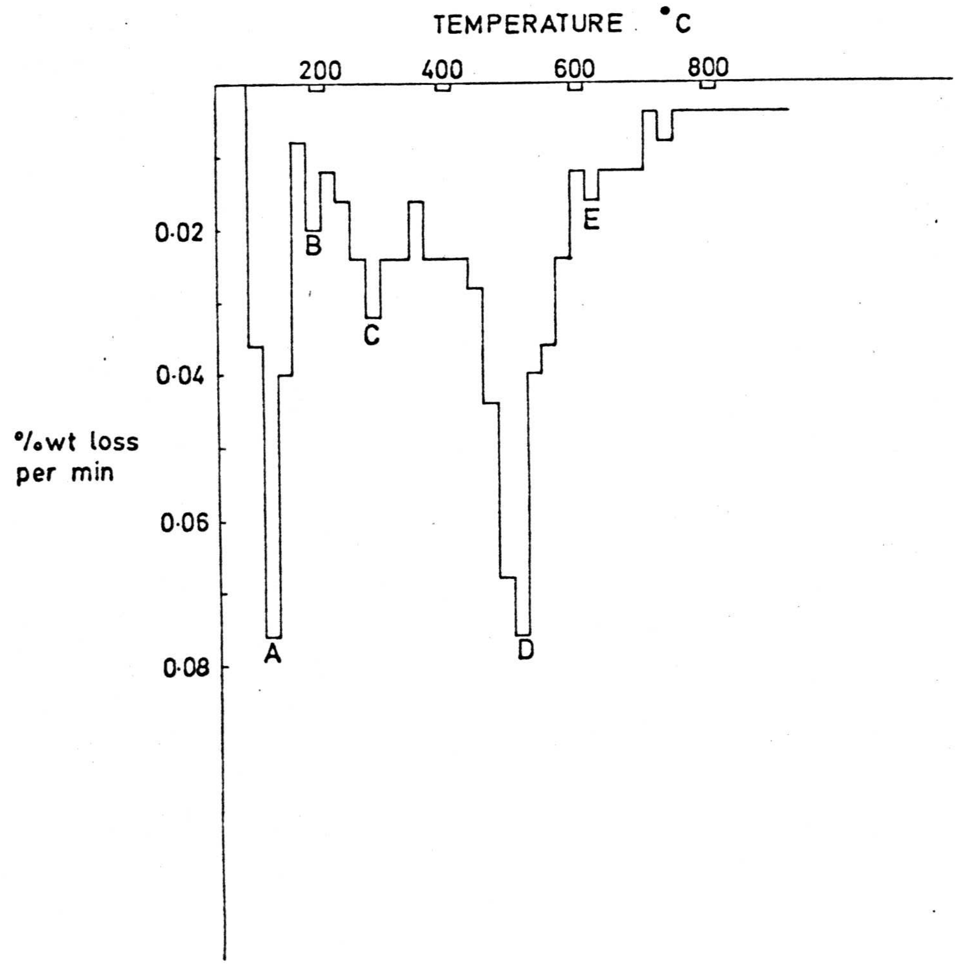
FIG A18

a: Eppleworth [CBT] 0·2μ>2·0μ 0·273g



TA 022325

b: Eppleworth [CBT] <75μ 0·5g

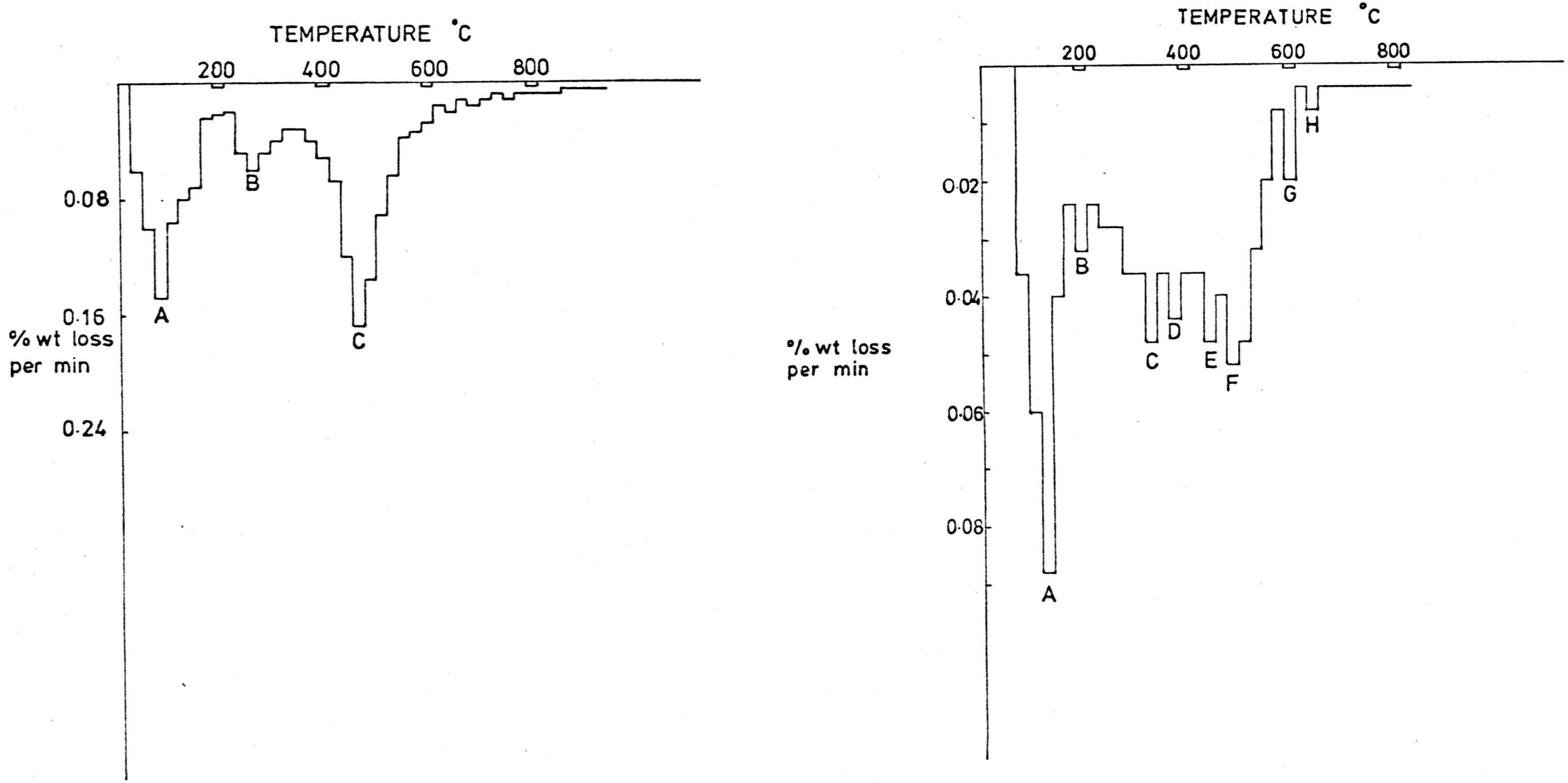


TA 022325

FIG A19

a: Etton Chalk Pit 2-10μ 0·5g

b: Callis Wold <75μ 0·5g



SE 970433

SE 829559

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MAP 1 THE DISTRIBUTION OF BRICKEARTH IN SOUTH-EAST ENGLAND