

STRATIGRAPHICAL AND PALAEOECOLOGICAL
APPLICATIONS OF VOLGIAN MICROFAUNAS

VOLUME I

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Stratigraphical and Palaeoecological applications of Volgian microfaunas: Volume I

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Geographical index

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European Russia & Russian Platform

Subject index

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Volume I

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STRATIGRAPHICAL AND PALAEOECOLOGICAL APPLICATIONS OF VOLGIAN MICROFAUNAS

INTRODUCTION

A detailed analysis of the late Jurassic calcareous microfaunas (i.e. Foraminiferida and Ostracoda) from key sections in England and Russia has been carried out. This analysis concentrated principally on the Kimmeridgian to Portlandian stratotype sequences of southern England (supplemented by material from eastern England and Southern North Sea Basin) and the Volgian stratotype area of the Russian Platform.

An important part of the project was to gain an understanding of the taxa in Russia and England and to come to terms with systematic problems. In addition to faunas collected during the fieldwork carried out as part of the project, collections in Nottingham, London, St Petersburg and Moscow were examined in order to form a systematic framework into which the biostratigraphical and palaeoecological studies could be placed.

This, the first volume, concentrates on stratigraphical details and the distribution of the microfaunas, both temporally and spatially. It concludes with biostratigraphical schemes and relates them to standard ammonite calibration. Systematic data is the subject of the second of the two volumes detailing the results of the research.

Text-fig. 1

A comparison of the standard ammonite zones in North-western Europe and Eastern Europe (after Mesezhnikov, 1988).

(It should be noted that some authors consider that the Late Volgian should be considered to be Lowest Cretaceous in age)

Stage	North-western Europe	Eastern Europe		
PORTLANDIAN	Lamplughi	Nodiger		VOIGIAN
	Preplicomphalus	Subditus		
	Primitivus	Fulgens		
	Oppressus	Opressus		
	Anguiformis	Nikitini	Nikitini	
	Kerberus		blakei	
	Okusensis	Virgatus	Rosanovi	
	Glaucolithus		Virgatus	
	Albani		Zarajskensis	
BOLONIAN	Fittoni	Panderi	Pavlovi	
	Rotunda			
	Pallasioides			
	Pectinatus	Pseudoscythica		
	Hudlestoni	Sokolovi		
	Wheatleyensis			
	Scitulus	Klimovi		
	Elegans			

1. STRATIGRAPHY

STAGE DEFINITIONS

The stages recognised in the Upper Jurassic have had a rather checkered history. This has in part been a result of error in the definition of stage bases, but national pride has also played a role, while others have tried to clarify the confusion by the use of yet other stage names. The present study deals with that part of the stratigraphical column that is dated to the Late Kimmeridgian and Portlandian (*sensu anglico*), Portlandian (*sensu franco*), Volgian (in the Russian sense and that of the hydrocarbon companies in the North Sea) and Tithonian (of the Tethyan province). In order to put the study into a stratigraphical framework, the following discussion summarises the problems.

Kimmeridgian

The modern concept of the Kimmeridgian Formation is based on the virtually unbroken sequence seen on the Dorset coast between Black Head and Ringstead Bay and between Brandy Bay and Chapman's Pool.

The earliest use of the clays at Kimmeridge as a geological unit was by William Smith who called it the Oaktree Clay on his map of 1815. The following year, Webster (1816) whilst mapping the Isle of Wight and Purbeck, referred to these deposits as "Kimmeridge Strata". Fitton (1836) described the deposits and their macrofaunal content and in modern times a great deal of data have been added (Arkell, 1933, 1945, 1947, 1956; Casey, 1967; Cope, 1967, 1978; Callomon, 1968, 1971). Gallois & Cox (1976) and Cox & Gallois (1981) showed the rhythmic nature of deposition throughout the Kimmeridgian deposits of England and Oschmann (1988a, 1988b, 1990, 1991, 1993, 1994) has taken this further by linking the formation and its macrofaunal content to palaeoenvironmental cyclicality.

The concept of Blake (1875), who regarded the lower part of the Formation to be part of the Corallian has largely not found favour, although Brookfield (1978) attempted to revive this idea. The top of the Kimmeridge Clay has traditionally been placed at the base of the arenaceous Massive Bed, although Townson (1975)

considered, on sedimentological grounds, that this boundary should be lowered to the base of the Rhynchonella Marls. Cope (1978) and Wimbledon & Cope (1978), however, rejected this notion.

The formation was subdivided into the Lower and Upper Kimmeridgian by Blake (1875) and this subdivision has a chronostratigraphical significance as each is characterised by ammonite associations. Hence the Lower part is characterised by *Pictonia*, *Rasenia* and *Aulocostephanus* and the Upper part contains diagnostic *Pectinatites*, *Pavlovia*. and *Vitgatopavlovia*. In terms of the beds recognised by Gallois & Cox (1976) and Cox and Gallois (1981), the boundary between the Upper Kimmeridge Clay and the Lower Kimmeridge Clay can be placed at the top of Bed KC35 (=base of Blake's Bed 42) at the *Autissiodorensis/ Elegans* zonal boundary. However, the local inception of *Gravesia* is about 3m below the Maple Ledge Stone Band in Dorset (Cox & Gallois, 1981) and this may have implications with regard to the base of the Portlandian *sensu gallico* (see below).

The earliest use of the Kimmeridge as a stage was by d'Orbigny (1842-1851, page 610) who coined the term "l'étage kimméridgien" for that period of time during which the Kimmeridge Clay was deposited. Salfeld (1913) related the stage to a number of ammonite zones and this, in turn, has been refined (Neaverson, 1925; Arkell, 1933, 1945, 1956; Ziegler, 1962, 1964; Casey, 1967; Cope, 1967, 1978; Callomon, 1968, 1971). Most British stratigraphers consider that the base of the Kimmeridgian stage, as defined by the ammonite content, is recognised by the incoming of *Pictonia baylei* and the top of the stage is placed at the extinction of *Virgatoavlovia fittoni* (Arkell, 1933, 1945, 1956; Casey, 1967; Cope, 1967, 1978; Callomon, 1968, 1971).

This concept differs from views held by workers in other parts of Europe who place the Kimmeridgian/Portlandian Boundary at the *Autissiodorensis/Gigas* or *Elegans* boundary (i.e. the Lower Kimmeridgian/Upper Kimmeridgian boundary *sensu anglico*). Although d'Orbigny had intended that the Kimmeridge Clay should be in the Kimmeridgian Stage and the Portland Stone and Portland Sand should be in the Portlandian Stage, two different concepts and subsequent confusion has arisen.

Portlandian

D'Orbigny defined the Portlandian as the highest stage of the Jurassic with its type section in Dorset. His concept of "l'étage portlandien" included the Portland Sand and Portland Stone and he listed the diagnostic macrofauna as Ammonites [=Titanites] giganteus, Ammonites [=Gravesia] irius and Trigonina [=Laevitrigonia] gibbosa. Salfeld (1913) defined the base of the Portlandian stage on the incoming of *Gravesia gravesiana*. and, as a result of Salfeld's work it became apparent that d'Orbigny had erroneously correlated Kimmeridgian limestones in France (containing *Gravesia*) with the limestones of the Portland Stone of Dorset (Arkell, 1946). Although the correlation is incorrect, this led to the concept used by many authors (*sensu gallico*). Other authors follow d'Orbigny's original concept (*sensu anglico*). The problems stemming from these two interpretations has been discussed, but there is no single consensus of opinion. Cope (1978) and Wimbledon & Cope (1978) have fixed the base of the Portlandian at the base of the Progalbanites albani Zone at Hounstout Cliff and it is this that has found favour in Britain. The top of the Portlandian in southern England is a problem. The boundary is within the lower part of the Purbeck facies (comprising fresh and brackish water deposits and lacking in ammonites) and it is not possible to recognise with ease. Charophytes and ostracods can be used to define the top of the Jurassic, but only in terms of the Jurassic/Berriasian (the basal Cretaceous of the Tethyan province) and not in terms of the Jurassic/Ryazanian (the basal Cretaceous of the Boreal Province), the boundaries of which are not contemporaneous.

Volgian

The Volgian Stage was defined by Nikitin (1881, 1884). It has its type section at Gorodishche, near Ulyanovsk, in cliffs on the western side of the Volga River. It is unfortunate that much of the section is somewhat condensed and, according to Casey (1967) and Cope (1978) incomplete. Much of the understanding of the ammonite zonation stems from work by Mikhailov (1957, 1962, 1964, 1966) and Gerasimov & Mikhailov (1966) and Gerasimov (1969). Mesezhnikov (1977) provided a more detailed discussion of the Kimmeridgian and Volgian macrofaunas.

The stage was originally erected for the very condensed part in the upper c.15m of the sequence, the lower boundary of the stage being placed at the base of

the Dorsoplanus Zone. Gerasimov & Mikhailov (1966) redefined the Volgian stage, however, by extending the base downwards to include deposits that had previously been regarded as Kimmeridgian. Hence, the Lower Volgian became Middle Volgian and the sequence characterised by the ammonite genus *Ilovaiskya* (i.e. the Klimovi, Sokolovi and Pseudoscythica zones) now formed the new Lower Volgian. Geologically speaking, there seems to be little reason for this, except that, as a consequence, it brought the Volgian more in line with the Portlandian *sensu gallico* and strengthened the argument that it should be used as an internationally standard. Nevertheless, the base of the stage is now placed at the base of the Klimovi Zone, where the ammonite fauna includes *Gravesia* cf. *gigas*. The top of the stage is placed at the top of the Nodiger Zone.

The Volgian has been recognised over a wide geographical area throughout northern Europe. It has found favour amongst hydrocarbon exploration companies, so that the nomenclature of the North Sea, even within the British sector, follows the "Continental" usage; the Kimmeridgian Stage being equivalent to the Lower Kimmeridgian of southern England and the Volgian being equivalent to the Upper Kimmeridgian and Portlandian of Southern England. (NB in the North Sea Basin, accumulation of the uppermost part of the Kimmeridge Clay Formation continued through the Portlandian and culminated in the Ryazanian).

There is an overlap of the upper parts of the Kimmeridgian stage (*sensu anglico*) and the lower part of the Volgian and Russian workers have correlated the stage with the Portlandian *sensu gallico* (Sasonov, 1964; Gerasimov *et al.*, 1974; Mesezhnikov, 1988). Casey (1967) and Cope (1978), however, considered that the erosional surface that separates the Middle and Upper Volgian substages at Gorodishche represents the period of time during which much of the Portlandian succession of England accumulated. Casey (1967) concluded that the name "Volgian" should be used only for the deposits normally placed within the Upper Volgian (Fulgens to Nodiger zones); that the Middle Volgian should be placed into the Portlandian and the Lower Volgian (Klimovi to Pseudoscythica zones) should be placed within the Kimmeridgian. This would result in the Kimmeridgian/Portlandian boundary being placed at the base of the Pavlovia zones. Although there is some merit in this suggestion, it has never been adopted by the scientific community.

One final complication is that there is increasing argument for the Upper Volgian to be considered to be earliest Cretaceous in age (Rostovtsev & Prozorowsky, 1997; Sey & Kalacheva, 1997). This is based on the ammonite faunas in the far east of Russia, which include *Durangites* (an Upper Tithonian taxon) in the Middle Volgian and *Pseudosubplanites*, *Berriasella* and *Dalmasiceras* (early Berriasian taxa) in the Upper Volgian. In the Caucasus, Berriasian ammonites have also been found in deposits traditionally regarded as equivalent to the upper Tithonian. Finally, in the Russian Platform, the ammonites at the base of the Ryazanian are contemporaneous with the late Berriasian faunas (*Boissieri* Zone) and it is inferred that the Upper Volgian must be of early Berriasian age (*jacobi* and *occitanica* zones), although this remains equivocal.

Tithonian

Oppel (1865) coined the term "Tithonian" for condensed limestones which are situated between Late Jurassic and Cretaceous deposits in the Tethyan province. As a stage it is poorly defined and subdivided (Arkell, 1946; Cope *et al.*, 1964) and type sections and the position of the basal boundary have still to be properly defined (Cope, 1995). However, where ever the stratotype is located, the lower boundary will be fixed at the base of the Hybonotum Zone. The lowest part of the Tithonian also contains *Gravesia* and this has been correlated with the *Gravesia gigas* Zone of north western Europe (Zeiss, 1968).

This stage has found favour, even amongst Russian workers (e.g. Mesezhnikov, 1988) and has been recognised in areas as far apart as Antarctica and northern Europe. Use of this name has one advantage; it overcomes the problem of the definition of the Kimmeridgian and Portlandian *sensu anglico* versus *sensu gallico*. However, that is about all it has in its favour as presently understood. The decision of the Jurassic Subcommittee, at the meeting at Poitiers in 1991 voted that the Tithonian Stage should be accepted as the world standard for the end-Jurassic. Despite this decision, it is simply not possible for areas outside the Tethyan realm to use it, as presently defined, as faunas of the Tethyan realm and consequently correlation cannot be recognised in the Boreal Realm. The Volgian, Portlandian and Kimmeridgian in its various senses will continue to be used for some time yet.

Bolonian

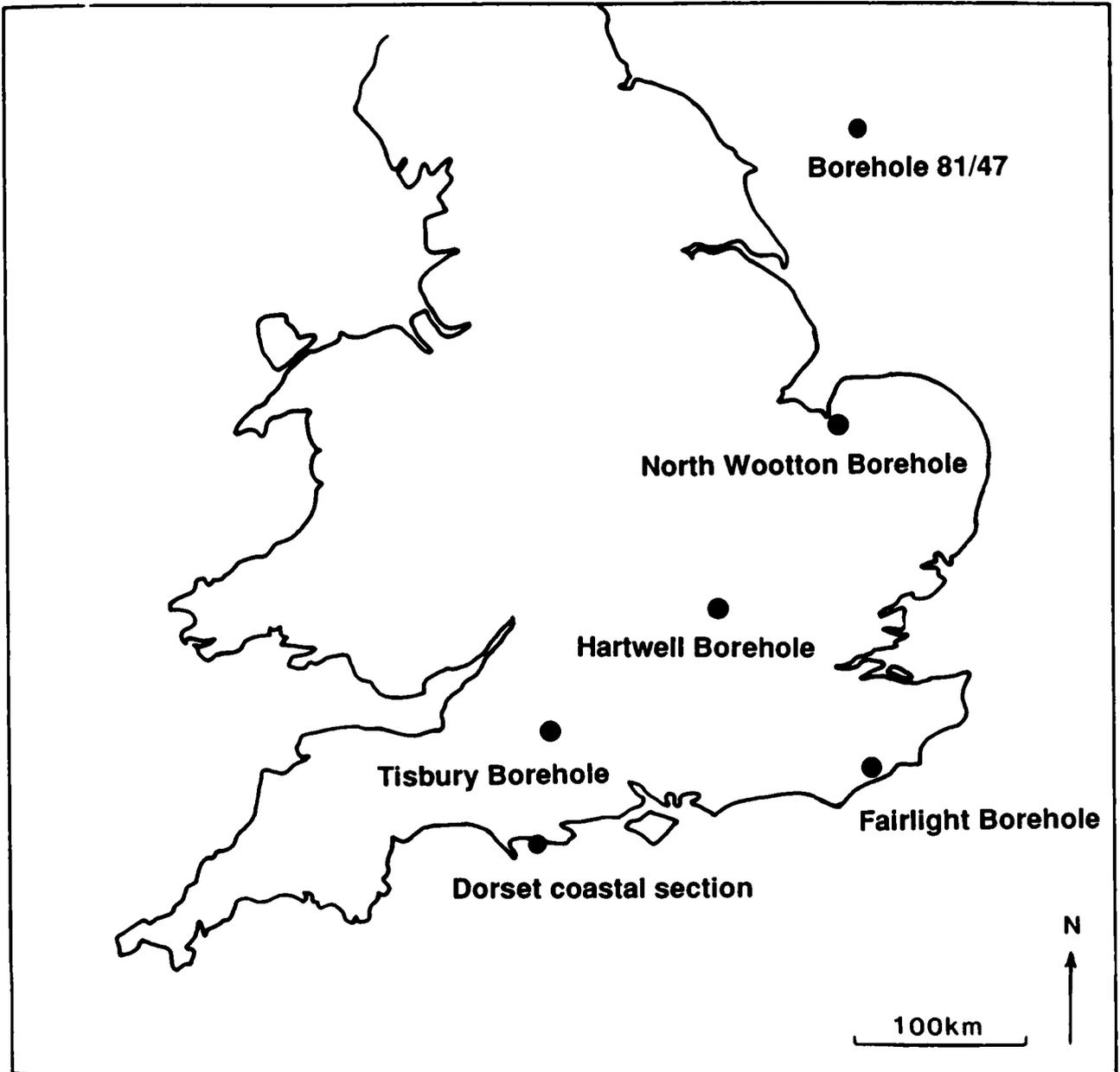
The adoption of the Tithonian as the terminal stage of the Jurassic means implicitly that the Kimmeridgian below it must be interpreted *sensu gallico*. This will result in further confusion in terms of the meaning of Upper Kimmeridgian and for this reason Cope (1993, 1995) has suggested resurrecting Blake's term for the Upper Kimmeridgian (*sensu anglico*) and Lower Portlandian (*sensu gallico*), namely the Bolonian. This usage would preclude (possibly expensive) misinterpretations for hydrocarbon exploration and also brings the new interpretation of the Kimmeridgianst age in line with its definitions in other parts of Europe.

The Bolonian Stage was established by Blake (1880, 1881), its base coinciding with with "the Lower Bolonian or zone of *Ammonite gigas*" (1881, page 582) Now known as *Gravesia*, this taxon has been found by Salfeld (1913) and by Cox & Gallois (1981) in the Kimmeridge Clay of England and although not common (and it is for this reason that Cope, 1967, suggested that it was not suitable to be used as a zonal index) it is widespread. The base of the Bolonian should be defined by the inception of the species. The lowest occurrence known is 3m below the Maple Ledge Stone Band (Cox & Gallois, 1981) and it therefore is convenient to place the base of the Bolonian at the base of Bed KC35 *sensu* Gallois & Cox (1976). Thus the inception of *Gravesia* is a powerful tool to correlate the base of the Tithonian, Volgian and Bolonian.

The upper boundary in the southern England is at the Fittoni/Albani junction. In Dorset this conveniently falls at the Kimmeridge Clay/Massive Beds boundary. However, elsewhere, the Massive Beds are not present and the boundary either cannot be recognised lithostratigraphically or it is transitional as in the case in the Fairlight Borehole. North of Dorset, erosion has resulted in the removal of the highest Bolonian and here the Kimmeridge Clay of *Pectinatus* or *Pallasioides* zonal age is overlain by uppermost Portlandian or Cretaceous deposits.

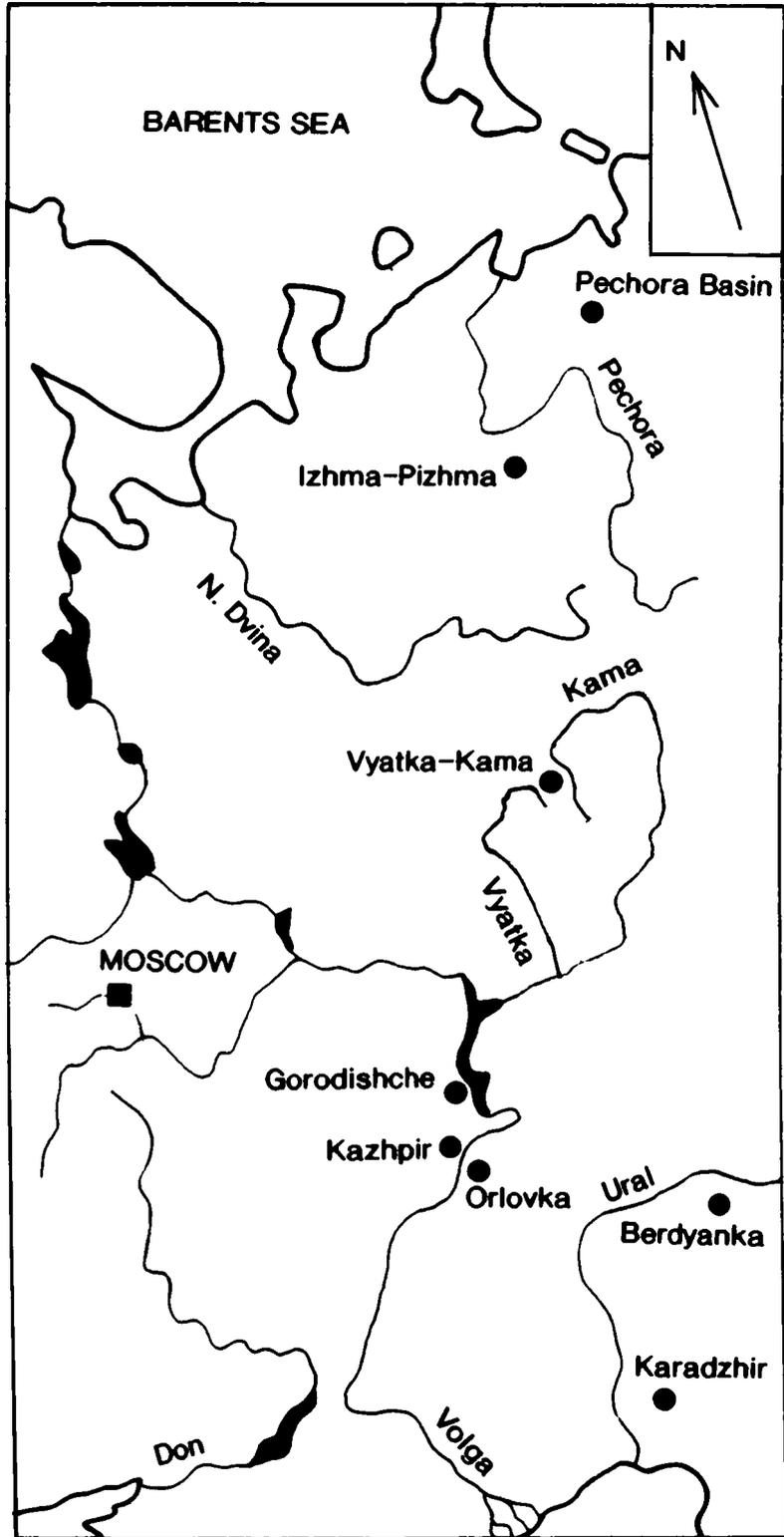
Text-fig. 2

Map of Britain showing the localities discussed in the text.



Text-fig. 3

Map of European Russia showing the localities mentioned in the text.



BARENTS SEA

N

Pechora Basin

Pechora

Izhma-Pizhma

N. Dvina

Kama

Vyatka-Kama

Vyatka

MOSCOW

Gorodishche

Kazhpir

Orlovka

Ural

Berdyanka

Karadzhir

Don

Volga

0 250 500 750

scale (km)

STRATIGRAPHY OF THE DORSET COASTAL SECTION

Introduction

The samples collected for the present study are indicated on the attached diagrams and related to the revised scheme of Kimmeridge Clay bed numbers, the lithostratigraphy and the standard ammonite zonal scheme.

The stratigraphy of much of the Bolonian part of the Kimmeridge Clay Formation of the Dorset Coast was discussed by Cox & Gallois (1981) continuing their work of the Lower (1976) and Upper (1979) Kimmeridge Clay of Norfolk. They recognised a total of 48 beds in the Kimmeridge Clay between the *Baylei* and *Pectinatus* zones on the basis of lithology and macrofaunal content. A number mis-correlations were subsequently recognised and the bed numbers revised. However, this revision has not been published by Gallois and Cox, but was transmitted to Wignall during his research into Kimmeridgian stratigraphy. Wignall (1990) presented this revised scheme (subdividing most beds) and extended the scheme to the Rotunda Nodule Bed, and although he introduced some variations, but failed to define any of the beds or subdivisions in detail.

The emended beds up to the Rotunda Nodule Bed, as defined by Cox and Gallois (and presented in Wignall, 1990), are recognised and, pending formal description and definition for the remainder of the Fittoni Zone a provisional system is utilised herein as shown in the attached figure. Beds of the Bolonian part of the Kimmeridge Clay have been described by Cox & Gallois (1976; in Gallois, 1979) brief comments and description of the sequence is outlined below.

The standard ammonite zonal scheme is followed with one exception; the *Gravesia* Zone is re-introduced. Evidence from boreholes has shown that *Gravesia* appears in Kimmeridge Clay in the upper part of Bed KC34 (Bed KC34p *sensu* Wignall, 1990) (late *Autissiodorensis* Zone). Cox & Gallois (1981) suggested that an appropriate position for the lower zonal boundary would be 3m below the Maple Ledge Stone Band in the Dorset coastal sequence, although *Gravesia* is confined to Bed 35 here. The top of the zone is recognised by the appearance of indices of the *Elegans* Zone at Blake's Bed 42. Although *Gravesia* is rare in Britain, its is a useful taxon for correlation having a wide distribution through northern Europe and into the Volgian of Russia.

Text-fig. 4

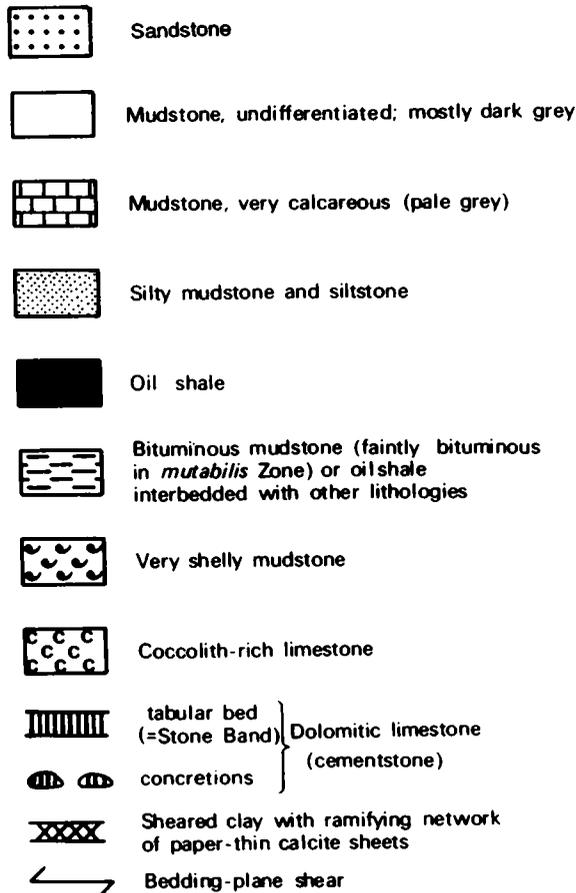
The Stratigraphy of the Kimmeridge Clay stratotype area of the Dorset coast together with sample points (Bed numbers after Cox & Gallois, 1981, emended by Wignall, 1990, and modified herein).

Kimmeridge Bay (SY908 791)

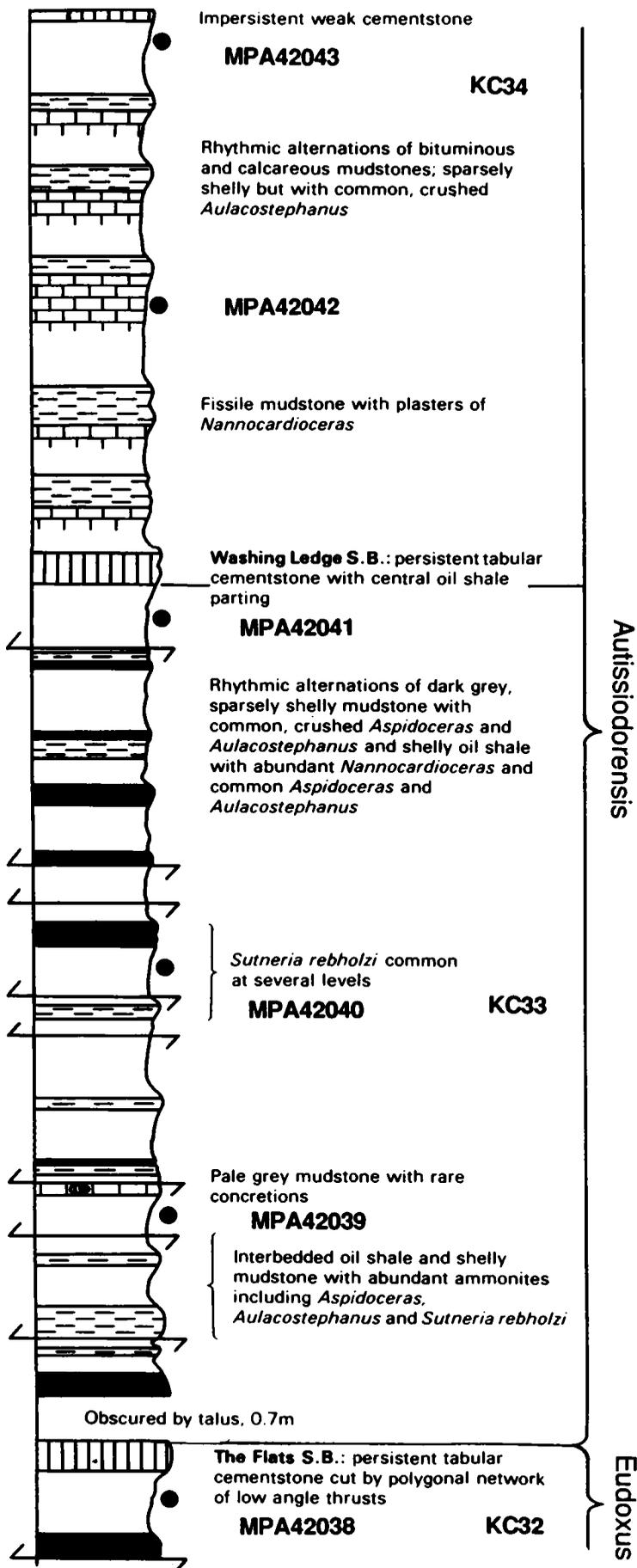
The uppermost Kimmeridgian and Bolonian sequence of the Dorset coast between Kimmeridge Bay, Chapman's Pool and Hounstout Cliff.

(In part modified from Cox & Gallois, 1981)

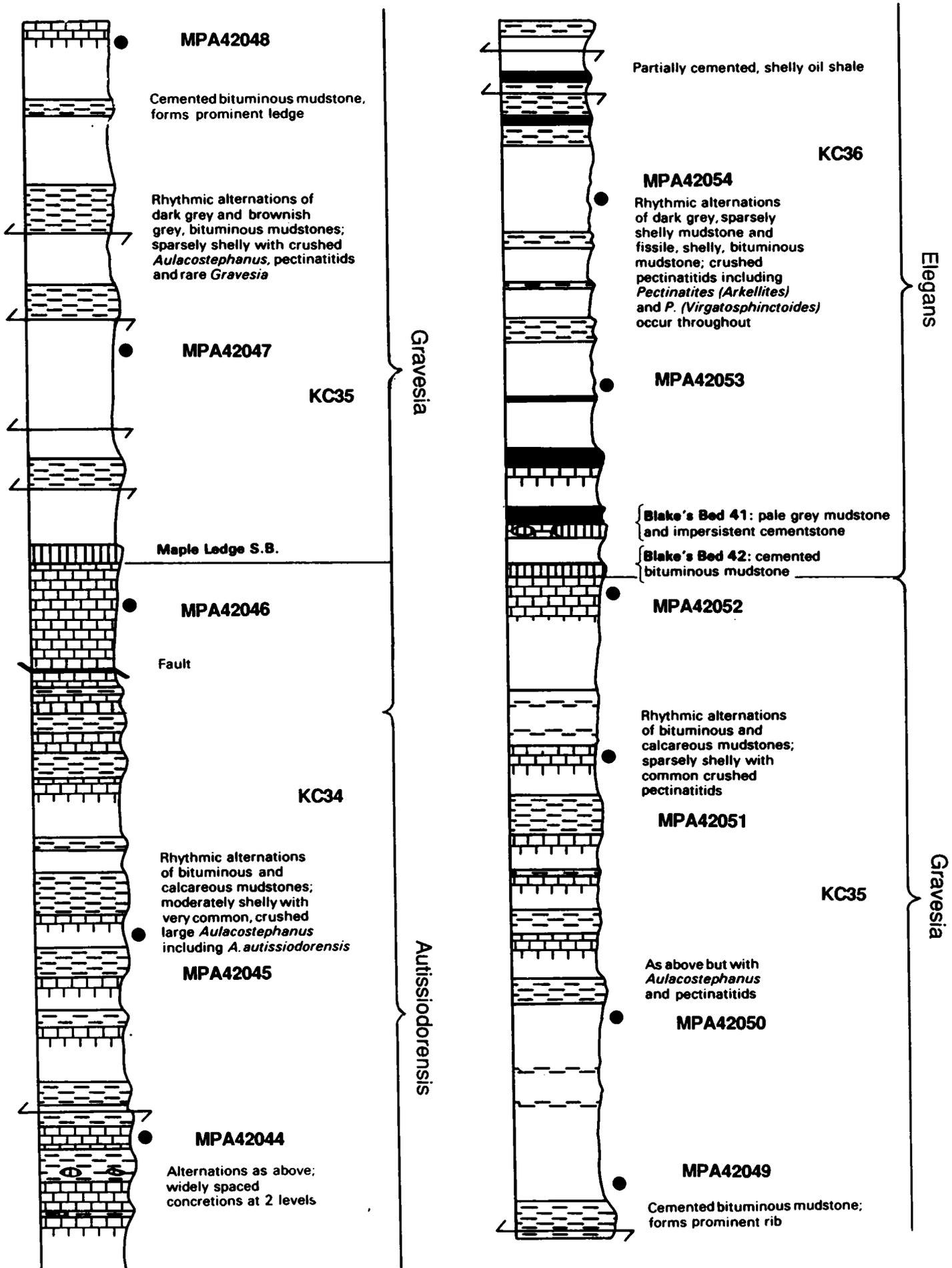
Samples were registered under the MPA symbol of the British Geological Survey. Their positions are shown by the black spot.



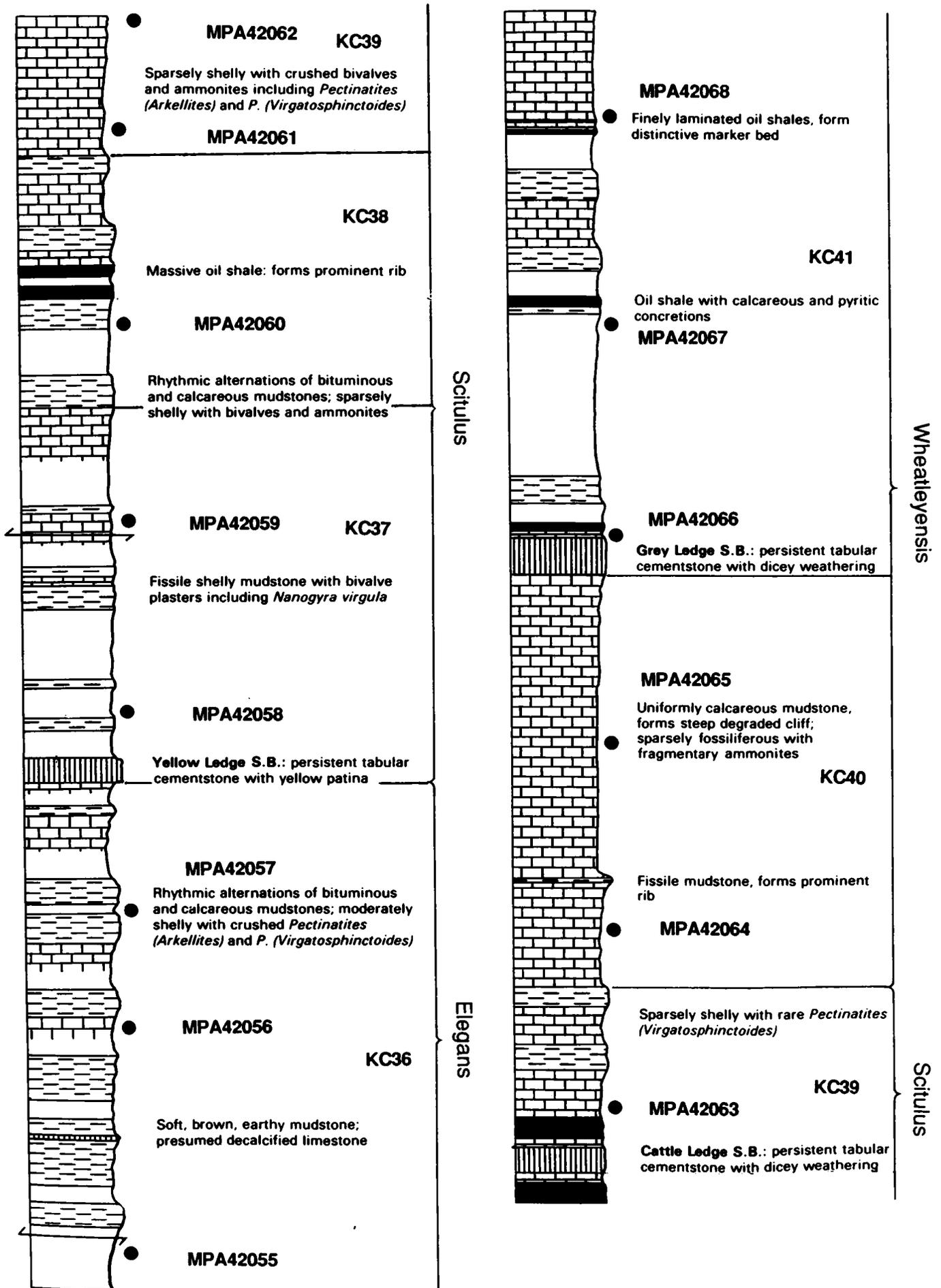
Scale: 1 to 100 (1cm to 1m)



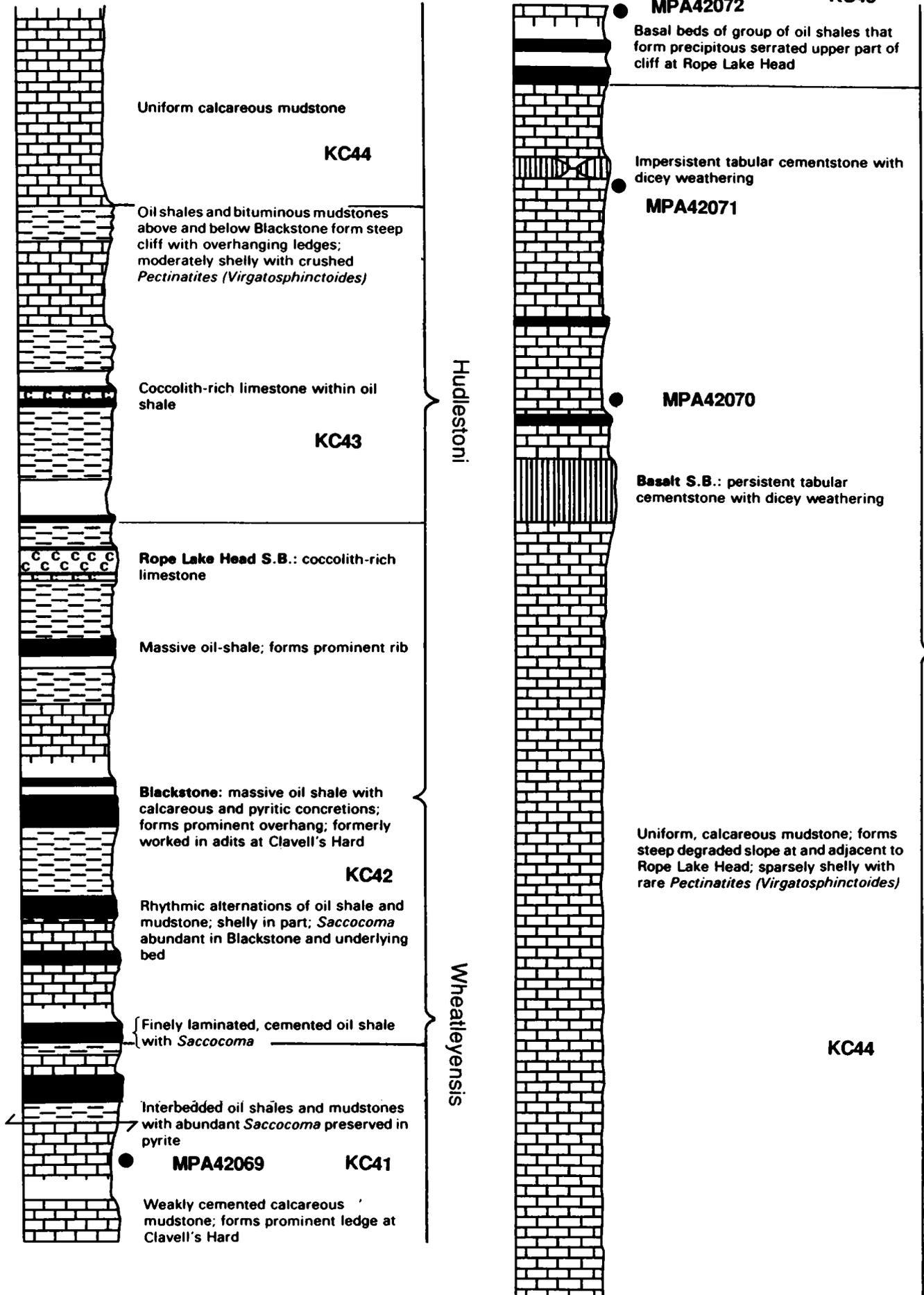
Kimmeridge Bay (SY908 791) to Cuddle (SY912 782)



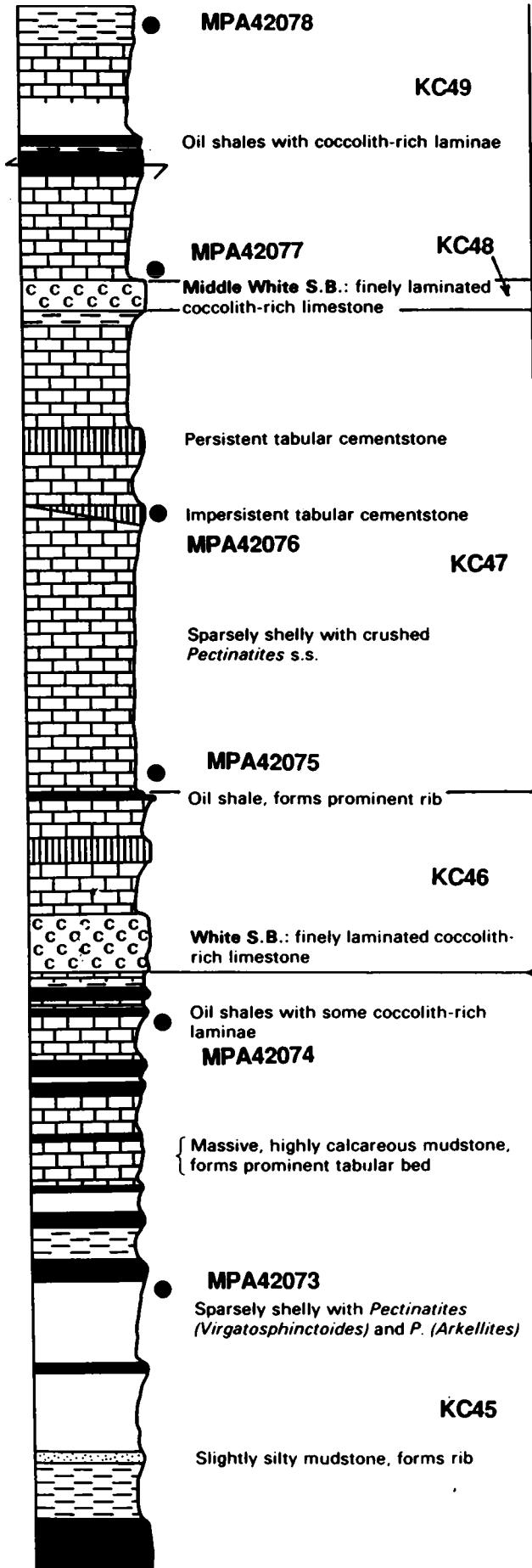
Cuddle (SY912 782) to Clavell's Hard (SY 920 777)



Clavell's Hard (SY 920 777) to Rope Lake Head (SY 927 775)

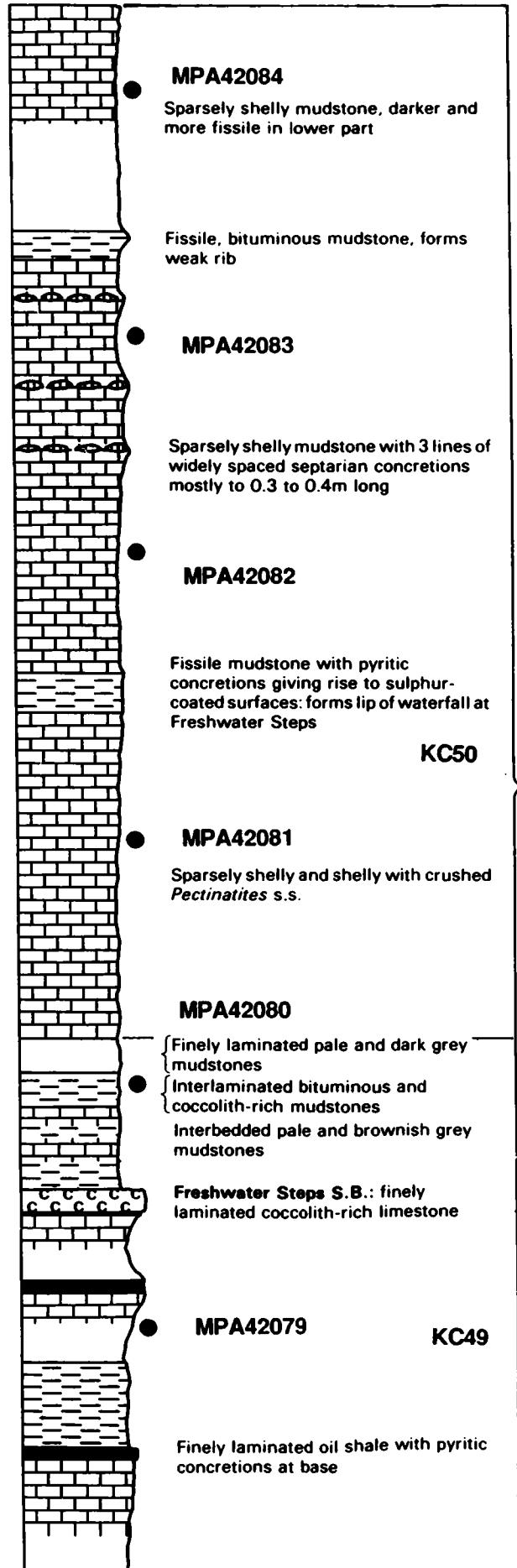


Rope Lake Head (SY 927 775) to Freshwater Steps (SY944 772)



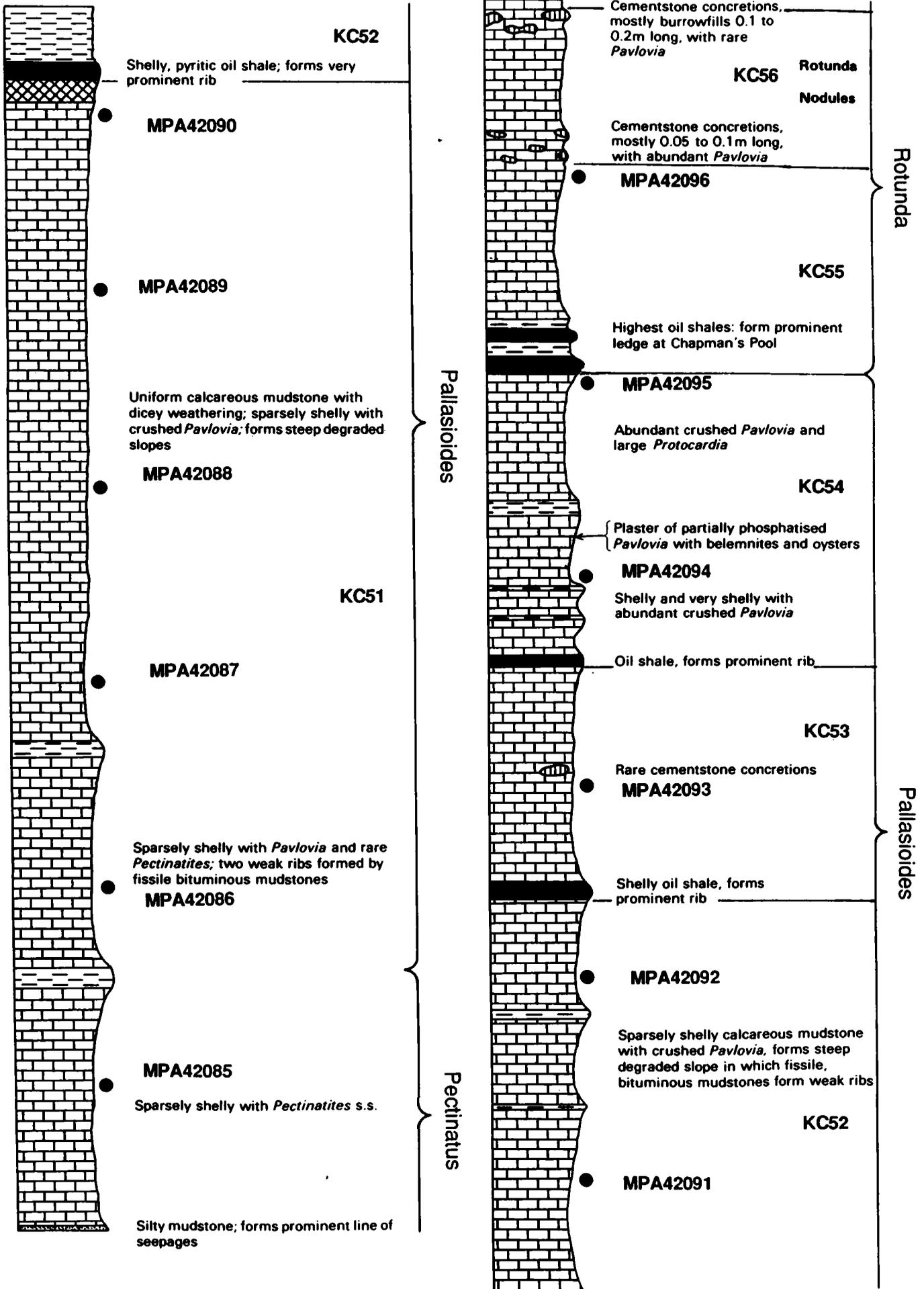
Pectinatus

Hudlestoni

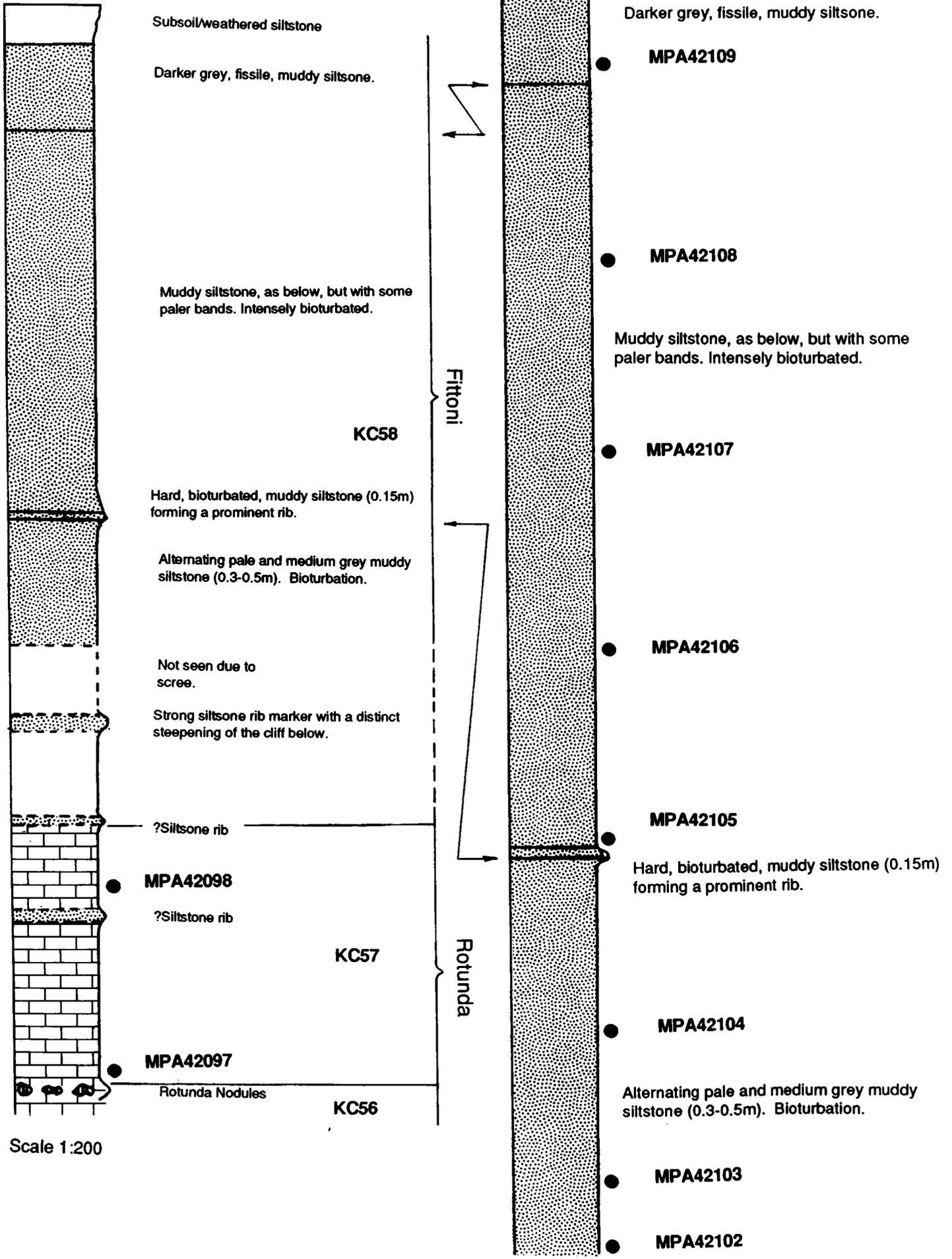


Pectinatus

Freshwater Steps (SY944 772) to Chapman's Pool (SY955 771)



Hounstout, western side of Chapman's Pool (SY 955 771 to 9512 7710)
(incorrectly shown as landslips on the 1:50K map)



Scale 1:200

Stratigraphy

Autissiodorensis Zone

Bed KC33

This bed comprises a rhythmic alternation of dark grey, sparsely shelly mudstones and bituminous mudstones or oil shales. *Aulacostephanus*, *Sutneria rebholzi*, *Nannocardioceras* and *Aspidoceras* are present at some horizons. The base is placed at the top of The Flats Stone Band and its top is placed at the top of the Washing Ledge Stone Band. Thickness: 13.9m

Autissiodorensis/Gravesia Zone

Bed KC34

A rhythmic alternation of dark grey mudstone, pale, calcareous mudstones and bituminous mudstones. The base is taken at the top of the Washing Ledge Stone Band. *Aulacostephanus*, including *A. autissiodorensis*, and plasters of *Nannocardioceras* are present at some horizons. The top is placed at the base of the Maple Ledge Stone Band. The highest part of the bed, which Wignall (1990) calls KC34p is a thicker pale, calcareous mudstone approximately 3m thick. Principally from borehole evidence, this is believed to be the base of the Gravesia Zone (on the coast *Gravesia* is confined to Bed KC35), thus permitting correlation with Germany and Russia. Thickness:22.7m

Gravesia Zone

Bed KC35

The base of this bed is taken at the base of the Maple Ledge Stone Band (cementstone). It comprises a rhythmic alternation of dark grey mudstone and brownish grey bituminous mudstones in the lower part, but pale grey mudstones are added to this alternation in the upper part of the bed. The top is placed at the base of "Blake's Bed 42" Rare *Gravesia* and *Aulacostephanus* occur. Thickness:24.1m

Elegans Zone

Bed KC36

This bed is recognised by an alternation of dark grey, fissile mudstones and bituminous mudstones with the occasional oil shale, particularly in the lower part. Its base is a cemented bituminous mudstone (which equates with Blake's Bed 42) and a little above this is an impersistent cementstone and pale grey mudstone (Blake's Bed 41). *Pectinatites (Arkillites)* and *P. (Virgatosphinctoides)* present

throughout. The top of the bed coincides with the top of the Elegans Zone at the base of the Yellow Ledge Stone Band. Thickness:21.2m

Scitulus Zone

Bed KC37

The base of the bed is recognised by the Yellow Ledge Stone Band, a tabular cementstone with yellow patina. The remainder of the bed comprises an alternation of medium grey mudstones and bituminous mudstones and occasional pale grey, calcareous mudstones in the upper part. Bivalve plasters of *Nanogyra virgula* and occasional ammonites are present. Thickness:7.4m

Bed KC38

Dark grey and bituminous mudstones form the bed, with, in the middle of this bed, massive oil shales that form a prominent rib. A pale grey, calcareous mudstones occurs towards the top of the bed. Thickness: 5.0m

Bed KC39

A pale grey, calcareous mudstone with *Pectinatites (Arkelites)* and *P. (Virgatosphinctoides)* occurs at the base of the bed. Overlying this is the Cattle Ledge Stone Band (a tabular cementstone) and thick oil shales, but the upper part of the bed comprises an alternation of pale grey, calcareous mudstones and bituminous mudstones. The top of the bed coincides with the top of the Scitulus Zone. Thickness: 7.1m

Wheatleyensis Zone

Bed KC40

A pale grey, very calcareous bed, with a thin fissile mudstone that forms a conspicuous rib 2m above the base of the bed. Its base is placed at the top of a thick bituminous mudstone. Sparsely fossiliferous, but fragments of ammonites are found. This is the basal bed of the Wheatleyensis Zone. Thickness: 8.2m

Bed KC41

The Grey Ledge Stone Band (a tabular cementstone) forms the base of this bed. Above this is an alternation of medium to dark grey mudstones, bituminous mudstones and oil shales. The upper part of the bed comprises an alternation of dark grey and pale grey, calcareous mudstones. Thickness: 14.9m

Wheatleyensis/Hudlestoni zones

Bed KC42

An alternation of bituminous mudstones and oil shales with medium and pale grey mudstones. The Blackstone, a massive oil shale at the top of the Wheatleyensis Zone, is present in the middle part of the bed. The Rope Lake Head Stone Band, a coccolith-rich limestone, is situated near the top of the bed. This bed straddles the Wheatleyensis/Hudlestoni zonal boundary.

Thickness:10.1m

Hudlestoni Zone

Bed KC43

An alternation of dark grey and bituminous mudstones with a coccolith limestone in the middle part.

Thickness: 5.9m

Bed KC44

A thick pale grey, calcareous bed with a bituminous mudstone near the base. Crushed specimens of *P. (Virgatosphinctoides)* are present. The Basalt Stone Bed and an impersistent cementstone, both with dicey weathering, are situated in the upper part (18.5-19.75 and 25.25-25.75 m, respectively, above the base of the bed).

Thickness: 27.1m

Bed KC45

An alternation of medium grey mudstones, bituminous mudstone and oil shales form the lower part of the bed, but pale grey, calcareous mudstone alternate with oil shales in the upper part of the bed. A silty mudstone forms a weak rib in the cliff in the lower part of the bed. The base of the bed is placed at the base of a thick oil shale. *Pectinatites (Virgatosphinctoides)* and *P. (Arkillites)* occasionally present.

Thickness: 10.9m

Pectinatus Zone

Bed KC46

The White Stone Band, a coccolith-rich limestone, forms the base of the bed and the base of the Pectinatus Zone. Most of the bed is composed of pale grey, highly calcareous mudstones, although a cement stone is present in the upper part. A thin oil shale forms a prominent rib at the top of the bed. Sparsely shelly with crushed *Pectinatites*.

Thickness: 2.8m

Bed KC47

A pale grey, highly calcareous mudstone comprises bed KC47. An impersistent cementstone is present towards the top. Crushed *Pectinatites* specimens are present.

Thickness: 5.4m

Bed 48

This bed comprises a persistent tabular cementstone. It can be traced into eastern England, but has been seen only in Donnington on Bain Borehole.

Thickness: 0.4m

Bed 49

The lower part of the bed comprises pale grey, calcareous mudstones. The Middle White Stone Band, a coccolith-rich limestone, is situated between 1.8 and 2.3m above the base of the bed. Much of the upper part of the bed comprises an alternation of pale grey mudstones, medium and dark grey mudstones, bituminous mudstones and oil shales. The Fresh Water Stone Band, a finely laminated coccolith-rich limestone, is situated at the top of the bed.

Thickness: 12.25m

Bed KC50

Pale grey, very calcareous, generally sparsely shelly mudstone of *Pectinatus* age. Thin bituminous mudstones occur at the base. Three bands of septarian nodules occur in the upper part of the bed (4.7, 6.0 and 7.0m below the top of the bed).

Thickness: 18.9m

Pectinatus/Pallasioides zones

Bed KC51

Pale grey, very calcareous mudstone with a siltstone at the base which forms a prominent line of seepage.. Two bituminous beds form weak ribs in the lower part (at 4.8-5.2 and 9.4-9.7m above the base). *Pectinatites* occurs in the lower part of the bed, but *Pavlovia* appears above the lower bituminous mudstone (which marks the *Pectinatus/Pallasioides* zonal boundary).

Thickness: 22.8m

Pallasioides Zone

Bed KC52

Shelly pyritic oil shale (0.4m thick) (forming a very prominent rib in the cliff) is overlain by bituminous mudstone (1.1m thick) above which is a pale grey, very calcareous, sparsely shelly mudstone with occasional bituminous mudstone

horizons (notably 5.6-5.7m and 6.9-7.1m above the base of the bed) which form weak ribs in the cliff. Crushed *Pavlovia* occasionally present.

Thickness: 9.3m

Bed KC53

Shelly oil shale (0.3m thick) forms a weak rib at the base of the bed, overlain by pale grey, very calcareous mudstone. Rare cementstone concretions towards the middle of the bed.

Thickness: 4.6m

Bed KC54

Oil shale (0.25m thick) overlain by pale grey, very calcareous, shelly mudstone with *Pavlovia*, *Protocardia*, belemnites and oysters. Three thin bituminous shales (at 0.9-1.0, 1.5-1.6 and 3.0-3.3m above the base of the bed) create weak ribs in the cliff.

Thickness: 5.6m.

Rotunda Zone

Bed KC55

Pale grey, very calcareous mudstone with two oil shales and associated bituminous shales at the base. This also forms the base of the Rotunda Zone.

Thickness: 4.25m

Bed KC56

The Rotunda Nodules. Two seams of nodules with a pale grey, very calcareous mudstone between. The lower concretions (0.05-0.1m long) contain common *Pavlovia* the upper nodules (0.1-0.2m long) contain rare *Pavlovia*.

Thickness: 3.0m

Rotunda/Fittoni Zone

Bed KC57*

Pale grey, very calcareous mudstones with thin siltstone rib at 3.3-3.6m above the base of the bed. Top of bed uncertain due to inaccessibility of cliff and slips. The bed apparently straddles the Rotunda/Fittoni boundary.

Thickness: c.11m

Fittoni Zone

Bed KC58*

This bed comprises an alternation of pale and medium grey, bioturbated, muddy siltstone. Several hard siltstones form ribs in the cliff in the lower part of the bed. Darker grey, fissile, muddy siltstone is present towards the top. The base and top have not been seen due to inaccessibility of cliff and slips. Thickness: approximately 19 m seen.

The highest part of the sequence seen was the c.7m below the base of the Massive Bed on Hounstout Cliff (National Grid Reference 9515 7719). Here 0.7m of muddy siltstone was overlain by a hard, calcareous sandstone 0.3m thick. The highest bed, 6.0m thick, comprised bioturbated muddy siltstones and silty mudstones. This part of the sequence is considered to be of Fittoni zonal age, although it could not be assigned bed numbers due to the obscured or inaccessible sequence between this and the next stratigraphically lower outcrop.

THE STRATOTYPE SECTION AT GORODISHCHE

Introduction

The stratotype section at Gorodishche is situated on the right bank of the Volga River, approximately 25km north of Ulyanovsk. Here the river has undercut the bank to create a steep, unstable cliff which is constantly being changed during the severe Russian winter. It is for this reason that the bed thicknesses are given as a range. It is not possible to sample the entire section as one exposure as slumping obscures parts of the sequence. However, with care, ammonites may be found which allows calibration of the sections and the standard beds may be recognised.

The section at Gorodishche exposes the top of the Kimmeridgian (i.e. the top of the Lower Kimmeridgian *sensu anglico*) and the Volgian (equivalent to the Upper Kimmeridgian *sensu anglico* or Bollonian and the Portlandian or Tithonian). Disconformably overlying the Volgian deposits are Valanginian and Hauterivian sediments, the Berriasian seen in Kashpir being absent at this locality.

Previous work

The section at Gorodishche has been known since 1801 when fieldwork was undertaken by Pallas. However, it was not studied in detail until almost fifty years later when Murchison (1845) described it. Further descriptions were given by Trautschold, Sintsov & Barbout de Marney and a complete description was provided by Pavlov (1884) and Rozanov & Zonov (1937).

More recently, the ammonite zonation of the Lower Volgian was established by Mikhailov (1964,1966) and Gerasimov & Mikhailov (1966), the D panderi Zone was refined and subdivided into subzones and the Upper Volgian deposits were proved. Mesezhnikov (1977) provided a more detailed subdivision of the Kimmeridgian and Volgian macrofaunas and recovered a large number of Haploceratidae in the Middle Volgian.

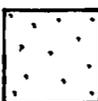
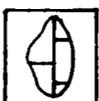
Turning to the microfaunas, a taxonomic study of some of the foraminifera was undertaken by Dain & Kuznetsova (1976), although the stratigraphical

Text-fig. 5

The Stratigraphy of the Volgian stratotype area of the Russian Platform together with sample points.

KIMMERIDGIAN		VOLGIAN										STAGE																									
UPPER		LOWER	MIDDLE							UPPER	SUBSTAGE																										
Eudoxus		Autissiodorensis	Klimovi	Sokolovi	Pseudoscythica	Panderi	Virgatus	Oppressus	Nodiger	Subditus	Fulgens	Nikitini	Nikitini	Zarajskensis	Pavlovi	Fallax	Subeumela	LITHOLOGY	BEDS	THICKNESS (m)																	
1	3.0-4.0	2	1.0-2.0	3	2.0-3.0	4	3.0-3.5	5	1.5-3.5	6	0.2-1.2	7	1.0-1.5	8	1.0-1.6	9	1.0-2.5	10	2.0-3.0	11	4.0-6.5	12	0.15	13	0.3-0.6	14	0.08	15a	0.4	15b	0.17	16	0.65	17	0.45	18	0.15

Sample positions

-  Marl
-  Mudstone
-  Oil shale
-  Sandstone
-  Calcareous concretion
-  Conglomerate

distribution was not considered in detail by them. A small suite of samples were reported on by Lord et al. (1987) who provided brief discussion of the ostracods, nannofossils and dinoflagellate cysts.

Stratigraphical details

The Gorodishche section has been divided into 20 beds, numbered from the base upwards, based on a combination of lithological characteristics and macrofaunal (i.e. ammonite) content.

1. Light grey calcareous clay grading into marl with *Aspidoceras* spp., *Physodoceras liparum* (Opp.), *Aulocostephanus jasonoides* (Pavlov), *A. volgensis* (d'Orbigny), *Subdichotomoceras sublacertosus* (Ilov) and *Sutneria* sp. 3.0-4.0m
2. Grey calcareous clay with *Aulocostephanus eudoxus* (d'Orbigny), *Subdichotomoceras sublacertosus*, *Amoeboceras* (*Nannocardioceras*) *volgae* (Pavlov) and *A. (N.) subtilicostatum* (Pavlov) 1.0-2.0m
3. Grey calcareous clay with *Aulocostephanus autissiodorensis* (Cotteau), *A. volgaensis*, *A. kirghisensis* (d'Orbigny), *Amoeboceras* (*Nannocardioceras*) *volgae*, *A. (N.) subtilicostatum*, *Sutneria* cf. *subeumela* (Schneid.) and *Sutneria* sp. 2.0-3.0m
4. Grey calcareous clay with *Aulocostephanus kirghisensis*, *A. autissiodorensis*, *A. undorae* (Pavlov), *Virgataxioceras fallax* (Ilov.), *Subdichotomoceras sublacertosus*, *Sutneria subeumela*, *Haploceras* cf. *subelimum* (Font.) and *Glochyceras* spp. 3.0-3.5m
5. Dark grey, calcareous clay with clayey carbonate nodules. and the following ammonites: *Ilovaiskyia klimovi* (Ilov.), *Sutneria* cf. *subeumela*, *Neochetoceras* cf. *steraspis* (Opp.) and *Glochyceras* spp. 1.5-3.5m
6. Grey calcareous clay with phosphatic nodules and *Ilovaiskyia klimovi*, *Gravesia* cf. *gravesiana* (d'Orbigny), *Gravesia* sp., *Sutneria* sp., *Neochetoceras* cf. *steraspis*, *Glochyceras* cf. *lithographicum* (Opp.) and *Glochyceras* spp. 0.7-1.2m

7. Dark grey clay with small carbonate nodules and the following ammonites: *Ilovaiskya* cf. *sokolovi* (Ilov.), *I. pavida* (Ilov.) *Sutneria* sp., *Haploceras* cf. *elimatum* (Opp), *Glochyceras* cf. *lithographicum*, and *Glochyceras* spp. 1.0m
8. Alternating dark grey clay and pale grey, clayey marl with *Ilovaiskya* cf. *pseudoscythica* (Ilov.), *Sutneria* sp., *Haploceras* sp. and *Glochyceras* sp. 1.2-1.6m
9. Greenish grey and pale grey clay or, locally, marl, with carbonate nodules and the following ammonites: *Zaraiskites quenstedti* (Rouill. & Vos.), *Pavlovia* cf. *pavlovi* (Mich.), *Glochyceras* sp., *Haploceras* sp. and *Sutneria* sp. 1.5-2.5m
10. Grey, marly clay locally passing into marl, with small carbonate nodules and lenticular bands of white marl. The bed has yielded the following ammonites: *Zaraiskites scythicus* (Visch.), *Z. quenstedti*, *Z. zarajskensis* (Mich.), *Dorsoplanites* cf. *panderi* (d'Orbigny), *Pavlovia pavlovi*, *P. cf. menneri* Mich., *Haploceras* sp., *Glochyceras* sp., *Sutneria* sp. 2.0-2.5m
11. Alternating grey to brown-grey calcareous clays and dark- grey, bituminous shaly clay (oil shale). Ammonites found: *Zaraiskites* spp., *Dorsoplanites* cf. *panderi* 4.0-6.5m
12. Phosphatic nodule bed with *Virgatites virgatus* (Buch) and *Virgatites* sp. 0.1m
13. Green and green-grey, glauconitic sandstone with phosphatic nodules. *Virgatites virgatus* and *V. pallasii* (Mich.) 0.4-0.6m
14. Phosphatic nodule bed with *Virgatites virgatus*, *V. pusillus* (Mich.) and *V. pallasii* 0.15m
15. Green-grey, glauconitic and calcareous sandstone with *Paracraspedites* sp., *Lomonossovella* sp., *Epivirgatites nikitini* (Mich.) *Laugeites stschurovskii* (Nik.) and *Buchia fischeriana* (d'Orbigny) 0.4-0.6m
16. Grey calcareous sandstone with *Kachpurites fulgens* (Trd.) 0.0-0.2m

17. Green-grey, with lenses of green, calcareous sandstone and the following ammonites: *Craspedites subditus* (Trd.), *C. okensis* (d'Orbigny), *Garniericeras catenulatum* (Fisch.) 0.6-1.2m

18. Grey calcareous sandstones with phosphatic nodules and pebbles of the underlying sandstone. Ammonite present: *Craspedites mosquensis* Gerass., *C. kashpuricus* (Trd.), *C. parakaschpuricus* Gerass., *C. milkovenski* (Strem.) 0.0-0.15m

19. Yellow-grey, ferruginous, conglomeratic sandstone with pebbles from the underlying sandstone. Ammonites: *Temnoptychites mokschensis* (Bog.) present in the sandstone matrix; *Buchia volgensis* (Lah.) and *Craspedites* sp in the sandstone pebbles. 0.4-0.5m

20. Dark grey clay with large septarian nodules containing *Speetoniceras versicolor* (Trd.) 1.0-2.0m

2. Previous work on Late Jurassic Microfaunas

1. Foraminifera

Introduction

Volgian deposits are widespread on the Russian Platform, where the proposed Volgian Stage lectostratotype is situated (at Gorodishche). The Gorodishche section lies on the right bank of the Volga River, 25km north of Ulyanovsk and within a few kilometres of the village of Gorodishche. Field work was carried out under the leadership of Prof. M.S. Mesezhnikov between 1971 and 1984 on the lectostratotype area, approximately 100 samples were collected from six sites along the river bank. The Bed numbers and ammonite zones used here, follow the scheme recognised at that time by Mesezhnikov (1984). The richest and best preserved assemblages of agglutinated and calcareous Foraminifera and Ostracoda are recorded from the Kimmeridgian and Volgian deposits at Gorodichshe.

In Britain, the Bolonian and Portlandian deposits are contemporaneous with the Volgian of the Russian Platform. The best exposures are those of the coastal section between Kimmeridge Bay and Chapman's Pool, in the stratotype area. Here the sequence is uninterrupted and dip makes continuous sampling possible for most of the sequence, although towards the top of the section, below the Massive Bed, the steepness of the cliff makes sampling difficult. The lithostratigraphy and the ammonite zonal scheme has been known for many years, but more recently detailed stratigraphical work has been carried out by, for example, Gallois & Cox (1978) and Oschmann (1988) for the Kimmeridgian and Townsend (1975) and Wimbledon and Cope (1978) for the Late Kimmeridgian and Portlandian.

Foraminifera have been recovered throughout the Upper Kimmeridge Clay although they are more common and more diverse in the upper parts. Ostracoda, on the other hand are present in the Scitulus Zone and above, but have yet to be found in the Autissiodorensis and Elegans zones. Preliminary observations on their distribution are presented below.

The Russian Platform

Foraminifera from the Volgian of Gorodishche were first reported by Mjatluk (1939) and from Pre-Caspian by Kasanzev (1934, 1936). These early workers laid the foundation of Jurassic micropalaeontology in Russia. After the Second World War, Furssenko and Polenova (1950) published studies on Volgian foraminifera from Karadzhir that had been started before war. They described and illustrated 51 species from lower and Middle Volgian deposits. More specific studies were undertaken by Dain and Kuznetsova (1971, 1976). They described more than 100 species from Upper Kimmeridgian and Volgian from the lectostratotype of the Volgian Stage. Dain and Kuznetsova (1971, 1976) erected a biostratigraphical scheme of nine foraminiferal assemblage zones for the Upper Kimmeridgian and Volgian of the Russian platform. The foraminiferal zonal scheme was correlated with the standard ammonite zonation. Later, Kuznetsova (1979) attempted a correlation of the Kimmeridgian and Volgian sequences between the Russian Platform and Southern England. The biostratigraphical significance of foraminifera as a tool for regional correlation of Volgian sections was discussed by S. Yakovleva (1985), who applied them to the Pechora Basin, Gorodishche, Kashpir, Orlovka, Karadzhir.

Useful papers of foraminifera from other parts of the Russian Platform include the following: several publications by Kuznetsova (1963, 1965, 1969), Chabarova (1959), Yakovleva (1982) and Yakovleva and Azbel (1993).

Foraminiferal trends in the Volgian of Gorodishche

The predominant groups of foraminifera in the Volgian of Gorodishche are: Nodosariidae, Ceratobuliminidae and Epistominidae. Arenaceous foraminifera are numerous only in the lower part of the Middle Volgian. The calcareous species of Gorodishche, as well as in other sections of the Russian Platform, occur in a good state of preservation.

The Upper Kimmeridgian and Lower Volgian are characterised chiefly by Nodosariidae, Epistominidae and Ceratobuliminidae. Common genera are *Lenticulina*, *Astacolus*, *Marginulina*, *Epistomina*, *Mironovella* and *Pseudolamarckina*. In some samples *Epistomina* consist 90% from the total population. Agglutinating forms play a much more subsidiary role. *Haplophragmium* with pseudolabyrinthic walls occurs frequently in the Upper Kimmeridgian and rarely in the Lower Volgian. *Ceratobulimina* is replaced in the Panderi Zone by dominant Lituolidae. Agglutinated forms, mainly *Haplophragmoides*, *Ammobaculites*, *Kutsevella* and *Spiroplectamina*, are dominant in the clays just low oil shale of the Zarajskensis Subzone).

In the Virgatus-Nodiger Zones foraminifera are very sparse with only a few specimens of *Nodosaria*, *Lenticulina*, *Astacolus*, and *Marginulina*.

United Kingdom

Foraminifera of southern England have been somewhat neglected. Lloyd (1958MS) carried out a taxonomic and stratigraphical examination of the faunas for his doctoral thesis, and later (1959, 1962) published some taxonomic work on arenaceous and some of the calcareous taxa (but excluding the Nodosariidae, the dominant group in the Kimmeridgian). J. Exton (in Shipp, 1989) outlined the general trends in the Kimmeridgian foraminifera, but no details were given. A few other papers include data from the Kimmeridgian (e.g. Medd, 1979), but they are confined to the lower part of the stage and fall outside the scope of this report. Portlandian foraminifera have not been studied in detail. Ship (1978) recorded a sparse fauna from the Albani Zone of Dorset and Copestake (in Lord & Bown, 1987) listed a few taxa from the Albani and Okusensis Zone in Dorset, southern England. Finally, Copestake (in Shipp, 1989) gave some information on some foraminifera from the Vale of Wadour, Wiltshire.

The faunas of the Kimmeridgian and Portlandian are dominated by Nodosariacea, but Textulariinae, Polymorphinidae and Epistomininae are also present at some horizons, notably in the Kimmeridgian. The existence of a single planktonic specimen has been reported in Shipp (1989). There are four broad trends in the foraminiferal assemblages.

4. Albani-Okusensis (Early Portlandian): Nodosariidae is common, particularly species of *Lenticulina*, *Saracenaria*, *Citharina* and *Marginulina*.
3. late Pectinatus-Fittoni zones (Late Kimmeridgian): The proportion of Nodosariidae is increased, to become common at some horizons, and Textulariidae is also common. The dimensions of the individuals also tends to increase in the later part of this interval.
2. Scitulus-early Pectinatus (Late Kimmeridgian): Textulariidae are common but low in diversity. Specimens of *Ammobaculites*, *Trochammina* and *Haplophragmoides* are common and in the Scitulus to Hudlestoni zones *Lenticulina* and *Marginulina* occur occasionally.
1. The Eudoxus-Autissiodorensis zones (latest Early Kimmeridgian) has a low diversity fauna (oil shales are particularly conspicuous in this part of the Kimmeridge Clay). *Haplophragmoides*, *Textularia* and *Lenticulina* are present, together with species of *Epistomina*, *Marginulina*. and *Vaginulina*.

North-western Europe

Published work in the North Sea area has not been forthcoming due principally to commercial interests, although faunas are frequently restricted in diversity and biostratigraphical usefulness and other microfossils, such as palynomorphs, have been more widely utilised. In north-western Europe, Bielecka & Pozaryski (1954), Bielecka (1960), Guyader (1968), Munk (1980), Barnard and Shipp (1981) produced some useful data although their value is not influential in the present work. Studies in German during the 1950's culminated in the important taxonomic and biostratigraphical work "*Leitfossilien der Mikropaläontologie*" in which further useful information may be found. Further afield in eastern Canada, Ascoli (1976, 1981), Ascoli *et al.* (1984), Gradstein (1976, 1978) and Wall (1983) and these also have application to the study area after seafloor spread has been taken into account.

2. Ostracoda.

Russia

Systematic study of Late Jurassic ostracods of the European part of the former Soviet Union began in the third decade of this century.

The first items of information about the distribution of ostracods in the Upper Jurassic deposits of the Russian Platform were published in 1937 (Sharapova, 1937). This work is very interesting, as she presents the results of study of ostracods in one of major section of Volgian stage - the Karadzhir Ravine section (Lake Inder, Western Kazakhstan). Seven species of ostracods, which are put into the genus *Eucythere* Brady, 1868 and *Cytherella* Jones, 1849 are present in the above named deposits. Five species are described, four of which are new. According to the description of each species, their distribution is within the limits of the Virgatus Zone, Lower Volgian Substage.

In the 1939 another article by that author, contains information about the distribution of ostracods in the Upper Jurassic deposits of a number of boreholes of the Ozinkov region (Saratov area) (Sharapova, 1939). In this investigated material, Sharapova determined 15 ostracods species from deposits of presumed Panderi and Virgatus Zones (Lower Volgian stage), eight of which are new, and six were found earlier in the section of Karadzhir Ravine.

With this paper the pre-war stage of study of Upper Jurassic deposits of Russian Platform finished.

A significant contribution to the study of Mesozoic ostracod faunas from various region of Russia. was made by Lyubimova, after many years of study. In 1955 she published the results of her research, which included ostracods from Triassic, Jurassic and Lower Cretaceous deposits of the Volga area and the Obshchyi Syrt (Lyubimova, 1955). The author's collection included rich material from Upper Jurassic deposits of a borehole on Samarskaja Luka ,from Upper Jurassic deposits of the classical Ulyanovsk Volga area and Karadzhir and from natural outcrops of Obshchyi Syrt. This work is of great significance from the point of view of the development the taxonomy of Mesozoic ostracods. Lyubimova described 69 new species belonging to 13 genus and allocated two new genus (*Pyrocytheridea* and *Mandelstamia*), as well as revising the generic position of 14 species, allocated earlier by Sharapova.

In 1978, a very interesting article by Dzik (Dzik, 1978) carefully described a unique find of Myodocopida with the preserved soft body. These ostracods were taken out of the stomach of Pleziozavre found in the Lower Volgian deposits of Saveliev mine in the Pugachev region, of the Saratov area.

M.N. Permyakova has been engaged in study of ostracods from Jurassic deposits of Ukraine. Although the majority of her articles were devoted to Middle Jurassic forms, in some publications it is possible to find information about the Upper Jurassic representatives of this fauna (Permyakova, 1974,1978).

For a number of years O.M. Lev was engaged in the definition of ostracods from marine Jurassic deposits of the Timano-Pechora Province (TPP). The article (Lev & Kravets, 1982) described eleven complexes, enabling., in opinion of those authors, to identify Bathonian, Callovian, Oxfordian and Kimmeridgian deposits in TPP by ostracods. Lev indicated the index -species characteristic for each complex and plotted the distribution of these complexes in the TPP and in other region of central sector the Russian Arctic. Unfortunately, the author did not publish the descriptions or illustrations of ostracod species and that considerably hinders further work based on O.M. Lev's scheme in subdividing Middle-Upper Jurassic deposits of TPP by ostracods.

In 1977, a small number of samples from Lectostratotype of Volgian stage at Gorodishche (Ulyanovsk) and Kashpir (Samara) were collected by P. Rawson, during an International Geological Congress excursion. An article, which was published in 1987, contains a cursory discussion of the characteristic nannofossils, foraminifera and ostracods (Lord, *et al.*, 1987). The part concerning the ostracods (Fuller, in Lord *et al.*, 1987) is extremely brief, but presents a table showing the distribution for 30 species related to 16 genera. The greater part of the ostracods listed can be attributed to species erected by Sharapova and Lyubimova.

Thus, at the present moment, late Jurassic ostracods have been examined from only a few isolated sections. In some localities ostracods are rare or absent. Little information exists regarding changes in the structure of ostracod complexes with time and space in the Russian Platform.

The United Kingdom

Kimmeridgian Ostracoda were not studied during the 19th century and although Blake (1876) named six species of Ostracoda, none were figured or described, so that all must be considered *nomina nuda*. It was not until the late 1950's and 1960's that work on the classic Dorset section began. The earliest publications incorporating material from the stratotype area are by Malz (1958a,b). He described several new taxa, principally members of the genus *Macrodentina*. The first paper by British workers was published in 1961 when Neale and Kilenyi described some Kimmeridgian species of *Mandelstamia*. Glashoff (1964) described some Oxfordian Ostracoda of north western Europe and also included species from the basal Kimmeridgian of Dorset.

In 1965 Kilenyi described a new genus, *Oertliana* (which proves to be a junior synonym of *Dicrorygma* Poag, 1962), but the most important work on Kimmeridgian Ostracoda was published by Kilenyi (1969) and Christensen & Kilenyi (1970), later summarised in Kilenyi (1978). Kimmeridge Clay Ostracoda were discussed both taxonomically and, to a limited extent, biostratigraphically by Kilenyi (1969), who recognised 58 species (although he confused juveniles and dimorphism in several species and his total can be reduced to 54). The Early Kimmeridgian assemblages are dominated by species of the genera *Schuleridea*, *Gailiaecytheridea*, *Mandelstamia*, *Amphicythere*, *Macrodentina* and *Exophthalmocythere*. He showed the middle part of the Kimmeridgian to be barren of Ostracoda or only sparsely populated, but the Upper Kimmeridge Clay yields abundant ostracods, although diversity is

low. These include *Galliaecytheridea spinosa*, *G. polita*, *Dicrorygma (Orthorygma) brotzeni*, *Paranotacythere (Unicosta) pustulate* and, at some horizons, *Hechticythere sigmoidea* and *Klentrnicella nealei*.

Although erecting six new species, Christensen & Kilenyi's (1970) paper is more notable for its biostratigraphical content and their attempt to correlate numerous sequences throughout north-western Europe. Using the Kimmeridge Clay stratotype in Dorset, with its excellent lithostratigraphical and macropalaeontological control, they recognised five ostracod assemblage zones:

5. *Galliaecytheridea polita* ostracod Zone equivalent to the bulk of the Fittoni Zone
4. *Galliaecytheridea spinosa* ostracod Zone from the upper part of the Pectinatus into the earliest Fittoni zones
3. *Mandelstamia maculata* ostracod Zone between the upper part of the Wheatleyensis to the lower part of the Pectinatus zones
2. *Galliaecytheridea elongata* ostracod Zone from the mid part of the Mutabilis into the Eudoxus Zone
1. *Galliaecytheridea dissimilis* ostracod Zone from the base of the stage to the mid part of the Mutabilis Zone.

They encountered difficulties in the middle part of the section, which lacks Ostracoda, and in the Upper Kimmeridgian, in which the assemblages are of low diversity and patchy distribution preventing the accurate location of zonal boundaries. Nevertheless, this forms an excellent basis for biostratigraphical work and has been modified by Wilkinson (1983a,b).

A sixth zone, defined by the appearance of *Galliaecytheridea compresses* was recognised by Christensen (1974), although it has not been recognised in eastern England due to the absence of sediments of that age. Its first occurrence is in the upper part of the Fittoni Zone (the highest part of the Kimmeridge Clay) in Dorset and it extends throughout the Portland Sand (Barker, 1966a).

Wilkinson (1983a, 1983b, 1987, in Cox *et al.*, 1987) carried out some biostratigraphical work on the ostracods of eastern England and related their distribution to the Palaeoenvironment. Ahmed (1987) mentioned Kimmeridgian Ostracoda from the Baylei and Cymodoce zones at South Ferriby, Southhumberside.

In the North Celtic Sea Basin, below the 'Wealden' deposits with their fresh-water ostracods, silty sand overlies limestones and silty clays (Colin *et al.*, 1981). These Kimmeridgian deposits contain abundant *Macrodentina (Macrodentina) cf. cicatricosa*, a species that has a somewhat restricted distribution onshore, and *Cetacella paucistriata* (Helmdach) which is unknown on mainland Britain.

The English Portlandian also has a long history of research, although research has been somewhat patchy. While describing the fresh-water Ostracoda from the "Purbeckian" of southern England, Jones (1885) included three marine, or near marine, species, *Cythere retirugata*, *C. retirugata var. rugulata*, and *C. transiens*, all belonging in the genus *Macrodentina* as demonstrated by (Malz, 1958b). The stage was not examined further until Anderson (1941) described a number of species from the Portlandian at Swindon. He included *Cythere retirugata var. rugulata*, *C. retirugata var. textilis* Jones, *Cytheridea politula* Jones & Sherborn, together with several new species and varieties *viz.* *Cythere retirugata var. decorata*, *Cytheridea visceralis*, *Cythereis serpentina*, *C. euscarca*, *C. calyptroides* and *Cytherella? decipiens*. The taxonomy of these species was subsequently modified by Barker (1966a,b) and Anderson (1985).

By far the most important work on Portlandian Ostracoda in Britain is by Barker who described faunas from Dorset (1966a) and Aylesbury (1966b). He stated that in Dorset, the first occurrence of typical Portlandian species is in the uppermost part of the Kimmeridge Clay, c.3m below the Massive Bed at Hounstout Cliff and Black Nore Sandstone at West Wear Cliff, and they extend up into the Portland Sand. This fauna is composed of *Macrodentina (Macrodentina) transiens* (Jones), *M. (Dictyocythere) retirugata* (Jones), *M. (P.) rudis* Malz, *Galliaecytheridea compressa* Christensen & Kilenyi, *Paranotacythere (Unicosta) rimosa* Martin, *P. (U.) elongata*, *P. (U.) levis* Barker and *Galliaecytheridea sp. (G. postrotunda sensu Barker)*. *Hechtycythere serpentina* Anderson and *Paraschuleridea eusarca* (Anderson) are also present. The Portland Stone has six species in common with the Portland Sand, but *Macrodentina (M.) rugulata* (Jones) and *Procytheropteron bicosta* Barker are peculiar to it and, significantly, *Galliaecytheridea compressa*, *Macrodentina (Polydentina) rudis* and *Paranotacythere (U.) elongata* are not present (Barker, 1966a).

The influence of the decreasing salinities on the Ostracoda during the Late Portlandian ("Purbeckian") was recorded by Barker (1966b). Fully marine forms (eg. species of *Protocythere*, *Macrocypris*, *Paraschuleridea*, *Paranotacythere*, *Procytheropteron* and

Wolburgia) were gradually replaced by euryhaline forms, such as species of *Fabanella* and *Mantelliana*, and finally oligohaline species of the genera *Cypridea*, *Klieana*, *Scrubiculocypris*, *Darwinula* and *Rhinocypris*. In a paper on the Purbeck Beds of the Weald (Anderson & Bazley, 1971), Anderson used the Ostracoda both biostratigraphically and palaeoecologically, recognising a series of brackish to nearly fresh-water (C-phase) and more saline to nearly fully marine (S-Phase) faunas. Although a large number of brackish to fresh-water species (mainly *Cypridea*) were discussed, a lesser number of brackish-marine species, falling within the genera *Eoparacypris*, *Macrodentina*, *Paranotacythere*, *Procytheropteron*, *Galliaecytheridea* *Stillina* and *Eocytheridea* were also described.

Anderson (1985) summarised his work on the Ostracoda of the Upper Portlandian, Purbeck and Wealden deposits just before his death. Although it deals with fresh-water forms in the main, a number of marine species are mentioned in the context of salinity variations and recognition of Anderson's "C" and "S" phases. Taxonomic revision of some of his earlier works is included.

No marine Ostracoda of this age are recorded from the North Celtic or Fastnet basins, although fresh to brackish water species such as *Mantelliana purbeckensis* (Forbes) and *Cetacella amata* Martin are present. Portlandian deposits in eastern England are composed of small patches of sand that have failed to yield an in situ ostracod fauna.

North-western Europe

France

Although Kimmeridgian Ostracoda of northern France have not been extensively studied, those from the subsurface of Vernon were examined in detail by Oertli (1957). Thirty five species were described, of which seven species and three genera were new and ten were left in open nomenclature. Several, are important components of the English faunas. Oertli later (1963) added to this information by illustrating a number of faunas from the Paris Basin. Material from the Paris Basin was included by Malz, in his work on the genera *Nodophthalmocythere* (1958a) and *Macrodentina* (1958b); Bassiouni (1974), in his paper on the genus *Paranotacythere*; and by Guyader (1962, 1966, 1968), in his short notes dealing with the area around the mouth of the Seine. Despite the lack of data, Christensen & Kilenyi (1970) were able to show the similarities in the ostracod faunas of the Paris Basin and southern England. Kimmeridgian Ostracoda from the Ile d' Oleron were described by Donze

(1960). The majority of species in the area are not present in England, however, *Eocytheropteron aquitanuin* is an exception and proves to be useful biostratigraphically.

Apart from the discussion on *Rectocythere* (Malz, 1966), there is no information on the Portlandian (*sensu anglico*) in the Paris Basin, although Bassiouni (1974) included specimens of *Paranotacythere* from Ile d'Oldron. The scant information relating to the Late Jurassic ostracod faunas in northern France, is reflected in the chapter on the Jurassic in the "Atlas des Ostracodes de France" (Dépêche, 1985).

Germany

A large amount of work has been carried out on the Late Jurassic Ostracoda of Germany. Lack of space prevents a complete coverage of all these contributions and only the more important papers are discussed here.

The earliest significant modern publications on marine Kimmeridgian and Portlandian ostracods of northern Germany are by Steghaus (1951), Triebel (1954), Schmidt (1954, 1955) and Klingler (1955). These were essentially taxonomic descriptions, but much stratigraphical detail was also included so that they remain useful in biostratigraphical work. Steghaus (1951) erected eleven new species several of which are useful biostratigraphically. Klingler (1955) partly revised Steghaus' work and placed the species in a stratigraphical context. Schmidt's (1954) work on the Kimmeridgian and Portlandian Ostracoda in north western Germany, in which he described several species of *Cytheropteron*, *Bythoceratina* and *Exophthalmocythere*, is over-shadowed by his 1955 publication. This attempts, using both Foraminiferida and Ostracoda, to correlate several sections through the Upper Jurassic of the Hannover-Osnabruck area and postulate the importance of the microfauna in correlative work on a continental scale. Taxonomic work was carried out during the 1950's by Malz (1956, 1957, 1958a, 1958b) who concentrated his efforts on relatively few genera, notably *Nodophthalmocythere* and *Macrodentina*, and, in the case of the latter genus, showed its usefulness in biostratigraphy.

This great expansion of studies during the 1950's culminated in the important taxonomic and biostratigraphical work "*Leitfossilien der Mikropaläontologie*" in which Klingler, Malz & Martin (1962) discussed the Malm ostracods from north-western Germany. This classic work is still an important source of data, although care must be exercised in some cases due to more recent stratigraphical and taxonomic changes.

Since 1963, very little additional work has been carried out on the German sequence, although Wienholz (1968) published a short account on the faunas across the Jurassic/Cretaceous boundary in the northern part of the German Democratic Republic. The most important work in recent years is that by Schudak (1994) and Schudack & Schudack (1995). Their data show that in the Bolonian and Lower Portlandian there was considerable similarities within the "sub-boreal" province (comprising Dorset, Eastern England, southern North Sea and the Danish Basin), and to a lesser extent with the "western European" subprovince of northern and western France, but that there was in common with the "Central European" subprovince of Northern Germany. This in turn had little in common with the "subtethyan" Province of the Polish Basin. Provincialism was an important factor during the latest Jurassic.

Danish-Polish Trough

The ostracod distribution in the Danish-Polish Trough was discussed in detail by Christensen (1970, 1974, 1988). In the Danish embayment a number of species common to the United Kingdom have been recorded, for example, *Galliaecytheridea compressa*, *Galliaecytheridea polita*, *Galliaecytheridea spinosa* and *Dicrorygma brotzeni* are characteristic of the Bolonian and Portlandian. Other taxa, which have a wide geographical distribution in the North Sea Basin in general have also been found, for example, *Aaleniella inornata*, *Eocytheridea eusarca*, *Mandelstamia maculata*, *Mandelstamia tumida*, *Prohutsonia elongata* and *Schuleridea moderata*.

Although there appears to have been communication between the North Sea Basin and the North Polish Trough via the Danish-Polish Basin, during the Kimmeridgian, by the Bolonian and Portlandian the connection was broken. As a result, there appears to have been a major biological barrier across northern Europe during the Bolonian and Portlandian, for very few taxa extend through to the Polish Basin. Kubiakowicz (1983) recorded a small number of Polish Portlandian ostracods that have also been noted in the North Sea Basin and Danish Trough: *Rectocythere* (*Lydicythere*) *rugosa* and *Paranotocythere* (*U.*) *rimosa*. A slightly larger number were common to European Russia, such as *Galliaecytheridea mandelstami*, *Hechticythere bisulcata* and *Cytherelloidea ornata* in the Lower and Middle Volgian (Klimovi and Pseudoscythica zones) and *Galliaecytheridea punctilataeformis* from the Scythicus Zone (in Russia this last species is confined to the Virgatus Zone). Fresh water, ostracod-bearing deposits overlie this sequence in Poland (Bielecka & Szejn, 1966). *Hechticythere serpentina* has been recorded in the Bolonian and Portlandian deposits of northern Poland and into the

Timan-Pechora Basin of northern Russia (e.g. Izhma and Pizhma), although it did not get as far as the Russian Platform. It seems likely that this species migrated rapidly, soon after its inception during the Bolonian, and was among the last to cross Europe before the termination of the seaways.

3. MICROFAUNAL DISTRIBUTION

MATERIAL

Attention was concentrated on two areas for the study. The first is Gorodishche on the Russian Platform, where samples from the Eudoxus zone to the top of the Okensis zone were obtained. The second area stretched from Kimmeridge Bay to Chapmann's Pool-where the Eudoxus to Fittoni zones were sampled. Material from a number of localities from the Russian Platform were collected by S.Yakovleva between 1971 and 1985 when field work was carried out under the leadership of M.S.Mesezhnikov. In addition to this, further fieldwork was carried out in 1995 for the present project so that, in total, more than 100 samples were collected from six sites along the Volga river bank near Gorodische. Comparative assemblages of foraminifera from the Volgian key sections of Russian Platform: Kashpir, Orlovka, Karadzhir as well as Pechora basin were also examined. The Bed numbers and ammonite zones used here, follow the scheme recognised by M. Mesezhnikov (1984).

Samples from Dorset were collected in 1994 with the assistance of R.W.Gallois. Material was collected and related to the standard ammonite zonation and the beds recognised by Cox & Gallois (1981). The highest part of the formation has not been lithologically subdivided as yet, so that in the present study, samples were measured from well marked features such as the White Stone Bed, the Freshwater Steps Stone Bed, Rotunda Nodule Bed, the base of the Massive Bed and so on. An attempt was made to take a sample every four metres through the Bolonian (i.e. Lower and Middle Volgian) part of the Kimmeridge Clay, starting in the uppermost part of the Eudoxus Zone. This was done for much of the sequence, the exceptions being Kimmeridge Clay Bed KC42 to the lower part of KC44 and in part of the Rotunda-Fittoni zones of Hounstout Cliff, where access was impossible. In all seventy samples of Kimmeridge Clay were collected.

The unprocessed weight of the samples from the Russian Platform was 100g and those from Dorset was 1000g. Standard preparation methods were employed. All specimens were picked, identified, and counted to show their range. Only 4 samples from Dorset, and 12 samples from the Upper Volgian of Gorodishche were found to be barren of foraminifera. Unfortunately the opposite was found to be the case for the Ostracoda, which were at best rare and generally absent in the Dorset coastal sequence. It is for this reason that material was collected from the Tisbury, Fairlight and Hartwell boreholes, in southern England, to supplement the meagre results from the stratotype. At Gorodische Ostracoda were generally rare, but sufficient were encountered to carry out the analysis.

FORAMINIFERA FROM GORODISHCHE

Introduction

Volgian deposits in the European part of Russia spread from the Timan-Pechora region, in the North, to the Pre-Caspian in the South. This area represented a large Epicontinental basin. The Volgian rocks cover the upper as well as the lower Kimmeridgian and Oxfordian. Their thickness reaches about 100m in Pechora basin, but thins to as little as about 25m in the Ulyanovsk region.

Three substages of the Volgian can be recognised: the Lower, Middle and Upper Volgian. Lithologically and genetically the Volgian can be divided into two. The Lower division corresponds to the Lower and Middle Volgian and is composed of normal marine deposits: clay, calcareous clay and oil shale. The Upper part in Gorodishche and Kashpir is composed of marine deposits of the upper part of the Middle Volgian and Upper Volgian, comprising sand, sandstone, clay and limestone. In the Pechora Basin, the Middle and Upper Volgian is approximately 100m thick and composed of clays and calcareous clays which are rich in marine fossils such as ammonites, bivalves, ostracods and foraminifera. The Volgian sequence is divided into biostratigraphical zones based on foraminifera and related to the standard ammonite zonation.

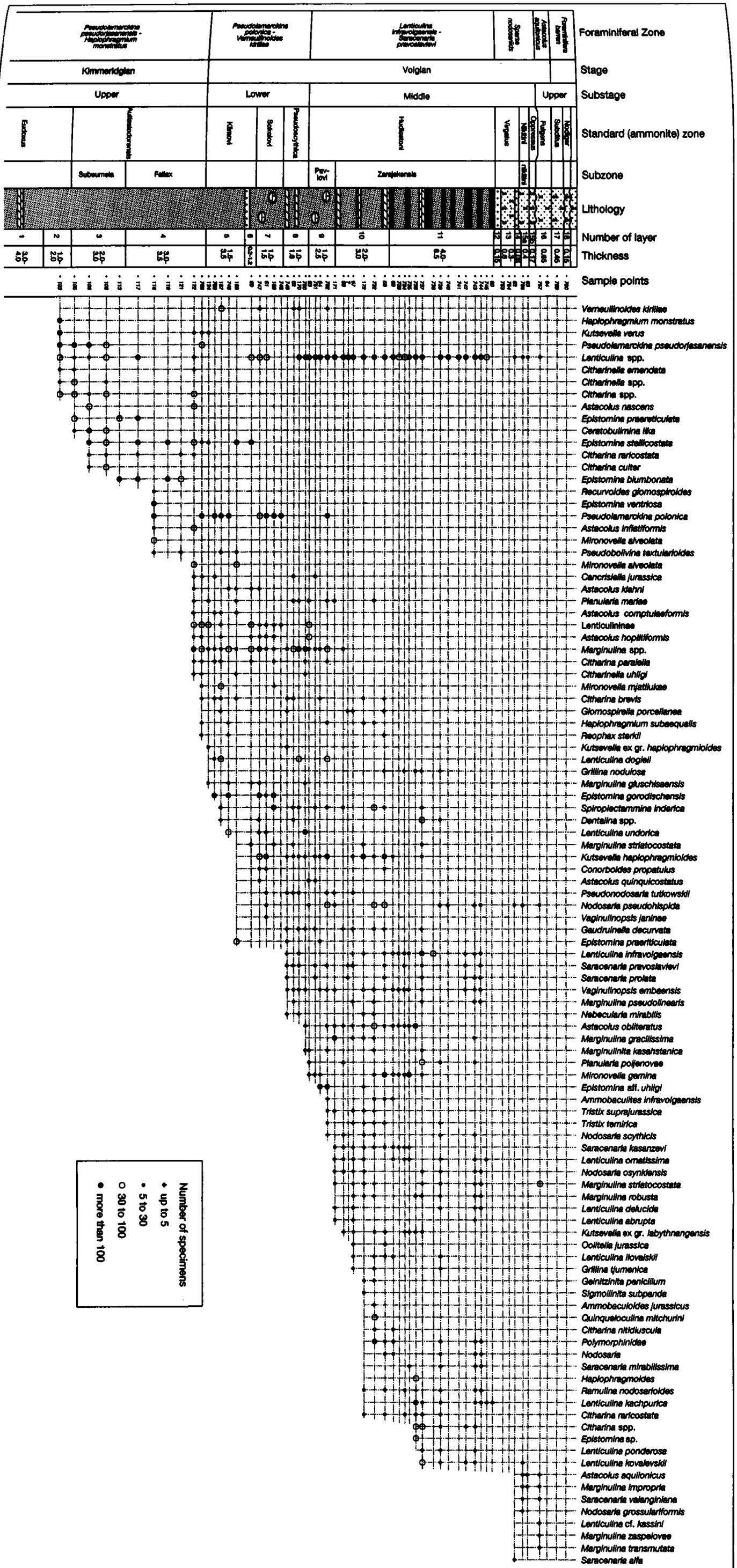
The foraminiferal zones are based on three basic criteria: species biozones, species phylogeny and species development. Thus, the foraminiferal zones were established as assemblage zones and each zone is named after index-species.

Upper Kimmeridgian

A single sample collected from the Eudoxus Zone (from the highest part of Gorodishche Bed 2) yielded abundant *Haplophragmium monstratum*, *Pseudolamarckina pseudorjasanensis* and *Kutsevella verus* together with smaller numbers of *Lenticulina* spp, *Citharina* spp and *Citharinella* spp (including *C. emendata*).

Text-fig. 6

The distribution of Foraminifera at Gorodishche.



Number of specimens

- ◆ up to 5
- 5 to 30
- 30 to 100
- more than 100

The Autissiodorensis Zone can be divided into two subzones, each with a distinctive foraminiferal fauna. The Subeumela Subzone (Gorodishche Bed 3) contained many of the species identified from the top of the Eudoxus Zone, but in addition *Epistomina praereticulata*, *E. stellcostata*, *E. umbonata*, *Ceratobulimina lika*, *Citharina raricostata* and *C. culter*. The last named species appeared at the top of the subzone but is more common in the overlying Fallax Subzone (Gorodishche Bed 4).

There are no inceptions at the lower boundary of the Fallax Subzone, although a little above the base *Pseudolamarckina polonica* and *Epistomina ventriosa* occur in abundance and other species which appear for the first time in the subzone include *Recurvoides glomospiroides*, *Astacolus inflatiformis*, *Mironovella alveolata* and *Pseudobolivina textularioides*.

The foraminiferal faunas of the Fallax Subzone are essentially transitional between the Upper Kimmeridgian and the Lower Volgian. Most of the taxa that range up from the Eudoxus and early Autissiodorensis zones become extinct before the close of the Fallax Subzone. However, in the highest part of the subzone, a number of species that form the largest part of the earliest Volgian associations have their inceptions. Among these are *Cancrisella jurassica*, *Astacolis Klahni*, *A. comptulaeformis*, *A. hoplitiformis*, *Planularia mariae*, *Citharina parallela*, *C. brevis*, *Mironovella mjtliukae*, *Haplophragmium subaequalis* and *Reophax sterkii*.

Lower Volgian

The Klimovi Zone, at the base of the Volgian, comprises Gorodishche Bed 5 and, immediately overlying a nodule horizon near the top of the zone, Bed 6. Within Bed 5 *Vernuilinoides kirillae* makes its first appearance. This is an important species in the Upper Jurassic of European Russia and is used as one of the zonal indices. *Pseudolamarckina polonica* continues to form a large part of the fauna, but *Epistomina gorodishchensis* is common in the Lower Volgian. Other species with inceptions at the basal part of the Volgian at Gorodishche are *Kutsevella ex gr. haplophragmoides*, *Lenticulina dogieli*, *L. undorica*, *Marginulina gluschisaensis*, *Spiroplectamina inderica* and *Epistomina praereticulata*. The early Volgian fauna is diverse and comprises Robertinacea, miliolids, nodosariids as well as agglutinated taxa. Many taxa continue through into the Sokolovi Zone, but

Text-fig. 7

Distribution of agglutinated (1) and calcareous (2) foraminifera from the Russian Platform and Pechora Basin.

(Horizontal scale: 1mm=200 specimens in 100 grams of sample)

Standard Russian stratigraphical notation:

V1= Lower Volgian V2= Middle Volgian V3= Upper Volgian

Notation	Ammonite Zone
V3n	Nodiger
V3sb	Subditus
V3f	Fulgens
V2n	Nikitini
V2v	Virgatus
V2p	Panderi
V1ps	Pseudoscythica
V1s	Sokolovi
V1k	Klimovi

	Karadzhir	Orlovka	Kashpir	Pechora Basin
V_3^n				
V_3^{sb}				
V_3^f				
V_2^n				
V_2^v				
V_2^p				
V_1^{ps}		1 2	1 2	
V_1^s				1 2
V_1^k	1 2			

Epistomina stellicostata, *Pseudobolivina textularioides* and *Mironovella alveolata* become extinct before the close of the Klimovi Zone. The foraminifera of Gorodishche Bed 6 is essentially similar to the of Bed 5.

The Sokolovi Zone is confined to Gorodishche Bed 7. Here *Kutsevelia haplophragmoides* s.s., *Conorboides propatulus*, *Astacolus quinquicostatus*, *Pseudonodosaria tutkowskii*, *Nodosaria pseudohispida* and *Vaginulinopsis janinae* made their first appearance. However, the species that continue up from below that comprise the larger part of the fauna, including *Pseudolamarckina polonica* and *Epistomina gorodishchensis* that occur in larger numbers. The fauna is essentially similar to that of the Klimovi Zone and also placed in the same foraminiferal zone.

The highest part of the Lower Volgian comprises Gorodishche Bed 8 and forms the Pseudoscythica Zone. An influx of foraminifera takes place at this horizon. *Marginulinopsis embaensis* is the most frequent of these, but other species are well represented including *Gaudrinella decurvata*, *Lenticulina infravolgaensis*, *Saracenaria pravoslavlevi*, *S. prolata*, *Marginulina pseudolinearis* and *Nubecularia mirabilis*. Bed 8 also yielded the last record of *Cancrissiella jurassica*, *Astacolus hoplitiformis* and *Citharinella uhligi*.

Middle Volgian

The base of the Middle Volgian is placed at the lower boundary of Gorodishche Bed 9 and at the lower boundary of Panderi Zone, Pavlovi Subzone. Few foraminifera make their first appearance immediately above the boundary, although *Planularia poljenovae* and *Mironovella gemina* are exceptions, but a number of taxa enter the record within the basal bed (and subzone) of the Middle Volgian. The Pavlovi Subzone sees the first appearance of *Ammobaculites infravolgensis*, *Epistomina* aff. *uhligi*, *Lenticulina abrupta*, *L. delucida*, *L. ornatissima*, *Marginulina gracilissima*, *M. striatocostata*, *Nodosaria osynkiensis*, *N. scythicus*, *Saracenaria kasansevi*, *Tristix suprajurassica* and *T. temirica*. Gorodishche Bed 9 also yields the last representatives of some biostratigraphically useful species including *Verneuilinoides kirillae*, *Pseudolamarckina polonica*, *Citharina parallela* and *Lenticulina dogieli*.

The larger part of the Panderi Zone is the Zarajskensis Subzone, which comprises Gorodishche Bed 10 and Bed 11. The lower part of the mudstones of

Bed 10 yield a number of species that range up from the Lower Volgian, together with the first specimens of *Kutsevella* ex gr. *labythnangensis*, *Oolitella jurassica*, *Lenticulina ilovaiskii* and *Grillina tjumenica*. The stepwise inception of taxa continues in the upper part of the bed with species such as *Geinitzinita penicillum*, *Sigmoilinita subpanda*, *Ammobaculooides jurassicus*, *Quinqueloculina mitchurini* *Citharina nitidiuscula* and *C. raricostata*.

One of the more striking lithological features of the Volgian sequence in the stratotype area is the sudden appearance of oil shales in the late Panderi Zone which are characteristic of Gorodishche Bed 11. Although the foraminifera are diverse in the lower part of the bed, diversity falls within the middle part of the bed before increasing again at the top. Few species have their inception at this level and *Lenticulina* is the most successful genus: *Lenticulina kachpurica* is common, but *L. ponderosa* and *L. kovalevskii* are also represented.

The upper boundary of the Panderi Zone is the extinction level of the majority of taxa at Gorodishche. A mass extinction of the foraminifera takes place here, partly as a result of the unstable environmental conditions associated with the formation of oil shales and partly due to the abrupt change in lithology across the Panderi/Virgatus boundary. Of the species present in the Lower and Middle Volgian at Gorodishche, only *Nodosaria pseudohispida*, *Marginulina striatocostata* and some species of *Lenticulina* (including *L. kovalevskii*) survive this boundary event to range up into the arenaceous part of the sequence.

Following the period of oil shale production late in the Panderi Zone, a period of erosion signalled a change in facies. The essentially argillaceous deposits of the Kimmeridgian and Volgian was replaced by an accumulation of arenaceous sediments.

The Virgatus Zone is represented by Gorodishche Bed 13, a sandstone, which was preceded and succeeded by nodule horizons. The sandstone is virtually barren of foraminifera, although very rare *Lenticulina* sp and *Nodosaria pseudohispida* were recorded from the top of the bed.

The Nikitini Zone (Gorodishche Bed 15a) is more productive with rare *Lenticulina* sp and *Nodosaria pseudohispida*, the last specimens of *Lenticulina kovalevski*, and the appearance of a number of additional species, notably *Astacolus aquilonicus*, *Marginulina impropria*, *Saracenaria valanginiana*, *Nodosaria grossulariformis* and *Saracenaria alfa*.

The strongly indurated sandstone that comprises the Oppressus Zone (Gorodishche Bed 15b) was not sampled for calcareous microfaunas.

The Upper Volgian

The Upper Volgian at Gorodishche is separated from the underlying Oppressus Zone by an erosion surface. The Fulgens Zone (Gorodishche Bed 16) yielded a small fauna, but samples from the Subditus Zone (Gorodishche Bed 17) and the Nodiger Zone (Gorodishche Bed 18) were barren. Bed 16 contained a number of species that also occur in the Nikitini Zone of Gorodishche, together with *Lenticulina* cf *kassini*, *Marginulina zaspelovae*, *Marginulina transmutata* together with *Marginulina striatocostata*, *Lenticulina* sp and *Nodosaria pseudohispida*. Although the *status quo* is followed herein with the Fulgens, Subditus and Nodiger zones being placed into the "Upper Volgian" and hence the Jurassic, there is some evidence that this part of the sequence should be regarded as earliest Cretaceous.

FORAMINIFERA FROM THE DORSET COASTAL SEQUENCE

Sampling of the Dorset section was carried out, so far as possible, at 4m intervals. Sea erosion prevented access to two part of the sequence, each side of the Wheatleyensis/Hudlestoni boundary and in the upper part of the Rotunda Zone. It was not possible to sample above the Massive Bed. Foraminifera proved to be abundant in the samples collected, dominated for the most part by agglutinated species. Zonally significant taxa were recognised and a zonal scheme can be erected. The distribution of the foraminifera recovered from the Dorset stratotype section is documented graphically on the range chart, but the main features are highlighted below.

Kimmeridgian

Eudoxus Zone

The lower part of the sequence, up to the top of the Hudlestoni Zone is dominated by indeterminate fragments of agglutinated taxa. This dominance is seen in the sample taken from highest Eudoxus Zone where *Kutsevella petaloiea*, *Lenticulina* spp and *Textularia* sp are also found.

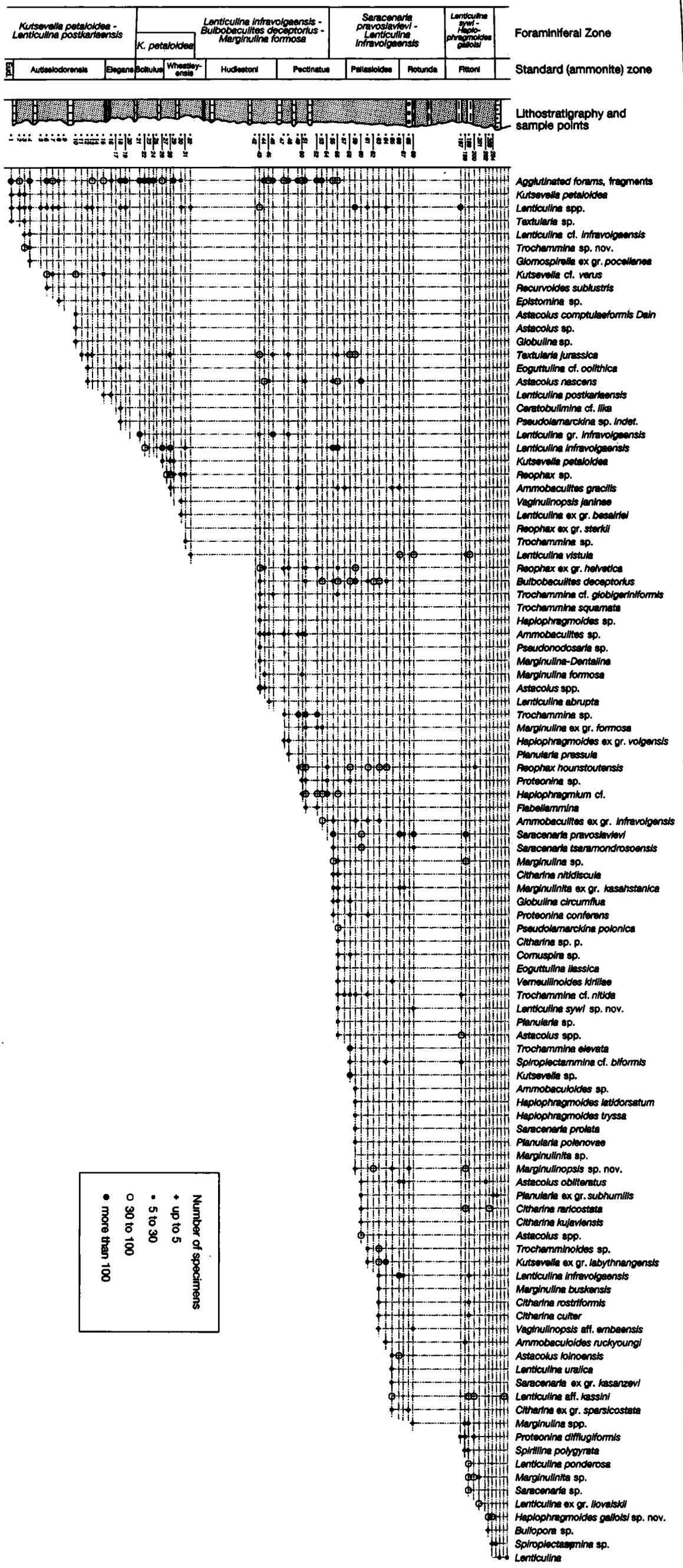
Bolonian

Autissiodorensis Zone

A gradual increase in diversity takes place through the Autissiodorensis Zone as additional species make their first appearance in a step-wise manner. *Lenticulina* cf. *infravolgensis* and *Trochammina* sp appear at the base, but these are added to throughout Bed KC33 and KC34 with the inception of species such as *Kutsevella* cf. *verbis* and *Recurvoides sublustris*. Immediately above the Maple Ledge Stone Band, Bed KC35, *Astacolus comptulaeformis*, *Astacolus* sp., *Textularia jurassica* and *Astacolus nascens* appear. This part of the succession is placed in the upper part of the Autissiodorensis Zone, but this appearance takes place at the base of the Gravesia Zone should this zone eventually be established.

Text-fig. 8

The distribution of foraminifera in the Dorset coastal section.



Elegans Zone

"Blake's Bed 42" marks the base of the Elegans Zone in the Dorset sequence, the zone falling entirely within Bed KC36 in terms of the accepted bed numbering system. *Lenticulina postkarlaensis* appear for the first time in the sequence, together with *Ceratobulimina cf. lika* and *Pseudolamarckina sp.* The fauna in this part of the sequence is not rich or diverse, presumably as a consequence of the thick development of bituminous shales.

Scitulus Zone

Beds KC37 to KC39 are placed in the Scitulus Zone. It is at the base of the zone that *Lenticulina ex gr. infravolgensis* becomes common and forms a characteristic element of the Foraminiferal association. Most of the specimens from this part of the sequence, however, are indeterminate fragments of agglutinated foraminifera.

Wheatleyensis Zone

Lenticulina infravolgensis forms a dominant part of the assemblage at the base of the zone. Although *Kutsevella petaloidea* is well represented, it is confined to the lower part of the zone, and *Reophax sp.* is also frequent. Above the Grey Ledge Stone Band, *Vaginulinopsis janinae*, *Lenticulina ex gr. besairiei*, *Reophax ex gr. sterkii* and *Lenticulina vistula* are all represented although in small numbers. The highest part of the Wheatleyensis Zone could not be sampled due to the erosion of the sea destroying the access to the beach and the unsafe nature of the cliffs.

Hudlestoni Zone

Access to the lower part of the Hudlestoni was also impossible as a result of the coastal erosion, but the upper part of the zone was sampled, above the Basalt Stone Band. The inception of a number of species was identified, and although generally rare, these including *Reophax ex gr. helvetica*, *Bulbobaculites deceptorius*, *Trochammina cf. globigeriniformis*, *Trochammina squamata*, *Marginulina formosa*, *Astacolus spp* and *Lenticulina abrupta*.

Pectinatus Zone

The Pectinatus Zone marks a major change in the Foraminifera fauna. The lower part of the Pectinatus Zone has a similar fauna to the upper part of the Hudlestoni Zone. *Marginulina ex gr. formosa*, *Reophax hounstoutensis* and *Trochammina sp*

and *Haplophragmium* sp form the largest part of the association, but *Haplophragmoides* ex gr. *volgensis*, *Ammobaculites* ex gr. *infravolgensis*, *Planularia pressula* and *Proteonina* sp are also present. The upper part of the Pectinatus Zone sees the inception of a large number of species. *Saracenaria pravoslavlevi*, *S. tsaramondrosoensis*, *Marginulina* sp., *Citharina nitidiscula*, *Marginulinita* ex gr. *kasahstanica*, *Globulina circumflua* and *Proteonina conferens* all appear at the base. A number of species are added to this assemblage in the overlying samples, including: *Pseudolamarckina polonica*, *Verneulinoides kirillae*, *Trochammina* cf. *nitida* and *Lenticulina sywi*.

Pallasioides Zone

Although not consistently present, *Saracenaria pravoslavlevi*, dominated several samples in the Pallasioides Zone. In addition, the sudden appearance of a number of additional taxa that took place in the upper part of the Pectinatus Zone, continued in the Pallasioides Zone. In the basal part of the zone *Trochammina elevata*, *Spiroplectammina* cf. *biformis*, *Kutsevella* sp, *Haplophragmoides latidorsatum* H. *tryssa*, *Saracenaria prolata*, *Planularia polenovae* are all added to the assemblage. A little higher, in stratigraphical terms, the inception of a large number of species were observed, including *Astacolus obliteratedus*, *Planularia* ex gr. *subhumilis*, *Citharina raricostata*, *C. kujaviensis*, *Kutsevella* ex gr. *labythnangensis*, *Lenticulina infravolgaensis*, *Marginulina buskensis*, *Citharina rostriformis*, *C. culter*, *Ammobaculites ruckyoungi* and *Vaginulinopsis* aff. *embaensis*,

Rotunda Zone

Landslips prevented sampling of much of this zone, but the basal part contained several taxa ranging up from the Pallasioides Zone, including abundant *Saracenaria pravoslavlevi*, together with *Astacolus loinoensis*, *Lenticulina uralica*, *Saracenaria* ex gr. *kasanzevi*, *Lenticulina* aff. *kassini* and *Citharina* ex gr. *sparsicostata*.

Fittoni Zone

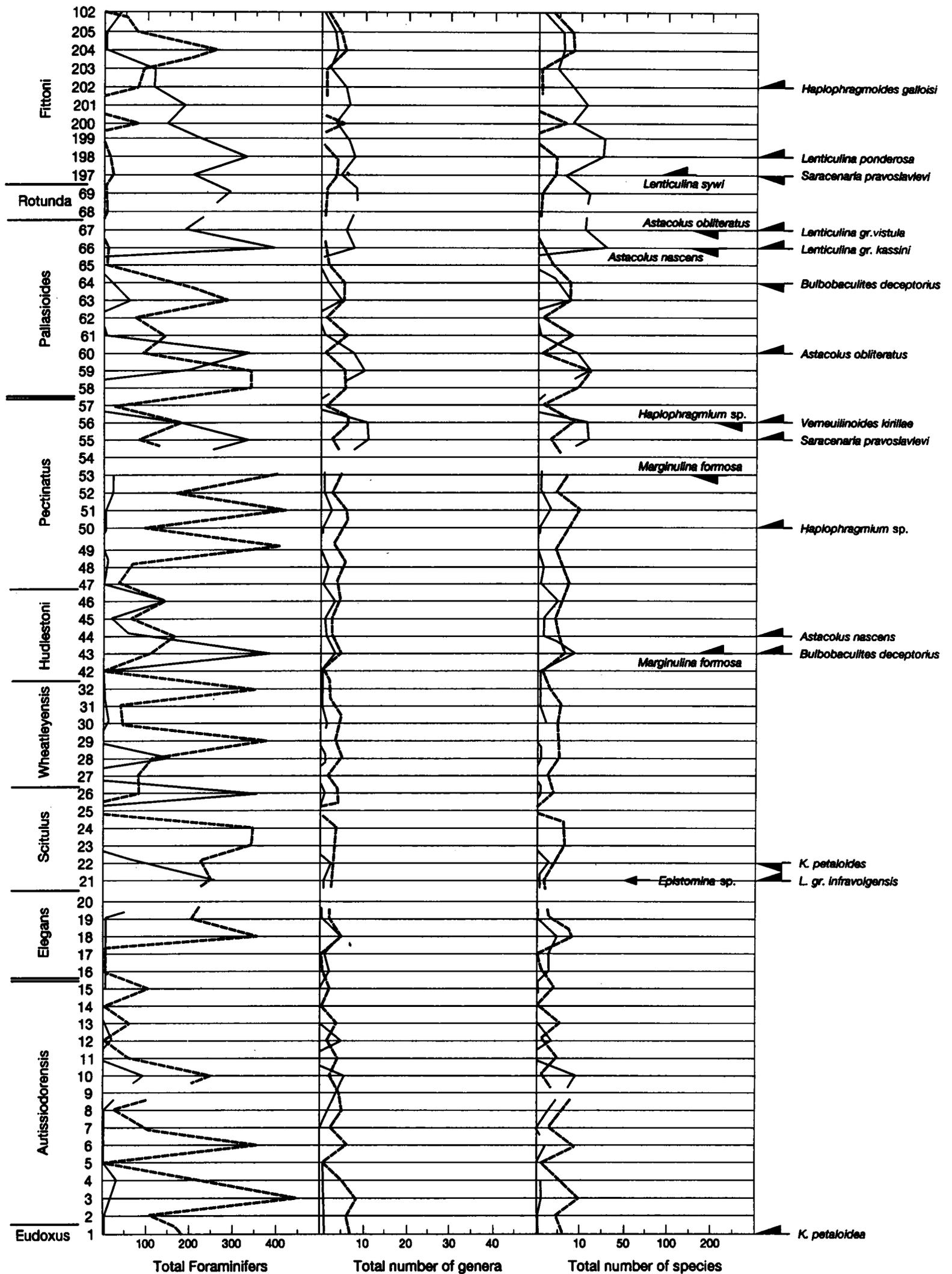
This zone was sampled as high as the Massive Bed. Several species continue up from below into the lower part of the Fittoni Zone. Amongst these are *Lenticulina vistula*, *Reophax hounstoutensis*, *Saracenaria pravoslavlevi*, *Trochammina* cf. *nitida*, *Spiroplectammina* cf. *biformis*, *Astacolus obliteratedus*, *Citharina raricostata*, *Lenticulina infravolgaensis*, *Citharina rostriformis*, *Citharina culta*, *Ammobaculites*

Text-fig. 9

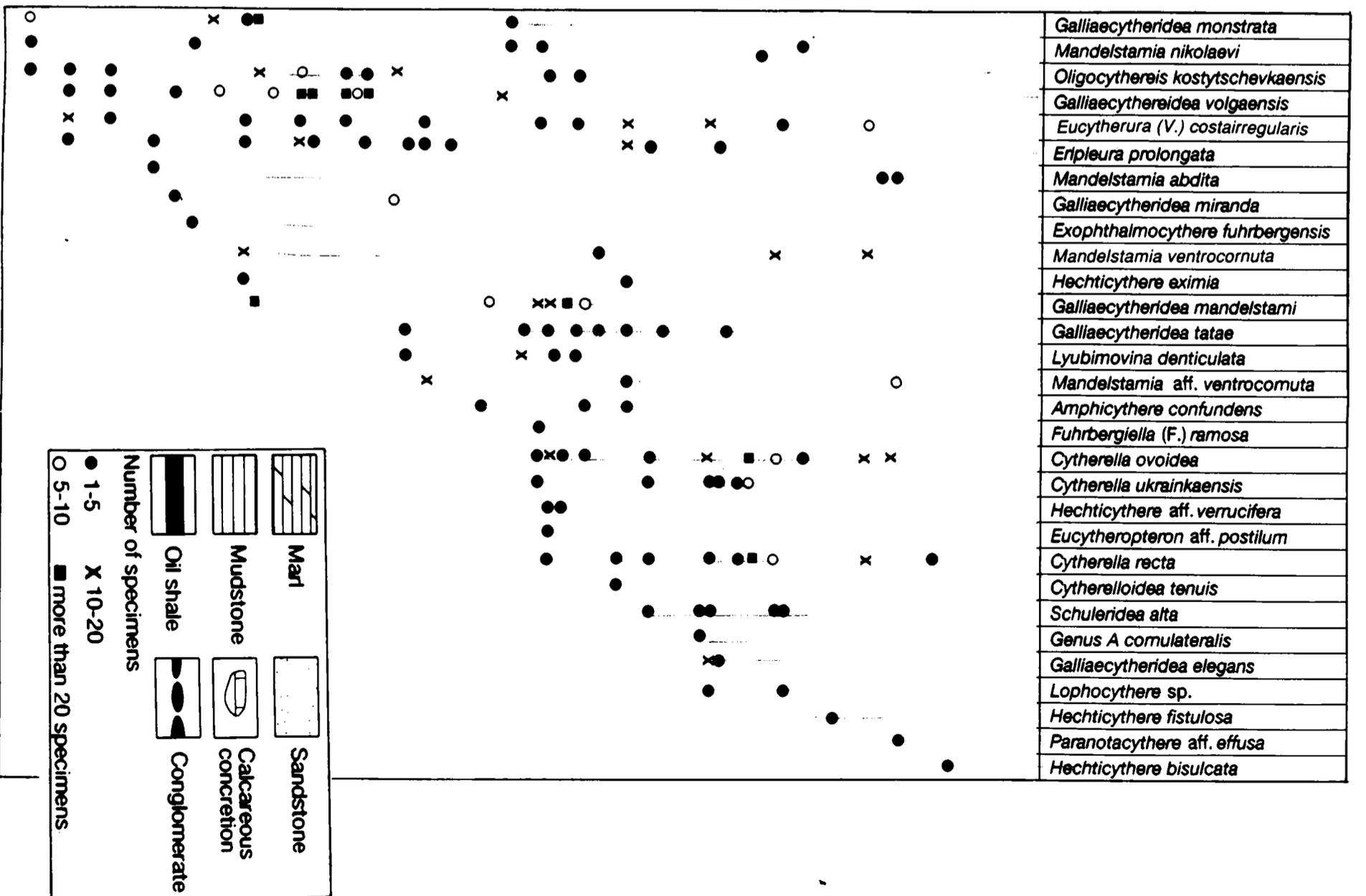
Foraminiferal assemblage structure through the Kimmeridge Clay Formation of Dorset between the Eudoxus to Fittoni zones together with key foraminiferal marker events. (Field numbers and BGS registration numbers are listed in Appendix VI)

Agglutinated taxa= dashed line. Calcareous taxa= solid line

▲ inceptions ▼ extinctions



KIMMERIDGIAN		VOLGIAN				STAGE
UPPER		LOWER	MIDDLE		3.	SUBSTAGE
Eudoxus		Kimovi	Panderi		Modiger Subditus	ZONE
Autissiodorensis		Sokolovi	Zarqskensis		Fulgens	SUBZONE
Subaurela		Pseudocythica	Pavlovi		Oppressus Nikriti	LITHOLOGY
Fallax					Virgatus	BEDS
						THICKNESS (m)
						Sample positions
1	3.0-4.0					
2	1.0-2.0					
3	2.0-3.0					
4	3.0-3.5					
5	1.5-3.5					
6	0.2-1.2					
7	1.0-1.5					
8	1.0-1.6					
9	1.0-2.5					
10	2.0-3.0					
11	4.0-6.5					
12	0.3-0.6					
13	0.15					
14	0.08					
15	0.17					
16	0.65					
17	0.45					
18	0.15					



ruckyoungi and *Lenticulina* aff. *kassini*. However, a few species have their first record in the zone, including *Spirillina polygyrata*, *Proteonina difflugiformis*, *Lenticulina ponderosa*, *Lenticulina* ex gr. *ilovaiskii* and *Haplophragmoides galloisi*.

VOLGIAN OSTRACODA FROM GORODISHCHE

Introduction

Ostracoda are not numerous at Gorodishche and have not been found at all above the Nikitini Zone. Nevertheless sufficient specimens have been recovered to show the biostratigraphical usefulness of the class. Their distribution is herein related to the ammonite zones and established beds of the locality. Ostracod distribution is illustrated in the range chart, but the main features are emphasised below.

Kimmeridgian

The Kimmeridgian at Gorodishche is seen at the base of the sequence between the channel of the River Volga to between 9 and 15m up the section. This part of the sequence is often obscured by slumping and great care has to be exercised in collecting accurately located samples from the isolated exposures. Two zones can be recognised: the Eudoxus Zone, in Beds 1 and 2, and the Autissiodorensis Zone in Beds 3 and 4.

Eudoxus Zone

The pale grey calcareous clays at the base of the succession, four to six metres above the water level yielded a sparse ostracod association, can be placed in the Eudoxus ammonite Zone. Ostracod faunas of Bed 1 are of low diversity (3 or 4 species per sample). The lowest sample, G1, yielded frequent specimens of *Galliaecytheridea monstrata* and very rare *Mandelstamia nikolaevi* and *Oligocythereis kostytschevkaensis*. To these species are added *Galliaecytheridea volgaensis*, *Eucytherura (Vesticytherura) costaeirregularis* and *Procytheridea prolongata* in the upper part of the bed (G2 and G3). The highest part of the Eudoxus Zone, Bed 2 (samples G4 and G5) yielded similarly low diversity faunas in which very rare *Mandelstamia ex gr. abdita* and *Galliaecytheridea miranda* were found.

Although sparse, the fauna recovered from the Eudoxus Zone of Gorodichshe is characteristic. The presence of *Galliaecytheridea volgaensis* and *G. monstrata* is considered to be of zonal importance. In this way the bed can be

Text-fig. 10

The distribution of Ostracoda at Gorodishche.

related to the Polish sequence (Kubiatowicz, 1983) where *G monstrata* is also a characteristic element of the fauna in the Eudoxus Zone. However, both of these species are long-ranging, having their inception in the Oxfordian.

Autissiodorensis Zone

The autissiodorensis Zone is divided into two, the lower, Bed 3, being the S subeumela Subzone and the upper, bed 4, is placed into the *V. fallax* Subzone.

The Autissiodorensis Zone contains a similar fauna to that in the lower ammonite zone. However, its base is marked by the presence of *Exophthalmocythere fuhrbergensis* and *Bythocythere* sp., both of which are not present elsewhere in the section. The presence of *Exophthalmocythere fuhrbergensis* is particularly important as this species has a widespread geographical distribution. In England, it has been recorded from the late Oxfordian and into the early Kimmeridgian. According to Kilenyi (1969) and Kilenyi & Christensen (1970) the species does not extend higher than Kimmeridge Clay Bed 23 (immediately above the *Astarte supracorallina* Bed). It has a slightly different distribution in eastern England (in the North Wootton Borehole) and the North Sea (boreholes 81/41 and 81/49) where it has been recorded through the lowest part of the Kimmeridgian up to the Eudoxus Zone, Bed KC27 and Bed KC29 respectively. It was presumably excluded from the North Sea Basin at this time due to the effects of oil-shale generation. It has been recorded widely in Germany throughout the Kimmeridgian (up to the Eudoxus Zone) (for example, Schmidt, 1955; Glashoff, 1964;; Gramann & Luppold, 1991; Schudack, 1994) and France where it has been recorded in the lower Kimmeridgian by Oertli (1957) and Depeche (1985). In Poland, *Exophthalmocythere fuhrbergensis* ranges through the lower Kimmeridgian (Bielecka et al., 1976) and up to the basal Autissiodorensis Zone (Kubiatowicz (1983). In Russia the species has been recorded (as *E. tricornis*) by Lyubimova (1955) as well as herein and the occurrence of the species at Gorodishche is, therefore an important link with the rest of Europe. Although very rare its presence in the basal Autissiodorensis is probably at the end of its range before its extinction at a slightly higher stratigraphical level than in western Europe.

Higher in the Autissiodorensis Zone, *Mandelstamia nikolaevi*, *Galliaecytheridea monstrata*, *Eucytherura* (*V.*) *costaeirregularis* and *Procytheridea*

prolongata are scattered through the bed in small numbers and in G9 *Mandelstamia ventrocornuta* and *Hechticythere exima* are added to the assemblage. In sample G8 and G11 *Galliaecytheridea volgaensis* is frequent and in G10 *Galliaecytheridea monstrata*, *Galliaecytheridea mandelstami* and *Oligocythereis kostytschevkaensis* become common and other species are excluded.

The ostracod faunas of Bed 4, the V. fallax Subzone, are dominated by common *Galliaecytheridea volgaensis*. *Oligocythereis kostytschevkaensis* is frequent at the base but becomes rare or very rare in the samples above and *Galliaecytheridea miranda* is frequent in sample G17. *Eucytherura* (V.) *costaeirregularis* and *Procytheridea prolongata* are also present in small numbers. There are few additional species that have their local inceptions in the bed, the two exceptions being *Galliaecytheridea tatae* and *Lyubimovina denticulata* at the very top (sample G18).

In Poland, Kubiatoicz (1983) showed the importance of *Galliaecytheridea oertlii* as a zonal indicator for the later part of the Autissiodorensis Zone. This species extends westward into the Danish-Polish Trough of Scania (Fennoscandian Border Zone), but did not extend further into the North Sea Basin where the high physical stress conditions related to the formation of oil shale, decimated the ostracod population. However, it does occur in the Paris Basin (Oertli, 1957, placed it in *G. wolburgi*), so that its absence in Dorset is something of a conundrum. Similarly, the species does not seem to have extended eastwards into the Russian Platform area, the reason for which is not readily apparent. The geographical distribution of the zonal index appears to be somewhat restricted.

Lower volgian

The Lower Vogian comprises deposits that were deposited during the Klimovi to Sokolov zones. In terms of the established beds that can be recognised at Gorodishche, this is represented by Beds 5 to 8.

Klimovi Zone (=Elegans and Scitulus zones of Western Europe)

The Klimovi Zone at Gorodishche comprises two beds, 5 (lower) and 6 (upper). *Procytheridea prolongata* is present in small numbers throughout the lower bed, but the remainder of the population is confined to *Eucytherura* (V.) *costaeirregularis* and

Mandelstamia aff. *ventrocornuta*. The upper bed contains frequent *Galliaecytheridea mandelstami* in sample G22, but the remainder of the fauna comprises rare or very rare *Galliaecytheridea volgaensis*, *Mandelstamia* sp and *Amphicythere* aff. *confundens*.

Amphicythere confundens has been recovered from a number of sites in northern and western Europe, although generally from the lower part of the Kimmeridgian (baylei to Mutabilis Zone, but rarely into the Eudoxus Zone). The stratigraphically highest specimens so far recorded are those from the Celtic Sea area (Ainsworth *et al.*, 1989). Although the exact stratigraphical position of those specimens cannot be identified exactly, the top of the association containing *A. confundens* is placed in the "lowermost upper Kimmeridgian" by Ainsworth *et al.*, (1989). However, the palynomorphs suggest that the age of their zone is no younger than the Autissiodorensis Zone, and possibly older.

The presence of *A.* aff. *confundens* in Gorodische is, therefore, stratigraphically higher than any other known record. But it must be said that it shows slight variation from that species which Oertli described, principally in the degree of overhang of the lateral surface. The Russian specimens do not fit comfortably within that species and it is likely to be a new species.

Sokolovi Zone (=Wheatleyensis and Huddlestoni zones of Western Europe)

Bed 7 is characterised by the zonal ammonite index *Ilovaiskya* cf. *sokolovi*. Ostracod diversity is low in the lower part of the zone, *Galliaecytheridea monstrata* and *Mandelstamia nikolaevi* being recovered from the base of the zone (Sample G24) and *Galliaecytheridea tatae* and *Lyubimovina denticulata* having been recorded from the middle of the bed (Sample G25). The highest sample (G26) from the top of the zone, however, is more diverse, although the species occur in low numbers: *Mandelstamia nikolaevi*, *Eucytherura* (V.) *costaeirregularis* and *Galliaecytheridea mandelstami*, together with three species that make their local inception within the zone, *Fuhrbergella ramosa*, *Cytherella ovoidea* and *Cytherella ukrainensis*.

Pseudoscythica Zone (=Pectinatus Zone of Western Europe)

The Pseudoscythica Zone is represented by Bed 8 of the Gorodishche sequence. The base of the zone (Sample G27) is moderately diverse in ostracods, although

none of the species is particularly common. *Oligocythereis kostytschevkaensis* continues to be present from below, together with *Lyubimovina denticulata*. *Cytherella ovoidea*, which had its local inception at the top of the Sokolovi Zone continues to occur and three additional species have also been recorded: *Cytherella recta*, *Hechtycythere verrucifera* and *Eocytheropteron* aff. *postilium*. The remaining species in the zone are all longer ranging from below, *Galliaecytheridea monstrata*, *G. tatae*, *G. mansdelstami*, *Eucytherura* (V.) *costaeirregularis* and *Amphicythere* aff. *confundens*.

The local extinction of four species took place within the zone. *Galliaecytheridea mandelstami mandelstami* has its last record in sample G30, *Lyubimovina denticulata* in G31, and *Galliaecytheridea monstrata* and *Oligocythereis kostytschevkaensis* in G32. These extinctions are good indicators for the top of the Lower Volgian and have biostratigraphical significance on a regional scale.

Galliaecytheridea mandelstami mandelstami is a long ranging species having its inception in the Oxfordian and ranging up to the top of the Lower Volgian in Russia. In Poland, the species is present in the lower Kimmeridgian (Bielecka & Styk, 1968) and extends up into the Lower Volgian, just below the top of the Pseudoscythica Zone, as at Gorodishche. In Western Europe, this species is represented by a different subspecies, namely *Galliaecytheride mandelstami kilenyii*, which is confined to the Mutabilis Zone of Engalnd and the Southern North Sea Basin. It seems probable that the species migrated from the Russian and Polish areas into the North Sea Basin via the Danish-Polish Trough. Once in the North Sea Basin, evolution progressed separately, and there is some evidence that the species ultimately evolved into *Galliaecytheridea spinosa*, intermediate morphs having been recorded by Wilkinson (1983a) from the Wheatleyensis Zone of the North Wootton Borehole.

Oligocythereis kostytschevkaensis also originated in the Oxfordian and ranges through the Kimmeridgian (in the Russian sense) to become extinct at the top of the Lower Volgian. It has been recorded from the Kimmeridgian in Poland (Bielecka & Styk, 1968) and from the Lower Volgian Pseudoscythica Zone (as *Pleurocythere* (*Klentnicella*) *kosytschevkaensis*) (Kubiatowicz, 1983). The only

other locality for the species is from the Tithonian of Czechoslovakia where it was also placed into *Pleurocythere (Klentnicella)* (Pokorný, 1973). This species does not occur in western Europe and appears to have its origins in southern or south-eastern Europe.

Galliaecytheridea monstrata has its inception within the Oxfordian and ranges through to the Upper Kimmeridgian (in the Russian sense) in Russia and Poland. Kubiatoicz (1983) used it as a zonal index equivalent to the Mutabilis Zone to the earlier part of the Autissiodorensis Zone in Central Poland. At Gorodishche, very rare specimens are found through to the top of the Pseudoscythicus Zone

Middle Volgian

The Middle Volgian comprises Bed 9 through to Bed 15 of the stratotype at Gorodishche. Chronostratigraphically it can be divided into four zones: the Panderi, Virgatus, Nikitini and Oppressus zones. In addition the Panderi Zone can be subdivided into the Pavlovi and Zarajskensis subzones.

Panderi Zone (=Pallasioides Zone to Fittoni Zone of Western Europe)

Pavlovi Subzone

Bed 9, deposited during the Pavlovi Subzone, commences with a low diversity fauna, but increasing at the top. *Mandelstamia ventrocornuta* and *Galliaecytheridea tatae* occur at the base (G33), *Cytherella recta* and *Cytherelloide tenuis* were recovered from the middle of the bed (G34). Seven species were recovered from near the top: *Eucytherura (V.) costaeirregularis*, *Procytheridea prolongata*, *Hechtycythere exima*, *Mandelstamia* aff. *ventrocornuta*, *Amphicythere confundens*, *Mandelstamia* sp. and *Galliaecytheridea tatae*.

With the exception of very rare specimens of *C. tenuis* (in G34), all of the taxa from Bed 9 continued up from below. *Amphicythere* aff. *confundens* and *Hechtycythere exima* disappeared from the record within the zone.

Zarajskensis Subzone

The subzonal index, *Zarajskites zarajskensis*, has been found within Bed 10, and although it has not been recorded in Bed 11, other members of the genus have.

Four species of ostracod range up from below into Bed 10, *Procytheridea prolongata*, *Cytherella ovoidea*, *Cytherella ukrainensis* and *Cytherella recta*. *Eucytherura* (V.) *costaeirregularis* and *Galliaecytheridea tatae* also continue from below and are found higher within Bed 10. *Schuleridea alta* has its local inception at the base of the zone and the upper part of the bed is characterised by the appearance of *Hechticythere cornulateralis*, *Galliaecytheridea elegans* and *Exophthalmocythere afarbra*. All these species are good indicators of the Panderi Zone, and although none have been recorded below this zone, most range up into the Virgatus Zone.

Faunas from the lower of Bed 11 Samples G41-44 are dominated by *Cytherella ovoidea*, *Cytherella recta* and, to a less extent, *Cytherella ukrainensis*. This is, perhaps not surprising, for the proportion of the Platycopina often increases with the commencement of oil shales (e.g. Whatley, 1991; Boomer & Whatley, 1992). Dysaerobic conditions are frequently associated with the formation of oil shales, which, in the Gorodishche section are particularly thick in bed 11. Order Platycopina, as a result of its filter feeding strategy involving passing water rapidly across the branchial plates and across the ventral (i.e. the respiratory) surface of the body, is able to withstand decreased levels of dissolved oxygen. The other species recorded from the lower part of Bed 11 are rare or very rare: *Mandelstamia ventrocornuta*, *Galliaecytheridea tatae* and *Schuleridea alta*.

The upper part of Bed 11 (samples G45-52) is extremely sparse in Ostracoda. *Mandelstamia nikolaevi*, *Eucytherura* (V.) *costaeirregularis* (which becomes frequent in sample G49), *Mandelstamia abdita*, *Mandelstamia ventrocornuta*, *Cytherella ovoidea*, *Cytherella recta*, *Schuleridea alta* and *Exophthalmocythere furhbergensis*. To this association, which comprises species ranging up from below, are two species with their local inception in Bed 11. These are *Hechticythere fistula* and *Paranotacythere* (*Unicosta*) cf. *caputmortuum*.

Paranotacythere (*Unicosta*) *caputmortuum caputmortuum* is geographically restricted. Present in Germany in the Mittlere Mundermergel (which is equivalent to the Portlandian in the English sense, Albani to Preplicomphalus zones) (Bassiouni, 1974; Schudack, 1994). However, closely related forms have been found in the

Hudlestoni Zone of Kimmeridge Clay Bed 45 in the North Wootton Borehole (Wilkinson, 1988MS). The English specimens are somewhat fragmentary, however, it can be seen to differ from *P. (U.) caputmortuum* in having a more coarsely reticulate ornament and more acute ribbing, particularly in the antero-ventral and postero-dorsal areas. The Russian specimens differ from both the older English and the contemporaneous German morphs. It is much closer to the German stock than is the English morph, differing principally in the degree of postero-dorsal inflation and, therefore, the disposition of the postero-dorsal rib. As the species is so rare in Gorodishche, however, it is not possible to state whether this is the norm. Nevertheless, its presence at Gorodishche implies migration from its origin in Germany during the Middle Volgian.

Virgatus Zone (=Albani-Okusensis zones)

Beds 12 and 14 prove to be barren of Ostracoda, however very rare specimens of *Cytherella recta* occur in Bed 13. This species is particularly common in the Panderi Zone, Lybimova (1955) reported that the species has been recorded from Samarskaya Luka, Common Syrt and Ural-Embensk regions where it is confined to the Panderi and Virgatus zones. Hence, although very rare at this horizon in Gorodishche, it is biostratigraphically useful.

Nikitini Zone (=Kerberus-Anguiformis zones)

The lower part of Bed 15 (herein referred to as 15a) contain the very large and characteristic ammonite *Epivirgatus nikitini*. Ostracoda are very rare in the bed, but *Hechticythere bisulcata* has been recovered. This species occurs in the Ozinkovskii, Syrt, and Samarskaya Luka regions where it is confined to the Panderi and Virgatus zones. Its occurrence in the Nikitini Zone of Gorodishche, therefore, extends its known range one zone higher.

Oppressus Zone

The upper part of Bed 15 (herein referred to as 15b), which can be assigned to the Oppressus Zone, proved to be barren of ostracods.

Upper Volgian

The Upper Volgian comprises four beds at Gorodishche, Bed 16 is of Fulgens zonal age, Bed 17 can be placed into the Subditus Zone and Beds 18-19 constitute the

Nodiger Zone. These have been correlated with the Primitivus to Lamplughi zones, but there is some doubt about this. There is a possibility that this part of the sequence should be placed in the Early Cretaceous.

Fulgens to Nodiger zones

Beds 16 to 19 proved to be barren of ostracods.

VOLGIAN OSTRACODA FROM KASHPIR

The sequence at Kashpir is considerably thinner compared to Gorodishche, although the general lithostratigraphy can be recognised at both localities.

Lithostratigraphy

Middle Volgian

The middle Volgian of the Kashpir region comprises between 4.15 and 4.6m of mudstones and oil shales with a small proportion of sandstone.

The lower part of the sequence comprises 1.8m of mudstones of the Panderi Zone (Bed 1), overlain by an alternating sequence of mudstone and oil shale (Beds 2-8) with a total thickness of between 2.25 and 2.7m. As in the sequence at Gorodishche, the oil shales fall within the upper part of the Panderi Zone.

An erosion surface separates the Panderi Zone from the Virgatus Zone. This is marked by a change in facies at the boundary where the mudstones are overlain by a sandstone, which in turn passes up into a mudstone. The zone is only 0.3m thick at this locality.

The Nikitini Zone can be subdivided into two subzones at Kashpir, the lower Blakei Subzone and the upper Nikitini Subzone, although there is little to separate them lithologically. The sandstones of Bed 10 and 11, which form the lower subzone, are between 0.25 and 0.55m thick and they are overlain by 0.15-0.3m of sandstone (Bed 12) comprising the higher subzone.

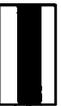
Upper Volgian

The Upper Volgian of the Kashpir region varies between 4.10 and 4.55m thick. Its lower boundary is an erosion surface where the sandstone of the Nikitini Zone is overlain by a 0.5m thick mudstone stratum (Bed 13), which can be placed within the Fulgens Zone. Sandstones (Beds 14-16) of the Subditus Zone, which range in thickness throughout the region between 1.3 and 1.6m, are overlain by 2.3-2.55m of sandstones with calcareous nodules (Beds 17-19) which are placed in the Nodiger Zone.

Text-fig. 11

The distribution of Ostracoda at Kashpir.

VOLGIAN		STAGE
MIDDLE	UPPER	SUBSTAGE
Panderi	Nodiger	ZONE
		SUBZONE
		LITHOLOGY
		BEDS
		THICKNESS (m)
		Sample positions
		<i>Eucytherura (v.) paula</i>
		<i>Hechticytherura aff. verrucifera</i>
		<i>Cytherella ovoidea</i>
		<i>Cytherella recta</i>
		<i>Cytherella ukrainkaensis</i>
		<i>Mandelstamia nikolaevi</i>
		<i>Pontocypris arcuata</i>
		<i>Cytherella aff. depressa</i>
		<i>Cytherelloidea tenuis</i>
		<i>Eripleura aff. prolongata</i>
		<i>Galliaecytheridea aff. mandelstami</i>
		<i>Macrodentina (P.) subtriangularis</i>
		<i>Hechticythere bisulcata</i>
		<i>Mandelstamia ventrocomuta</i>
		<i>Schuleridea alta</i>
		<i>Galliaecytheridea tatae</i>
		<i>Protocythere dominici</i>



Oil shale



Mudstone



Calcareous concretion



Sandstone



Conglomerate

● 1-5

○ 5-10

× 10-20

Quantity of specimen

Barren

Ostracoda at Kashpir

The Ostracoda are essentially confined to the mudstones at the top of the Panderi Zone and Virgatus Zone. The fauna is dominated by *Cytherella ovoidea* and *C. recta*, although *C. ukrainkaensis* and *Mandelstamia nikolaevi* are well represented. Bed 5 contained the local appearance of several species, including *Cytherelloidea tenuis* and *Cytherella* aff. *depressa*, *Eripleura* aff. *prolongata* and *Pontocypris arcuata*.

The highest bed of the Panderi Zone and the Virgatus Zone were characterised by the appearance of *Macrodentina* (P.) *subtriangularis*, *Hechticythere bisulcata*, *Mandelstamia ventrocornuta* and *Schuleridea alta*, together with *Galliaecytheridea* aff. *mandelstami* in the highest sample of the Virgatus Zone.

The sands of the Upper Volgian of Kashpir are essentially barren of ostracods. However, in the upper part of Bed 14 (low in the Subditus Zone) *Protocythere dominici* was found. This appearance of this genus is particularly characteristic of the Early Cretaceous in northern and north-western Europe. Although rare and patchily distributed, its first appearance is consistently within the Upper Volgian throughout the in the Russian Platform.

OSTRACODS FROM THE DORSET COAST

INTRODUCTION

The classical Upper Kimmeridge Clay exposures of the Dorset Coast between Kimmeridge Bay and Chapman's Pool have been studied many times. The lithostratigraphy and the distribution of the macrofaunas of much of the sequence has been described bed-by-bed. The Ostracods have also been examined to some extent, but their very patchy distribution means that nobody has yet come to a full understanding of their distribution. Kilenyi (1969) systematically described the ostracods throughout the Kimmeridge Clay of the Dorset coast, although there were large gaps in his coverage, notably in the Eudoxus Zone and in the Fittoni zones. The distribution of ostracods through the formation is also difficult to understand as his ammonite stratigraphy is both out of date and, in the upper Kimmeridgian, erroneous. His biostratigraphical findings were included in a work by Christensen & Kilenyi (1970), but here there appear to be discrepancies in some of the given ranges in the upper Kimmeridge Clay faunas. Barker (1966a) gave some information about the Fittoni faunas, although only those from the very top (the upper c.3m) so that there is a gap between the highest of Kilenyi's samples and the lowest of Barker's. This is in part due to the inaccessibility of the highest beds of the Kimmeridge Clay at Chapman's Pool and Hounstout Cliff.

The recovery of ostracods from the stratotype sequence for the present study is very disappointing, but is outlined below.

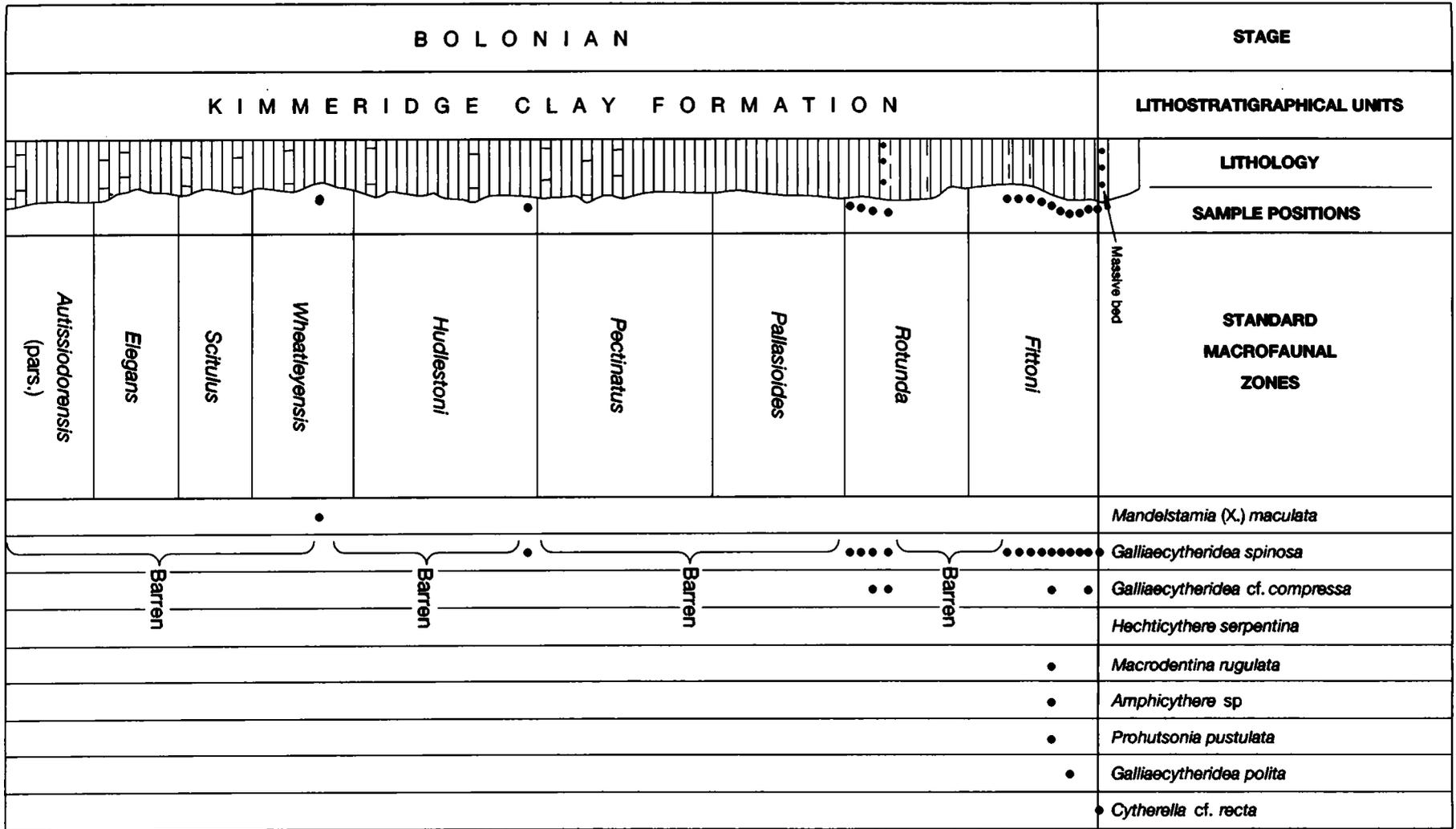
THE OSTRACODA

Although sampling of the Kimmeridge Clay Formation began in the highest Eudoxus Zone, the stratigraphically oldest fauna was recovered in the late *Wheatleyensis* Zone (top of Bed KC41) where a single specimen of *Mandelstamia* (*X.*) *maculata* was recovered. This species is biostratigraphically significant in that it is the index species for the eponymous ostracod zone.

The pale grey mudstone (Bed KC45) c.1m below the White Stone Band yielded a specimen of *Galliaecytheridea* cf. *spinosa*. This species is apparently an

Text-fig. 12

The distribution of Ostracoda of the Dorset Coastal Section.



intermediate between *G. mandelstamia maculata* and *G. spinosa* and distributed throughout the Wheatleyensis Zone of the North Wootton Borehole and Hunstanton Borehole of eastern England.

The base of the *G. spinosa* ostracod Zone was recognised in the late Pallasioides Zone of the Dorset Coastal section in sample MPA42094 (within Bed KC50) by the first up sequence appearance of *Galliaecytheridea spinosa*. This species then dominates assemblages throughout the remainder of the Kimmeridgian up to the Massive Bed. This differs from the results shown by Christensen & Kilenyi (1970), but is probably due to a gap in the samples taken during the 1960s. Kilenyi (1969) appears not to have collected through to the top of the Formation and Barker (1966a) seems to have taken samples immediately below the Massive Bed. It is accompanied in the Rotunda and Fittoni Zones of the coastal sequence by rare specimens tentatively assigned to *Galliaecytheridea compressa*. However, they appear to be transitional morphs between *Galliaecytheridea spinosa* and *G. compressa*. The compressed appearance of the latter species is variable such that it is difficult to define the point of specific change between the end-members of an apparently perfectly gradational series.

The Fittoni Zone yielded a number of additional species, notably *Galliaecytheridea polita*, which is useful as a biostratigraphical index species in southern England, Southern North Sea and into the Danish Embayment. Its inception is mid way through the Fittoni Zone and it apparently becomes extinct before the close of the Bolonian. Other species occur at about the same level, including *Hechticythere serpentina*, *Macrodentina (M.) rugulata* and *Prohutsonia pustulata*, all of which are characteristic of the upper Bolonian and early Portlandian.

The sample immediately below the Massive Bed yielded a single specimen of *Cytherella cf. recta*. There is some confusion in the published range of this species and this, together with confusion in taxonomy, limits its usefulness in a biostratigraphical sense. The Dorset specimen is similar to that from the Volgian of the Russian Platform and if its identification is correct it may prove a useful link. However considerably more specimens from the North Sea Basin and northern Europe need to be examined to clarify the taxonomy of this difficult genus as well as to elucidate the temporal distribution of its member species.

BOLONIAN AND PORTLANDIAN OSTRACODA

FROM THE FAIRLIGHT BOREHOLE

Introduction

In south-eastern England, deposits across the Bolonian/Portlandian boundary are known only from boreholes. The Fairlight Borehole was, therefore, examined to compare microfauna with those of Dorset and to seek relationships. The borehole was sited at national grid reference TQ8592 1173, a short distance from Hastings. Having penetrated the Purbeck beds and Portlandian Formation, it terminated in the Bolonian Upper Kimmeridge Clay at a depth of 396.80m.

Stratigraphy

Unlike Dorset, where the Kimmeridge Clay Formation/Portlandian Formation boundary is placed at the base of the arenaceous Massive Bed, in south-eastern England coeval sediments are predominantly argillaceous throughout. The sequence is dominated by mudstones, silty mudstones and siltstones. The position of the Kimmeridgian/Portlandian boundary is, therefore, difficult to locate lithologically and it can best be described as transitional. Nevertheless, the Rotunda Nodule Bed is believed to be at 391.9m depth and the base of the Purbeck Beds can be placed at 339.91m.

The macrofauna and stratigraphy of the Wealden and Purbeck beds of the Fairlight Borehole have been discussed in detail by Morter (BGS Internal report PD81/44). The Lower Purbeck comprises the Broadoak Calcareous Member and underlying Gypsiferous Member. The lower boundary of the Purbeck Formation is an erosion surface. The lack of good ammonite control prevents an accurate assessment of situation, but it is argued part of the sequence is missing here such that the Warren Faunicycle (*sensu* Anderson, 1985) rests on either the Okusensis or Kerberus zones. Thus the Anguiformis and Opressus zones are missing as well as the Quainton Faunicycle (*sensu* Anderson, 1985) at the base of the Purbeck Formation.

Text-fig. 13

The distribution of Ostracoda of Fairlight Borehole.

Although the base of the Portlandian, as recognised on the Dorset Coast, cannot be recognised lithologically in Fairlight Borehole, on macrofaunal grounds it is considered to be at 373.5m depth, immediately below a more sandier interval. The macrofauna of the borehole is dominated by bivalves, but other groups are represented (e.g. gastropods, brachiopods, serpulids, crustacea and fish). Ammonites are rare and fragmentary due to the diameter of the core. Those below 394.7m can be placed within *Pavlovia*; between 367.6 and 368.5m depth *Epivirgatites* was found; and *Glaucolithites* has been recorded from the 358.1 to 368.5m interval (Cox, 1976).

The stratigraphy of the Fairlight Borehole can thus be summarised as follows:

Portlandian

Purbeck Formation	Base at 339.9m
Gypsiferous Member	320.0-339.91m
Portland Formation	339.91-373.6m
Portland Stone Member equivalent	339.9-352.4m
Portland Sand Member equivalent	352.4-373.6m

Bolonian

Kimmeridge Clay Formation (upper)	373.6-396.80m
(base not seen)	

The Ostracoda

Ostracods have been recorded from a number of samples through the late Kimmeridgian and Portlandian of the borehole, although diversity is generally low.

Bolonian

The three samples taken below the presumed Rotunda Bed (at 391.9m) yielded at best seven species of Ostracoda. *Hechticythere serpentina* and *Paracypris problematica* dominated the faunas. Other species were also present including *Dicrorygma brotzeni*, *Prohutsonia pustulata*, *Klentnicella nealei* and *Galliaecytheridea spinosa*. The occurrence of *Hechticythere serpentina* is surprising here as elsewhere in southern England its first up sequence appearance is close to the top of the Kimmeridge Clay (Barker, 1966a; Christensen & Kilenyi, 1970).

However the remainder of the fauna is as expected for the top of the *G. spinosa* ostracod Zone (and the top of the Pallasioides Zone).

Immediately overlying the "Rotunda nodule Bed" (in a sample from a depth of 389.92m) the fauna is much reduced in diversity and richness. Few samples yielded Ostracoda and whereas the basal sample contained a population comprising four species, the other productive samples were monospecific. Single specimens of *Paranotacythere (Paranotacythere) pustulata* and *Galliaecytheridea spinosa* were encountered, but it is not clear whether they were recovered *in situ* or whether they had been reworked from below. However, the stratigraphically lowest specimen of *Macrodentina (Dictyocythere) retirugata* known from Britain was also found in the sample.

The 385.88-373.68m interval proved to be barren of ostracods with the exception of two samples (at 382.83 and 379.78m) which contained rare specimens of *Galliaecytheridea polita*. This is an important record for it is the index of the eponymous ostracod zone which equates with the mid-Fittoni Zone of the Dorset coastal sequence (Kilenyi, 1969, 1978; Christensen & Kilenyi, 1970). It has also been recorded in the Dutch Sector of the Southern North Sea Basin (Witte & Lissenberg, 1994) and in the Danish Embayment (Christensen & Kilenyi, 1970; Christensen, 1988). Thus, although rare, it is a stratigraphically important species.

Portlandian

The Albani macrofaunal Zone, the earliest zone of the Portlandian, is considered to be between the depths of 373.53 and 367.51m. Unfortunately most of the zone is devoid of ostracods, however, the highest sample examined (at 367.59m) yielded a small fauna comprising four species. *Hechtycythere serpentina* and *Macrodentina (Dictyocythere) retirugata* were again present, as was a crushed carapace of *Cytherelloidea* sp. cf. *paraweberi* (*sensu* Barker, 1966a) and *Galliaecytheridea compressa*. This last named species was used as a zonal index by Christensen (1974) equating with the latest Fittoni and early Portlandian.

The Glaucolithus Zone is considered to be located between 367.51m and 356.35m. It yielded abundant ostracods, particularly *Hechtycythere serpentina*, *Macrodentina (Dictyocythere) retirugata*, *Galliaecytheridea compressa*, together with

less common *Paranotacythere (Unicosta) caputmortuum* and *Prohutsonia elongata*. The first three listed continue from below and the *G compressa* ostracod Zone is indicated. *Paranotacythere (U.) caputmortuum* has been widely reported from the Bolonian and Lower Portlandian of Germany, northern France and the Dutch Sector of the Southern North Sea, but in Britain it has been recorded only as rare fragments to date. It is common only in the sample from 364.54m of the Fairlight Borehole. *Prohutsonia elongata* was originally placed in *Paranotacythere (Unicosta)*, but Witte & Lissenberg (1994) showed its correct generic assignment and also its wider geographical range, being present in the "Upper Kimmeridgian or Lower Portlandian" of the Dutch Sector of the Southern North Sea Basin. The stratigraphically highest British occurrence of *Dicrorygma (Orthorygma) brotzeni* is in the Fairlight Borehole, at 364.54m, for although it has been recorded from the Portlandian in the North Sea Basin and Danish Embayment, in southern England it has not been noted above the Rotunda Zone. Thus the Fairlight Borehole, although imperfect in terms of distribution of ostracods, brings the known range of several important species more in line with those on the continent.

The base of the Portland Stone (the base of the Okusensis Zone) is inferred to be at 352.35m (Cox, 1976), ranging through to the base of the Purbeck Beds at 339.91m. However, evidence of this zone and the following Oppressus Zone is wanting in the borehole. Ostracods were found in only two samples from this part of the sequence, at 343.2m, where a single specimen of *Macrodentina (Macrodentina) transiens* was recovered, and at 340.16m where a moderate fauna was found. This, the highest sample to yield a marine fauna, contained common *Macrodentina (Macrodentina) transiens*, *Paranotacythere (Unicosta) rimosa*, *Paranotacythere (Unicosta) caputmortuum* and *Hechticythere serpentina*. Euryhyaline taxa, such as *Fabanella*, were absent and fully marine shallow water conditions are interpreted from the fauna. Species recorded are typical of the Upper Portlandian Okusensis-Kerberus zones elsewhere in southern England and show several similarities to contemporaneous assemblages in the southern North sea and Germany.

The base of the Purbeck Beds is placed at 339.91m. The incoming of *Damonella ellipsoidea*, accompanied by *Fabanella boloniensis* and *Mantelliana purbeckensis*, at 338.36-338.44m is considered to indicate the Warren Faunicycle (Anderson, 1985). If this interpretation is correct, then the basal (Quainton)

faunicycle is either exceedingly thin (and thus unexamined) or missing. The continued occurrence of species such as *Hechticythere serpentina* and other Jurassic taxa at this horizon, elsewhere (Anderson, 1985), is indicative of a Portlandian rather than early Cretaceous age for this horizon. However, in the Fairlight Borehole, immediately overlying samples failed to yield ostracods, the next sample to yield a fauna is 22m higher where *Cypridea* and other "non-marine" taxa are characteristic of the Upway faunicle, which is of Berriasian in age. Thus the position of the upper stage boundary is unclear in this borehole.

BOLONIAN AND PORTLANDIAN OSTRACODA FROM HARTWELL BOREHOLE

Introduction

The Hartwell Borehole was sited on the outcrop of the Purbeck Formation near the classic section of the Bugle Pit at National Grid Reference SP7926 1223. The borehole was cored, below 2.20m, with excellent recovery below 2.85m, and was terminated at a depth of 76.69m in the Oxfordian Ampthill Clay Formation. The upper part of the borehole was examined for the present study and the following stratigraphical units were recognised:

Portlandian

Purbeck Formation	2.85-5.16m
Portland Formation	5.16- 17.95
Portland Stone Member	5.16-12.19m
Portland Sand Member	12.19-17.95m

Bolonian

(Upper) Kimmeridge Clay Formation	17.95-51.82m
Hartwell Silt Member	17.95-29.45m
Swindon Member	29.45-35.57m
Elmhurst Silt Member	35.57-43.65m
Watermead Clay Member	43.65-47.20m
Holman's Bridge Shale Member	47.20-51.82m

Samples were collected from twenty two positions throughout the Bolonian and Portlandian part of the borehole. Due to the small diameter of the core, the thin beds (especially in the *Elegans-Scitulus* and "Anguiformis" zones) and the presence of macrofossils, it was not possible to sample all beds for Ostracoda. In some cases it was possible to take small pieces from macrofossil and lithological samples, which enabled channel samples representing 20-30 centimeters to be analysed. It is believed that a suitable quantity of material was available at a reasonable number of positions throughout the borehole so that a good representative sample set has been examined.

Text-fig. 14

The distribution of Ostracoda of Hartwell Borehole.

Stratigraphy

Bolonian

The Upper Kimmeridge Clay in the borehole differs from that of the Dorset Coast in that it is in part much siltier. It can be subdivided on a combination of lithology and macrofaunal content into the five members recognised by Oates (1991) and, in part, the standard Kimmeridge Clay beds recognised by Cox & Gallois (1979, 1981) (which are given the prefix KC). The more arenaceous units, the Hartwell Silt Member and Emhurst Silt Member separate the argillaceous Swindon Clay Member. The Hartwell Silt and Swinodn Clay members are of *Pallasioides* zonal age and the Elmhurst Silt falls within the *Pectinatus* Zone (Cox *et al.*, 1994). The Lower Lydite Bed at 35.57m and the Upper Lydite Bed at 17.95m represent periods of erosion that coincide with K9 (*Pectinatus* Zone) and P1 (*Glaucolithus* Zone) sequence boundaries of Wignall (1991) and Coe, (1996)

The lower part of the Upper Kimmeridge Clay, between 51.82 and 43.65 have been subdivided into the Watermead Clay Member (KC44-45) and Holman's Bridge Member (KC36 to KC42) and whereas the former is assigned to the *Hudlestoni* Zone, the latter is placed into the *Elegans* to *Wheatleyensis* zones (Cox *et al.*, 1994). Although the boundary between the Lower and Upper Kimmeridgian Clay is conformable, there are several minor erosion surfaces within this part of the sequence, notably at the *Elegans/Scitulus* and *Wheatleyensis/Hudlestoni* zonal boundaries.

Portlandian

The Purbeck Formation comprises an alternation of thin limestones and marls, becoming siltier and sandier towards the base. A laminated marl crowded with ostracods (known as "Pendle" by quarrymen) is situated between 4.61 and 4.99m. This has traditionally been taken to be the base of the Purbeck Formation (Radley, 1991), but it is underlain by a 0.17m thick mudstone (the Upper Shelly Marl of Radley, 1991), which is also considered to be Purbeck Formation by some (Cox *et al.*, 1994; Horton *et al.*, 1995). As will be argued below, the Pendle ostracods can be related to the Quanton faunicycle (*sensu* Anderson, 1985). The 'non-marine' Purbeck Formation cannot be related to the 'marine' macrofaunal zonation directly, but the continuous sedimentation across the Portland/Purbeck formational boundary and the fact that the stratigraphical highest Portlandian deposits are of *Kerberus*

age, is interpreted as indicating an Anguiformis zonal age, at least up to and including the Pendle. This confirms the notion held by Wimbledon (1980) that the 'non-marine' sequence is older here compared to the Dorset coastal sequence

It is not possible from the small diameter core to recognise the Portlandian ammonite zones *per se*, but the lithological characteristics of the borehole permit extrapolation to nearby quarries where calibration is possible. Thus the Creamy Limestones, Crendon Sands and upper part of the Ayelsbury Limestone (sometimes called Rubbly Limestone) is considered to be of Kerberus zonal age. Much of the Ayelsbury Limestone can be placed into the Okusensis Zone and although the Glauconitic Beds of the Portland Sand Member is predominantly of Glaucolithus age, its uppermost part may also fall within the earliest Okusensis Zone.

The ostracoda

Bolonian

The lowest sample examined for ostracoda was taken at 51.4-51.75m from the Elegans Zone (Bed KC36) of the Holman's Bridge Shale Member. Deposits of this age from Britain and its continental shelf have consistently proved to be barren of ostracods. It was, therefore, unusual to find an ostracod here, albeit a single specimen, and surprising that it was a female carapece of *Galliaecytheridea elongata*. That species is the zonal index for the eponymous zone in the Lower Kimmeridge Clay and has not been found higher than the Eudoxus Zone. The specimen may be reworked, but, judging from its preservation, this seems to be unlikely and its range has to be extended.

The Wheatleyensis Zone has at its base a cement bed (KC40) that is too indurated to be broken down for microfaunal analysis. The overlying Bed (KC41), yielded a number of decalcified moulds at its base (49.25-49.45m) that could not be identified with any certainty. However, at 48.85-49.15m a large monospecific fauna was recovered. Flood proportions of *Mandelstamia (X.) maculata* is characteristic of the zone throughout southern and eastern England and can be used as a zonal marker. The flood abundance can be extended up into Bed KC42, of late Wheatleyensis age, although here the number of specimens recorded is reduced.

The Watermead Clay Member can be divided into a lower bed (KC44) and an upper one (KC45) a sample was taken from each. The lower bed (at 46.25-

46.38m) yielded a fauna dominated by *Schuleridea moderata* (56.48%) and *Pseudohutsonia pustulata* (31.61%), but included smaller numbers of *Dicrorygma brotzeni* (3.63%), *Micrommatocythere reticulata* (1.55%) as well as the zonal index *Eocytheropteron aquitanum* (6.74%). This fauna compares closely with those associations of eastern England and the *aquitanum* Ostracod Zone is proved. Unfortunately the succeeding sample (44.0m) from Bed KC45 proved much less fossiliferous compared to other localities, but its relationship with the association in Bed KC44 is indicated by the presence of *Pseudohutsonia pustulata*, which was represented by only a single specimen.

The Emhurst Silt Member, which is dated to the Pectinatus Zone, was sampled at two positions (39.0 and 36.0m) both of which lacked ostracods. However, sample of the Swindon Clay Member contained a small fauna. *Pseudohutsonia pustulata* and *Dicrorygma brotzeni* continued up from below, but rare specimens of *Macrodentina* (*P.*) *rudis*, *Macrodentina* sp. cf. *foveolata* and *Galliaecytheridea spinosa* were also present. The last named species, which was recorded at 30.0m, is an important taxon, being useful as an index for the *spinosa* Ostracod Zone. Although much of the Hartwell Silt Member proved to be barren (at 27.0, 21.0 and 18.05m) the sample at 24.0m contained rare specimens of *Galliaecytheridea spinosa*, thus proving the continuation of the ostracod zone.

Portlandian

Between 17.50, immediately above the Upper Lydite Bed, and 15.0m depth, i.e. the larger part of the Glauconitic Beds of the Portland Sand Member, samples were found to be devoid of Ostracoda. This highly glauconitic interval is considered to fall within the Glaucolithus Zone. At the very top of the member (12.90m depth), where the proportion of glauconite was greatly reduced, a sparse fauna was recorded. Here, at a level that probably falls within the earliest part of the Okusensis Zone, *Galliaecytheridea compressa* makes its first appearance in the borehole. This species, which is the ostracod zonal index, is accompanied by *Protocythere serpentina*, *Macrodentina* (*M.*) *transiens*, *Paraschuleridea buglensis*, *Rectocythere visceralis* and *Procytheropteron barkeri*, species that extend through the Portlandian. A number of these species (*Protocythere serpentina*, *Macrodentina* (*M.*) *transiens* and *Galliaecytheridea compressa*) have their origins in the Fittoni Zone, represented in the highest part of the Kimmeridge Clay on the Dorset coast,

but that part of the sequence is missing here due to erosion. Others (*Paraschuleridea buglensis*, *Rectocythere visceralis* and *Procytheropteron barkeri*) are more restricted in their geographical distribution, but have been recorded in the Portland Stone Member.

At the base of the Portland Stone Member, within the Aylesbury (Rubbly) Limestone, (11.90m depth), *Procythere serpentina*, *Rectocythere visceralis*, *Macrodentina transiens* and ?*Paraschuleridea buglensis* were again recovered, together with the first representative of *Procytheropteron bicostata* in the borehole. The last named species has been recorded from the Upper Kimmeridge Clay (Fittoni Zone) on the south coast of England and ranges up through much of the Portlandian. Essentially similar faunas were also recorded in the overlying Crendon Sand (at 9.80m) and Creamy Limestones (6.0m) (Portland Stone Member), both of which are considered to be of Kerberus zonal age. There is a notable increase in the numbers of specimens up-sequence in the Portland Stone Member and the appearance of several additional taxa at the top (*Paracypris?* sp of Barker, *Galliaecytheridea* sp. cf. *postrotunda*, and *Paranotacythere rimosa*). The faunas are essentially marine or brackish marine in composition and euryhaline species were not seen.

The Pendle, at the base of the Purbeck Formation (at 4.99m) contained abundant Ostracoda, which, for the first time in the borehole, indicate reducing salinities. A few species (but almost 50% of the specimens) range up from below, e.g. *Paracypris* sp. (0.3%), *Paraschuleridea buglensis* (4.6%), *Hechticythere serpentina* (5%) and *Procytheropteron barkeri* (37.5%). However, the largest number of taxa (and a little over 50% of the specimens) appear for the first time: *Macrodentina* (*M.*) *rugulata* (15%), *M. (D.) retirugata* (17%), *Paranotacythere (U.) rimosa* (10%), *Macrocypris alexanderi* (3.6%). Also appearing for the first time in the borehole is *Fabanella boloniensis* (7%), a species that is euryhaline in nature. This species is the harbinger of what was later to have become the non-marine Purbeck facies. The fauna is interpreted as brackish marine, true fresh water taxa such as *Cypridea* and *Darwinula* are not present even in the highest sample (at 3.0m) where the limestones yielded a small fauna comprising *Klieana alata*.

The fauna recovered from the Pendle of Hartwell Borehole can be compared with those of the basal Purbeck facies of Portesham Quarry of Dorset (Barker *et al.*, 1975) and the Bugle Pit, North Whitchurch Pit and Warren House Farm Pit near Aylesbury (Barker 1966b). It contains most of the essential species described by Anderson (1985) from the Quainton Faunicycle and lacks species of *Damonella*, *Darwinula*, *Rhinocypris*, *Scrabiculocypris* and *Theriosynoecum* which are characteristic of the succeeding Warren, Ridgeway and Stair faunicycles. However, the faunicycles are related to environmental rather than phylogenetic parameters and thus it is not possible to relate them chronostratigraphically. As pointed out above, on the basis of the continuous sedimentation across the Portland/Purbeck formational boundary and the fact that the Pendle rests directly on deposits of Kerberus age, this horizon is apparently older than comparative horizon exposed on the English Channel coast.

OSTRACODS FROM THE TISBURY BOREHOLE

Introduction

Ostracods in the Tisbury Borehole have a patchy distribution. Some parts of the sequence yielded only rare fragmentary assemblages, but at other horizons, faunas are rich, although diversity is moderately low as might be expected (Wilkinson, 1983).

Stratigraphy

The Tisbury Borehole is similar to the sequence on the Dorset coast in that it exhibits continuous sedimentation through the uppermost Bolonian and into the Portlandian. However, fundamental differences can be recognised, the most noticeable being the absence of the Massive Bed, which forms an easily recognisable Bolonian/Portlandian boundary on the Dorset Coast. The boundary is a transitional one, in some respects similar to that of Hartwell Borehole, but in the present situation the transition is more restricted stratigraphically.

Bolonian

The Kimmeridge Clay was examined between 126.70m to 38.75m.

The top of the Hudlestoni Zone is placed at 125.82m where interbedded mudstones and oil shales (BedKC45) changes to paler grey mudstones with only thin oil shales (Bed KC46). A thin cement stone at this horizon is taken to be the lateral equivalent of the White Stone Band. With the absence of stone bands at higher stratigraphical level, it is not possible to subdivide the overlying lithological sequence with certainty.

The top of the Pectinatus Zone is thought to fall at about 96.5m, probably within within Bed KC51, a pale grey mudstone, although it may be as high as 91.50m, at which depth the lithology gradually passes up into siltier deposits. The lithological and macropalaeontology characteristics are inconclusive. From the point of view of the

Text-fig. 15

The distribution of Ostracoda of Tisbury Borehole.

ostracods, however, the boundary at 91.50m is probably the Pallasioides/Rotunda boundary at the top of Bed KC54 (the siltier deposits are seen principally in Bed KC57 and above). The problem arises where the stonebands and prominent oil shales, so important for subdivision, are missing. The Rotunda Zone is traced through to a depth of 50.83 herein, although the Kimmeridge Clay beds cannot be recognised with confidence.

The upper part of the Fittoni Zone is situated between 48.20m and 38.75m. The lithology is distinctly silty here, becoming sandier upsequence. It seems probable that the period of erosion equivalent to Wignall's (1991) K10 sequence boundary is within this part of the Kimmeridge Clay Formation, immediately below 48.20m depth. There is no evidence for the lower part of the Fittoni Zone, which may have been removed by erosion at that time.

Portlandian

The transitional boundary between the Kimmeridge Clay and the Portland Formation (Wardour Member) is between 38.75 and 36.7m. Here the silty Kimmeridge Clay becomes more arenaceous and passes up through siltstone, sandy siltstone and silty sandstone so that at 36.7m depth sedimentation is arenaceous and typical of the Wardour Member. Hence it is difficult to recognise the Bolonian/Portlandian boundary lithologically. From the point of view of the Ostracoda, the appearance of *Eocytheridea eusarca* at 38.19m depth is indicative of the Portlandian.

The Wardour Member is considered herein to extend from a depth of c.38.75m through to 13.9m. Much of the member comprises sandstone, shelly in part, with occasional thin limestones and bioturbated horizons. Heavily bioturbated siltstones occur towards the upper part of the Member. Much of this interval is considered to be of Albani Zone, although the highest part may be of Glaucolitus zonal age (Coe, 1996).

Overlying the Wardour Member are 4.0m of micrite (between the depths 9.0 and 13.9m). This is considered to be equivalent to the Chicksgrave Limestone of the Vale of Wardour and of Glaucolithus age. The Tisbury Member at the top of the borehole

comprises calcareous sandstone in the lower part, with occasional bioturbated siltstones, but becomes a shelly bioturbated sandstone in the upper part. Unfortunately this highest interval was not available for sampling.

The stratigraphy as understood herein can be summarised as follows:

Portland Formation	down to 38.75m (top not seen)
Tisbury Member	down to 9.0m
Chicksgrove Member	9.0 - 13.9m
Wardour Member	13.9 - 38.75m
Kimmeridge Clay Formation	below 38.75m (base not seen)

The Ostracoda

Ostracoda have a patchy distribution throughout the Tisbury Borehole, very rare or absent in some intervals and common in others. It is assumed that this is a function of the environment of deposition and low oxygenated bottom water conditions (Wilkinson, 1983).

Bolonian

Although the lowest samples proved barren, or yielded very rare specimens, an ostracod assemblage of ten species was found at a depth of 122.65m. *Dicrorygma*, including *D. brotzeni*, and *Micrommatocythere reticulata* dominated the fauna, but rare specimens of *Mandelstamia tumida* are present and very rare specimens of *Paralesleya perforata* were also recorded. Comparison with the coastal sequence and boreholes in eastern England, which have excellent lithological and biostratigraphical control, indicates that the inception of *D. brotzeni* is in the late Pectinatus Zone and *M. tumida* is restricted to the Pectinatus Zone. *Paralesleya perforata* has been recorded in the Rotunda/Fittoni zonal boundary interval of Dorset, in the highest Argilles de Wimereux and basal Assises de Croi of the Boulonnais (?latest Pectinatus to Pallasioides/Rotunda zones) and in the Upper Kimmeridgian deposits off Denmark and Holland (Witte & Lissenberg, 1991). Its presence at 122.65m and again at 48.2m and 45.4, indicates the late Pectinatus to early Fittoni Zones for this interval. It is surprising that the ostracod zonal index for the late Hudlestoni to early Fittoni zones,

Galliaecytheridea spinosa, is not present (it does not occur between the samples at 122.65 and 76.30m in the borehole) but this may be due to palaeoenvironmental considerations.

The 119.9m to 87.20m interval of the Tisbury Borehole, yielded very sparse assemblages. Rare specimens of *Prohutsonia pustulata* were found in a number of samples above 115.85m, *Paranotacythere (U.) caputmortuum* was present at 96.4m and *Schuleridea moderata* was recorded in a number of samples above 96.4m. It is not possible to place an age on this interval with certainty. *Schuleridea moderata* is long-ranging throughout most of the late Kimmeridgian, *Prohutsonia pustulata* ranges from the Pectinatus through to the late Rotunda zones in Dorset (its inception is within the Hudlestoni Zone in eastern England) and *Paranotacythere (U.) caputmortuum* extends throughout the Late Kimmeridgian (its inception on the continent is in the Autissiodorensis Zone and offshore, in the Southern North Sea Basin it ranges up into the earliest Portlandian). In terms of the British succession, the species has only been recorded in the Hudlestoni Zone of eastern England.

There is a sudden appearance of additional species at 84.25 and 81.00m in the Tisbury Borehole. *Schuleridea moderata* occurs in abundance, *Hechticythere serpentina* is common and *Aaleniella (A. inornata and A. gracilis)*, *Macrodentina* sp. cf. *transiens*, *Klentnicella nealei* and *Dicrorygma maior* are also present. This is clearly an important biostratigraphical event, so far as the ostracods are concerned. Comparison with the stratotype sequence (Christensen & Kilenyi, 1970) suggests that it is within the younger part of the Rotunda Zone (within the "Lingula Shales"). However, it should be pointed out that the ostracods from this part of the Kimmeridge Clay are not well known and reliance has to be placed on only a small data set.

As mentioned previously, *Galliaecytheridea spinosa* appears for the first time in the borehole at 76.30m, and almost immediately dominates the faunas. It is consistently present between 76.30 and 52.3m and is accompanied by less persistent *Aaliniella inornata*, *Aaliniella gracilis*, *Mandelstamia tumida*, *Dicrorygma maior*, *Dicrorygma brotzeni*, *Micrommatocythere* sp. and *Hechticythere serpentina*. This assemblage is similar to that described from the late Rotunda Zone of the Dorset Coast

and the younger part of the Late Kimmeridgian in the offshore boreholes of the southern North Sea Basin.

Galliaecytheridea spinosa continues to dominate faunas between 48.20 and 38.19m, in which interval *Hechtycythere serpentina* is common. Other species appear for the first time in the borehole within this interval, some of which are surprising. *Procytheropteron brodei*, *Cytheropteron* cf. *prolongatum* and *Macrodentina* sp. appear at 48.20m; the inception of *Procytheropton bicostata* is at 45.40m in the same sample as the last specimens of *Dicrorygma brotzeni*; and *Paranotacythere* cf. *rimosa* was recorded at 40.50m. Many of these species are more characteristic of the youngest Kimmeridgian (late Fittoni Zone) and early Portlandian as recorded by Barker (1966). He recorded them from the uppermost 10 feet (3.05m) of the Kimmeridge Clay on the Dorset coast, just below the Massive Bed and Black Nore Sandstone, where the youngest ostracod zonal index, *Galliaecytheridea compressa*, has been found. However, no specimens of *Galliaecytheridea polita* or *Galliaecytheridea compressa* (respectively the ostracod zonal indices equating with the 'mid' and 'late' Fittoni Zone of the coastal sequence) were encountered in the Tisbury Borehole. The reason for this is unclear at the present time. It may be due to sample failure, facies, patchy distribution of the key taxa (*G. polita* is particularly uncommon and stratigraphically restricted) or alternatively, part of the Fittoni Zone has been removed by erosion prior to the deposition of the Portlandian sediments (perhaps associated with the sequence boundary K10 of Wignall, 1991).

Portlandian

The occurrence of *Eocytheridea eusarca* at 38.19m is interpreted as indicating that this horizon is of Portlandian age, by comparison with other areas of southern Britain. It is unfortunate that the Wardour Formation proves to be barren of Ostracoda although there are wood chips, moulds of mollusc, echinoid spines and fish debris together with very rare agglutinating foraminifera. Most of the Chicks Grove Member is similarly barren of ostracods, however at 10.35m a small fauna was found. Here the ostracod population is dominated by *Macrodentina retirugata* and *Eocytheridea eusarca*, but also included are *Procytheropteron barkeri*, ?*Paranotacythere (Unicosta) levis* (a single partly decalcified carapace) and a number of indeterminate fragments.

This fauna is considered to be of Portlandian age (the Chicksgrove Member is placed into the *Glaucolithus* macrofaunal Zone), the presence of *Eocytheridea eusarca* being indicative of the eponymous ostracod zone.

NORTH WOOTTON BOREHOLE

Introduction

The North Wootton Borehole was sited approximately 5km north east of King's Lynn, Norfolk (TF6439 2457) and is, therefore, an important borehole for the understanding of the Bolonian of the Southern North Sea Basin. It was used by Gallois & Cox(1976) as the standard for their Kimmeridge Clay bed sequence.

Stratigraphy

Superficial deposits, which are 8.90m thick at this locality, overlie 10.85m of Sandringham Sands (which are in part Portlandian in age but devoid of microfossils) and 99.65m of Kimmeridge Clay (of which the upper 31.4m can be placed into the Bolonian). The borehole was terminated at 170.34m in the Upper Oxfordian Amptill Clay.

Of the 47 beds in the Kimmeridge Clay, which were recognised by a combination of lithological characteristics and macrofaunal content, 12 are Bolonian. They were assigned the numbers KC36 to KC47 and span the interval between the *Elegans* and lower part of the *Pectinatus* Zone. The lower part of the sequence was deposited in similar conditions as those obtaining for the top of the Lower Kimmeridge Clay. Oil-shales are common through the *Elegans* and earlier part of the *Scitulus* zones (beds KC36 and 37) and, as a result, ostracods are sparse. The pale and medium grey clays, however, yielded small populations. Diversity is always low, generally between one and four species, and the highest diversity was found in Bed KC45 (latest *Hudlestoni* Zone) where seven species were recorded.

The Ostracoda

Elegans Zone

The *Elegans* Zone (Bed KC36) is barren of Ostracoda and in this respect is identical with southern England. Although beds of earliest *Scitulus* zonal age (beds KC37 and basal 38) are also barren of ostracods, the highest part of Bed KC38 yielded a sparse fauna. *Schuleridea moderata* was present, at a slightly older stratigraphical level compared to that in southern England, and rare specimens of *Paranotacythere* (*Unicosta*) *effusa* were also found. Although diversity remains low in the upper part of

Text-fig. 16

The distribution of Ostracoda in the North Wootton Borehole (after Wilkinson, 1983b).

Where less than 100 specimens were recorded, numbers of specimens are shown

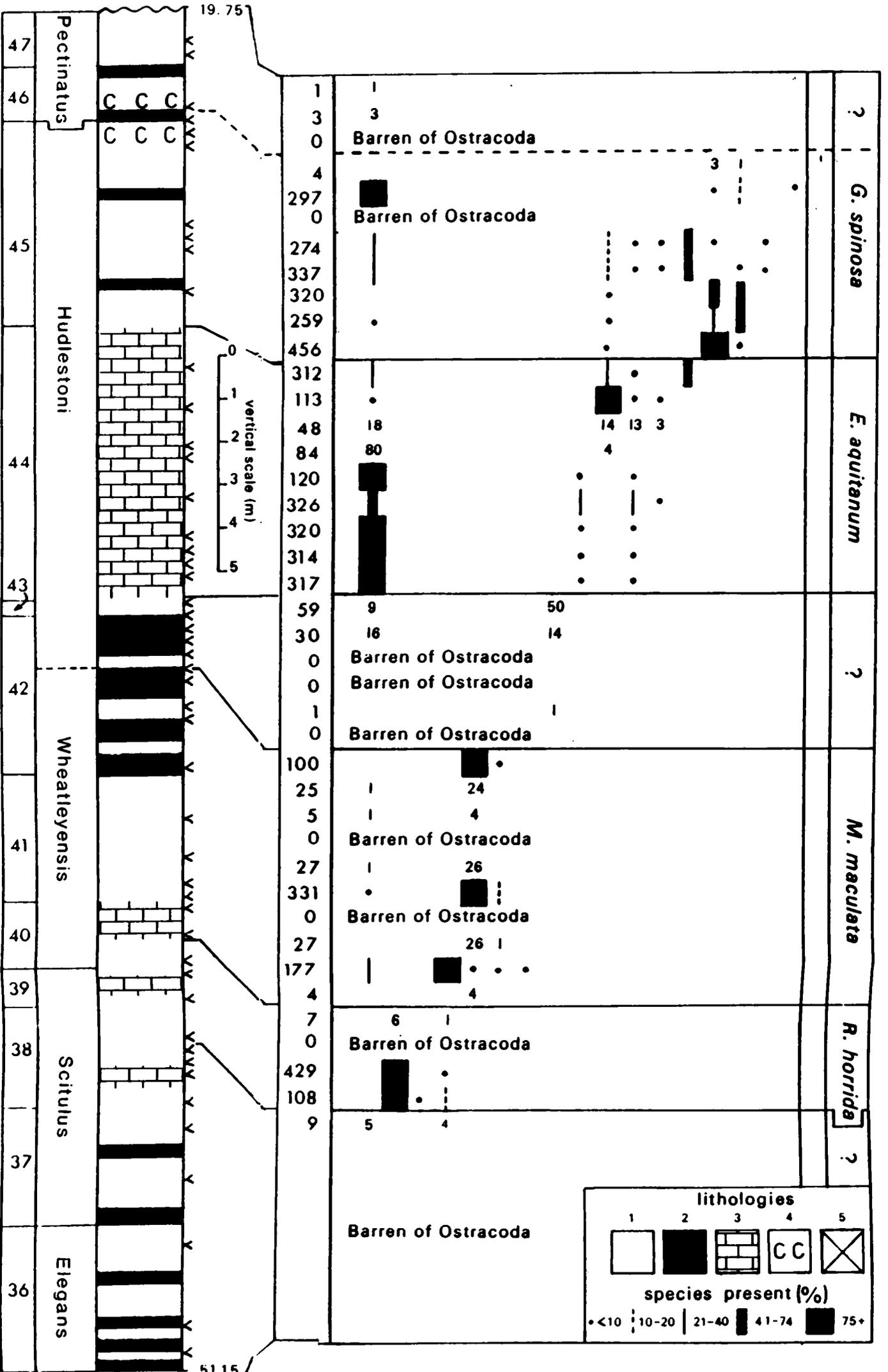
Lithologies:

- 1. Mudstone**
- 2. Oil shale**
- 3. Calcareous mudstone**
- 4. Coccolith-rich bands**
- 5. Core loss**

Ostracod zones

- Paranotacythere (U.) aff caputmortuum*
- Dicrorhynchus (O.) cf reticulata*
- Gallaecytheridea spinosa*
- Mandelstamia (X.) tumida*
- Macrodonia (P.) woottonensis*
- Micrommatocythere reticulata*
- Eocytheropteron aquitanum*
- Paranotacythere (U.) pustulata*
- Paranotacythere (U.) cf pustulata*
- Paranotacythere (U.) cf neall*
- Paranotacythere (U.) cf effusa*
- Gallaecytheridea cf spinosa*
- Mandelstamia (X.) maculata*
- Paranotacythere (U.) effusa*
- Gen. indet.
- Rectocythere (L.) horrida*
- Schuleridea moderata*

Specimens per sample



the Scitulus Zone (Bed KC38 to the basal part of Bed KC40, between 43.40 and 41.40m depth) numbers of specimens are high, for *Rectocythere (Lydicythere) horrida* occurs in flood abundance (up to 99% of the total ostracod population). This species is one of a limited number that occur in great numbers for geologically short periods of time and can be considered to be opportunistic. They are able to take advantage of relatively short periods of favourable environmental conditions in order to reproduce. As such they are presumably able to tolerate kenoxia better than other taxa in the North Sea Basin. Although *Paranotocythere (Unicosta) effusa* is rare in the Scitulus Zone, in the succeeding Wheatleyensis Zone, it also reaches flood proportions and forms over 77% of the population and is thus another opportunistic taxa.

Wheatleyensis Zone

In Dorset, *Mandelstamia (X.) maculata* is found in the Wheatleyensis Zone where it is restricted to the mudstones (beds KC41 and 42) a little above the Blackstone. In the North Wootton Borehole, the species was recovered from the upper part of Bed KC40 through to KC42, occurring in flood proportions in Bed KC42 (at a depths of 35.10 and 39.20m). Very rare specimens of *Galliaecytheridea cf. spinosa* were also found in beds KC40-42, apparently being transitional between *Galliaecytheridea mandelstami kilenyii* and *Galliaecytheridea spinosa*. With the exception of the samples from the very calcareous interval at the top of Bed KC40, which has a diversity of five species, assemblages from this part of the sequence are frequently almost monospecific.

Hudlestoni Zone

Between 35.00 and 33.25m (i.e. the upper part of Bed 42 and 43) samples are very poorly fossiliferous or barren. *Paranotocythere (U.) cf. nealei* and *Schuleridea moderata* were, however, recovered in small numbers and the latter is present in flood abundance (97-98% of the total fauna) in much of the lower part of Bed KC44 (between 32.70 and 30.90m depth).

Eocytheropteron aquitanum was recorded in the upper part of the Hudlestoni Zone (Bed KC44) in Dorset (Kilenyi, 1969) and it has also been found in western France (Donze, 1960; Oertli, 1963). In the North Wootton Borehole, it is present in the Hudlestoni Zone (beds KC44-45) between the depths 32.70 and 24.60m. It is accompanied by *Prohutsonia pustulosa*, which occurs in flood proportions (87%) at 28.80m depth and extends up into the basal part of Bed 45 where it is found in

association with *Galliaecytheridea spinosa*. The latter species is a useful biostratigraphical index for the upper part of the Pectinatus Zone to the lower part of the Fittoni Zone in Dorset (Kilenyi, 1969 and herein). In North Wootton Borehole the first appearance of the species is within the latest part of the Hudlestoni Zone. (Bed KC45), however, it was not found in the overlying Pectinatus Zone (beds KC46-47), presumably due to the presence of kenoxia associated with oil shale production.

Mandelstamia (X.) tumida is common in the lower part of Bed KC45 and *Macrodentina (P.) woottonensis* dominates the assemblage in the middle part of the bed, having first appeared in the top part of Bed 44 (it forms 42% of the population at 27.90m). Faunas become sparse in the upper part of Bed KC45, although at 22.50m *Schuleridea moderata* occurs in flood proportions (82%). *Prohutsonia pustulata* and *Mandelstamia (X.) tumida* occur in a lower stratigraphical level compared to Dorset, where they are not found below the upper part of the Pectinatus Zone (Bed KC48) according to Kilenyi (1969).

Pectinatus Zone

The upper 2.50m of the Kimmeridge Clay in North Wootton Borehole (beds KC46-47) were assigned to the Pectinatus Zone by Cox & Gallois (in Gallois, 1979a). Although Bed KC46 is barren of ostracods, very rare specimens of *Schuleridea moderata* have been recovered from Bed KC47 (at 20.70-20.40m depth).

4. BIOSTRATIGRAPHY

1. Introduction

Volgian deposits are widespread on the Russian Platform, where the proposed Volgian Stage lectostratotype is situated (at Gorodishche). The Gorodishche section lies on the right bank of the Volga River, 25km north of Ulyanovsk and within a few kilometres of the village of Gorodishche. Field work was carried out under the leadership of Prof. M.S. Mesezhnikov between 1971 and 1984 on the lectostratotype area, approximately 100 samples were collected from six sites along the river bank. The Bed numbers and ammonite zones used here, follow the scheme recognised at that time by Mesezhnikov (1984). The richest and best preserved assemblages of agglutinated and calcareous Foraminiferida and Ostracoda are recorded from the Kimmeridgian and Volgian deposits at Gorodishche.

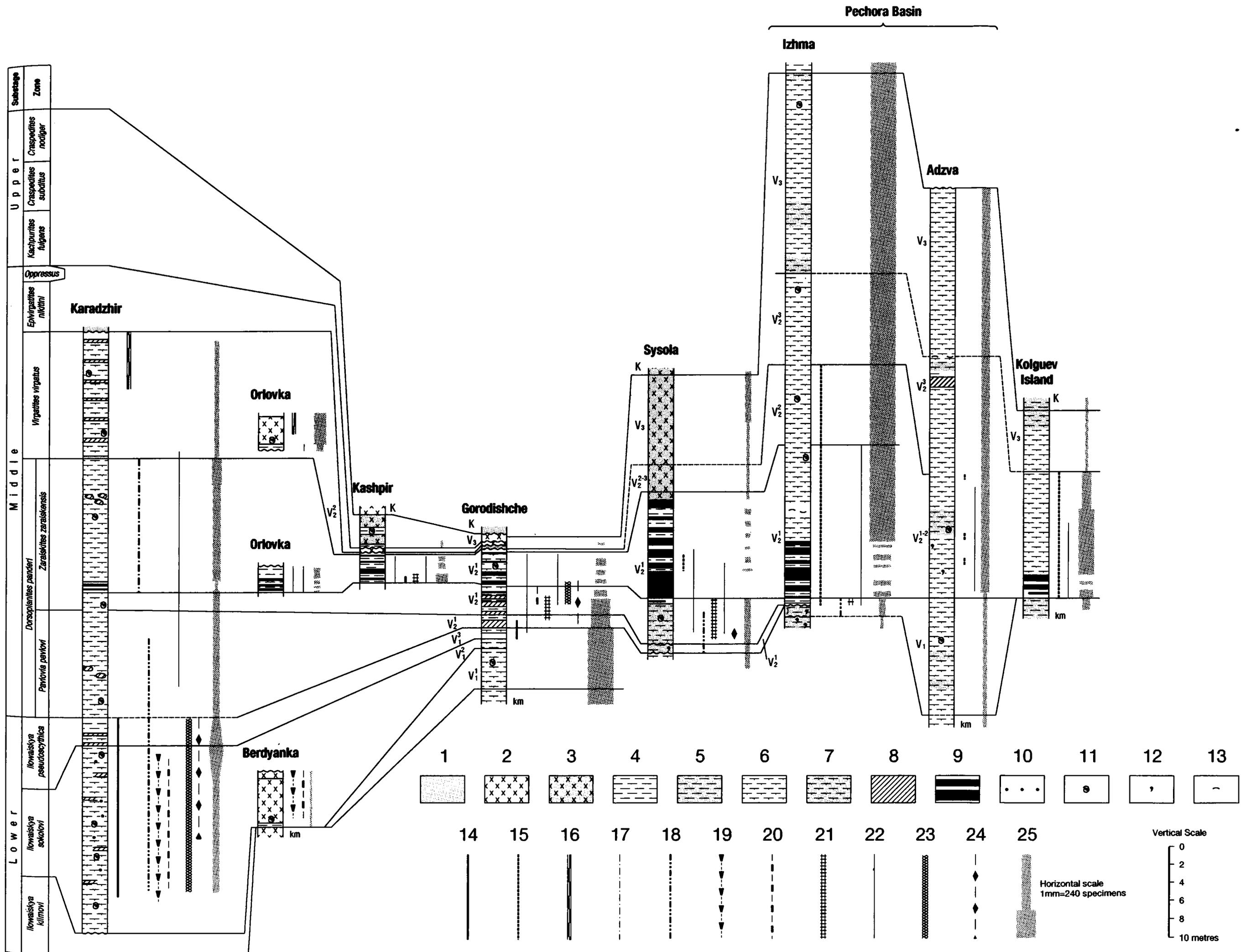
In Britain, the Bolonian and Portlandian deposits are contemporaneous with the Volgian of the Russian Platform. The best exposures are those of the coastal section between Kimmeridge Bay and Chapman's Pool, in the stratotype area. Here the sequence is uninterrupted and dip makes continuous sampling possible for most of the sequence, although towards the top of the section, below the Massive Bed, the steepness of the cliff makes sampling difficult. The lithostratigraphy and the ammonite zonal scheme has been known for many years, but more recently detailed stratigraphical work has been carried out by, for example, Gallois & Cox (1978) and Oschmann (1988) for the Kimmeridgian and Townsend (1975) and Wimbledon and Cope (1978) for the Late Kimmeridgian and Portlandian.

Foraminifera have been recovered throughout the Upper Kimmeridge Clay although they are more common and more diverse in the upper parts. Ostracoda, on the other hand are present in the Scitulus Zone and above, but have yet to be found in the Autissiodorensis and Elegans zones. Preliminary observations on their distribution are presented below.

Text-fig. 17

Correlation of Volgian sections and the distribution of stratigraphically significant foraminiferal species on the Russian Platform (modified from Yakovleva, 1985).

1. siltstone
2. sand
3. silty sand
4. clay
5. silty clay
6. calcareous clay
7. silty calcareous clay
8. limestone
9. oil shale
10. nodules
11. ammonite
12. glauconite
13. shell debris
14. *Dorothia patovcevi*
15. *Dorothia tortuosa*
16. *Flabellamina lidiae*
17. *Lenticulina infravolgaensis*
18. *Lenticulina ornatissima*
19. *Lenticulina dogieli*
20. *Lenticulina dofleini*
21. *Lenticulina selecta*
22. *Saracenaria pravoslavlevi*
23. *Saracenaria ilovaiskii*
24. *Saracenaria kasanzevi*
25. Number of specimens found (see scale)



2. Foraminiferida

1. The Russian Platform

Mjatliuk, in her classic monograph of 1939, was the first to describe foraminifera from the Volgian stage, but it was Kuznetsova (1965) and Dain & Kuznetsova (1976) who gave the most complete foraminiferal zonal scheme. Later, Kuznetsova (1978) attempted a correlation of the Kimmeridgian and Volgian sequences between the Russian Platform and Dorset. The biostratigraphical significance of foraminifera as a tool for regional correlation of Volgian sections, was discussed by Yakovleva (1985), who applied them to the Pechora Basin, Gorodishche, Kashpir (on the Volga near Syzran), Lake Inder and Orlovka (in the Pre-Caspian region).

The very detailed subdivision of the Volgian sequences, suitable microfaunal and ammonite zonal schemes, good preservation and abundant faunas, make the lectostratotype section favourable for East-West correlation. Four main zones were developed in VNIGRI for the purposes of correlation. These are:

- i. *Haplophragmium monstratus*- *Pseudolamarckina pseudorjasanensis* (RFZ1)
- ii. *Pseudolamarckina polonica*-*Verneuilinoides kirillae* (RFZ2)
- iii. *Lenticulina infravolgaensis*-*Saracenaria pravoslavlevi* (RFZ3)
- iv. *Astacolus aquilonicus*-*Lenticulina kassini* (RFZ4)

RFZ1 *Haplophragmium monstratus*- *Pseudolamarckina pseudorjasanensis*

Concurrent Range Zone

Stratigraphical range: Upper Kimmeridgian (Gorodishche Beds 1-4); Eudoxus and Autissiodorensis zones

Typical species: *Kutsevelia verus*, *Haplophragmium monstratus*, *Lenticulina segregata*, *Astacolus klahni*, *Astacolus nascens*, *Epistomina stellcostata*, and *Globigerina?* sp.

Definition: The lower limit is defined by the inception (First Appearance Datum or FAD) of *Haplophragmium monstratus* and *Pseudolamarckina pseudorjasanensis*. The upper limit is taken at the Last Appearance Datum (LAD) of *Haplophragmium monstratus* and *Kutsevelia verus*.

Remarks: The assemblage includes more than 80 species of agglutinating and calcareous species. Particularly diverse and abundant are species of the genera *Kutsevelia*, *Lenticulina*, *Astacolus*, *Marginulina*, *Epistomina* and *Pseudolamarckina*.

Text-fig. 18

A comparison between the foraminiferal zonal indices of the Russian Platform (Karadzhir to Sysola) and those of the Pechora Basin (Izhma and Adzeva) and Barents Sea Kolguev Island).

Geographical distribution: Zone RFZ1 has a widespread geographical distribution on the central part of the Russian Platform. (Yakovleva & Azbel, 1993).

RFZ2 *Pseudolamarckina polonica-Verneuilinoides kirillae*

Concurrent Range Zone

Stratigraphical Range: Lower Volgian (Gorodishche Beds 5-8); Klimovi, Sokolovi and Pseudoscythica zones.

Typical species: *Glomospirella porcellanea*, *Kutsevella haplophragmoides*, *Verneuilinoides kirillae*, *Spiroplectamina inderica*, *Lenticulina undorica*, *Lenticulina dogieli*, *Lenticulina ex gr. infravolgaensis*, *Vaginulinopsis embaensis*, *Citharina raricostata*, *Marginulinita kasahstanica*, *Epistomina stellicostata*, *Epistomina gorodishchensis* and *Pseudolamarckina polonica*.

Definition: The lower limit is defined by the FAD of *Verneuilinoides kirillae*, *Lenticulina undorica*, *Lenticulina dogieli* and *Epistomina gorodishchensis*. The upper zonal boundary is defined by the LAD of *Pseudolamarckina polonica*, *Lenticulina dogieli* and *Epistomina gorodishchensis*,

Remarks: There are minor differences in the foraminiferal assemblages in each ammonite zone of RFZ2. These may prove to be important at a subzonal level after further detailed research has been undertaken. Within RFZ2 there are several inceptions, including the FAD of *Kutsevella haplophragmoides*, *Spiroplectamina inderica* and *Lenticulina postkarlaensis*, within the Sokolovi Zone, and the FAD of *Gaudryinella decurvata*, *Vaginulinopsis embaensis* and *Marginulinita kasahstanica* within the Pseudoscythica Zone.

Assemblages contain more than 100 species, including representatives of such typical genera as *Pseudolamarckina* and *Epistomina*. Species diversity is similar to that of the Upper Kimmeridgian, but with a rapidly increasing number of *Epistomina* species. Nearly 40% of species within RFZ2 can also be recognised in the Upper Kimmeridgian zone RFZ1.

Geographical distribution: RFZ2 extends through central and southern parts of the Russian Platform. Assemblages from RFZ2 can be compared with contemporaneous assemblages from the Lower Volgian deposits of Poland and England where *Pseudolamarckina polonica* is numerous (Kuznetsova, 1979; British Geological Survey collections).

RFZ3 *Lenticulina infravolgaensis*-*Saracenaria pravoslavlevi*

Total Range Zone

Stratigraphical range: Middle Volgian (Gorodishche Beds 9-11); Panderi Zone.

Typical species: *Ammodiscus giganteus*, *Glomospirella porcellanea*, *Ammobaculites infravolgensis*, *Kutsevella haplophragmoides*, *Kutsevella ex gr. labithnangensis*, *Lenticulina infravolgaensis*, *Lenticulina ornatissima*, *Lenticulina ilovaiskii*, *Saracenaria pravoslavlevi*, *Saracenaria kasanzevi*, *Astacolus obliteratus*, *Marginulina striatocostata*, *Marginulina robusta*, *Marginulina pseudolinearis*, *Marginulina nupera*, *Nodosaria osynkiensis*, *Vaginulinopsis embaensis*, *Sigmoilinita subpanda*, *Mironovella gemina* and *Epistomina* sp.

Definition: The zone is defined by the total ranges of *Lenticulina infravolgaensis* and *Saracenaria pravoslavlevi*.

Remarks: The lower boundary of the zone can also be recognised by the first appearance, up sequence, of the following taxa: *Astacolus obliteratus*, *Kutsevella ex gr. labithnangensis*, *Marginulina gracilissima* and *Nodosaria osynkiensis*. In the Zaraiskensis Subzone, a number of species become abundant: *Kutsevella haplophragmoides*, *Mironovella gemina*, Polimorphinidae and species of the genus *Nodosaria*.

Geographical distribution: During the period represented by RFZ3 (Panderi Zone), the Late Jurassic transgression on to the Russian Platform reached its maximum extent. As a consequence, the foraminiferal zone has a very wide spatial distribution. It can be traced as far north as the Pechora Basin, throughout the Russian Platform and south into the Precaspian region. A broad correlation is also possible with Poland and England.

Un-named Zone

Stratigraphical range: Upper part of the Middle Volgian (Gorodishche Beds 12-15); Virgatus and Nikitini zones.

Typical species: Foraminifera are rare, but include members of the family Nodosariidae: *Lenticulina ex gr. ornatissima*, *Astacolus ex gr. aquilonicus*, *Nodosaria pseudohispida* and *Marginulina* spp (ribbed).

Remarks The foraminiferal faunas from the Virgatus Zone (Beds 12-14) and the Nikitini Zone (Bed 15) are similar.

RFZ4 *Astacolus aquilonicus*-*Lenticulina kassina*

Total Range Zone

Stratigraphical range: Upper Volgian (Gorodishche Bed 16); Fulgrens Zone.

Typical species: *Nodosaria pseudohispida*, *Astacolus aquilonicus*, *Lenticulina kassini*, *Saracenaria valanginiana*, *Marginulina transmutata*, *Marginulina impropria*, *Marginulina* spp (ribbed) (numerous) and *Citharina* sp.

Definition: The zone is defined by the total ranges of *Astacolus aquilonicus* and *Lenticulina kassina*.

Remarks: The assemblage comprises 30 species of Nodosariidae and Lagenidae.

Geographical distribution: *Astacolus aquilonicus*, *Lenticulina kassini*, *Marginulina impropria* and *Marginulina transmutata* are typical of the Upper Volgian and allow correlation of RFZ4 with identical zones of the Pechora Basin and Kashpir (Yakovleva, 1985).

2. Southern England

Foraminifera of southern England have been somewhat neglected. Lloyd (1958MS) carried out a taxonomic and stratigraphical examination of the faunas for his doctoral thesis, and later (1959, 1962) published some taxonomic work on arenaceous and some of the calcareous taxa (but excluding the Nodosariidae, the dominant group in the Kimmeridgian). J. Exton (in Shipp, 1989) outlined the general trends in the Kimmeridgian foraminifera, but no details were given. A few other papers include data from the Kimmeridgian (e.g. Medd, 1979), but they are confined to the lower part of the stage and fall outside the scope of this report. Portlandian foraminifera have not been studied in detail. Ship (1978) recorded a sparse fauna from the Albani Zone of Dorset and Copestake (in Lord & Bown, 1987) listed a few taxa from the Albani and Okusensis Zone in Dorset, southern England. Finally, Copestake (in Shipp, 1989) gave some information on some foraminifera from the Vale of Wadour, Wiltshire.

The faunas of the Kimmeridgian and Portlandian are dominated by Nodosariacea, but Textulariinae, Polymorphinidae and Epistomininae are also present at some horizons, notably in the Kimmeridgian. The existence of a single planktonic specimen has been reported in Shipp (1989). There are four broad trends in the foraminiferal assemblages.

4. Albani-Okusensis (Early Portlandian): Nodosariidae is common, particularly species of *Lenticulina*, *Saracenaria*, *Citharina* and *Marginulina*.

Text-fig. 19

Foraminifera from the Upper Kimmeridge Clay Formation of southern England recovered during the present study, compared to those recorded by Kuznetsova (1979).

E N G L A N D

Stage	Zone	Foraminiferal zone		Zone
		Yakovleva (this paper)	Kuznetsova 1979	
Upper Kimmeridgian	Albani			Albani
	Fittoni	<i>Lenticulina sywi</i> - <i>Haplophragmoides galloisi</i>		Rotunda
	Rotunda	<i>Saracenaria pravoslavlevi</i> - <i>Lenticulina infravolgaensis</i>		Pallasioides
	Pallasioides			
	Pectinatus	<i>Lenticulina</i> <i>infravolgaensis</i>	<i>Bulbobaculites deceptorius</i> - <i>Marginulina formosa</i>	Pectinatus
	Hudlestoni			Hudlestoni
	Wheatleyensis		<i>Kutsevella petaloidea</i>	Wheatleyensis
	Scitulus			Scitulus
	Elegans	<i>Kutsevella petaloidea</i> - <i>Lenticulina postkarkaensis</i>		Elegans
	Autissiodorensis			Autissiodorensis
Eudoxus	Eudoxus			
Lower Kimmeridgian		<i>Pseudolamarckina</i> <i>pseudorjasanensis</i>		Mutabilis

3. late *Pectinatus*-*Fittoni* zones (Late Kimmeridgian): The proportion of *Nodosariidae* is increased, to become common at some horizons, and *Textulariidae* is also common. The dimensions of the individuals also tends to increase in the later part of this interval.
2. *Scitulus*-early *Pectinatus* (Late Kimmeridgian): *Textulariidae* are common but low in diversity. Specimens of *Ammobaculites*, *Trochammina* and *Haplophragmoides* are common and in the *Scitulus* to *Hudlestoni* zones *Lenticulina* and *Marginulina* occur occasionally.
1. The *Eudoxus*-*Autissiodorensis* zones (latest Early Kimmeridgian) has a low diversity fauna (oil shales are particularly conspicuous in this part of the Kimmeridge Clay). *Haplophragmoides*, *Textularia* and *Lenticulina* are present, together with species of *Epistomina*, *Marginulina*. and *Vaginulina*.

The following zones have been recognised during the current project.

EFZ1. *Kutsevella petaloidea*-*Lenticulina postkarlaensis* Zone

EFZ2. *Lenticulina infravolgaensis* Zone

Kutsevella petaloidea Subzone

Bulbobaculites deceptorius-*Marginulina formosa* Subzone

EFZ3. *Saracenaria pravoslavlevi*-*Lenticulina infravolgaensis* Zone

EFZ4. *Lenticulina sywi*-*Haplophragmoides galloisi* sp.nov. Zone

EFZ1. *Kutsevella petaloidea*-*Lenticulina postkarlaensis* Zone

Stratigraphical range: The zonal range is confined to the *Eudoxus*, *Autissiodorensis*, and *Elegans* Zones (Dorset Coastal sequence, samples MPA42038-42057).

Typical species: *Glomospirèlla* ex gr. *porcellanea*, *Recurvoides sublustris*, *Kutsevella petaloidea*, *K.* cf. *verus*, *Textularia jurassica*, *Lenticulina postkarlaensis*, *Astacolus nascens*.

Definition: The zone is defined by the total range of *Lenticulina postkarlaensis* and First Appearance Datum (FAD) of *Kutsevella petaloidea* in basal part.

Remarks: The assemblage includes about 15 species. Species of the *Kutsevella*, *Trochammina* and fragments of agglutinated foraminifera are abundant. The zone is characterized by the occurrence of *Lenticulina postkarlaensis*, which is typical of the *Eudoxus* and *Autissiodorensis* zones of Gorodishche. A diverse, but quantitatively very

sparse assemblage of calcareous foraminifera comprise several species of *Lenticulina*, *Astacolus*, very rare *Epistomina* sp. and *Ceratobulimina* cf. *lika*.

Geographical distribution: Southern England.

EFZ2. *Lenticulina infravolgaensis* Zone

***Kutsevella petaloidea* Subzone**

Stratigraphical range: The zonal range is confined to the Scitulus-Pectinatus Zones and the subzone is contemporaneous with the Scitulus and Wheatleyensis Zones.

Typical species: *Reophax* sp., *Kutsevella petaloidea*, *Ammobaculites gracilis*, *Lenticulina infravolgaensis*, *Vaginulinopsis janinae*.

Remarks: Characteristic species in this interval (Dorset coastal sequence, samples MPA42058-42069) are much fewer in number than in either the underlying or overlying assemblage zones. The base of the subzone is defined by the FAD of numerous *Lenticulina infravolgaensis*. The position of the upper boundary of the zone is not precisely established because samples in upper part of the Wheatleyensis Zone and lower part Hudlestoni Zone could not be collected.

Geographical distribution: Southern England.

***Bulbobaculites deceptorius*-*Marginulina formosa* Subzone**

Stratigraphical range: Upper part Hudlestoni and Pectinatus Zones (Dorset coastal sequence samples MPA42070-42082).

Typical species: *Reophax* ex gr. *helvetica*, *R. hounstoutensis*, *Bulbobaculites deceptorius*, *Trochammina globigeriniformis*, *Textularia jurassica*, *Lenticulina infravolgaensis*, *Astacolus nascens*, *Marginulina formosa*.

Definition: The subzone is defined by the total range of *Marginulina formosa* and *M. ex. gr. formosa* and also abundant *Trochammina*. Lower boundary is noted by FAD of *Bulbobaculites deceptorius*.

Remarks: The subzone is characterised by dominant agglutinated foraminifera of the genera *Proteonina*, *Reophax*, *Bulbobaculites*, *Haplophragmium?*, *Trochammina*, *Textularia*. *Nodosariida* (mainly *Lenticulina infravolgaensis* and *Astacolus nascens*) is numerous only in two samples (MPA42071 and MPA42074).

Geographical distribution: Southern England and the Tisbury Borehole.

EFZ3. *Saracenaria pravoslavlevi-Lenticulina infravolgaensis* Zone

Stratigraphical range: This zone comprises uppermost part of the Pectinatus, the Pallasioides and the basal part of the Rotunda zones (Dorset coastal Sequence samples MPA42083-42097).

Typical species: *Reophax hounstoutense*, *Bulbobaculites deceptorius*, *Textularia jurassica*, *Verneuilinoides kirillae*, *Trochammina* cf. *nitida*, *Lenticulina infravolgaensis*, *Astacolus obliterated*, *Saracenaria pravoslavlevi*, *Citharina* spp.

Definition: The base of the zone is defined by the FAD of *Verneuilinoides kirillae*, *Saracenaria pravoslavlevi*, *S. tsaramondrosoensis*, *Marginulinita kasahstanica*. The upper boundary is defined by the first appearance of the superadjacent zonal index.

Remarks: This zone is characterized by the appearance of a large number, about 50-60, foraminiferal species. Approximately 15 species of agglutinated foraminifera were found in the zone, represented by *Trochammina*, *Kutsevella* and *Bulbobaculites*. Numerous representatives of nodosariida (40-45 species) were also present. Abundant *Pseudolamarckina polonica* occurs only in one sample- MPA42084. Numerous Polymorphinidae are recorded in the zone. Moreover, almost all the species known from the underlying *B. deceptorius-Marginulina formosa* Subzone are represented here. In the higher part of zone (samples MPA42093-42097) *Saracenaria kasanzevi*, *Lenticulina uralica* and *L. loinoensis* are found.

Geographical distribution: Southern England (Dorset and the Tisbury Borehole), Polish Lowland, Russian platform, Pechora basin, Kolduev Island.

EFZ4. *Lenticulina sywi-Haplophragmoides galloisi* sp.nov. Zone

Stratigraphical range: The foraminiferal zone comprises of the Fittoni Zone; (Dorset Coastal sequence samples MPA42103-42109).

Typical species: *Haplophragmoides galloisi* sp.nov., *Lenticulina sywi*, *Lenticulina* aff. *kassini*, *Lenticulina ponderosa*, *Lenticulina ilovaiskii*, *Spirillina polygyrata*.

Definition: The zone is defined by the range of *Haplophragmoides galloisi*., *L. sywi* and *Saracenaria ilovaiskii*.

Remarks: The zone is determined by highly rich nodosariids and the appearance of agglutinated forms with coarsely-grained wall. Characteristic species in this interval are much fewer in number than in the underlying one

Geographical distribution: Southern England (Dorset and Tisbury).

3. Ostracoda

1. The Russian Platform

The earliest work to be carried out on the Late Jurassic Ostracoda of the Russian Platform was that of Sharapova (1937, 1939), who described fifteen species of ostracod from the Volgian deposits. Later, Ljubimova (1955) described about 60 new species from the Mesozoic deposits from the middle part of the Volga Basin, although few species were recorded from the Volgian. A few samples were collected from the Gorodishche during 1977 and the microfauna, including ostracods, was described by Lord *et al.*, (1977). They listed 30 species, most of which were recognised by Sharapova and Ljubimova.

Ostracods have not been examined in sufficient detail to provide a regional biostratigraphical zonal scheme, however, ostracods from the Gorodishche and Kashpir sections can be used to recognise two broad biostratigraphical zones:

ROZ1. *Galliaecytheridea volgaensis*-*Galliaecytheridea monstrata* Partial Range Zone

ROZ2. *Cytherella ovoidea*-*Cytherella recta* Total Range Zone

ROZ1. *Galliaecytheridea volgaensis*-*Galliaecytheridea monstrata* Partial Range Zone

Stratigraphical range: Upper Kimmeridgian and Lower Volgian (Gorodishche Beds 1-6, thickness 9-12.5m); Eudoxus, Autissiodorensis, Klimovi zones.

Typical species: *Galliaecytheridea volgaensis*, *Galliaecytheridea monstrata*, *Galliaecytheridea miranda*, *Galliaecytheridea mandelstami*, *Galliaecytheridea tatae*, *Ljubimovina denticulata*, *Mandelstamia nikolaevi*, *Macrodentina ex gr. abdita*, *Macrodentina ventrocornuta*, *Oligocythereis kostytschevkaensis*, *Eucytherura (Vesticytherura) costaeirregularis*, *Procytheridea prolongata*, *Exophthalmocythere fuhrbergensis*, *Cytherella* sp. aff. and *Cytherella collapsa*

Text-fig. 20

The stratigraphical relationship of ostracod associations in Britain and European Russia.

Definition: The lower boundary is defined by the First Appearance Datum (FAD) of *Galliaecytheridea volgaensis* and *Galliaecytheridea monstrata*. The upper boundary is recognised by the last appearance of consistently present *Galliaecytheridea volgaensis* and the appearance of the succeeding zonal indicators.

ROZ2. *Cytherella ovoidea*-*Cytherella recta*

Total Range Zone

Stratigraphical range: Lower and Middle Volgian (Gorodishche Beds 7-14; thickness 9.5-15.3m); Sokolovi, Pseudoscythica, Panderi and Virgatus zones.

Typical species: *Cytherella ovoidea*, *Cytherella recta*, *Cytherella ukrainensis*, *Cytherelloidea tenuis*, *Eocytheropteron* sp. aff. *E. postilum*, *Hechticythere eximia*, *Hechticythere verrucifera*, *Hechticythere fistulosa*, *Hechticythere? cornulateralis*, *Paranotacythere (Unicosta) extendata*, *Procytheridea prolongata*, *Eucytherura (Vesticytherura) costaeirregularis*, *Oligocythereis kostytshevkaensis*, *Amphicythere* sp. aff. *confundens*, *Mandelstamia nikolaevi*, *Mandelstamia ex gr. abdita*, *Mandelstamia ventrocornuta*, *Mandelstamia* sp. aff. *ventrocornuta*, *Ljubimovina denticulata*, *Galliaecytheridea tatae*, *Galliaecytheridea elegans*, *Galliaecytheridea mandelstami*, *Galliaecytheridea miranda*, *Galliaecytheridea monstrata*, *Galliaecytheridea volgaensis* and *Lophocythere* sp.

Definition: The zone is defined by the total ranges of *Cytherella ovoidea* and *Cytherella recta*

Remarks: Numerous specimens of *Cytherella* spp is typical of the zone.

2. Southern England

Ostracoda from the Kimmeridgian deposits of southern England have been examined a number of times. Malz (1958) and Neale & Kilenyi (1961) included ostracods from southern England for their taxonomic work on *Macrodentina* and other taxa and *Mandelstamia*, respectively. Kilenyi (1965; 1969) undertook a taxonomic study of the Kimmeridge Clay faunas of the stratotype area, which was partly modified by Christensen & Kilenyi (1970) who showed the usefulness of ostracods on a regional scale. Finally, taxonomic work on *Paranotacythere* by Bassiouni (1974) included faunas from the Dorset sequence.

Fifty three species were recorded from the Kimmeridge Clay at this time of southern England, of which twenty were recorded from the Bolonian sequence (= lower and part of the Middle Volgian).

Christensen & Kilenyi (1970) and, later, Christensen (1974) biostratigraphically subdivided the sequence on the basis of the ostracods. However, they encountered difficulties, particularly in the Upper Kimmeridge Clay, where faunas were sparse so that zonal boundaries were poorly defined. This zonal scheme was partly modified by Wilkinson (1983a,b), after a further study of faunas from eastern England, and five additional taxa (three of which were recovered from the Upper Kimmeridge Clay) were described and several others were left in open nomenclature. Wilkinson (1988) erected a few additional species in his unpublished PhD thesis, but these remain manuscript names only.

Lists of Kimmeridgian ostracods were given by Fuller (in Lord & Bown, 1987), but details are limited. Other work that includes Kimmeridgian ostracods from southern England, e.g. the Winterbourn Kingston Borehole (Wilkinson 1982) and the Dorset coast (Glashoff, 1964) are not included as they are concerned predominantly with the lower part of the formation (the Kimmeridgian *sensu franco*).

Portlandian Ostracods from Dorset and Aylesbury were examined by Barker (1966a,b) and "Purbeckian" ostracods (which is in part of late Volgian age) have been examined in detail by Anderson in many papers, but which was summarised by Anderson and published shortly after his death (see Anderson, 1985, for a complete bibliographic list). Barker's work was essentially taxonomic in nature, but he showed the influence of decreasing salinities at this time, although placing these palaeoenvironmental variations in a stratigraphical framework is not possible as the details of the sample collections is not given.

The combined work of Kilenyi (1969), Christensen & Kilenyi (1970), Christensen (1974) and Wilkinson (1983a,b, 1988) can be used to identify

EOZ1. *Galliaecytheridea elongata* Total Range Zone

Macrodentina (Polydentina) steghausi steghausi Total Range Subzone

un-named zone

EOZ2. *Rectocythere (Lydicthere) horrida* Total Range Zone

EOZ3. *Mandelstamia (Xeromandelstamia) maculata* Total Range Zone

un-named zone

EOZ4. *Eocytheropteron aquitanum* Partial Range Zone

EOZ5. *Galliaecytheridea spinosa* Total Range Zone

EOZ6. *Galliaecytheridea polita* Total Range Zone

EOZ7. *Galliaecytheridea compressa* Partial Range Zone

EOZ8 *Eocytheridea eusarca* Total Range Zone

Wolburgia visceralis Partial range Subzone

EOZ1. *Galliaecytheridea elongata* Total Range Zone

Stratigraphical range: Upper Kimmeridgian and Bolonian (Kimmeridge Clay Beds KC18 to lower part of KC36), mid-Mutabilis to early Elegans zones.

Typical species: *Galliaecytheridea elongata*, *Galliaecytheridea mandelstami kilenyii*, *Paranotacythere (Unicosta) extendata*, *Mandelstamia (Mandelstamia) rectilinea*, *Exophthalmocythere fuhrbergensis*, *Macrodentina (Polydentina) steghausi*

Definition: The total range of *Galliaecytheridea elongata*.

Remarks: This species is particularly characteristic of the Kimmeridgian, normally disappearing with the onset of thick oil shale production in the later part of the Eudoxus Zone. However, its presence in the early Elegans Zone of the Hartwell Borehole indicates that the zone must be extended into the earliest Bolonian.

Geographical distribution: Southern and eastern England and the North Sea Basin.

***Galliaecytheridea elongata* Total Range Zone**

***Macrodentina (Polydentina) steghausi steghausi* Total Range Subzone**

Stratigraphical range: The zonal range is confined to the Lower Kimmeridgian (Kimmeridge Clay Beds KC18-31); Mutabilis and Eudoxus Zones. The ostracod subzonal range is confined to Kimmeridge Clay Beds 24-31; Eudoxus Zone

Typical species: *Galliaecytheridea elongata*, *Galliaecytheridea postrotunda*, *Macrodentina (Polydentina) steghausi steghausi*, *Macrodentina (Polydentina) ornata*, *Macrodentina (Macrodentina) pseudomaculata*, *Cytherelloidea*, *Dicorygma (Orthorygma) reticulata*, *Exophthalmocythere fuhrbergensis* and *Paranotacythere (Unicosta) extendata* and *Mandelstamia rectilinea*

Definition: The subzone is defined by the total range of *Macrodentina (Polydentina) steghausi steghausi* in the upper part of the *Galliaecytheridea elongata* Zone.

Remarks: The upper boundary is sometimes difficult to recognise due to the presence of thick oil shales that are barren, or virtually so.

Geographical distribution: Southern and eastern England and Southern North Sea.

***Galliaecytheridea elongata* Total Range Zone**

un-named subzone

Stratigraphical range: Uppermost Kimmeridgian and lowest Bolonian (Kimmeridge Clay Beds 32 to lower part of 38); latest Eudoxus, Autissiodorensis and Elegans zones

Typical species: Very rare *Mandelstamia* (*Mandelstamia*) *rectilinea*, *Cytheropteron* sp., *Paranotacythere* (*Unicosta*) sp. and *Schuleridea moderata*.

Definition: Between the last occurrence of *Macrodentina* (*Polydentina*) *steghausi* and the first occurrence of *Rectocythere* (*Lydicthere*) *horrída*.

Remarks: The latest Eudoxus to Elegans zones are for the most part devoid of ostracods in Britain, although, occasionally rare specimens are found. The presence of *Galliaecytheridea elongata* in the Elegans Zone of Hartwell Borehole proves its zonal position. The First Appearance Datum (FAD) of *Schuleridea moderata* appears to be within the middle part of the Scitulus Zone and when the range of this species is better understood, its inception may prove to be biostratigraphically useful.

Geographical distribution: Throughout England and the southern North Sea.

EOZ2. *Rectocythere* (*Lydicthere*) *horrída* Total Range Zone

Stratigraphical range: Bolonian (upper part of Kimmeridge Clay Bed 38-lower part of Bed 40); late Scitulus and earliest Wheatleyensis

Typical species: *Rectocythere* (*Lydicthere*) *horrída*; *Paranotacythere* (*Unicosta*) *effusa*, *Schuleridea moderata* and *Galliaecytheridea* sp. cf. *G. spinosa*.

Definition: The zone is defined by the total range of *Rectocythere* (*Lydicthere*) *horrída*.

Remarks: The zonal index occurs in flood proportions in eastern England in some samples it forms up to 99% of the total fauna. The rare specimens of an angular species of *Galliaecytheridea* (*G.* sp. cf. *spinosa*) with a pointed, slightly spinose posterior, appears to be a form intermediate between *Galliaecytheridea mandelstami kilenyii* and *Galliaecytheridea spinosa*.

Geographical distribution: Although present in eastern England, it has not been recognised in Dorset, where sampling has failed to yield any ostracods. It is not clear whether this is due to sample failure or palaeoenvironmental conditions.

EOZ3. *Mandelstamia (Xeromandelstamia) maculata* Total Range Zone

Stratigraphical range: Bolonian (Kimmeridge Clay Beds 41-42 in Dorset and 40-42 in eastern England); *Wheatleyensis* and earliest *Hudlestoni* zones.

Typical species: *Mandelstamia (Xeromandelstamia) maculata*, *Schuleridea moderata*, *Galliaecytheridea* sp. cf. *G. spinosa*, *Paranotacythere (Unicosta) effusa*, *Paranotacythere (Unicosta)* sp.

Definition: The zone is defined by the total range of the index species.

Remarks: The zonal index has been recorded between the Grey Ledge Stone Band and the Blackstone in Dorset (Beds 41-42) according to Kilenyi (1969), but in eastern England, it has been recorded in Bed 40 (Wilkinson, 1983a,b). The Last Appearance Datum (LAD) of *Paranotacythere effusa* is within the lower part of the ostracod zone (the stratigraphically highest specimen so far recovered is from the upper part of Kimmeridge Clay Bed 41).

In some cases, e.g. in North Wooton and Hunstanton boreholes (Wilkinson, 1983b, 1988) the zonal index occurs in flood proportions but in the upper part of Bed 42, it may be absent or very rare. Diversity is usually low

Geographical distribution: Southern and eastern England and the Southern North Sea.

un-named Zone

Stratigraphical range: Bolonian (Kimmeridge Clay Bed 43); early *Hudlestoni* Zone.

Typical species: *Schuleridea moderata* and *Paranotacythere (Unicosta)* sp. cf. *P. (U.) nealei*.

Definition: Interval between the LAD of *Mandelstamia (Xeromandelstamia) maculata* and the FAD of *Eocytheropteron aquitanum*.

Remarks: Kimmeridge Clay Bed 43 is usually devoid of ostracods, but may yield small numbers of *Schuleridea moderata* and *Paranotacythere (Unicosta)* sp. cf. *P. (U.) nealei*. When the latter is better known, it may prove biostratigraphically useful.

Geographical distribution: Known from eastern England, and inferred to be present in Dorset from the data included by Kilenyi (1969).

EOZ4. *Eocytheropteron aquitanum* Partial Range Zone

Stratigraphical range: Bolonian (Kimmeridge Clay Bed 44); early Hudlestoni Zone.

Typical species: *Eocytheropteron aquitanum*, *Paranotacythere (Unicosta) pustulata*, *Paranotacythere (Unicosta) sp. cf. pustulata*, *Paranotacythere (Unicosta) sp.*, *Macrodentina (Polydentina) wootonensis*, *Micrommatocythere reticulata sp. nov.* and *Schuleridea moderata*.

Definition: The base of the zone is defined by the FAD of *Eocytheropteron aquitanum*. The upper boundary is defined by the first appearance of the superadjacent zonal index.

Remarks: The sparse faunas that Kilenyi (1969) found in Dorset led Christensen & Kilenyi (1970) to extend the upper boundary of the *M.(X.) maculata* Zone up to the first occurrence of *Galliaecytheridea spinosa*, although *M. (X.) maculata* is not present above Kimmeridge Clay Bed 42. Wilkinson (1983a,b) therefore used *E. aquitanum* to close this stratigraphical gap for the sequences in eastern England. In Dorset, the species is quite rare, although Kilenyi (1969) shows it to be present just above the Basalt Stone Band (i.e. in Bed 44).

Other species that appear for the first time in the ostracod zone are *Micrommatocythere sp.* and, in the highest part of the zone, *Macrodentina (Polydentina) wootonensis* and *Paranotacythere (Unicosta) pustulata* (which may occur in proportions in some samples). The latter species has an ancestral form that is referred to as *P. (U.) sp. cf. pustulata*, in the lower part of the ostracod zone, and which may prove to be a distinct species after further work.

Geographical distribution: Southern and eastern England and the Southern North Sea.

EOZ5. *Galliaecytheridea spinosa* Partial Range Zone

Stratigraphical range: In Dorset: Bolonian (Kimmeridge Clay Bed KC48) to the upper part of the Kimmeridge Clay (late Fittoni Zone). Eastern England: Bolonian (Kimmeridge Clay Beds 45-47); Pectinatus Zone (the top of the Pectinatus and succeeding ammonite zones have been removed by erosion prior to deposition of the Sandringham/Spilsby Sands).

Typical species: *Galliaecytheridea spinosa*, *Dicrorygma (O.) brotzeni*, *Micrommatocythere reticulata* Wilkinson, sp. nov., *Paranotacythere (Unicosta) pustulata*, *Paracypris problematica*, *Hechticythere serpentina*, *Klentnicella nealei*,

Aalenia inornata, *Aalenia gracilis*, *Schuleridea moderata*, *Mandelstamia (Xeromandelstamia) tumida* and *Macrodentina wootonensis*

Definition: The zone is defined by the inception of *Galliaecytheridea spinosa*. Its upper boundary is defined by the appearance of *Galliaecytheridea compressa*. The zone is divided into a subzone by the appearance of *Galliaecytheridea polita*.

Remarks: *Micrommatocythere reticulata* is synonymous with *Monoceratina* sp. 1 of Kilenyi (1969). The LADs of *Schuleridea moderata*, *Mandelstamia (X.) tumida* and *Macrodentina (P.) wootonensis* are in the lower part of the ostracod zone (probably within the Pectinatus Zone), the FAD of the genus *Aalenia* is in the middle part of the Rotunda Zone (according to Christensen & Kilenyi, 1970), and those of *Paracypris problematica*, *Klenticella nealei* and *Hechticythere serpentina* are near the top of the ostracod zone (in the upper part of the Rotunda Zone).

Geographical distribution: Southern and eastern England and the Southern North Sea.

EOZ6. *Galliaecytheridea polita* Total Range Zone

Stratigraphical range: Bolonian (mid Fittoni Zone)

Typical species: This is situated a sparsely populated part of the Kimmeridge Clay in southern England. *Galliaecytheridea spinosa* may occur, but often only the subspecies is present.

Definition: The total range of *Galliaecytheridea polita*.

Remarks: Christensen & Kilenyi (1970) used this species as a zonal indicator. As it is very restricted stratigraphically and having a patchy geographical distribution, it is here considered as a subzonal index.

Geographical distribution: Southern and eastern England and the North Sea Basin.

EOZ7. *Galliaecytheridea compressa* Partial Range Zone

Stratigraphical range: Bolonian (highest Kimmeridge Clay); Late Fittoni Zone.

Typical species: *Galliaecytheridea compressa*, *Paranotocythere (Unicosta) elongata*, *Paranotocythere (Unicosta) rimosa*, *Hechticythere serpentina*, *Macrodentina rudis*, *Macrodentina transiens*, *Macrodentina retirugata*, *Galliaecytheridea* sp. (*G. postrotunda* sensu Barker, 1966a) and *Cytherelloidea* sp. (*C. paraweberi* sensu Barker, 1966b).

Definition: The base of the zone is defined by the inception of *Galliaecytheridea compressa* and the upper boundary is defined by the inception of the superadjacent zonal index (see below).

Remarks: This zone was recognised by Christensen (1974) who quoted the range given by Barker (1966a). The zone as recognised herein differs from the concept of Christensen (1974), in that it is confined to the highest Kimmeridge Clay.

Geographical distribution: Southern England, North Sea and Danish embayment.

EOZ8. *Eocytheridea eusarca* Total Range Zone

Stratigraphical range: Lower Portlandian (Portland Sand and Portland Stone); Albani-Anguiformis zones.

Typical species: As for the *G. compressa* Zone, but also including *Eocytheridea eusarca* and *Paranotacythere (Unicosta) caputmortuum*. In the higher part of the zone (in the Portland Stone), *Wolburgia visceralis*, *Fabanella boloniensis*, *Procytheropteron bicosta* and *Paracypris weedonensis* appear according to Anderson (1985).

Definition: The FAD and LAD of *Eocytheridea eusarca* defines zone.

Remarks: The boundaries of the subzone are poorly defined due to the sparse and patchy nature of the faunas in the Portland Sand and Portland Stone and to the major palaeoenvironmental changes associated with the commencement of the accumulation of the Purbeckian facies.

Geographical distribution: Southern England (Dorset and the Aylesbury regions).

***Eocytheridea eusarca* Total Range Zone**

***Wolburgia visceralis* Partial range Subzone**

Stratigraphical range: Lower Portlandian (Portland Stone); Okusensis-Anguiformis zones.

Typical species: As for the zone, but including *Wolburgia visceralis*, *Fabanella boloniensis*, *Procytheropteron bicosta* and *Paracypris weedonensis*.

Definition: The lower boundary of the zone is defined by the inception of *Wolburgia visceralis*. The upper boundary is difficult to define due to the palaeoenvironmental conditions, but in southern England it is considered to be in the basal Purbeck where species of *Cypridea* and *Damonella* make their first appearance.

Remarks: The fauna is very heavily controlled by the palaeoenvironment and facies so that the subzone is poorly defined and of only local relevance.

Geographical distribution: Southern England (Dorset and the Aylesbury regions).

5. THE JURASSIC/CRETACEOUS BOUNDARY

1. Introduction

The fundamental problem encountered in biostratigraphical studies of "fresh water" Ostracoda such as those of the Early Cretaceous of southern England, is relating them to an internationally recognised stratigraphy. Most systems of calibration and correlation are based on marine faunas such as ammonites, foraminifera etc., so that the position of boundaries in the non-marine realm remain conjectural. Whereas fresh water ostracods are often useful in biostratigraphical subdivision on both intra- and inter- basinal scales, they cannot be used satisfactorily in correlations with marine sequences. Inevitably, other criteria have to be used such as pollen (which is dispersed by wind and therefore may be found in both the marine and non-marine milieu), charophytes (dispersed in estuarine conditions and thus having links with the open marine milieu), sequence stratigraphy and, to a more limited extent, lithological and mineralogical characteristics. In the case of the Purbeck/Wealden sequences of southern England, occasional marine transgressions have allowed the incursion of foraminifera and ostracods tolerant of brackish or brackish-marine conditions, and these form a useful link with marine-based stratigraphy. They are a guide only, for they are generally rare or patchily distributed both geographically and stratigraphically, but they give some important additional points of reference.

Assemblages from the Tisbury, Fairlight, Hartwell, Kingsclere, Mountfield and Henfield boreholes (for locality details see Anderson, 1985), together with collections from Dorset and Town Quarry Gardens, Swindon have been examined in order to determine the distribution of "marine" ostracods. The term "marine" is used in a loose sense to distinguish it from the fresh water *Darwinula* and *Cypridea*-dominated assemblages and the brackish water *Fabanella-Theriosynoecum-Mantelliana* dominated associations. Several positions have been postulated for the Jurassic/Cretaceous boundary, options usually favoured being either 1) the base of the Purbeck or 2) the Cinder Beds. Neither are satisfactory in terms of the "marine" ostracod faunas, however, a position a little above the base of the Purbeck

facies, between the Stair and Swindon Faunicycles, is the best fit in southern England.

2. The Jurassic Cretaceous boundary in Britain

There has been much debate as to the stratigraphical significance of the Cinder Beds, and its age. Traditionally it has been regarded as the base of the Cretaceous, in England, and, following Casey's understanding of the boundary, it would equate with the base of the Ryazanian Stage, ie. the *P. runctoni* Zone (Casey, 1963). This is also the case if the concept of Hoedemaeker (1987) is followed, as he associated the boundary with the *S. alpina* Subzone. Oertli (1963) and Cope *et al.* (1980) regarded the type Purbeck as being entirely Berriasian, thus considerably lowering the boundary. The notion in favour of lowering of the Jurassic/Cretaceous boundary is supported by the ostracods (see below) and charophytes (Feist *et al.*, 1995), although the favoured position is a little above the base of the Purbeck, at about the level of the Adit Limestone.

The Portlandian is overlain conformably by the Purbeck facies (the Lulworth Formation) in Dorset, although further east in the Weald area there is said to be a gap in the sequence (Wimbledon & Cope, 1978). In the Weald the Purbeck facies disconformably overlies the Portlandian, the underlying Portlandian being of Kerberus and Glaucolithus zones. The gypsiferous beds of the Weald have generally been considered to be coeval with the gypsiferous beds of Dorset, but Wimbledon and Hunt (1983) and Allen & Wimbledon (1991) came to the conclusion that the basal Purbeck deposits of Dorset are not represented in the southern Weald. The Broadoak Member contains a marine ostracod fauna that closely resembles that of the latest Bolonian and early Portlandian and there is no evidence for a Cretaceous age. This conclusion is also reached by the examination of the charophytes (Feist *et al.*, 1995) which are of Tithonian age in the basal Broadoak Formation, but Berriasian immediately above the Adit Limestone. This would indicate that the Jurassic/Cretaceous boundary is present in the south Weald and that the basal Purbeck facies are latest Jurassic rather than earliest Cretaceous.

Ogg *et al.* (1991) showed that the Portlandian had a normal magnetic polarity which they assigned to CM19. The Pubeck Beds on the other hand, show an alternation of normal and reversed polarity. Normal polarity was recognised at

Text-fig. 21

Uppermost Jurassic and basal Cretaceous stratigraphy in England and coeval deposits in mainland Europe.

Note that the Upper Volgian is placed into the earliest Cretaceous here in an attempt to account for the appearance of *Protocythere*.

(RM= Ridgeway Member. H. Cockle= Hard Cockle)

(Modified from Neale, 1962; Christensen, O.B. 1963, 1968, 1974; Ogg *et al.*, 1991; Allen & Wimbledon, 1991; Schudack, 1994; Elstner & Mutterlose, 1996; Westhead & Mather, 1996; Rostovtsev, K.O. & Prozorowsky, V.A., 1997)

about the level of the Cypris Freestone and Hard Cockle beds, straddling the Soft Cockle Bed/ Marly Freshwater Bed boundary and in the Durlestone Formation. Although it is difficult to compare this signature directly with the internationally recognised magnetostratigraphy (based on Tethyan ammonites, calcipionellids), it would appear to represent chrons M16-18. This method of correlation has potential, but it has only been attempted to a limited extent to date.

3. Latest Jurassic/earliest Cretaceous Ostracoda from England

The examination of the Jurassic Cretaceous boundary is fraught with problems brought about by the rapid environmental changes. Not only was the climate becoming less maritime, but the climate was becoming more arid. So that by the beginning of the Cretaceous, evaporite deposits were accumulating, for example, southern England.

The marine or brackish marine species, which occur in the generally non-marine deposits of the Purbeck/Weald area, can be considered to be opportunistic taxa, able to take advantage of short term incursions of more saline water conditions during short periods of transgression. Wilkinson (1983) argued that a number of late Kimmeridgian taxa took advantage of the unstable environment during oil-shale formation and a few of these same genera were also capable of invading areas of lower salinities when conditions permitted, namely *Galliaecytheridea*, *Paranotacythere*, *Macrodentina* and *Schuleridea*.

The late Bolonian (in the sense of Cope 1995, i.e. late Kimmeridgian *sensu anglico*), between the close of the Palassioides Zone through to the Fittoni Zone, was a time when *Hechticythere serpentina*, *Paranotacythere pustulosa*, *Paracypris* sp, *Monoceratina* sp, *Galliaecytheridea polita* and, during the latest Fittoni Zone, *Galliaecytheridea compressa* dominated the low diversity ostracod populations. Towards the close of the Bolonian, rare specimens of *Macrodentina retirugata* and *Prohutsonia elongata* entered the record, species that were to become more common during the Portlandian.

As the data presented by Barker (1966a,b) and Barker *et al.* (1975) show, the Portlandian was a period of transition between the fully marine Kimmeridge Clay and the non-marine Purbeck and Wealden sequences. This is reflected in the assemblages in Dorset, the area around Aylesbury and Swindon, as well as the assemblages recovered from the Weald boreholes. During the early Portlandian, at

Text-fig. 22

Stratigraphical distribution of key "marine" Ostracoda in the Jurassic/Cretaceous boundary interval of Britain.

the time when the Portland Sand accumulated, assemblages continued to be dominated by *Hechtythere serpentina* and *Galliaecytheridea compressa*, but *Macrodentina retirugata* and *M. transiens* were common to abundant at times and species such as *Paranotacythere caputmortuum*, *Paraschuleridea buglensis*, *Galliaecytheridea* sp (*G. postrotunda* sensu Barker 1966, non Oertli), *Eocytheridea eusarca*, *Prohutsonia elongata* and *Cytherelloidea* sp (*C. paraweberi* sensu Barker, non Oertli) were also represented.

Assemblages from the Portland Stone of Dorset and the Fairlight Borehole are essentially similar to those in the Portland Sand, although *Galliaecytheridea* is lacking, species of *Macrodentina* are more common and *Procytheropteron bicostata*, *Wolburgia visceralis* and *Fabanella boloniensis* are present (Anderson, 1941, 1985; Barker, 1966a,b; Wilkinson, unpublished data). Very rare specimens of *Cypridea* (*C. dunkeri* and *C. tumescens*) may be present according to Anderson (1985), based on his work at Town Gardens Quarry, Swindon.

The lowest part of the Purbeck Beds are missing in the Weald (e.g. the Fairlight Borehole), the earliest assemblage being placed in the Warren Faunicycle. The missing Quanton Faunicycle (see Anderson, 1985 and references) and the Portlandian /Purbeck boundary can be seen in Dorset, in the Aylesbury district, and the Town Gardens Quarry, Swindon. The assemblage is transitional. *Macrodentina* and *Wolburgia*, which together form over 60% of the population in the Portland Stone, are much reduced in proportion, their place being taken by *Fabanella* and *Mantelliana*. Nevertheless, the "S-phase" element of the fauna forms over 99% of the fauna in the Quanton faunicycle and 11 of the 16 species occur in the Portland Stone. The presence of *Hechtythere serpentina*, *Macrodentina retirugata*, *M. rugulata*, *Eocytheridea eusarca*, *Paranotacythere rimosa*, *Paraschuleridea buglensis* and so on, represents an undoubted late Jurassic assemblage rather than an early Cretaceous one. These species are again present in the Warren Faunicycle, (together with species of *Damonella*, *Rhinocypris* and *Theriosynoecum*, which appear for the first time), and although assemblage from the Stair faunicycle is associated with evaporite deposits and is consequently only poorly known, it also appears to be similar.

Hence Assemblage 1 of Anderson (1985 and references) contains typically late Jurassic species. It undoubtedly represents a transition in the fauna between the marine Portlandian and non-marine Berriasian, but the fauna is an extension of the Portlandian association and there are no grounds for separating it from the Jurassic. This conclusion is supported by the presence of Tithonian charophytes Feist *et al.* (1995).

Assemblage 2 of Anderson, beginning with the Swindon Faunicycle, is characterised by the absence of typical Jurassic species such as *Hechticythere serpentina*, *Macrodentina retirugata*, *M.transiens* and *M. rugulata*, and the appearance of large numbers of *Cypridea* and taxa more characteristic of the Cretaceous (*Pseudosubplanites grandis* Subzone). To a great extent this change in the fauna is a function of the palaeoenvironmental regime, which precludes marine and near marine taxa. The base of the assemblage zone must be the favoured position for the Jurassic Cretaceous boundary in southern England and apparently equates with concept that the base of the Cretaceous should be placed at the base of the *B. jacobi* Subzone (Saks, 1975).

The genus *Paranotacythere* is similarly of biostratigraphical importance across the Jurassic Cretaceous boundary according to Bassiouni (1974) and Schudack (1993). Unfortunately, however, the genus is rare in the Purbeck of most borehole material.

One of the spatially more restricted species is *Paranotacythere (Unicosta) nodosaria*. It has a patchy distribution between the Cinder Beds and Mupes faunaicycles in Sussex, Surrey and Dorset, but so far has not been recognised outside southern England. *Paranotacythere (Paranotacythere) cineraria* has been recorded between the Peveril and Corfe Faunicycles, and particularly in the Cinder Beds Faunicycle (Anderson, 1985), and although not common outside the Cinder Beds it has been found in the German Wealden 3 (Bassiouni, 1974).

Paranotacythere (Unicosta) rimosa has a wide geographical range, having been recovered from the Portlandian of Poland (Bielecka, 1975; Kubiaticz, 1983), the Danish Basin (Christensen, 1968) and southern England (Barker, 1966a,b; Barker *et al.*, 1975; Kilenyi, 1978; Wilkinson, unpublished data) and Berriasian of northern Germany (Bassiouni, 1974; Schudack, 1993, 1994). It occurs in the

Portland Stone Member (Kerberus Zone) of Hartwell Borehole, uppermost Portland Stone (?Okusensis Zone) of Fairlight Borehole and Upper Kimmeridge Clay (Fittoni Zone) of Tisbury Borehole. It is particularly common in the Quainton Faunicycle, but is rare and patchily distributed to the Swanage Faunicycle (Barker, 1966a,b; Anderson, 1885).

Finally, *Paranotacythere (Unicosta) favulata*, although not common, ranges sporadically from the Wardour Faunicycle through to the Durlston faunicycle in Dorset Sussex and Surrey. It thus ranges through much of the lower part of the Berriasian and into the basal part of the Ryazanian. It is extremely rare in the Southern North Sea Basin. Witte & Lissenberg (1994) recorded it in the Scruff Greensand Formation, and suggested a Ryazanian origin for it although their specimen may have been caved from the Schill Grund Member. It is restricted to the early Berriasian in Germany (Serpulit and the "Weald 1" at the base of the Buckeberg Formation) according to Bassiouni (1974), who also recorded it from the Berriasian of France, Switzerland, and Poland. It is, therefore, a very useful taxon in terms of recognising the early Berriasian throughout Europe.

4. Ostracoda at the Portlandian/Ryazanian boundary

Stratigraphically, one of the most valuable package of events in the earliest Cretaceous is the sudden and major decline in the pollen *Classopolis*, followed by the inception and extinction of the short lived fresh water ostracod species *Cypridea posticalis* and the eustatic sea level change that resulted in a quasi marine incursion that can be recognised throughout much of Europe (Allen & Wimbledon, 1991). In southern England this package of events took place in the Middle Purbeck and culminated in the Cinder Bed. In the Netherlands and Northern Germany the first two parts of the package is seen in the Katzberg Member, but the third is more problematical. The quasi-marine incursion has been correlated to the Serpulit, but this is contains a non-marine ostracod fauna. However, there is a quasi-marine incursion towards the middle of the Buckeberg Member (in what is sometimes called Weald 3). In the Danish Embayment these events appear to take place in the Rabekke Formation and Vitaback Beds of Bornholm and Scania respectively. Finally, in Poland, this triplet is seen in the Purbeck, possibly culminating in the marine event of the *ryasensis* and *spasskensis* zones.

The Cinder Beds, it has been argued, were deposited during a period of transgression. If so correlation between the Cinder Beds with the termination of E Beds development and the start of accumulation of the D Beds of the Speeton Clay, Yorkshire, becomes a distinct possibility. Several lines of evidence lead to the conclusion that the Purbeck Beds above the Cinder Beds can be correlated with the D7 (upper part of the *S. stenomphalus* Zone and lowest *P. albidum* Zone), D6 (lower *P. albidum* Zone) and (?) lower part of D5 (upper *P. albidum* Zone) of the Speeton Clay. For example, Knox (1991) showed that the marked increase in the kaolinite:illite ratios, which is well known in the Cinder Beds and subsequent deposits, compare exactly to the increase that takes place in the D6 and D7 beds of the Speeton Clay, Yorkshire. A further peak in the Ashdown Beds appears to correlate with a sudden increase in the ratios in the upper part of the Lower Valanginian deposits at Speeton. This clay mineral signature can be related to other areas of Europe such as the Vocontian Trough (Persoz & Remane, 1976; Persoz, 1982).

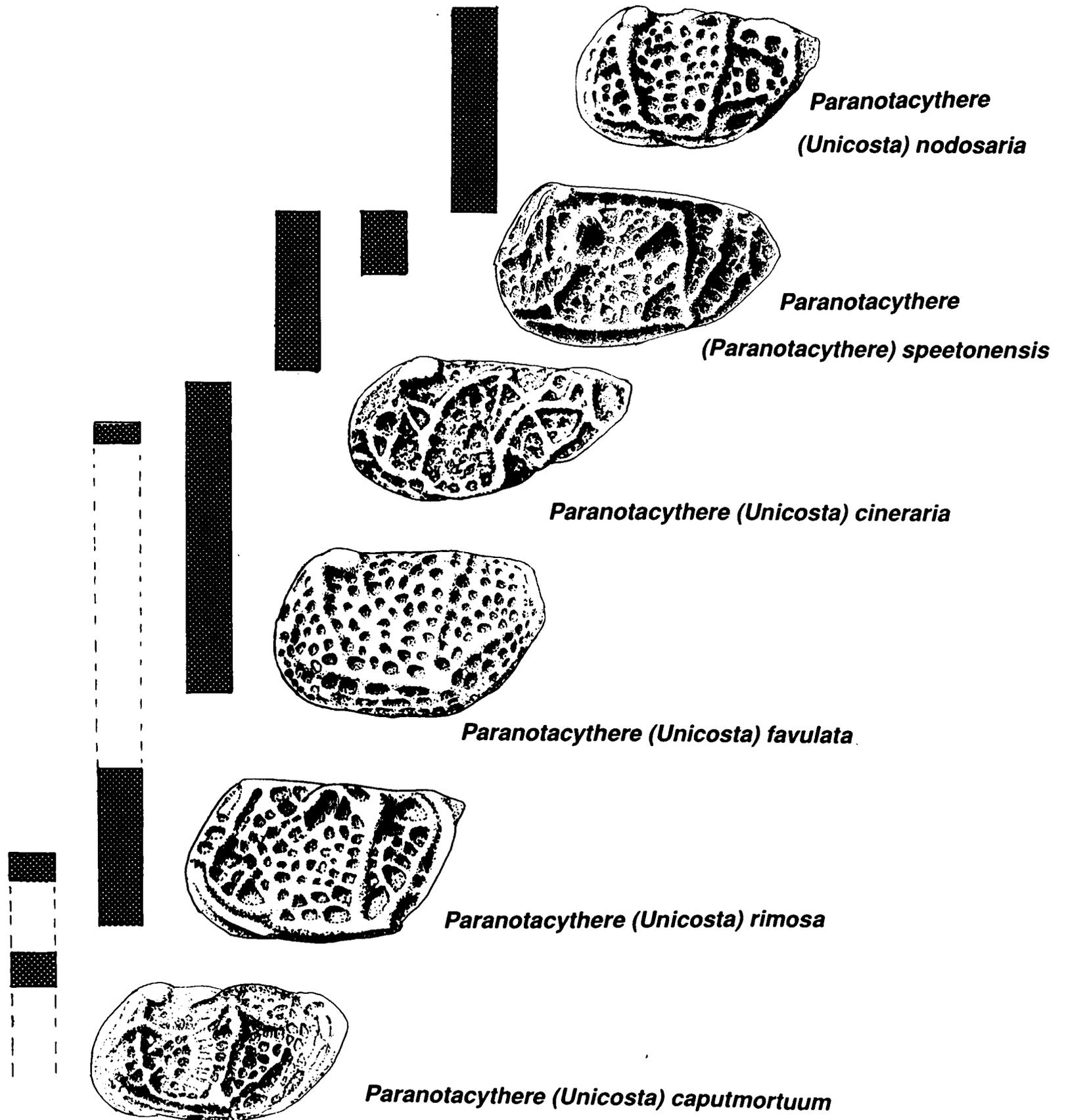
The quasi-marine event which culminates the package of events is characterised by the introduction of *Galliaecytheridea postsinuata* into assemblages dominated by *Cypridea*, *Mantelliana*, *Theriosynoecum*, *Damonella*, etc. This taxon is very closely related to *Galliaecythere teres* of the Speeton Clay of Yorkshire and the Southern North Sea Basin, so much so that intraspecific variation could include both species without too much difficulty. Without getting involved in the "lumper versus splitter" argument, it is worth considering how the two species can be defined and differentiated from each other and whether they should be considered synonymous..

Anderson (1985) recorded the occurrence of *Galliaecytheridea postsinuata* between the Swanage Faunicycle and the Corfe Faunicycle, although 90% of all specimens came from the Cinder Beds Faunicycle and c.4% came from the succeeding Nothe Faunicycle. The extremities of the range varies slightly from borehole to borehole due to its rarity immediately after its inception and prior to its extinction. In the Fairlight Borehole, for example, it extends from the Peveril to Corfe faunicycles, although as in so many localities, its maximum is in the Cinder Beds Faunicycle. *Galliaecytheridea postsinuata* was erected by Wolburg (1962), for a species that was found in the German Wealden 3 and this range was confirmed by

Text-fig. 23

The distribution of *Paranotacythere* across the Jurassic/Cretaceous boundary in Britain.

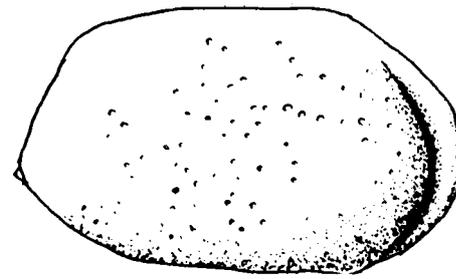
		AMMONITES	OSTRACODA			
CRETACEOUS	RYAZANIAN	<i>albidum</i>	6 Tyneham Durdle Tisbury Brede Mupes Lulworth Greenwood			
			5 Poxwell Bacon Studland Scallop Langton Worth Corfe Royal			
				4 <i>stenomphalus</i> Cinder Beds Peveril		
					4 <i>icenii-runctoni</i> Durlston Netherfield Swanage Ashdown Goldspur	
				BERRIASIAN		3 Mounfield Burwash Robertsbridge Ringstead Penshurst U. Soft Cockle L. Soft Cockle
		2 Wardour Hard Cockle Upway Swindon				
			1 <i>Preplicomphalus</i> <i>Primitivus</i> <i>Oppressus</i>			
		PORTLANDIAN			1 Ridgeway Warren Quinton	
			ALBANI			
BOL.	Fittoni Rotunda Pallasioides					



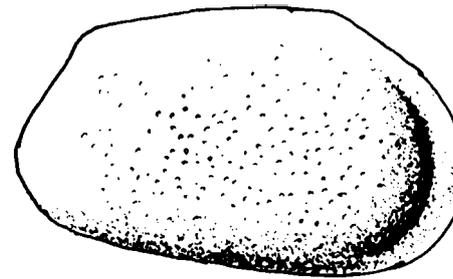
Text-fig. 24

The distribution of *Galliaecytheridea* across the Jurassic/Cretaceous boundary in Britain.

CRETACEOUS	RYAZANIAN	AMMONITES	OSTRACODA				
		<i>albidum</i>	6 Tyneham Durdle Tisbury Brede Mupes Lulworth Greenwood				
			5 Poxwell Bacon Studland Scallop Langton Worth Corfe Royal Croydon Nothe				
				4 Cinder Beds Peveril			
		<i>iceni-runctoni</i>					
		BERRIASIAN		<i>lamplughi</i>	3 Swanage Ashdown Goldspur Mountfield Burwash Robertsbridge Ringstead Penshurst U. Soft Cockle L. Soft Cockle		
					2 Wardour Hard Cockle Upway Swindon		
			JURASSIC		PORTLANDIAN	1 Preplicomphalus	Stair
						Primitivus	Ridgeway Warren Quainton
						Oppressus	
Anguiformis							
Kerberus							
Okusensis							
Glaucolithus							
Albani							
BOL.	Fittoni						
	Rotunda						
	Pallasioides						



Galliaecytheridea postsinuata
(England)



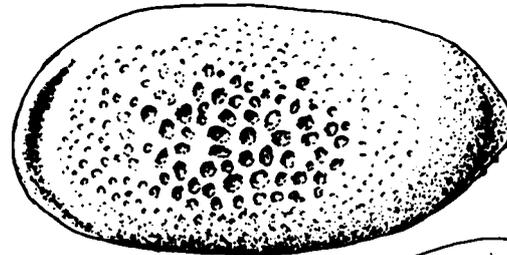
Galliaecytheridea postsinuata
(Germany)



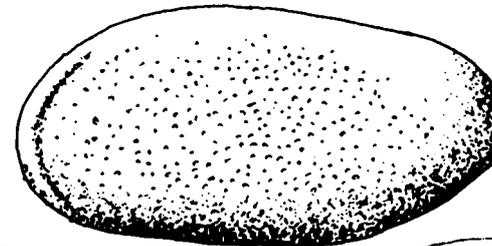
Galliaecytheridea teres



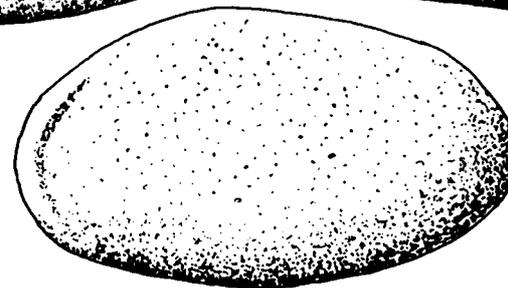
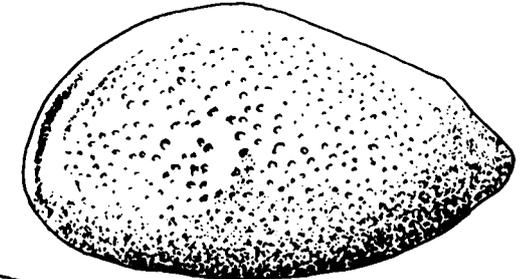
Galliaecytheridea spinosa



Galliaecytheridea compressa



Galliaecytheridea crendonensis



Galliaecytheridea polita



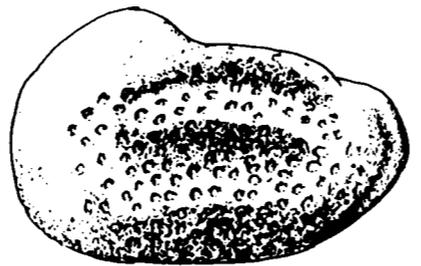
Galliaecytheridea "postrotunda"



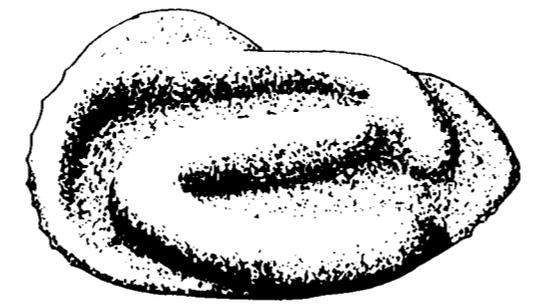
Text-fig. 25

The distribution of Protocytherinae across the Jurassic/Cretaceous boundary.

CRETACEOUS		AMMONITES	OSTRACODA	
L. VALANGINIAN	Polyplichites	7	Hythe	
			Maresfield	
	Platylenticeras	7	Nuffield	
			Eastbourne	
	RYAZANIAN	albidum	6	Bexhill
				Hastings
				Battle
				Tyneham
				Durdle
				Tisbury
stenomphalas		4	Brede	
			Mupes	
icenii-runctoni		4	Lulworth	
			Greenwood	
BERRIASIAN	lamlughi	3	Poxwell	
			Bacon	
			Studland	
			Scallop	
			Langton	
			Worth	
			Corfe	
			Royal	
			Croydon	
			Nothe	
PORTLANDIAN	Preplicomphalus	1	Cinder Beds	
			Peveril	
	Primitivus		Durlston	
			Netherfield	
	Oppressus		Swanage	
			Ashdown	
	Anguiformis		Goldspur	
			Mountfield	
	Kerberus		Burwash	
			Robertsbridge	
Okusensis	Ringstead			
	Penshurst			
Glaucolithus	U. Soft Cockle			
	L. Soft Cockle			
Albani	Wardour			
	Hard Cockle			
Fittoni	Upway			
	Swindon			
Rotunda	Stair			
	Ridgeway			
BOL	Warren			
	Quainton			

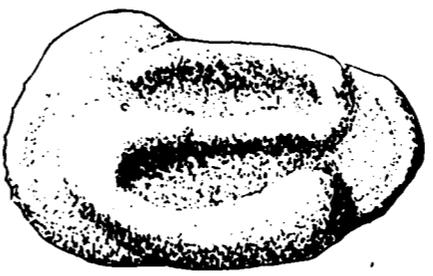
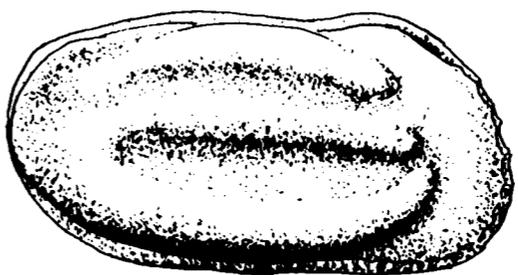


Protocythere hannoverana



Hechticythere serpentina

Protocythere dominici



Hechticythere levae



- Nodiger
- Subditus
- Fulgens
- Opressus
- Nikitini

Upper Volgian
Middle Volgian (pars)

Elstner & Mutterlose (1996). It has a very characteristic lateral outline, particularly at the posterior: the posterior cardinal angle is very well formed, the postero-dorsal margin is slightly concave and the posterior, which is below mid-height, is round to bluntly pointed. The anterior marginal area is flattened which gives a very characteristic shape, particularly in dorsal view.

Galliaecytheridea teres (Neale) was erected by Neale (1962) for a species that was recovered in Speeton Clay Bed D6, Yorkshire. It is identical in shape with the German species, *Galliaecytheridea postsinuata*, figured by Wolburg (1962 page 219, pl.32b, figs.4-5), although, judging from the rather meagre information, it appears to be very slightly smaller.

The present author considers that *Galliaecytheridea postsinuata* Wolburg is synonymous with *Galliaecytheridea teres* (Neale). There are very minor differences between the two, but these are within the limits of specific variability, but may be sufficient to subdivide at the subspecific level. It is an important species that dominates the faunicles both above and below the Cinder Beds Faunicycle (*sensu* Anderson, 1985) and can be used to correlate the Upper Ryazanian *albidum* and (?)*stenomphalas* zones with the Middle Purbeck Cherty Freshwater Beds, Cinder Beds and Arenaceous Beds of southern England and the Wealden 3 in the Lower Saxony Basin of Germany. Further afield, this species has been recorded in the Vedsted Formation of the north-west Danish Embayment and possibly the Vitaback Beds in Scania, where *Galliaecytheridea cf teres* was been recorded by Christensen (1968, 1974).

5. The European context

The stratigraphical distribution of "marine" ostracods of southern England can be used as a standard for comparison and correlation with other areas.

Southern North Sea

Witte & Lissenberg (1994) described the ostracods from the latest Jurassic and earliest Cretaceous of the Southern North Sea Basin. Unfortunately the data is based on ditch cuttings and samples were barren in the highest Portlandian. Nevertheless, a number of taxa are present in both southern England and the North Sea. In the Lower Portlandian *Macrodentina* (*D.*) *retirugta*, *M.* (*M.*) *transiens*, *M.*

(*M.*) *rugulata* *Paranotacythere* (*U.*) *caputmortuum*, *Galliaecytheridea crendonensis*, *G. compressa*, *Prohutsonia elongata*, *Hecticythere serpentina*, *Eocytheridea eusarca*, and so on. These typically Jurassic forms are followed by a sequence devoid of ostracods and when they return they are typically late Ryazanian forms seen at Speeton: *Paranotacythere* (*P.*) *speetonensis*, *P. (P.) reticulata*, *Galliaecytheridea teres*, *Schuleridea juddi*, *Cytheropteron triebeli* and *Mandelstamia (X.) sexti*. There is, therefore, a crucial interval that lacks data so that it does not help in the boundary interval.

Germany

A large amount of research into the ostracods of latest Jurassic and earliest Cretaceous age has been carried out notably by Schmidt (1954), Klingler (1955), Malz (1958), Klingler, Malz & Martin (1962), Bassiouni (1974), M. Schudack (1993) and U. Schudack (1994). Problems in using non-marine ostracod assemblages for correlation over long distances can be appreciated by comparing the distribution of faunas in Germany as outlined by Elstner & Mutterlose (1996) with those in England described by Anderson (1985). The rarity of "marine" ostracods are limit their usefulness, although comparison of the distribution of some of taxa reveal useful relationships. These include *Paranotacythere* and *Macrodentina* from the M\nder Mergel Formation, Katzberg Member, Serpulit Member and B\ckeberg Formation and *Galliaecytheridea postsinuata* in the Weald 3.

Portlandian (i.e. late Tithonian) assemblages comprise low salinity species of *Darwinula*, *Klieana*, *Fabanella* and *Manteliana*, but a low diversity "marine" assemblage including *Paracypris* sp A of Schmidt, "*Mandelstamia*" *inflata*, *Ecytheropteron purum*, *Paranotacythere (U.) caputmortuum*, *Macrodentina maculata*, and *Cytheropteron acutissimum* are also present. This fauna is replaced in the earliest Berriassian (Katzberg and Serpulit members) by *Macrodentina (M.) dictyota*, *Paranotacythere favulata*, *P. (U.) rimosa* and "*Mandelstamia*" *fragilis*, the only taxon to extend up from below being *Paracypris* sp A.

Danish-Polish Trough

Christensen (1963, 1966, 1968, 1974, in Christensen & Kilenyi, 1970) described late Jurassic and early Cretaceous faunas of the Danish embayment. Connection between the Danish and Polish Troughs closed during the Bolonian so that whereas

the *G. dissimilis* and *G. elongata* ostracod zones of the early Kimmeridgian can be recognised in both areas, latest Jurassic ostracod zones recognised in Britain do not extend into Poland. The *Galliaecytheridea compressa* Zone can be recognised only in the Bolonian of Denmark. "Non-marine" conditions persisted through the Jurassic/Cretaceous boundary interval, but marine conditions returned during the Ryazanian. In the Vedsted Formation of the north-west Danish Embayment and possibly the Vitaback Beds in Scania, *Galliaecytheridea cf. teres* was been recorded by Christensen (1968, 1974), which allows correlation with Britain and Germany

Russian Platform

Unlike many areas of northern and northwestern Europe, the palaeoenvironmental conditions of the Russian Platform continued to be dominated by the marine milieu throughout the closure of the Jurassic and in the earliest Cretaceous.. This is reflected in the ostracod assemblages, the continuance of taxa such as *Galliaecytheridea*, *Hechtycythere*, *Mandelstamia* and so on, and the absence of *Cypridea-Fabanella-Thiosynoecum* dominated assemblages.

Assemblages from the Middle Volgian (Panderi and Virgatus zones) of the Russian Platform are dominated by those same genera (although not species) that are also typical of the Bolonian (Upper Kimmeridgian *sensu anglico*, Portlandian *sensu franco*) elsewhere in northern and north western Europe. The total ranges of *Cytherella ovoidea* and *Cytherella recta* are used to define an ostracod zone seen in the Middle Volgian throughout the Russian Platform, but other taxa typical of the Middle Volgian are species of *Cytherella*, *Eocytheropteron*, *Hechtycythere*, *Paranotacythere*, *Mandelstamia* and *Galliaecytheridea*.

The sandstone at the top of the Volgian (Nikitini to Nodigera zones) of the type area at Gorodische are devoid of ostracods, however, Upper Volgian associations have been found in the Viatka and Kama regions further north. These differ from Middle Volgian assemblages by the reduced proportion of *Galliaecytheridea*, the disappearance of *Mandelstamia* and appearance of *Hechtycythere fistulosa*. Upper Volgian sediments (Fulgens-Nodiger ammonite zones) of the Izshma and Pizshma regions, have also yielded ostracod associations that are similar to those from the Middle Volgian, but again differ by a reduced diversity and richness. In this case, *Cytherella* and *Galliaecytheridea* are

particularly reduced, but there is an increase in the diversity and abundance of *Hechticythere*. The Upper Volgian assemblages of the Izshma and Pizshma regions, are characterised by the presence of *Hechticythere levae* and a new species of *Protocythere* (which bears some resemblance to the Berriasian species of the Vocontian Trough) in upper part of Upper Volgian.

One of the characteristic evolutionary advances that took place at the Jurassic/Cretaceous boundary is the *Hechticythere-Protocythere* lineage. *Protocythere* has not yet been identified in the Upper Jurassic (those recorded are without exception members of the genus *Hechticythere*). Thus in areas where marine conditions prevailed across the Jurassic Cretaceous boundary, the evolutionary step from *Hechticythere* to *Protocythere* should form a biostratigraphically useful event. The exact position of this is a problem in northern Europe as this stenohaline genus does not tolerate salinity changes associated with the period. Unfortunately in Britain and other countries surrounding the North Sea Basin, this change is not seen. *Hechticythere serpentina* occurs in the late Portlandian, but the next occurrence of the lineage is in the Valanginian where *Protocythere hannoverana* appears. In southern Europe, in the Vocontian Trough, a number of species appear in the early Berriasian, including *Protocythere gondranensis*.

In Russia *Hechticythere* is frequently found in the Kimmeridgian and Volgian, but the earliest species of *Protocythere* is in the Late Volgian (where a new and as yet undescribed species has recently been recovered. There has been much controversy as to the age and relationship with the standard ammonite calibration, but Russian workers, such as Meseznikov have traditionally placed the Upper Volgian in the highest Jurassic. More recently consensus of opinion is coming round to the idea that the Upper Volgian is Berriasian in age. Thus the appearance of the earliest *Protocythere* species in southern Europe and the northern part of European Russia coincides with the basal Cretaceous.

Southern Europe

Ostracods during the latest Jurassic and earliest Cretaceous in Mesogean area and Vocontian Trough have been described in detail, an ample summary being given in Oertli (1985). Unlike northern Europe, the Vocontian Trough of southern France

remained under the influence of fully marine conditions through the Jurassic/Cretaceous boundary interval. At a time when fresh and brackish water associations dominated the northern regions of Europe, true marine taxa were present here.

Latest Jurassic associations are not well known, but "*Macrodentina retirugata*" and "*Paranotacythere aff interrupta*" have been recorded although they do not seem to be identical to those species in North Western Europe. During the Berriasian the central part of the trough (e.g. Berrias and Pertuiset) was submerged under deeper water, although areas of shallower conditions were located around the margins (e.g. Montagnole, Bauges and Chartreuse). As a consequence a variety of ostracod associations were supported, such that *Cytheropteron*, *Protocythere*, *Bythoceratina*, *Baidopillata*, *Paracypris*, *Cytherella* and *Cytherelloidea* are common and diverse in the Mesogean area. However, there are no species in common between southern France and contemporaneous faunas of northern Europe.

The same is true to the west where shallow water assemblages are characteristic of the Iberian Peninsula. Brenner (1976) described a number of low salinity ostracods from Spain, but Late Jurassic faunas in Portugal as described by, for example Ramalho & Rey (1971, 1975), include shallow water marine species such as *Schuleridea*, *Amphicythere* and *Cytherelloidea* and the earliest Cretaceous taxa include *Doloccytheridea*, *Cythereis*, *Cytherella*, *Cytherelloidea* and *Cytheropterina*. The Berriasian of Eastern Spain has yielded *Macrodentina*, *Paranotacythere* and *Clithrocytheridea* (Granier & Fourcade, 1984)@ as well as *Cytherella* and *Bairdia* (Damotte, in Rasplus, Fourcade *et al.*, 1987). Despite the use of several specific names of northern European species, none of the ostracod species of the Iberia Peninsula can be traced into north Western Europe.

6. Conclusions

Although a great deal of effort has been invested in the study of *Cypridea* of the Purbeck/Weald facies during the last fifty years or so, their usefulness in relating sequences to the usual, marine-orientated stratigraphy has met with only limited success. However, by re-evaluating certain opportunistic, euryhaline taxa that entered the region, it is possible to recognise biostratigraphical relationships.

The earliest Purbeck Beds of southern England (i.e. those of the Swindon area and the Weald) are equivalent to the Anguiformis Zone, (late Portlandian/late Tithonian/Middle Volgian) rather than latest Jurassic or even earliest Cretaceous as some have supposed. The concept still held by some, that the appearance of *Cypridea*-bearing Purbeck facies falls wholly within the Cretaceous is clearly erroneous. It also means that the *Fabanella ansata* event, considered so important by Elstner & Mutterlose (1996) takes place in the late Jurassic, not earliest Cretaceous in Britain. Thus, while the event may be a useful marker for the Cretaceous in some basins on a local level, its widespread use as a marker of the basal Cretaceous is flawed and unsafe.

The use of "marine" taxa has limited value due to their rarity. The distribution of *Galliaecytheridea*, *Paranotacythere* and *Protocythere*, however shows a number of stratigraphical relationships which have promise biostratigraphically.

With so many taxonomic and stratigraphical problems associated with the Jurassic/Cretaceous boundary in Europe, a multidisciplinary approach is the only method that will prove useful. No single fossil group or stratigraphical technique has all the answers, but the use of magnetostratigraphy and clay mineralogy, together with more traditional biostratigraphical techniques ("marine" and "non-marine" ostracods, charophytes, pollen, and so on) permit correlation.

6. SPATIAL DISTRIBUTION, MIGRATION AND PALAEOENVIRONMENTAL CONTROLS

1. Spatial distribution and migration

The Kimmeridgian and Volgian foraminiferal assemblages from Gorodishche are very different from those found in the Dorset and it is difficult to compare the two areas. The Kimmeridgian-Volgian foraminifera of Russian Platform are the best known and most studied compared to those from England.

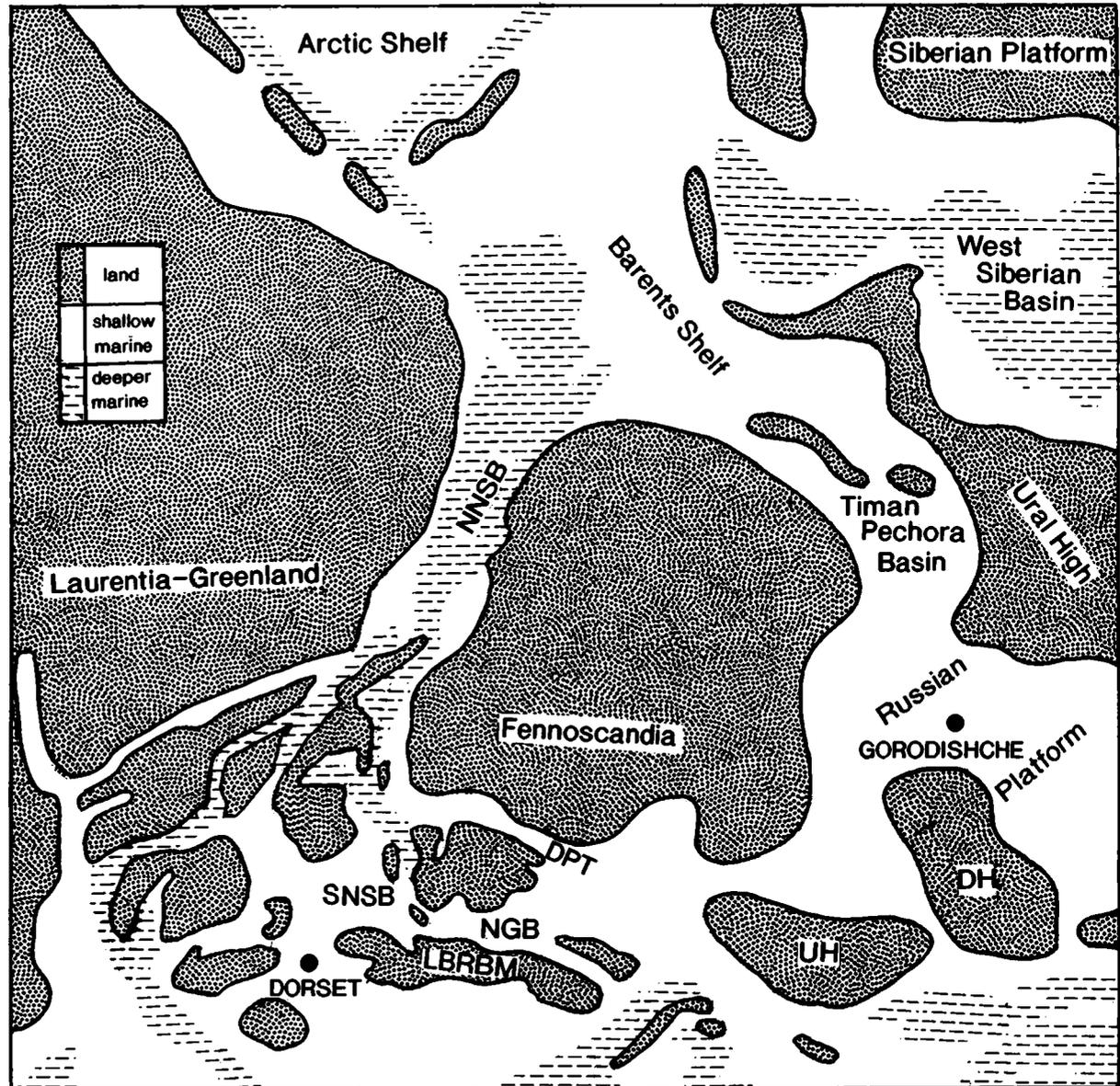
Kuznetsova (1976) divided the Kimmeridgian clay from Eudoxus to Rotunda Zones in the Dorset into four zones, but none of these are recognizable in the present study. Unfortunately, Kuznetsova had only 20 samples from that interval (we have 70 samples). Our conclusions regarding the distribution of foraminifera in Dorset agree with those of Lloyd (1962) and Exton (in Jenkins & Murray (eds), 1989). Although Volgian assemblages in Dorset and Gorodishche contains agglutinated and calcareous foraminifera, there are many differences in the genera and species. In Dorset representatives of the genera *Reophax*, *Kutsevella*, *Trochammina*, *Ammobaculites*, *Textularia*, *Lenticulina*, *Astacolus*, *Citharina*, and *Marginulina* are dominant. In Gorodishche, however, *Ammobaculites*, *Kutsevella*, *Dorothia*, *Lenticulina*, *Astacolus*, *Citharina*, *Citharinella*, *Marginulina*, *Nodosaria*, *Epistomina*, *Mironovella* and *Pseudolamarckina* dominate. Comparison of the Kimmeridgian-Volgian foraminifera of both Dorset and Gorodishche indicated that the following species are common to both areas: *Ammobaculites infravolgensis*, *Kutsevella restricta*, *Kutsevella haplophragmioides*, *Verneuiliinoides kirillae*, *Lenticulina infravolgaensis*, *Lenticulina sywi*, *Astacolus aquilonicus*, *Astacolus nascens*, *Saracenaria pravoslavlevi*, *Saracenaria prolata*, *Marginulina robusta*, *Marginulina striatocostata* and *Pseudolamarckina polonica*.

Portlandian foraminifera of the Polish Lowlands (Bielecka and Pozaryski 1975) appear to be most similar to those from the Lower and Middle Volgian of the Russian Platform. Out of the 64 species recognizes in the Lower and Middle

Text-fig. 26

Palaeogeography of northern Europe during the late Bolonian/middle Volgian (after Ziegler, 1982).

(DH: Donets High. DPT: Danish-Polish Trough. LBRBM: London-Brabant, Rhenish and Bohemian Massif. NGB: North German Basin. NNSB: Northern North Sea Basin. SNSB: Southern North Sea Basin. UH: Ukrainian High.)



Portlandian of the Polish Lowlands, 34 species are known from the Lower and Middle Volgian of the Russian Platform. Lower Volgian assemblages of the Russian Platform and Polish Lowland are characterised by *Pseudolamarckina polonica*. It was found also at Lower Volgian in Borehole 81/47 (Wilkinson, in Cox et al., 1987).

Lenticulina infravolgaensis (= *L. munsteri* (Roemer) of some authors) is the most common species in Dorset, Seine Estuary, France (Guyader 1968), Polish Lowland and Russia. Agglutinating foraminifera are numerous in Kimmeridgian and Volgian deposits of Dorset and Volgian sediments of the Pechora Basin. Moreover, *Reophax*, *Haplophragmoides*, *Recurvoides*, *Ammobaculites*, *Ammobaculoides*, *Kutsevella*, *Trochammina* and *Dorothia* in the Pechora Basin are recorded together with numerous nodosariida and polymorphinida (Yakovleva, 1982). Undoubtedly the mixed microfaunas of typically Boreal and Sub-boreal from the Pechora Basin could be helpful in correlating the sub-boreal, predominantly calcareous, assemblages of Gorodishche with agglutinated-calcareous assemblages of England and North sea.

Comparison of the coeval ostracod associations between the sections are presented in the species diffusion diagrams. The percentage of the identical species in the coeval ostracod associations have been calculated using the formula $C / A+B+C$ (where C is the number of identical species in the two sample being compared; A and B are the total numbers of the species in the two associations being compared).

The ostracod associations of the Upper Kimmeridgian in four section (Izshma, Pizshma, Gorodishche and Karadzir) contain a few identical species, but at the generic level composition they are similar (*Cytherella*, *Galliaecytheridea*, *Mandelstamia*, *Hechticythere*, *Oligocythereis*, and *Eucytherura*). This is indicative of a united basin at this time.

Most species that are present in Upper Kimmeridgian deposits of European Russia, are not present on the West Europe, with the exception of *Hechticythere serpentina*, *Exophthalmocythere fuhrbergensis*, *Amphicythere confundens* and *Galliaecytheridea volgaensis*. In the area of the Russian platform *Hechticythere serpentina* and *G. volgaensis* are present only in Upper Kimmeridgian deposits, but

Text-fig. 27

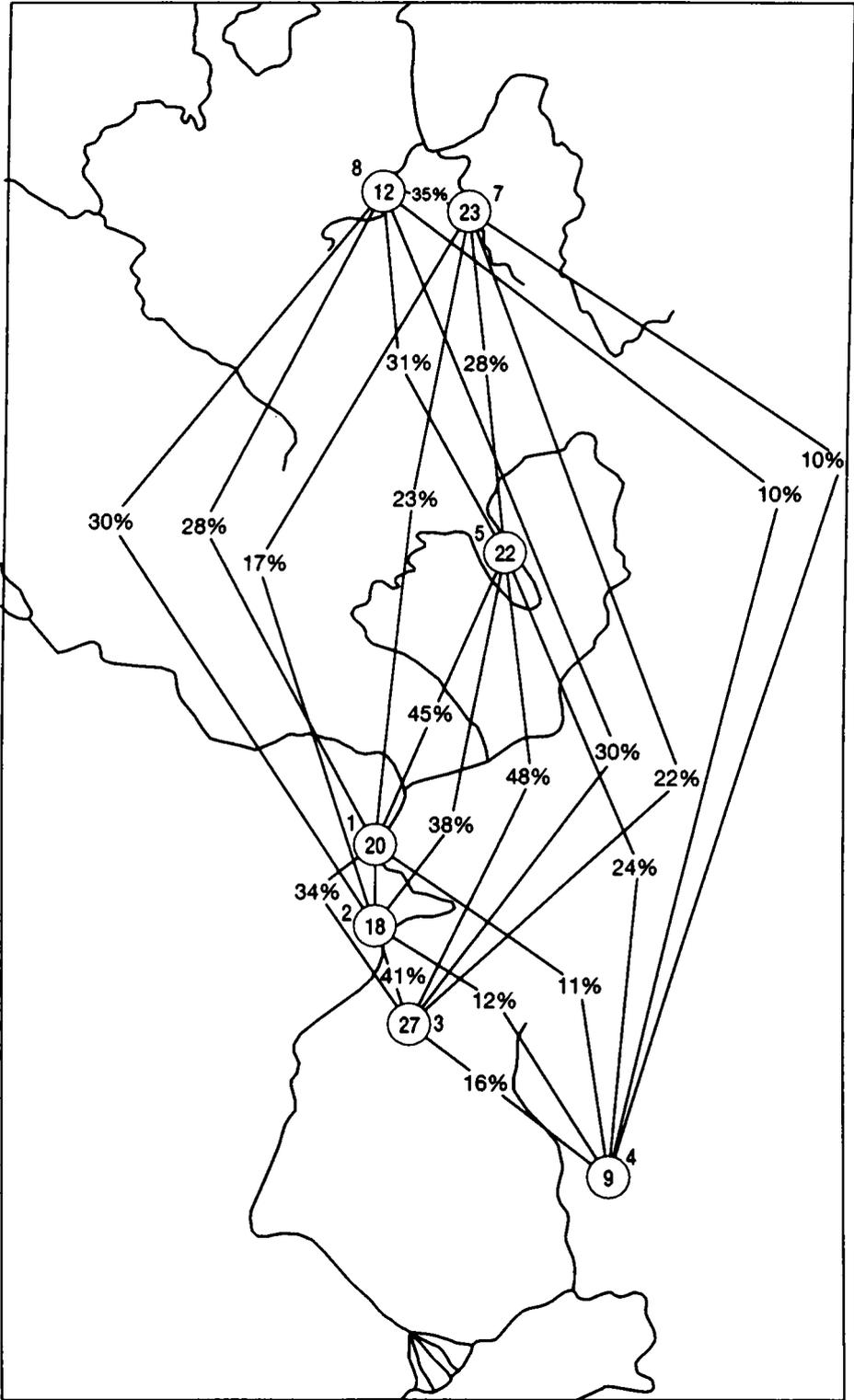
The percentage of ostracod species in common between different sections on the eastern part of the Russian Platform during the Panderi and Virgatus zones (mid Volgian).

Numbered sections:

1. Gorodishche
2. Kashpir
3. Orlovka
4. Karadzir
5. Vyatka-Kama
6. Southern Makariev (ostracods not present)
7. Izhma
8. Pizhma
9. Neritsa

⑩ The number of species at a locality.

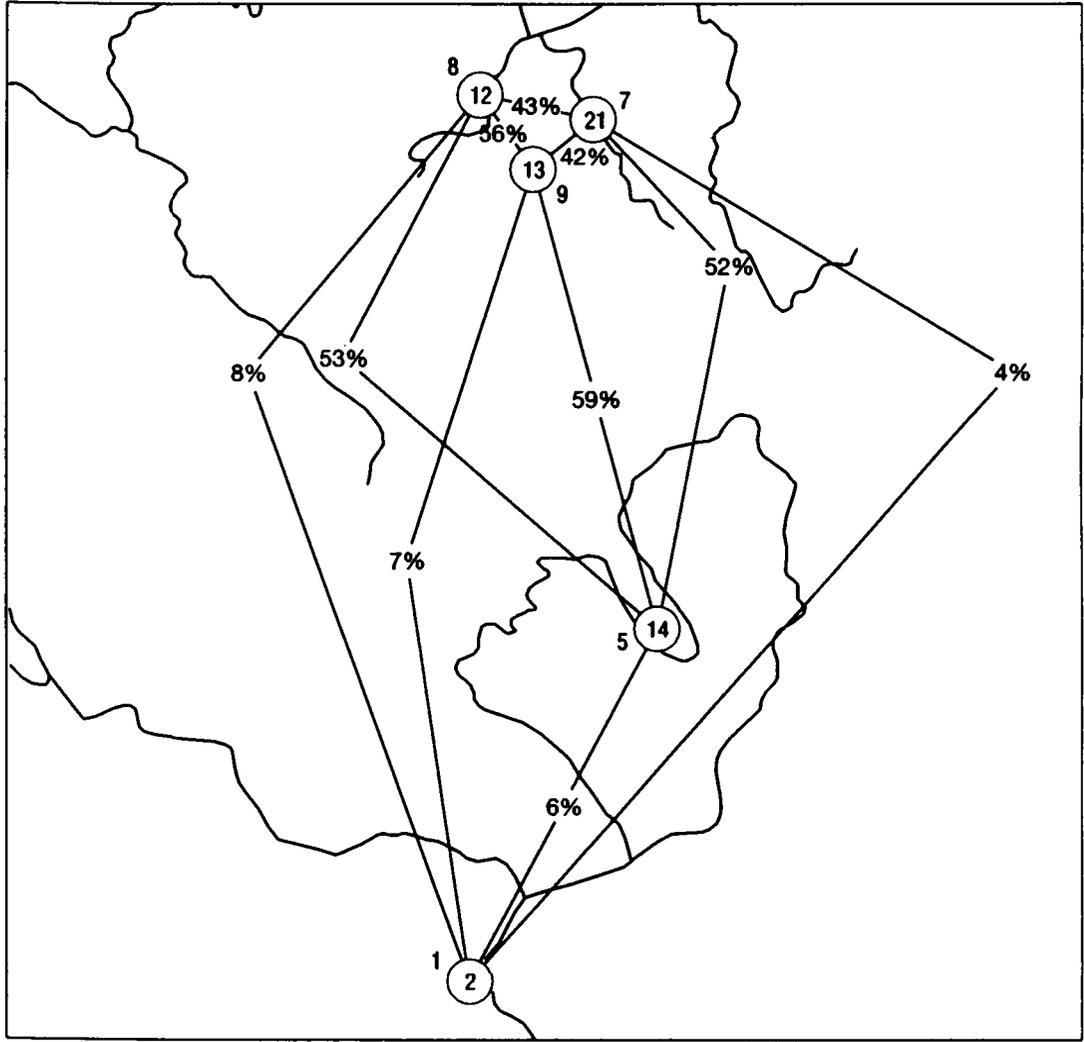
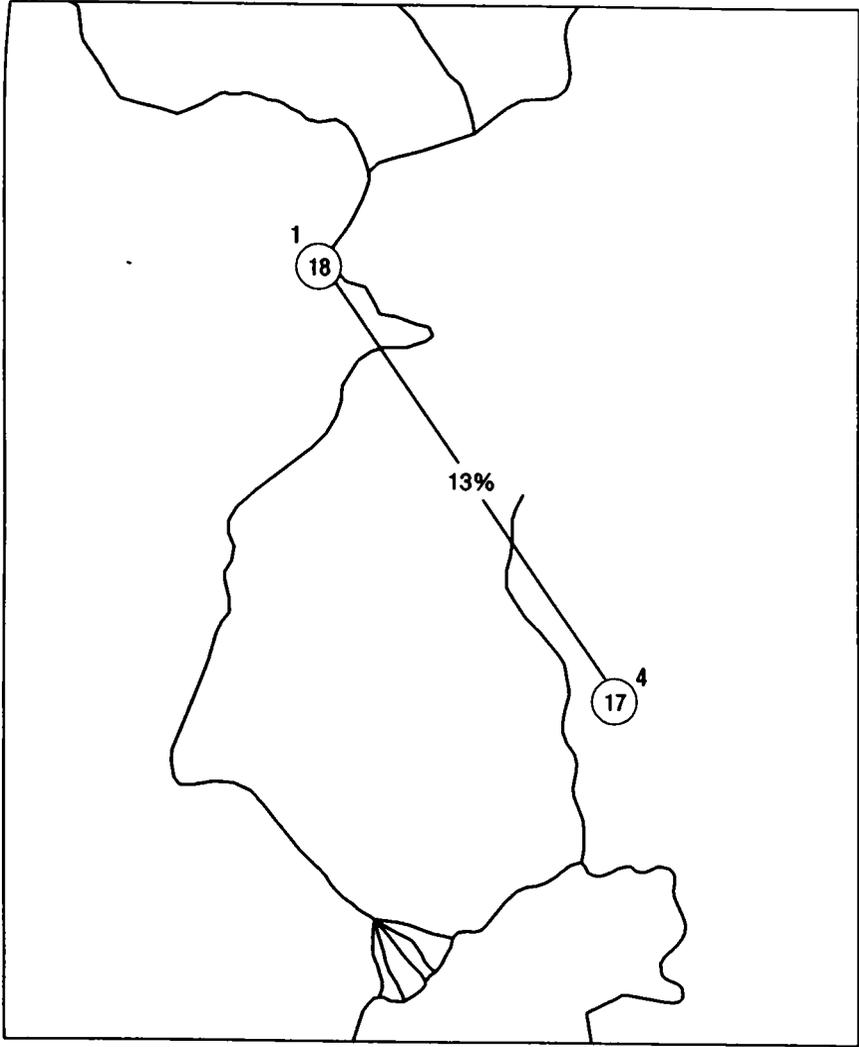
7% The percentage of species common between the two sections



Text-fig. 28

The percentage of ostracod species in common between different sections on the eastern part of the Russian Platform during the Early Volgian (left) and Nikitini Zone of the mid-Volgian (right).

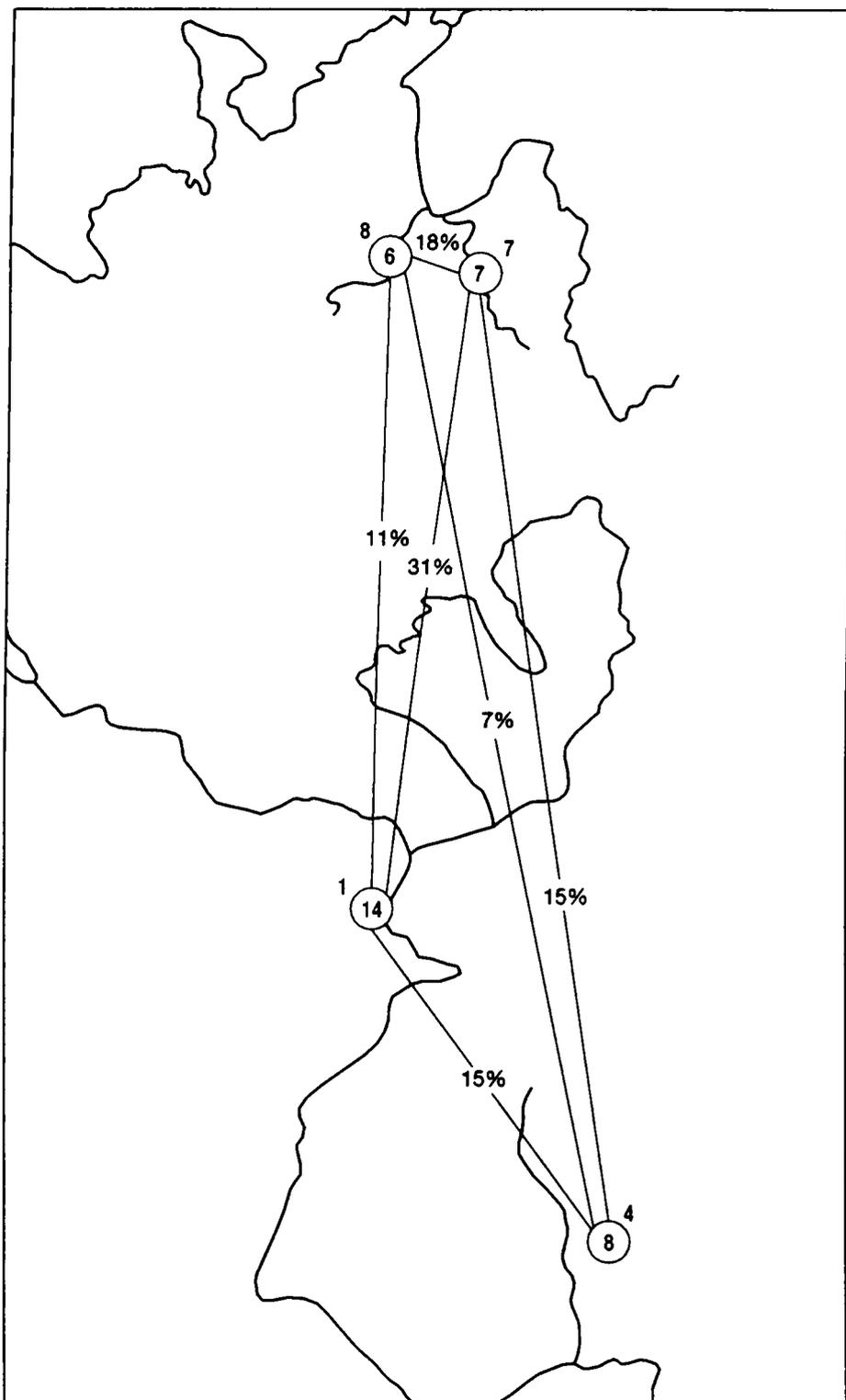
(See text-fig. 27 for an explanation of the numbers)



Text-fig. 29

The percentage of ostracod species in common between different sections on the eastern part of the Russian Platform during the Late Kimmeridgian.

(See text-fig. 27 for an explanation of the numbers)



in Western Europe they have a greater stratigraphic range. *Exophthalmocythere fuhrbergensis* extends from the Oxfordian through to the Volgian (Pseudoscithicus and Sokolovi zones), but is unknown above the Eudoxus Zone in Britain. The ostracod associations of the Lower Volgian at Gorodishche and Karadzir contain a few species in common and the generic composition is similar- *Cytherella*, *Galliaecytheridea*, *Mandelstamia* and *Hechticythere*. The richness of the species composition and the number of genera are typical of the entire Volgian stage.

The *Cytherella ovoidea* - *Cytherella recta* Zone, which are characterized by wide expansion of genus *Cytherella*, *Galliaecytheride* and *Mandelstamia*, can be traced in all of the sections studied in the upper part of Lower Volgian (Sokolovi and Pseudoscythica zones) and Middle Volgian.

From point of view of the biostratigraphy, recognition of the *Macrodentina* (*Polydentina*) *subtriangularis* Zone is very important. It can be traced between the rivers Viatka and Kama, Kashpir, Orlovka, Karadzhir and correspond to the Panderi and Virgatus zones. The zone is geographically widespread and can be recognised in most of the southern regions as well as in the north. In the Karadzhir section it is present in the Panderi zone, while between the rivers Viatka and Kama it is in the Virgatus Zone. Unfortunately, in the Gorodishche section, the *M. (P.) subtriangularis* Zone has not been seen. However, associations with *C. ovoidea* and *C. recta*, have very similar compositions in terms of the genera and species composition, compared to associations with *M. (P.) subtriangularis*. The similarity of the ostracod associations in the Panderi and Virgatus zones of the studied sections show the existence of a single basin.

A sharp difference in ostracod distribution occurs in the Nikitini Zone between the south (Volga Basin) and north (Timano-Pechora Province). In the Volga Basin (at Gorodishche and Kashpir), deposits of Nikitini and late Volgian age (and the Opressus Zone at Gorodishche) are sandstones. They are barren of ostracods. In the Timano-Pechora Province and between the rivers Viatka and Kama, however, this interval is represented by mudstone and calcareous mudstone, which contain a rich association of ostracods.

Apparently, a late Jurassic regression caused the separation of the southern

and northern basins in Russian platform and resulted in the appearance of shallow marine facies, which lacked ostracodes in the Volga River Basin. Comparison of Volgian ostracod associations in east part of Russian platform with associations of the same age in West Europe reveal the considerable difference of fauna as a consequence of the separation of the basins.

None of the species from Russian platform, except *M. (P.) subtriangularis*, are known in West Europe. There is also a difference at the generic level. Only *Galliaecytheridea* is widespread in the Russian platform and Northwestern Europe. *Cytherella* and *Hechticythere* are widespread in Russian Platform, but they are not widespread in England, Germany, France or Poland.

None of England's ostracodes zones are recognisable in east part of Russian platform. However, the species composition from Kimmeridgian and Volgian deposits in Russian Platform and Kimmeridgian to Portlandian deposits in England shows several morphologically very similar, although taxonomically different, species.

Analysis of the stratigraphical ranges and geographical distributions of some key species allows us to make the following observations regarding the foraminifera:

1. The centre of concentration of Volgian calcareous species: *Lenticulina ornatissima*, *L. ilovaiskii*, *L. ornatissima*, *Saracenaria pravoslavlevi* and *S. kasanzevi* was in Karadzhir (Southern Russia). These species migrated from South of Russia across Gorodishche and Poland to England. *Lenticulina ilovaiskii*, *L. ornatissima*, and *Saracenaria kasanzevi* appeared in Karadzhir in early Volgian times. They penetrated into Gorodishche in the Panderi Zone (Pavlovi Subzone and lower part of the Zaraiskensis Subzone) and into Dorset in the Fittoni Zone.
2. *Marginulina formosa* and *Astacolus obliterated* are recorded in Dorset earlier than at Gorodishche.
3. The distribution of *Lenticulina infravolgaensis*, which has a long stratigraphical range, is more complicated. It is reported from the Scitulus to Rotunda Zones of Dorset, but on the Russian Platform and Polish Lowland, *L. infravolgaensis* is a typical species only in Panderi Zone.

4. Few species have the same stratigraphical range in Dorset and Gorodishche. Exceptions are: *Saracenaria pravoslavlevi*, *Astacolus nascens*, *Kutsevella verus*, and *Pseudolamarckina polonica*.

5. *Lenticulina sywi* is a key species for the Virgatus and the Fittoni Zones in the following sections: Kashpir, Orlovka, Karadzhir and Dorset. This implies very rapid migration.

6. During the Panderi Zone (in Russia) and Pallasioides-Rotunda (in England) *Saracenaria pravoslavlevi* together with *Lenticulina infravolgaensis* were recorded in flood proportion in Dorset, Polish Lowland, Pre-volgian region and Pechora Basin. Rapid migration of *S.pravoslavlevi* at that time indicates a possible similarity of environments in Dorset and the European part of Russia (excluding Pechora Basin).

2. Palaeoenvironmental Controls

During the period of eustatic sea level rise that reached its peak in the late Oxfordian and early Kimmeridgian (*sensu anglico*) many species of both foraminifera and ostracods appeared or increased in numbers (on occasions reaching flood proportions). Diversity also reaches its greatest during the late Oxfordian to early Kimmeridgian. With the regression that commenced during the Late Kimmeridgian and continued through the Portlandian (early and Mid Volgian), culminating in the fresh to brackish conditions and the deposition of the Purbeck facies, these taxa disappeared from the record.

The cyclicity, that is a characteristic of the Kimmeridge Clay, resulted in the accumulation of pale grey mudstones, dark mudstones, bituminous mudstones, oil shales and coccolith-rich beds, before returning to the pale grey mudstones. This cyclicity is generally regarded as being associated with the oxygenation of the sediment and sediment:water interface. The oxygen content of the water was never particularly high during the deposition of the Kimmeridge Clay, but a moderately diverse macro- and micro- fauna was supported during the period represented by the pale grey clays, implying that oxygenation of the water was adequate. The kenoxia during the accumulation of the bituminous mudstones and oil shales resulted in, at best, very impoverished benthonic faunas. This oscillation of the low oxygen concentration in the water resulted in high physical stress in the faunas and only those able to tolerate these harsh conditions survived.

Text-fig. 30

Palaeoenvironmental parameters during the Kimmeridgian (*sensu anglico*) and Portlandian in the England and the North Sea Basin. Major erosion surfaces (which are sequence boundaries) are after Wignall (1991) and Coe (1996), minor erosion surfaces that bound many of the Kimmeridge Clay beds are not shown.

Stage	Ammonite zones	Oil shale	Erosion surfaces	Palaeoenvironmental conditions
PORTLANDIAN	Lamplughi		◀ P4	Portland Stone Formation & Purbeck Limestone Formation: Deposition of shallow water oolitic grainstones, shelly packstones, micrites etc; a change from fully marine to non-marine; and a shallowing from subtidal to supratidal depths takes place in southern England. Dysaerobic muds continue to accumulate in the North Sea Basin.
	Preplicomphalus			
	Primitivus			
	Oppressus			
	Anguiformis		▶ P3	Portland Sand Formation: A higher energy phase with deposition of sands and silts in southern England. Carbonaceous in the lower part. Continuation of mudstone facies in the North Sea Basin.
	Kerberus		▶ P2	
	Okusensis		▶ P1	
	Glaucolithus			
Albani				
BOLONIAN	Fittoni		▶ K10	Quiet, oxygenated, muddy bottom conditions in southern England. More dysaerobic in the North sea basins
	Rotunda			
	Pallasioides	▬	▶ K9	Decrease in sedimentation. Faunal change.
	Pectinatus	▬		
	Hudlestoni	▬	▶ K8	Mudstones and oil shales. High stress conditions related to dysaerobia & oil shale production.
	Wheatleyensis	▬	▶ K7	
	Scitulus	▬		Climatic change commencing in the Late Kimmeridgian reaching a period of aridity during the Hudlestoni Zone.
	Elegans	▬	▶ K6	
KIMMERIDGIAN	Autissiodorensis			Accumulation of silts and muds in quiet shallow marine conditions.
	Eudoxus	▬	▶ K5	
	Mutabilis		▶ K4	
	Cymodoce		▶ K3	
	Baylei		▶ K2 ▶ K1	

Text-fig. 31

Palaeoenvironmental parameters during the Kimmeridgian (*sensu franco*) and Volgian of European Russia. (Insufficient published information exists on the erosion surfaces in terms of their scale and relationships with sequence boundaries).

Stage	Ammonite zones		Oil shales	erosion surfaces	Palaeoenvironmental conditions	
VOLGIAN	LATE	Nodiger		▲	Lowered sea levels and high energy conditions result in the accumulation of conglomerates and coarse sandstones. Erosion surfaces are numerous. Each ammonite zone is bounded by a disconformity. Dysaeroia and 'oil shale' production Normal marine, low energy milieu and the accumulation of muds, calcareous muds. Aerobic conditions Phosphatic nodules occur in the Klimovi Zone to the early part of the Panderi Zone. Mudstones are particularly calcareous in the Pseudoscythicus Zone and lower part of the Panderi Zone	
		Subditus		▲		
		Fulgens		▲		
	MID	Opressus				▲
		Nikitini	Nikitini			▲
			blakei			▲
		Virgatus	Rosanovi			▲
			Virgatus			▲
		Panderi	Zarajskensis	■		▲
	Pavlovi					
	EARLY	Pseudoscythica				
		Sokolovi				
Klimovi						
KIMMERIDGIAN	LATE	Autissiodorensis				
		Eudoxus				
		Acanthicum				
	E.	Kitchini				

The distribution of some taxa, such as *Mandelstamia*, *Schuleridea* and *Galliaecytheridea*, indicate that they were more tolerant genera and indeed at times they are found in flood proportions (for example *Mandelstammia* (X.) *tumida* in the late Hudlestoni and early Pectinatus zones and *Mandelstamia* (X.) *maculata* in the Wheatleyensis Zone). However, in some parts of the Kimmeridge Clay, notably in beds of thick oil shales and coccolith-rich beds, ostracods are absent. Presumably tolerance levels had been exceeded in the low oxygen and unstable environment.

A second controlling phenomenon during the Kimmeridgian, the climatic conditions, also affected both ostracods and foraminifera. There is considerable weight of evidence indicating that climatic variability took place through the late Jurassic of the Northern Hemisphere. Hallam (1984, 1985) showed that the warm humid conditions of the Callovian and Oxfordian was gradually replaced during the Kimmeridgian and Volgian by a belt of arid conditions which was expanding from the south and this influenced run-off and sedimentation. The climatic change to arid conditions is reflected in the evaporite deposits of Oxfordian age in the Central Asian part of the Former Soviet Union. Aridity reached Poland and Germany by the Kimmeridgian/Volgian boundary interval, as indicated by evaporite deposits of that age (Demowska, 1976; Jordan, 1971). Indications are that the arid conditions had reached southern France during the Eudoxus Zone (Courtinat, 1989) and by the Volgian limestone accumulation had commenced and kaolinite had disappeared from the clay mineral associations (Deconinck, 1987).

In southern England (Townson, 1975; Townson & Wimbledon, 1979) and the Celtic Sea (Millson, 1987) the influence of the arid conditions is reflected in the accumulation of red beds, but accumulation of evaporites, did not begin until late in the Portlandian (i.e. late Volgian) at the base of the Purbeck facies. This was also a period of decline in the proportion of kaolinite in the Kimmeridge Clay. This decline had commenced in the Hudlestoni Zone (Wignall & Ruffell, 1990) and by the Portlandian (Mid Volgian), the kaolinite had disappeared from the clay mineral signatures (Quest, 1985). There are still some unanswered questions here, however, as there are some high peaks in the signature in the Pectinatus Zone, nevertheless it seems likely that although the arid climatic belt had not taken a sufficiently tight hold as to trigger the accumulation of evaporites, it was beginning to affect conditions in the area early in the late Kimmeridgian (i.e. early to mid Volgian)

as reflected in the faunas. It seems to be a strong possibility that the influence of maritime conditions and the movement of colder waters from the North (Oschmann, 1988) had the effect of delaying the arrival of these conditions in Britain. It was only when the regression cut off the direct influence from the North during the late Portlandian (Mid Volgian) that the full influence of the aridity was reflected in the deposits.

By the close of the Eudoxus Zone, a number of taxa disappeared and the Autissiodorensis and Elegans zones of Britain and southern North Sea were devoid of ostracods. This was probably due to a combination of environmental parameters: oil shale production and subsequent dysaerobia, climatic changes as well as the regional lowering of sea levels. The reappearance of ostracods in the Scitulus Zone was associated with the origination of a number of new taxa in the region.

The late Hudlestoni to Pectinatus zones in Dorset, eastern England and the North Sea Basin was a period of change for the ostracod fauna. A number of species of *Paranotacythere*, *Galliaecytheridea* and *Dicrorygma* made their first appearance, but this was also the time that *Mandelstamia* disappeared from the area.

Much of the Hudlestoni Zone in marginal marine areas such as Central England and northern France (Boulonnais) is missing, although further into the basin, such as in eastern England and the Southern North Sea, little if any of the succession has been removed and in Dorset sedimentation was continuous. The culmination of the low stand during the mid Hudlestoni Zone, in which Kimmeridge Clay Bed KC44 accumulated, coincides with sequence boundary K8 of Wignall (1991).

The Pectinatus Zone was also a time of regression and the top of the zone is again missing in areas closest to shorelines such as central England (Aylesbury and Swindon areas), eastern England and northern France (Boulonnais). This forms sequence boundary K9 of Wignall (1991) and was followed soon afterwards by the Rotunda Zone event (K10 of Wignall, 1991). These intervals were periods of instability resulting in stress conditions for a number of ostracods, e.g. *Mandelstamia*. The Southern North Sea Basin apparently retained more stable

conditions for in the Dutch Sector some species persisted at least until the close of the late Kimmeridgian and possibly into the early Portlandian (the mid-Volgian) (Witte & Lissenberg, 1994). However the regression and restricted water circulation in the Southern North Sea Basin was sufficient to preclude many taxa.

Grey mudstones with occasional more arenaceous horizons dominate the Upper Jurassic succession and the thick, highly bituminous oil shales that are characteristic of the North Sea are not present in the Kimmeridgian of the Russian Platform. The thickest oil shales in the Ulyanovsk-Kashpir region northwards into the Izhma, Orlovka and Vyatka-Kama regions are in the mid-Volgian Panderi Zone. The major lithological change took place during the Nikitini Zone of the mid-Volgian when end-Jurassic eustatic changes resulted in the accumulation of sandstones with phosphatic nodule horizons.

Environmental conditions during the Kimmeridgian through to the mid-Volgian in Russia rarely approached the high stress conditions of western Europe. The connections with high latitudes remained open and because of continuous marine conditions, the affects of increasing aridity were not apparent here. Selection pressures on ostracoda and foraminifera were less strong in this region. Hence, a number of species that had become established during the Oxfordian tended to range through to the Late Volgian.

However, the eustatic sea level change during the later part of the Volgian resulted in a major environmental change and the disappearance of many species. On the Russian Platform, in the Ulyanovsk-Kashpir area, the long period of accumulation of mudstones in a low energy milieu came to an end with the Panderi Zone and the commencement of the *Virgatus* Zone saw a change in the depositional regime to one dominated by arenaceous sedimentation in higher energy conditions. Ostracods and, except for a very few specimens, foraminifer are not present. In the Timan-Pechora Basin and Pre-Caspian region, however, where mudstones were deposited throughout the Volgian, microfaunas survived.

The Kimmeridgian and Volgian represent a period of maximum eustatic sea level rise according to Hallam (1978). That is reflected in the assemblages of foraminifera. In comparison with those of the Dorset coast the Volgian foraminifera

in the Russian Platform contain more varied nodosariid together with a great number of form such as *Epistomina*, *Mironovella*, *Pseudolamarckina* and large agglutinating forms (*Haplophragmium*) thought to indicate warmer, normal marine and possibly deeper water conditions. The greater variety of nodosariids suggest more stable environments.

The upper part the Middle Volgian and Upper Volgian in Gorodishche and Kashpir were deposited under generally shallow water conditions. This may account for the low number of foraminifera. In Southern England the fauna consist of agglutinating forms together with representatives of nodosariids, but without *Epistomina*. Abundant small, flattened, fine-grained agglutinated *Kutsevella*, *Trochammina*, *Textularia* and pyritised or dissolved tests of calcareous species (*Lenticulina*) usually indicate stagnant low energy fairly deep condition in the late Kimmeridgian and early Volgian period in Dorset. These stagnant periods were probably of short duration. *Lenticulina infravolgaensis* appears to be more tolerant of these dysaerobic conditions compared to other nodosariids. It is usually numerous in all sections. In later Kimmeridgian and early Volgian times in the central and southern parts of Russian Platform the depth of water appears to have been less than in Dorset.

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APPENDICES

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APPENDIX I

Foraminiferal species list

- Ammobaculites gracilis* Dain, 1976
Ammobaculites infravolgensis Mjatliuk, 1939
Ammobaculoides jurassicus Yakovleva, 1977
Ammobaculoides ruckyoungi Hedinger, 1993
Astacolus aquilonicus (Mjatliuk, 1939)
Astacolus comptulaeformis Dain, 1976
Astacolus hoplitiformis K. Kuznetsova, 1976
Astacolus inflatiformis Dain, 1972
Astacolus klahni (Mjatliuk, 1961)
Astacolus loinoensis Dain, 1976
Astacolus nascens K. Kuznetsova, 1976
Astacolus obliterated Furssenko, 1969
Astacolus quinquecostatus K. Kuznetsova, 1976
Bulbobaculites deceptorius (Haeusler, 1883)
Cancrisiella jurassica (Mjatliuk, 1953)
Ceratobulimina cf. *lika* Dain, 1976
Ceratobulimina lika Dain, 1976
Citharina brevis (Furssenko, Polenova, 1950)
Citharina culter (Furssenko, Polenova, 1950)
Citharina kujaviensis Bielecka, Pozaryski, 1954
Citharina nitidiuscula K. Kuznetsova, 1976
Citharina paralella Bielecka, Pozaryski, 1954
Citharina raricostata (Furssenko, Polenova, 1950)
Citharina raricostata (Furssenko, Polenova, 1950)
Citharina ex gr. *sparsicostata* (Reuss, 1863)
Citharina spp.
Citharinella emendata K. Kuznetsova, Umanskaja, 1970
Citharinella spp.
Citharinella uhligi (Furssenko, Polenova, 1950)
Conorboides propatulus Dain, 1976
Dentalina spp.
Eoguttulina liassica (Strickland, 1846)
Eoguttulina oolithica (Terquem, 1874)
Epistomina biumbonata Mjatliuk, 1953

Epistomina gorodischensis (Dain, 1971)
Epistomina praereticulata Mjatliuk, 1953
Epistomina praereticulata Mjatliuk, 1953
Epistomina stellcostata Bielecka, Pozatyski, 1964
Epistomina aff. *uhligi* Mjatliuk, 1939
Epistomina ventriosa Espital, Sigal, 1963
Epistomina sp.
Gaudrinella decurvata Dain, 1976
Geinitzinita penicillum (Furssenko, Polenova, 1950)
Globulina circumflua Dain, 1976
Glomospirella porcellana (Furssenko, Polenova, 1950)
Glomospirella porcellanea (Furssenko, Polenova, 1950)
Grillina nodulosa (Furssenko, Polenova, 1950)
Grillina tjumenika (Tylkina, 1972)
Haplophragmium monstratus (Dain, 1971)
Haplophragmium subaequalis (Mjatliuk, 1939)
Haplophragmoides sp.
Haplophragmoides tryssa Loeblich, Tappan, 1950
Haplophragmoiges latidorsatum (Bornemann, 1855)
Kutsevella haplophragmioides (Furssenko, Polenova, 1950)
Kutsevella ex gr. *haplophragmioides* (Furssenko, Polenova, 1950)
Kutsevella ex gr. *labythnangensis* (Dain, 1972)
Kutsevella petaloidea Yakovleva, 1980
Kutsevella verus (Dain, 1976)
Lenticulina abrupta Dain, 1976
Lenticulina ex gr. *besairiei* Espital, Sigal, 1963
Lenticulina delucida Dain, 1976
Lenticulina dogieli (Furssenko, Polenova, 1950)
Lenticulina ilovaiskii Furssenko, 1965
Lenticulina infravolgaensis (Furssenko, Polenova, 1950)
Lenticulina kachpurica (Mjatliuk, 1939)
Lenticulina cf. *kassini* Yakovleva, 1989
Lenticulina kovalevskii Dain, 1976
Lenticulina ornatissima (Furssenko, Polenova, 1950)
Lenticulina ponderosa Mjatliuk, 1971
Lenticulina postkarlaensis K. Kuznetsova, 1976
Lenticulina spp.
Lenticulina undorica K. Kuznetsova, 1969

Lenticulina uralica (Mjatluk, 1939)
Lenticulina vistula Bielecka, Pozaryski, 1954
Marginulina formosa Mjatluk, 1939
Marginulina gluschisaensis Dain, K.Kuznetsova, 1971
Marginulina gracilissima Reuss, 1862
Marginulina impropria Basov, 1976
Marginulina pseudolinearis K.Kuznetsova, 1965
Marginulina robusta Reuss, 1862
Marginulina spp.
Marginulina striatocostata Reuss, 1862
Marginulina transmutata Basov, 1967
Marginulina zaspelovae Romanova, 1959
Marginulinita kasahstanica (Kasanzev, 1934)
Mironovella alveolata Mjatluk, 1951
Mironovella gemina Dain, 1976
Mironovella mjatlukae Dain, 1970
Nodosaria grossulariformis Basov, 1969
Nodosaria osynkiensis Mjatluk, 1939
Nodosaria pseudohispida Gerke, 1968
Nodosaria scythicis Furssenko, Polenova, 1950
Nodosaria spp.
Nubecularia mirabilis E.Bykova, 1952
Oolitella jurassica Yakovleva, 1989
Planularia mariae K.Kuznetsova, 1969
Planularia poljenovae K.Kuznetsova, 1976
Proteonina conferrens Lloyd, 1959
Proteonina difflugiformis (Brady, 1879)
Pseudobolivina textularioides Dain, 1976
Pseudolamarckina polonica Bielecka, Pozaryski, 1954
Pseudolamarckina pseudorjasanensis Dain, 1967
Pseudonodosaria tutkowskii (Mjatluk, 1939)
Quinqueloculina mitchurini Dain, 1971
Ramulina nodosarioides Dain, 1959
Recurvoides glomospiroides Dain, 1976
Recurvoides sublustris Dain, 1972
Reophax ex gr. *helvetica* Haeusler, 1883
Reophax hounstoutensis Lloyd, 1959
Reophax sterkii Haeusler, 1883

Reophax ex gr. *sterkii* Haeusler, 1883
Saracenaria alfa K.Kuznetsova, 1976
Saracenaria kasanzevi Furssenko, Polenova, 1950
Saracenaria mirabilissima Furssenko, Polenova, 1950
Saracenaria pravoslavlevi Furssenko, Polenova, 1950
Saracenaria prolata K.Kuznetsova, 1962
Saracenaria tsaramondrosoensis Espital, Sigal, 1963
Saracenaria valanginiana bartenstein, Brand, 1951
Sigmoilinita subpanda (Lloyd, 1962)
Spirillina polygyrata (Gumbel, 1862)
Spiroplectammina cf. *biformis* (Parker, Jones, 1865)
Spiroplectammina inderica Furssenko, 1969
Textularia jurassica (Gumbel, 1862)
Tristix suprajurassica (Paalzow, 1932)
Tristix temirica Dain, 1936
Trochammina elevata Kosyreva, 1972
Trochammina cf. *globigeriniformis* (Parker, Jones, 1865)
Trochammina cf. *nitida* Brady, 1881
Trochammina squamata (Jones, Parker, 1860)
Vaginulinopsis embaensis (Furssenko, Polenova, 1950)
Vaginulinopsis janinae sp.nov.
Verneuilinoides kirillae Dain, 1971

APPENDIX II

Ostracod species list

- Aaleniella (Danocythere) gracilis* Christensen & Kilenyi, 1970
Aaleniella (Danocythere) inornata (Kilenyi, 1969)
Amphicythere confundens Oertli, 1957
Cytherella recta Sharapova, 1939
Cytherella ukrainkaensis Lyubimova, 1955
Cytherelloidea sp cf. *paraweberi* Oertli *sensu* Barker, 1966
Cytherelloidea tenuis Sharapova, 1939
Dicrorygma (Orthorygma) brotzeni Christensen, 1965
Dicrorygma aff. *reticulata* Christensen, 1965
Eocytheridea eusarca (Anderson, 1941)
Eocytheropteron aquitanum (Donze, 1960)
Eripleura prolongata (Sharapova, 1939)
Eocytheropteron aff. *postilum* Lyubimova, 1965
Eocytherura (Vesticytherura) costaeirregularis Whatley, 1970
Exophthalmocythere fuhrbergensis Steghaus, 1951
Fabanella boloniensis (Jones, 1882)
Fuhrbergiella (Fuhrbergiella) ramosa (Lyubimova, 1955)
Galliaecytheridea compressa Christensen & Kilenyi, 1970
Galliaecytheridea denticulata (Sharapova, 1937)
Galliaecytheridea elegans (Sharapova, 1937)
Galliaecytheridea elongata Kilenyi, 1969
Galliaecytheridea mandelstami (Lyubimova, 1955)
Galliaecytheridea miranda (Lyubimova, 1955)
Galliaecytheridea monstrata (Lyubimova, 1955)
Galliaecytheridea polita Kilenyi, 1969
Galliaecytheridea sp cf. *postrotunda* Oertli, 1957
Galliaecytheridea spinosa Kilenyi, 1969
Galliaecytheridea tatae Kolpensskaya, 1993
Galliaecytheridea volgaensis (Lyubimova, 1955)
Genus A *cornulateralis* (Lyubimova, 1955)
Hechtycythere bisulcata (Sharapova, 1939)
Hechtycythere eximia (Sharapova, 1939)
Hechtycythere fistulosa (Lyubimova, 1955)
Hechtycythere serpentina (Anderson, 1941)

Hechticythere aff. verrucifera (Lyubimova, 1955)
Klenticella nealei (Kilenyi, 1969)
Klieana alata Martin, 1940
 ?*Lophocythere* sp.
Macrocypris alexanderi sp. nov.
Macrodentina (Dictyocythere) retirugata (Jones, 1885)
Macrodentina (Macrodentina) cf. foveata Malz, 1958
Macrodentina (Macrodentina) klingleri Malz, 1985b
Macrodentina (Macrodentina) rugulata (Jones, 1885)
Macrodentina (Macrodentina) transiens (Jones, 1885)
Macrodentina (Polydentina) rudis Malz, 1958
Macrodentina (Polydentina) subtriangularis (Sharapova, 1937)
Macrodentina (Polydentina) woottonensis Wilkinson, 1983a
Mandelstamia (Xeromandelstamia) maculata Kilenyi, 1961
Mandelstamia (Xeromandelstamia) tumida Christensen & Kilenyi, 1994
Mandelstamia abdita Lyubimova, 1955
Mandelstamia nikolaevi Kolpensskaya, 1993
Mandelstamia ventrocornuta (Sharapova, 1939)
Micrommatocythere reticulata nov. sp.
Micrommatocythere sp MPA368
Oligocythereis kostytschevkaensis (Lyubimova, 1955)
Paracypris bellula Lyubimova, 1955
Paracypris problematica Kilenyi, 1969
Paracypris? sp of Barker, 1966
Paralesleya perforata Witte & Lissenberg, 1991
Paranotacythere (Paranotacythere) primogenitus sp. nov.
Paranotacythere (Unicosta) caputmortuum (Martin, 1957)
Paranotacythere (Unicosta) sp. aff. caputmortuum (Martin, 1957)
Paranotacythere (Unicosta) effusa Wilkinson, 1983a
Paranotacythere (Unicosta) aff. effusa Wilkinson, 1983a
Paranotacythere (Unicosta) rimosa (Martin, 1940)
Paranotacythere sp MPA358
Paraschuleridea buglensis Barker, 1966b
Pontocypris arcuata Lyubimova, 1955
Procytheropteron barkeri Anderson, 1971
Procytheropteron bicosta Barker, 1966
Prohutsonia elongata (Barker, 1966)
Prohutsonia pustulata (Kilenyi, 1969)

Protocythere dominici sp. nov.

Rectocythere? horrida (Wilkinson, 1983a)

Rectocythere visceralis (Anderson, 1941)

Schuleridea alta (Lyubimova, 1955)

Schuleridea moderata Christensen & Kilenyi, 1970

APPENDIX III

A preliminary examination of foraminifera from boreholes in Southern England and North Sea Basin.

1. Introduction

The results from the Dorset coastal section were disappointing from the point of view of the Ostracoda and for this reason several borehole sequences from elsewhere in southern England and North Sea Basin were examined. The foraminifera were examined from a limited number of these samples in order to establish whether the stratigraphical distribution noted in Dorset was constant across the country and whether the foraminiferal zones seen in Dorset could be recognised elsewhere. Five boreholes were examined.

1. B.G.S. Borehole 81/47: this borehole, which is situated in the Southern North Sea, penetrated the Autissiodorensis to Scitulus zones. It proved to be barren of ostracods, but contained numerous foraminifera.

2. Fairlight Borehole: Foraminifera from the Pallasioides to Okusensis zones were examined.

3. Fairlight Borehole: The foraminifera of Hudlestoni-Fittoni zonal age were examined.

4. North Wootton Borehole: Samples from the Elegans to early Pectinatus zones were examined for foraminifera.

5. Tisbury Borehole: Foraminifera were recorded from the late Hudlestoni to Glaucolithus zones.

2. Foraminifera from the Autissiodorensis to Scitulus zones of B.G.S. Borehole 81/47, Southern North Sea

Borehole 81/47 (situated at 54° 16.586'N, 0° 23.168'E) penetrated 4.5m of superficial deposits before entering 27.8m of Kimmeridge Clay (the base was not seen). Ostracoda were not observed in any of the samples examined, but moderately diverse foraminiferal faunas were found.

2.1. Stratigraphical framework

Although small amounts of pale grey, calcareous mudstone were noted, the sequence for the most part comprises medium and dark grey mudstones, with interbedded, fissile, brownish-grey bituminous mudstones. A thin, brownish-grey

cementstone is situated between 10.90 and 11.02m depth. Ammonites are present, including *Aulocostephanus* below c.18.0m depth, including *Aulocostephanus* cf. *autissiodorensis* (Cotteau) at c.29.5m. Specimens of *Pectinatites* are present at and above c.17.4m. A combination of lithology and ammonite content permits a refined stratigraphical calibration for the cores. Kimmeridge Clay Beds KC34 and KC35 (Autissiodorensis Zone) are recognised between 32.30m (the T.D.) through to c.17.5m. Above this, Bed KC36 (Elegans Zone) is considered to extend from c.17.5m to 11.02m. A cementstone marks the base of the Scitulus Zone in south Yorkshire and can be correlated with the Yellow Ledge Stone Band of Dorset. Thus the 11.20-4.50m depth interval of borehole 81/47 is assigned to Bed KC37 (Scitulus Zone).

2.2. Foraminifera

The good lithological and ammonite control provides an excellent calibration on which to test the foraminiferal biostratigraphy established for Dorset. Ostracoda were not found in any of the samples examined, a characteristic of the Autissiodorensis to Scitulus zone throughout much of England and the Southern North Sea Basin.

Pseudolamarckina polonica dominates the faunas between 28.93 and 11.90m and is also present at 6.50m. It proves to be a useful marker for the 'mid'-Kimmeridgian in the North Sea Basin as well as the Russian Platform (Kutznetsova, 1979). *Lenticulina* sp, although recorded in very small numbers, is also generally present through to 6.50m.

The lower part of the Autissiodorensis Zone of the borehole, is characterised by the appearance of calcareous foraminifera such as *Lenticulina postkarlaensis*, *Astacolus* ex gr. *nascens*, *Citharina* sp. cf. *macilenta* and *Marginulinita pyramidalis*. Agglutinating taxa were not found commonly, but *Reophax* sp and *Trochammina* ex gr. *annaë* were recorded a little above the base. The upper part of the Autissiodorensis Zone yielded a sparse fauna, but including the inception of *Saracenaria pravaslavleri* and *Textularia* sp.

The earliest part of the Elegans Zone is a horizon of newly introduced taxa: *Lenticulina kaschpuriae*, *L. ornatissima* and *Marginulinopsis* ex gr. *embaensis*. A little higher, towards the middle of the zone *Lenticulina segregata* and *Astacolus compterleformis* appear for the first time. The assemblage continues to be

dominated by *Pseudolamarckina polonica* together with rare *Lenticulina postkarlaensis*, which are useful biostratigraphical indices.

Few of the species discussed above survived into the Scitulus Zone of B.G.S. borehole 81/47, which was almost devoid of foraminifera. However, *Lenticulina ex gr. biexcavata* and other species of *Lenticulina* were found together with two agglutinating taxa, *Kutsevella* sp. and *Trochammina* sp.

3. Foraminifera from the Bolonian and Portlandian of the Fairlight Borehole

3.1. Stratigraphy

The stratigraphy of Fairlight Borehole has been discussed previously.

3.2. Foraminifera

The Pallasioides zone is characterised by a number of nodosariids, *Lenticulina*, *Saracenaria*, *Astacolus* and *Citharina*. *Lenticulina infravolgaensis* is the more numerous species, but *Saracenaria pravoslavlevi* also occurs. Similar faunas extend into the Rotunda Zone and the *infravolgaensis/pravoslavlevi* Zone is considered to extend into the Rotunda Zone, although the index species are at best very rare and usually absent. At the top of the Bolonian, the Fittoni Zone is almost devoid of foraminifera, although *Lenticulina* is present including specimens tentatively identified as *L. sywi*.

Foraminifera from the Portland Sand equivalent are not common or well preserved. Nodosariids dominate in the form of *Lenticulina*, *Saracenaria*, *Citharinella*, but in the upper part (and in the base of the Portland Stone equivalent) agglutinated taxa appear, notably *Haplophragmoides* spp.

4. Foraminifera from the Elegans to Pectinatus zones of North Wootton Borehole

4.1. Stratigraphy

The stratigraphy of the Borehole is discussed elsewhere in this report.

4.2. Foraminifera

The Elegans Zone yielded only a sparse foraminiferal assemblage, including very rare *Lenticulina postkarlaensis*, *Lenticulina* sp and *Marginulina costata*, and the *polonica-postkarlaensis* zone is inferred. The sample from the Scitulus Zone was found to be barren.

Although the Wheatleyensis Zone is similarly impoverished in foraminifera, *Lenticulina* cf. *infravolgaensis* and *L.* cf. *postkarlaensis* were found together with *Citharina* sp. (= *C. macilenta sensu* Lloyd, 1959) and *Marginulina costata* in a very poorly preserved, pyritised association.

Foraminifera are more numerous in the Hudlestoni Zone. *Lenticulina infravolgaensis* is abundant and other nodosariids include *Marginulina costata*, *Marginulina formosa*, *Dentalina* sp cf. *D. linearis* and *Saracenaria* sp. *Reophax* and *Cornispira* are also present. The incoming of *Marginulina formosa* is biostratigraphically useful as it can be used to correlate the sequence with Dorset.

Only the earlier part of the Pectinatus Zone is present in the Borehole. It contained numerous crushed *Kutzevella* sp together with *Kutzevella* ex gr. *haplophragmioides*, together with *Lenticulina infravolgaensis*, *Marginulina formosa* and *Citharina* spp. The presence of *M. formosa* indicates the presence of the *Bulbobaculites deceptorius*-*Marginulina formosa* Zone, although *B. deceptorius* was not found in the borehole.

5. Foraminifera from the Bolonian and Portlandian of the Tisbury Borehole

5.1. Stratigraphy

The stratigraphy of the Tisbury Borehole has already been discussed.

5.2. Foraminifera

The lowest assemblages seen were from the Hudlestoni Zone. The fauna at this point is of very low diversity and comprises a few rare agglutinated taxa such as *Haplophragmoides* sp and *Kutzevella* sp.

In contrast to the Hudlestoni Zone, foraminiferal assemblages from the Pectinatus Zone were diverse, although not rich. Hyaline taxa dominate, particularly nodosariids such as *Lenticulina infravolgaensis* and several species of *Citharina*, *Lenticulina*, *Saracenaria Vaginulinopsis* and *Astacolus*, although agglutinated taxa are present, including *Haplophragmium*, *Trochammina* and *Kutzevella*. Miliolids were found to be very rare, but *Cornispira* was found in the lower part of the zone as was the robertinid, *Epistomina*. Of particular interest is the occurrence of *Marginulina formosa*, which appears at the base of the Pectinatus Zone (at 124.6m), and *Bulbobaculites deceptorius*, which has its local inception at a depth of 122.65m. These two species form a characteristic part of the assemblage in the Hudlestoni and particularly the Pectinatus Zone elsewhere.

The sample from the presumed Pallasiodes Zone was found to be poorly fossiliferous.

A number of species were recovered from the Rotunda Zone including the last specimens of *Lenticulina infravolgaensis*. Species with their first occurrence include *Lenticulina ponderosa*, *L. delucida*, *Astacolus cf nascens*, *Vaginulinopsis embaensis* and *Sigmoilina subpanda*. Although very rare specimens of *Saracenaria aetheria* were found at 70.65m depth, *Saracenaria pravoslavlevi* was not seen.

Lenticulina sywi was recovered from the 45.40 and 38.19m interval and is a useful species to correlate this part of the sequence with the Fittoni Zone in Dorset. *Haplophragmoides galloisi*, which is also a useful marker for the Fittoni Zone in Dorset was not found in the borehole. *Lenticulina* dominates the association in this part of the borehole, but *Vaginulinopsis medius* and *Marginulinita* sp is also present.

The Portland Formation, Wardour Member (Albani Zone), contains a sparse microfauna dominated by agglutinated taxa including *Haplophragmoides*, *Ammodiscus* and *Flabelammia*. The overlying Chicks Grove Member (Glaucolithus Zone) yielded rare *Lenticulina* spp and a specimen of *Tristix* at 10.35m.

6. Conclusions

The Bolonian foraminifera zones defined in the Dorset coastal sequence are recognised in the boreholes examined. The *polonica-postkarlaensis* foraminifera zone was seen in the Autissiodorensis to Elegans macrofaunal zone of Borehole 81-47. The Scitulus-Wheatleyensis macrofaunal zones contains sparse faunas such that foraminiferal zones could not be recognised. The *deceptorius-formosa* foraminifera zone was noted in the Hudlestoni and Pectinatus macrofaunal zones of the North Wootton and Tisbury boreholes. The last named borehole, together with the Failight Borehole also yielded taxa characteristic of the *pravoslavlevi-infravolgensis* and *sywi-galloisi* foraminiferal zones.

Portlandian deposits yielded few foraminifera, of which none is biostratigraphically diagnostic. The foraminiferal populations are dominated by *Haplophragmoides* spp., including "*Haplophragmoides canui*", and an informal "*Haplophragmoides* Zone" can be suggested.

APPENDIX IV

THE TEMPORAL AND SPATIAL DISTRIBUTION OF *MANDELSTAMIA*, WITH PARTICULAR EMPHASIS ON THE KIMMERIDGIAN AND VOLGIAN

ABSTRACT *Mandelstamia* is generally placed within the family Loxoconchidae, although its basic morphology is sufficiently different from that of *Loxoconcha* for it to be considered a member of a separate subfamily.

The stratigraphically earliest *Mandelstamia* appears to be *M. (Palaeomandelstamia)* in the Late Triassic, but the earliest known representative of *Mandelstamia (Mandelstamia)* is from the Aalenian. The genus was rare during the mid Jurassic, but during the Oxfordian to Volgian, it diversified and migrated rapidly, to form a characteristic element in the late Jurassic faunas of the Russian Platform, the Timan Pechora Basin, as well as of Poland. It was periodically common in the late Jurassic of the North Sea Basin and surrounding countries, notably Britain and Denmark, although it is remarkably rare in France and Germany. The last known species survived into the Valanginian, having been recorded in deposits of that age in eastern England, The Netherlands and in the Caucasus.

The distribution of the genus within the argillaceous deposits of the "Boreal Realm" and the more continuous presence of relatively long-ranging species in the Russian "Province", compared to the sporadic appearance of relatively short-ranging species in the North West European "Province" can be related to palaeoenvironmental parameters, of which eustatic sea level changes, temperature and the oxygen content of the bottom waters seem to have been important criteria.

1. Introduction

Mandelstamia occupied marine and near marine conditions during much the Mesozoic. Although to some extent its early history remains obscure, it formed a small part of the community during the mid-Jurassic. By the Late Jurassic it formed a large proportion of the ostracod population throughout Europe. The present study examines the distribution of the genus, in both palaeoenvironmental and temporal terms in northern Europe, from Britain to the Russian Platform. The genus *Mandelstamia* is placed into its super generic context and an attempt is made to

trace the subfamily Mandelstaminae (family Loxoconchidae) from its origins in the Late Triassic through to the Late Cretaceous.

2. Origins of *Mandelstamia*

The origin of *Mandelstamia*, a member of the family Loxoconchidae, is far from clear. According to the Zoological Record (Whatley *et al.*, 1993), the Loxoconchidae originated in the Triassic. This is based on the genus *Gemanella* Schneyder (1956), a taxon that resembles some members of the family in terms of its ovate carapace, few straight and simple marginal pore canals and has an adont hinge. It differs in possessing a marginal, particularly ventral, rib-like inflation. The subgenus *Mandelstamia* (*Palaeomandelstamia*) of Buetler & Gründel (1963), from the late Trias of Germany, was distinguished from other members of the genus principally on the basis of the adont hinge. It is closely related to *Gemannella*, which appears to be the root-stock of *Mandelstamia*.

Unfortunately, there are no species or genera known to the authors to link *Mandelstamia* (*Palaeomandelstamia*) to the earliest *Mandelstamia* (*Mandelstamia*) or to the other members of the genus that have been placed in *Camptocythere*. This last named genus ranges from the Toarcian to the Aalenian and Bajocian in Europe, but in the Western Interior of the U.S.A. it extends, together with its junior synonym *Aparchitocythere*, up into the Bathonian, Callovian and Oxfordian (Swain & Peterson, 1952; Peterson, 1954; Lord & Sherrington, 1976). Triebel (1950), Morkhoven (1962) and Plumhoff (1963) all considered *Camptocythere* to be a member of Loxoconchidae, although more recently the genus has been placed into Cytheridae Baird 1850 (Michelsen, 1975) and Progonocytheridea Sylvester-Bradley, 1948 (Bate & Coleman, 1975; Ainsworth, 1990). It is not within the scope of this paper to consider the position of *Camptocythere*, but the very close similarity of some species to *Mandelstamia* is worthy of note.

During the Sinon Zone (earliest late Aalenian) and again in the Obtusa-Concava zones (latest late Aalenian), *Camptocythere* evolved such *Mandelstamia*-like species as *C. modesta* Triebel 1950 and *C. parvula* Plumhoff, 1963. The former bears a striking similarity to *Mandelstamia brandi*, which ranges through the Sinon to Staufensis zones, and probably evolved from it. According to Plumhoff (1963),

Text-fig. 32

The evolution of the Mandelstaminae.

MANDELSTAMINAE

LOXOCOCHINAE

UPPER CRETACEOUS

MIDDLE CRETACEOUS

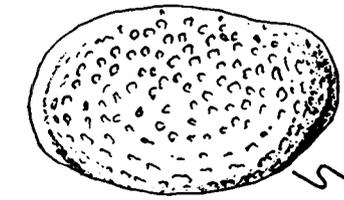
LOWER CRETACEOUS

UPPER JURASSIC

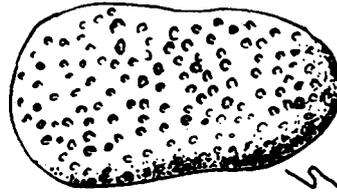
MIDDLE JURASSIC

LOWER JURASSIC

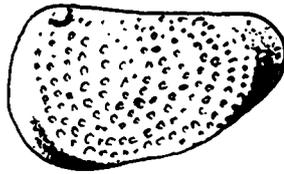
UPPER TRIASSIC



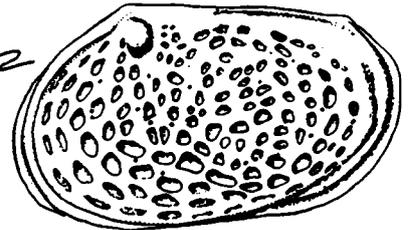
Phthanoloxoconcha



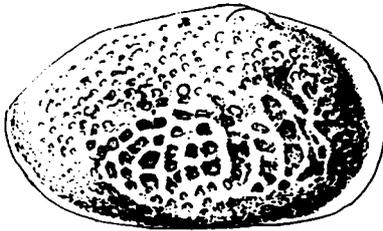
Dolocythere



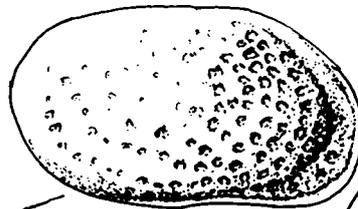
"Camptocythere"



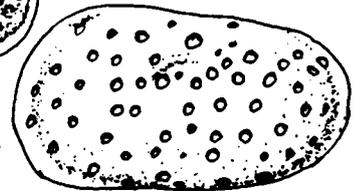
M. (Xeromandelstamia)



Rectocythere

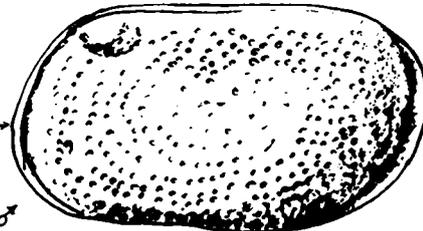
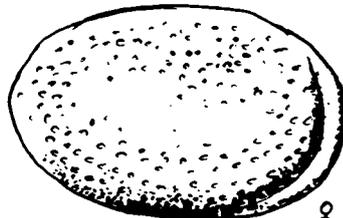
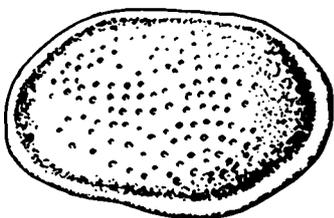


"Archaeocuneocythere"

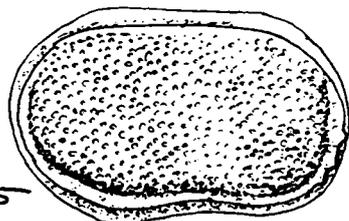
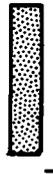
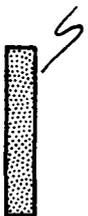


"Dolocythere"

Gemanella



M. (Mandelstamia)



M. (Palaeomandelstamia)

M. brandi can be differentiated from these species by its hinge, overlap and ornamentation (of which the last is probably a specific characteristic only). These species of *Camptocythere* (such as *C. modesta*) should be placed into *Mandelstamia* (*Mandelstamia*).

Mandelstamia brandi Plumhoff (1963) (= *Mandelstamia* sp.118 Brand, in Brand & Fahrion, 1962) from the Upper Aalenian of Germany, is the stratigraphically earliest known species that can be assigned, without a doubt, to *Mandelstamia* (*Mandelstamia*). Its dimorphism; outline, ornament, muscle scars, lophodont hinge, marginal pore canals and so on, are identical to other members of the genus. The only possible difference between this species and Late Jurassic members of *Mandelstamia* is that *M. brandi* may lack a vestibulum (although there is some uncertainty concerning this as pointed out by Plumhoff, 1962).

There are few European descendants emanating from *Mandelstamia* (*M. brandi*), linking it to the Oxfordian members of the genus. In Britain, low sea levels during the Bajocian precluded the genus from the region, but during the Bathonian, representatives are present in the Cave Oolite in Yorkshire (by original designation *Dolocythere maculosa* Bate, 1963). The outline, hinge, radial pore canals and muscle scars are identical to *Mandelstamia*, although it appears to lack a vestibulum and the marked sexual dimorphism so characteristic of this genus, has not been observed. However, the species is not a member of *Dolocythere*, an Early Cretaceous genus (see below). but should be referred to as *Mandelstamia* (*Mandelstamia*) *maculosa* (Bate).

The range of *Mandelstamia* can, be extended into the Middle Jurassic of Kazakhstan via its junior synonym *Archaeocuneocythere* Mandelstam, 1947, which was previously placed in the Cuneocytherinae. According to Mandelstam (1947) it ranges through the Upper Jurassic and into the Lower Cretaceous, although no details are given or figured specimens shown for the upper part of this long range. The hinge is typical of *Mandelstamia* and its outline and ornament also fits well within the range of variability of the genus. The illustration of *A. reniformis*, the genotype, would appear to be a male morph of *Mandelstamia*, whereas the second species described, *A. mocrinskyi* Mandelstam (1947), is considered to be a female morph. Considering that both species are from the same horizons, it is likely that

they represent the dimorphism of the same species. Unfortunately, both taxa are missing from the V.N.I.G.R.I. collections.

3. The distribution of *Mandelstamia*

North-western Europe

Pre-Kimmeridgian

Following the origination and eventual extinction of *Mandelstamia brandi* in the Aalenian of Germany, there are few known north-western European members of the genus until the Oxfordian. However, *Mandelstamia (M.) maculata* (Bate) and possibly *M. bathonica* (Ware & Whayley) from the British Bathonian, and perhaps *Leptocythere?* of TRIEBEL (1941) from the "Dogger" of Germany, partially fill that gap. The absence or rarity of the genus at this time is possibly due to the palaeoenvironmental regime that took hold during the Bajocian and extended through much of the overlying Bathonian.

Whatley (1965, MS) recorded "*M. (M.) angulata*" from the Cordatum Zone of Furzy Cliff, Dorset, the Densiplicatum Zone of the Berkshire-Oxfordshire area and from the Densiplicatum, Regulare and Rosenkrantzi zones in Dorset. This record is somewhat anomalous compared to the other records of this species and the identification is questionable. The specimens were all small juveniles rendering identification difficult and it seems probable, although not unequivocal, that these species should be placed within *Mandelstamia (Mandelstamia) rectilinea*.

The earliest record of rare specimens of undoubted *Mandelstamia rectilinea* (recorded as *M triebeli*) are from the Tenuiserratum Zone, Blakei Subzone, of the Warboys Borehole, Cambridgeshire (Fuller, 1983, MS) and Winterborne Kingston borehole, Dorset (Wilkinson, 1982). However, this species becomes more frequent and widespread through the Oxfordian, so that by the Glosense Zone it has been recorded as far afield as the coastal section of Dorset and Melton, Yorkshire. It is abundant by the regulare Zone throughout Dorset, Bedfordshire, Cambridgeshire and Yorkshire (Fuller, 1983, MS; Whatley, 1965 MS; Glashoff, 1964; Wilkinson, 1982; Ahmed, 1987).

Text-fig. 33

The ranges of species of *Mandestamia* in the Late Jurassic of Europe.

(Note the long ranges of taxa in eastern Europe compared to those of North western Europe.)

Early Kimmeridgian (sensu anglico)

Mandelstamia rectilinea ranges through the early Kimmeridgian (*sensu anglico*), where it sometimes occurs in flood proportions, to become extinct at or a little below the top of the substage. Its last record is from the latest Eudoxus Zone (Bed KC32 *sensu* Gallois & Cox, 1976) in Dorset (Kilenyi, 1969) and in the basal Autissiodorensis Zone (Bed KC33) in eastern England (Wilkinson, 1983a). Its distribution is widespread in the early Kimmeridgian of the Southern and Central North Sea and has been recorded in a number of oil company well reports and in published records for the UK and Dutch sectors of the southern North Sea Basin (Cox *et al.*, 1987; Witte & Lissenberg, 1994). It has also been recorded from the *Galliaecytheridea dissimilis* and *G elongata* ostracod zones (Baylei to Eudoxus zones) of the Lower Kimmeridgian part of the Børglum Formation of the Danish Trough (Christensen, 1974, 1988; Christensen & Kilenyi, 1970). *Mandelstamia (M.) angulata* is more restricted in distribution, being present in the Baylei and Cymodoce zones of Dorset (Kilenyi, 1969), Baylei of eastern England (Wilkinson, 1983a) and early Kimmeridgian of the Danish Basin (Christensen & Kilenyi, 1970).

The genus is notably lacking in much of France and Germany. Guyader (1968, MS) recorded *Mandelstamia rectilinea* from the lower "Pseudomutabilis" Zone of the Baie de la Seine, a locality not very distant from the Dorset stratotype section, but apart from a questionable record from the Lower Kimmeridgian of Lorraine (Dépêche, 1985), it is apparently absent. The only other species to have been recorded from the early Kimmeridgian is *Mandelstamia aff. tumida* from the early Kimmeridgian JWM1 zone of northern Germany (Gramann & Luppold, 1991). The heavily reticulate carapace figured, is not well preserved, but appears to be a male *M. (M.) reticulata*. Most males of this species show fine secondary reticulation, but this is not always the case and this appears to be one of the exceptions. It is certainly not a typical member of that species, but equally, it differs from *M. (M.) tumida sensu stricto*.

Late Kimmeridgian (sensu anglico)

There is a gap in the biostratigraphical record of *Mandelstamia* between the top of the Autissiodorensis Zone and the top of the Scitulus Zone. This was a time of oil shale accumulation and a period when ostracods were rare or absent in many parts of North West Europe. When the genus reappeared, it was as a form with a more complex (hemimerodont) hinge and is consequently placed within a separate

subgenus, *Xeromandelstamia*. This bioevent is a useful stratigraphical marker in countries surrounding the North Sea Basin.

Mandelstamia (X.) maculata is the stratigraphically oldest member of the subgenus, having been recovered from the Wheatleyensis and earliest Hudlestoni zones (beds KC40-42) in Dorset, East Anglia, Lincolnshire and the Southern North Sea (Kilenyi, 1969; Christensen & Kilenyi, 1970; Wilkinson, 1983a,b; Cox *et al.*, 1987). It is often found in low diversity faunas where it occurs in flood proportions, which is considered to have palaeoenvironmental implications (Wilkinson, 1983b). It is also recorded from the Upper Kimmeridgian of the Danish Basin (Christensen & Kilenyi, 1970), although there its exact stratigraphical position remains unpublished.

During the latest Hudlestoni Zone, *M. (X.) maculata* evolved into *M. (X.) tumida*. This latter species has been recorded in beds KC45 to 47 in eastern England by Wilkinson (1983a,b) and from Bed 48 in Dorset by Kilenyi (1969), as *M. (X.)* sp 1, and Christensen & Kilenyi (1970), but to date in Britain no specimens have been located in deposits younger than the Pectinatus Zone. This is probably due to unfavourable palaeoenvironmental conditions as discussed below, while in eastern England sediments younger than the Pectinatus have been removed by erosion. In the Danish Basin, it is also found in sediments inferred to be of Pectinatus Zonal age, however in the more complete sequence in the Dutch sector of the Southern North Sea, it appears to range up into the Portlandian (Witte & Lissenberg, 1994). Although their samples were cuttings, these authors have been able to relate the first downhole occurrences to the Portlandian sequences 1.3-1.4 of Haq *et al.* (1988), suggesting that the stratigraphically youngest specimens were of Okusensis to Praeplicomphalus zonal age.

It is worth noting that Oertli (1963) figured a specimen of *Mandelstamia* sp. from the "Kimmeridgien moyen, partie supérieure (Portlandien inférieur)" from the Cap de la Crèche to Boulogne-sur-Mer area of northern France. Although the illustration is not sufficiently detailed to identify this taxon further, it is important in that it represents one of the very few records of the genus in France. Of course the Pas-de Calais is not far from the Dorset section, so that its occurrence there is, perhaps, not surprising.

Finally, the youngest Jurassic species to have been recorded from the North Sea Basin is *Mandelstamia* (M.) aff. *ventrocornuta* of Witte & Lissenberg (1994) from the Dutch Sector of the Southern North Sea Basin. The present authors consider that the name *Mandelstamia* (M.) aff. *nikolaevi* would be more appropriate. Although recovered from ditch cuttings, the first downhole occurrence was in the lower part of the Lower Portlandian, but the species was also found in the Upper Kimmeridgian (although caving cannot be ruled out in this case). It seems a possibility that the presence of this taxon is the consequence of a link between Eastern Europe and the North Sea, *via* the Danish embayment, during the latest Kimmeridgian.

Early Cretaceous

Following the late Kimmeridgian (and possibly Portlandian) report of *Mandelstamia* in the Dutch Sector of the Southern North Sea, there is a gap in the records, partly as a consequence of unsuitable facies (either the brackish-fresh water Purbeck facies or dysaerobic to anaerobic bottom waters of the deeper basins) and partly due to the absence of suitably aged sediments (onshore). However, the genus reappears in the earliest Cretaceous of both Yorkshire (Neale & Kilenyi, 1961; Neale, 1978) and the Southern North Sea (Witte & Lissenberg, 1994). When it did reappear, it did so with yet a more complex hinge structure, in which the median element is very weakly denticulate/locellate; thus the earlier lophodont hinge had become hemimerodont and finally weakly antimerodont.

Mandelstamia (*Xeromandelstamia*) *sexti* was originally recovered from Bed D6 of the Speeton Clay (Neale & Kilenyi, 1961; Neale 1962), with a number of other relict Jurassic taxa. Since that time, the species has been found in the Danish Embayment, where it occurs in the Vedsted Formation and coeval deposits immediately below proven Valanginian sediments (Christensen, 1974). Rare specimens have been recorded in the basal Claxby Ironstone of Nettleton Hill Quarry, northern Lincolnshire. The base of this deposit is earliest Valanginian in age at this locality according to Rawson *et al.* (1978), so that either the range of the species is extended, or the age of the deposit must be reconsidered (its base is diachronous as in the south of the county it is latest Ryazanian), or the specimens are reworked. The first of these suggestions is the more likely and it is interesting to note that the species has also been recorded in the basal Valanginian in the

eastern part of the Netherlands (Witte & Lissenberg, 1994). In the Dutch sector of the Southern North Sea, Witte & Lissenberg have recovered this species in the Late Ryazanian part of the Kimmeridge Clay Formation, Vlieland Claystone Formation and Scruff Greensand Formation (Stortemelk Member).

Although *Mandelstamia* became extinct with *M. sexti*, subfamily Mandelstaminae appears to have continued in the form of *Dolocythère*. This genus is identical to *Mandelstamia* in all respects except that it does not bear a vestibulum, its adductor muscle scar is accompanied by a U- or C- shaped frontal scar (rather than having two frontal scars) and sexual dimorphism does not result in such a markedly different carapace shape. At the moment, the connection between *Mandelstamia* and *Dolocythère* is unclear for, whereas the former disappears from the record in the late Ryazanian (=Berriasian) or basal Valanginian, the latter is unknown below the base of the Hauterivian;

Dolocythère is important for it ranges through the early Cretaceous into the Albian and it is here that *Phthanoloxoconcha* makes its first appearance. This genus extends from the late Albian and through the Cenomanian and appears to be the ancestral stock of the Loxoconchinae.

Eastern Europe

Pre-Kimmeridgian

The genus *Mandelstamia* has been recorded from the Middle Jurassic deposits of Kazakhstan as *Archaeocuniocythere* (*A. reniformis* and *A. mocrinskyi*) and these species may be the link between the Aalenian species of Plumhoff (1963) and late Jurassic taxa. It appears to have migrated into the Karla Basin (near Takovara, Tatarstan) during the early Oxfordian, where it evolved into *Mandelstamia* (*Mandelstamia*) *ventrocornuta* Lyubimova (1955).

As in north western Europe, diversity increased in the Oxfordian. Rare specimens of other members of the genus, *Mandelstamia* (*M.*) *verrucifera* and *M.* (*M.*) *ventrocornuta* have been recorded in the Lower Oxfordian deposits of Tatarstan (Lyubimova, 1955). In south-western Siberia, one species of *Mandelstamia* has been recorded from the Oxfordian, *Mandelstamia ventrocornuta*

(Lyubimova, 1960). Finally The Oxfordian of the Ukraine has yielded *Mandelstamia (M.) kowalwskyi* and *M. (M.) ventrocornuta* (Permyakova, 1978).

The genus has been recorded in the Upper Oxfordian of a number of localities. In the Karla Basin (Tartastan), for example, *Mandelstamia (M.) ventrocornuta* occurs in association with *Cardioceras* spp. Near Ulyanovsk, *M. (M.) ventrocornuta* and *M. (M.) verrucifera* have been recorded. The last named originated within the Upper Oxfordian and according to Lyubimova (1955), *Mandelstamia (M.) verrucifera* is confined to the Oxfordian in the Volga region. *Mandelstamia (M.) ventrocornuta*, however, has a longer range, extending from the Upper Oxfordian through to the Middle Volgian (Lyubimova, 1955).

Kimmeridgian

The Lower Kimmeridgian deposits (in beds with *Amoebites* and *Prorasenia*) of the Karla Basin, Tatarstan, Samarskaya Luka and Gorodishche (Volga Basin) have yielded rare *Mandelstamia (M.) ventrocornuta*, but *M. (M.) verrucifera* has not been found, its extinction being within the highest part of the Upper Oxfordian (Lyubimova, 1955). The range of *M. (M.) ventrocornuta*, however, continues into the Eudoxus and Autissiodorensis zones in the Gorodishche area and its northward migration resulted in the species reaching the Timan-Pechora Basin during the "late Kimmeridgian" where mudstones were accumulating.

The appearance of rare specimens of *Mandelstamia (M.) abdita* is also a characteristic of the Mutabilis to Autissiodorensis zones in the Timan-Pechora Basin

Mandelstamia (M.) nikolaevi originated in the Upper Oxfordian of the Pre-Caspian area and Western Kazakhstan. During the early Kimmeridgian it had migrated into the Volga Basin and by the late Kimmeridgian (Mutabilis Zone) it had entered the Timan-Pechora Basin, although in small numbers (it was to become common in that region only during the Volgian). It is common in the Vyatka-Kama region, although only in the Volgian. *Mandelstamia (M.) percostata*, the apparent ancestral stock of *M. (M.) nikolaevi*, has been recovered from the Kimmeridgian mudstones of south-western Siberia.

Elsewhere in eastern Europe, records of the genus are sparse. However, Bielecka, Blaszyk & Styk (1976) recorded the presence of *Mandelstamia* (*M.*) *rectilinea* in the Lower Kimmeridgian of Strzalkow, northern Poland. This is an interesting record, for it shows the existence of a migratory route from the North Sea Basin through the Danish Trough into eastern Europe. To date, this species has not been as found as far east as the Timan-Pechora Basin or the Russian Platform. It is also interesting to note that the genus does not seem to have extended higher than the Kimmeridgian in Poland, presumably as a result of unfavourable facies and the brackish water conditions.

Volgian

Unlike north-western Europe, the subgenus *Mandelstamia* (*Mandelstamia*) ranged throughout the Volgian of Russia and *Mandelstamia* (*Xeromandelstamia*) failed to enter the region

By the beginning of the Volgian (Klimovi Zone), *M. (M.) ventrocornuta* was present between the Pre-Caspian area and the Timan-Pechora Basin where it is found in mudstones and calcareous mudstones. *Mandelstamia* (*M.*) *abdita* remained rare, but occupied the Volga Basin and Timan-Pechora Basin during the mid-Volgian (Panderi to Nikitini zones). *Mandelstamia* (*M.*) *nikolaevi*, however, had disappeared from the Pre-Caspian area by the close of the early Volgian (its last record is in the Pseudoscythicus Zone), although it remained in the Volga Basin until the early Virgatus Zone and occupied the Vyatka-Kama area and the Timan Pechora Basin at least until the mid-Volgian (Nikitini Zone). Little information exists regarding the Upper Volgian (Fulgens, Subditus and Nodiger zones) in eastern Europe, but *M. (M.) nikolaevi* and *M. (M.) ventrocornuta* have been recorded from calcareous mudstones of this age in the Timan-Pechora Basin.

Early Cretaceous

There are no records of *Mandelstamia* during the early Cretaceous on the Russian Platform, although the genus has been recovered from the Berriasian of the Caucasus (Kolpenskaya, unpublished data).

4. Palaeoenvironmental controls during the Kimmeridgian and Volgian

One of the most striking aspects of *Mandelstamia* is its spatial and temporal distribution. Common and diverse in Russia, Britain and the North Sea Basin, it almost absent from France, Germany and Poland. Secondly, the temporal distribution in the two areas contrasts markedly; in Russia the individual species are long-ranging, whereas in western Europe they are relatively short lived. Thirdly, only in north-western Europe, did the hinge of the genus undergo rapid change, allowing this character to be used to recognise different subgenera.

In the North Sea Basin, *Mandelstamia* (*Mandelstamia*) is rare or absent during much of the Middle Jurassic and lower part of the Upper Jurassic. However, during the period of eustatic sea level rise that reached its peak in the late Oxfordian and early Kimmeridgian (*sensu anglico*) it becomes more common (on occasions being present in flood proportions). Its diversity also reaches its greatest during the Kimmeridgian. With the regression that commenced during the Late Kimmeridgian and continued through the Portlandian (early and Mid Volgian), culminating in the fresh to brackish conditions and the deposition of the Purbeck facies, *Mandelstamia* disappeared from the record. It can be postulated that the genus required fully marine conditions associated with the open shelf seas.

The cyclicity, that is a characteristic of the Kimmeridge Clay, resulted in the accumulation of pale grey mudstones, dark mudstones, bituminous mudstones, oil shales and coccolith-rich beds, before returning to the pale grey mudstones. This cyclicity is generally regarded as being associated with the oxygenation of the sediment and sediment:water interface. The oxygen content of the water was never particularly high during the deposition of the Kimmeridge Clay, but a moderately diverse macro- and micro- fauna was supported during the period represented by the pale grey clays, implying that oxygenation of the water was adequate. The kenoxia during the accumulation of the bituminous mudstones and oil shales resulted in, at best, very impoverished benthonic faunas. This oscillation of the low oxygen concentration in the water resulted in high physical stress in the faunas and only those able to tolerate these harsh conditions survived.

The distribution of *Mandelstamia* indicates that this was one of the more tolerant genera and indeed at times it is found in flood proportions (for example

Mandelstammia (X.) *tumida* in the late Hudlestoni and early Pectinatus zones, *Mandelstammia* (X.) *maculata* in the Wheatleyensis Zone and *Mandelstammia* (M.) *rectilinea* in the Mutabilis and Eudoxus Zones. However, in some parts of the Kimmeridge Clay, notably in beds of thick oil shales and coccolith-rich beds, ostracods are absent. Presumably tolerance levels had been exceeded in the low oxygen and unstable environment. With the amelioration of the environment, however, *Mandelstammia* was frequently one of the first genera to respond to the conditions.

A second controlling phenomenon during the Kimmeridgian, the climatic conditions, also affected *Mandelstammia*. There is considerable weight of evidence indicating that climatic variability took place through the late Jurassic of the Northern Hemisphere. Hallam (1984, 1985) showed that the warm humid conditions of the Callovian and Oxfordian was gradually replaced during the Kimmeridgian and Volgian by a belt of arid conditions which was expanding from the south and this influenced run-off and sedimentation. The climatic change to arid conditions is reflected in the evaporite deposits of Oxfordian age in the Central Asian part of the Former Soviet Union. Aridity reached Poland and Germany by the Kimmeridgian/Volgian boundary interval, as indicated by evaporite deposits of that age (Demowska, 1976; Jordan, 1971). Indications are that the arid conditions had reached southern France during the Eudoxus Zone (Courtinat, 1989) and by the Volgian limestone accumulation had commenced and kaolinite had disappeared from the clay mineral associations (Deconinck, 1987).

In southern England (Townson, 1975; Townson & Wimbledon, 1979) and the Celtic Sea (Millson, 1987) the influence of the arid conditions is reflected in the accumulation of red beds, but accumulation of evaporites, did not begin until late in the Portlandian (i.e late Volgian) at the base of the Purbeck facies. This was also a period of decline in the proportion of kaolinite in the Kimmeridge Clay. This decline had commenced in the Hudlestoni Zone (Wignall & Ruffell, 1990) and by the Portlandian (Mid Volgian), the kaolinite had disappeared from the clay mineral signatures (Quest, 1985). There are still some unanswered questions here, however, as there are some high peaks in the signature in the Pectinatus Zone, nevertheless it seems likely that although the arid climatic belt had not taken a sufficiently tight hold as to trigger the accumulation of evaporites, it was beginning to

affect conditions in the area early in the late Kimmeridgian (i.e. early to mid Volgian) as reflected in the faunas. It seems to be a strong possibility that the influence of maritime conditions and the movement of colder waters from the North (Oschmann, 1988) had the effect of delaying the arrival of these condition in Britain. It was only when the regression cut off the direct influence from the North during the late Portlandian (Mid Volgian) that the full influence of the aridity was reflected in the deposits.

The Lower Kimmeridge Clay yielded *Mandelstamia* (*Mandelstamia*) in large numbers. However, by the close of the Eudoxus Zone, the genus together with a number of other taxa disappeared so that the Autissiodorensis and Elegans zones of Britain and southern North Sea were devoid of ostracods. This was probably due to a combination of environmental parametres: oil shale production and subsequent dysaerobia, climatic changes as well as the regional lowering of sea levels. The reappearance of ostracods in the Scitulus Zone was associated with the origination of a number of new taxa in the region and, in the earliest Wheatleyensis Zone, a new subgenus of *Mandelstamia*. This subgenus, *Xeromandelstamia*, was a form with a hemimerodont hinge. The earliest species was *M. (X.) maculata*, but this was soon followed by *M. (X.) tumida* in the Hudlestoni Zone.

The late Hudlestoni to Pectinatus zones in Dorset, eastern England and the North Sea Basin was a period of change for the ostracod fauna. A number of species of *Paranotacythere*, *Galliaecytheridea* and *Dicrorygma* made their first appearance, but this was also the time that *Mandelstamia* disappeared from the area.

Much of the Hudlestoni Zone in marginal marine areas such as Central England and northern France (Boulonnais) is missing, although further into the basin, such as in eastern England and the Southern North Sea, little if any of the succession has been removed and in Dorset sedimentation was continuous. The culmination of the low stand during the mid Hudlestoni Zone, in which Kimmeridge Clay Bed 44 accumulated, coincides with sequence boundary K8 of Wignall (1991).

The Pectinatus Zone was also a time of regression and the top of the zone is again missing in areas closest to shorelines such as central England (Aylesbury and

Swindon areas), eastern England and northern France (Boulonnais). This forms sequence boundary K9 of Wignall (1991) and was followed soon afterwards by the Rotunda Zone event (K10 of Wignall, 1991). These intervals were periods of stress for *Mandelstamia*, for the genus never recovered its pre-Pectinatus position and soon disappeared entirely. Even in Dorset where sedimentation was more or less continuous throughout the entire late Kimmeridgian, the genus has not been found. The Southern North Sea Basin apparently retained more stable conditions for in the Dutch Sector *Mandelstamia* (*Xeromandelstamia*) persisted at least until the close of the late Kimmeridgian and possibly into the early Portlandian (the mid-Volgian) (Witte & Lissenberg, 1994). However the regression and restricted water circulation in the Southern North Sea Basin was sufficient to preclude the genus from the region.

Grey mudstones with occasional more arenaceous horizons dominate the Upper Jurassic succession and the thick, highly bituminous oil shales that are characteristic of the North Sea are not present in the Kimmeridgian of the Russian Platform. The thickest oil shales in the Ulyanovsk-Kashpir region northwards into the Izhma, Orlovka and Vyatka-Kama regions are in the mid-Volgian Panderi Zone. The major lithological change took place during the Nikitini Zone of the mid-Volgian when end-Jurassic eustatic changes resulted in the accumulation of sandstones with phosphatic nodule horizons.

Environmental conditions during the Kimmeridgian through to the mid-Volgian in Russia rarely approached the high stress conditions of western Europe. The connections with high latitudes remained open and because of continuous marine conditions, the affects of increasing aridity were not apparent here. Selection pressures on *Mandelstamia* were less strong in this region. Hence, species that had become established during the Oxfordian tended to range through to the Late Volgian. On the Russian Platform, for example, *Mandelstamia* (*Mandelstamia*) appeared during the Oxfordian, spread during the Upper Kimmeridgian to mid-Volgian, and was greatly reduced during the Late Volgian.

The genus was very conservative in European Russia and the first major environmental change that occurred resulted in its disappearance. On the Russian Platform, in the Ulyanovsk-Kashpir area, the long period of accumulation of

mudstones in a low energy milieu came to an end with the Panderi Zone and the commencement of the Virgatus Zone saw a change in the depositional regime to one dominated by arenaceous sedimentation in higher energy conditions. *Mandelstamia* is not found above the Panderi Zone; the genus obviously showed a preference for the low energy, off-shore marine conditions with its muddy substrates muddy substrates. In the Timan-Pechora Basin and Pre-Caspian region, where mudstones were deposited throughout the Volgian, *Mandelstamia* survived.

5. Systematic Palaeontology

Suprageneric position

Lyubimova (1955) originally placed *Mandelstamia* into the Palaeocytherinae, but Malz (1958) considered that it to belong to Progonocytherinae, Pokorny (1958) tentatively suggested that it is related to the Limnocytherinae and in Chernysheva (1960), placed the genus in Palaeocytherideinae, Tribus Camptocytherides. With the exception of the Treatise (Moore, 1961) where *Mandelstamia* is placed into "Family uncertain", most authors have followed Neale & Kilenyi (1961) and placed it either into Family Loxoconchidae or Family Cytheridae, Subfamily Loxoconchinae (e.g. Kilenyi, 1969; Christensen & Kilenyi, 1970; Schudak, 1994; Witte & Lissenberg, 1994). Whatley (in press) argues that the Loxoconchidae, through the Timeriaseviinae, gave rise to the Mandelstaminae in the late Triassic and that he agrees with Pokorny (1958) on the proximity of *Mandelstamia* to the Limnocytheridae, but that it is a loxoconchid.

Family Loxoconchidae comprises a number of small to medium sized, dimorphic genera. They are generally reniform or subreniform in shape, but may be elongate or more ovate in some taxa. Ornamentation of the lateral surface varies from very weakly punctate to coarsely punctate, and occasionally reticulate. Normal pores are large and some are sieve-like. Internally, the muscle scars comprise an oblique row of four elongate adductors, which may be divided, and a U- or C-shaped frontal scar and the hinge structure may be adont, lophodont, merodont or gongyodont. The marginal area is broad and marginal pore canals are few, straight and simple. A narrow anterior vestibulum is usually present and in some taxa a narrow posterior vestibulum may also occur.

Subfamily Loxoconchinae comprises reniform to subreniform genera. Muscle scars comprise a slightly obliquely disposed, vertical row of four adductors and a U- or C-shaped frontal scar. An anterior and sometimes a posterior vestibulum may be present. The subfamily ranges from the Middle Cretaceous to Recent, the earliest known being *Phthanoloxoconcha* Wilkinson 1988.

Subfamily Mandelstaminae is medium sized and ovate to rectangular. The muscle scars comprise a slightly obliquely disposed, vertical row of four adductors and a pair of frontal scars, the hinge is adont, lophodont to merodont and a narrow anterior vestibulum is present. The subfamily, which ranges from the Triassic to the Late Cretaceous, comprises *Mandelstamia* Lyubimova, 1955, *Dolocythère* Mertens, 1956 and ?*Rectocythere* Malz, 1958. Although *Dolocythère* has a lophodont hinge, *Mandelstamia* has either in the Triassic an adont hinge, *Mandelstamia* (*Palaeomandelstamia*) of Buetler & Gründel (1963), or in the Aalenian to Volgian a lophodont hinge, *Mandelstamia* (*Mandelstamia*) or in the Kimmeridgian to Volgian a hemimerodont hinge, *Mandelstamia* (*Xeromandelstamia*). In the case of the Ryazanian-early Valanginian species, *Mandelstamia* (*Xeromandelstamia*) *sexti* Neale, the median bar/groove is very weakly denticulate/locellate (antimerodont). *Rectocythere* is questionably assigned to the subfamily on the basis of its outline, general ornamentation, hinge and marginal pore canals, but it lacks a vestibulum. Further work on this genus is required to clarify its position more firmly.

Genus *Mandelstamia* Lyubimova, 1955

Genotype: *Mandelstamia ventrocornuta* (Sharapova, 1939)

When Lyubimova (1955) erected the genus *Mandelstamia* she elected *Mandelstamia facilis* Lyubimova, 1955, to be the genotype. However, *M. facilis* is shown to be synonymous with *Mandelstamia ventrocornuta* (Sharapova, 1939). The latter has priority so that the genotype must now be changed.

Subgenus *Mandelstamia* Lyubimova, 1955

Mandelstamia (*Mandelstamia*) *ventrocornuta* (Sharapova, 1939)

Pl.20 Fig.1,4

1939 *Cytherissa ventrocornuta* Sharapova:12, pl.1, fig.4.

1955 *Mandelstamia ventrocornuta* Sharapova; Lyubimova, 63, pl. 6, figs. 9.

1955 *Mandelstamia facilis* Lyubimova: 65, pl.7, fig.2.

1960 *Mandelstamia ventrocornuta* Sharapova; Lyubimova, 100, pl. 10, figs. 3.

1978 *Mandelstamia ventrocornuta* Sharapova; Permiakova, 159, pl. 72, fig. 9.

Diagnosis: Female: Oval to triangular in outline, tapering to the posterior. Anterior and posterior broadly rounded. Dorsal margin straight, ventral margin slightly convex. A weak swelling is situated postero-dorsally. Lateral surface ornamented with concentrically arranged, circular fossae and weak ribs may be present. The fossae are not more than 0.012mm in diameter.

Male: Oval to quadrate outline with broadly rounded posterior and anterior margins. Dorsal and ventral margins parallel. A small swelling is situated postero-dorsally. Lateral surface reticulate, the fossae being up to 0.04mm in diameter.

Remarks. The marked sexual dimorphism has caused confusion, the male having been called *M. facilis* by Lyubimova. The male is very rare and has a somewhat patchy distribution: it is known to occur in the Upper Oxfordian of western Kazakhstan and Volga Basin, Upper Kimmeridgian of Dolinovka, Middle Volgian of the Timan-Pechora Basin and late Vogian in the Pre-Caspian, Volga basin and Timan-Pechora Basin. *Mandelstamia ventrocornuta* is similar to *M. nikolaevi*, but is less swollen postero-dorsally, smaller and more rounded fossae and a more acute posterior. Externally it bears some resemblance to *M.(X.) tumida*, but that species differs in its more rounded posterior and in its hinge line

Mandelstamia (Mandelstamia) abdita Lyubimova, 1955

Pl.20, Fig.3

1955 *Mandelstamia abdita* Lyubimova: 65, pl.7, fig.1.

Diagnosis. Triangular outline. Anterior broadly rounded, posterior drawn out and acutely rounded at mid-height. Dorsal margin straight and ventral margin weakly convex. The postero-dorsal and postero-ventral margins taper quickly to the acute posterior. Cardinal angles well formed. Inflated postero-ventrally. Small conical tubercle situated postero-ventrally. Lateral surface ornamented by rounded to angular fossae which are largest towards the central part and smaller towards the margins.

Remarks. The acutely drawn out posterior and the postero-ventral tubercles distinguish this species from other members of the genus.

Mandelstamia (Mandelstamia) angulata Kilenyi, 1961

Pl.20, Fig.13,15

1961 *Mandelstamia angulata* Kilenyi: in Neale & Kilenyi, 443-444, pl. 71, figs.11-12, 16-18.

1969 *Mandelstamia (Mandelstamia) angulata* Kilenyi; Kilenyi, 134-135, pl.29, figs. 11-16.

Diagnosis. A small species of *Mandelstamia (Mandelstamia)* with a weakly arched to straight dorsal margin, a straight ventral margin and an acutely rounded posterior at mid-height. Lateral surface pitted and slightly sulcate. Highest anterior of mid-length and widest posterior of mid-length.

Remarks. A rare species apparently confined to the Baylei and Cymodoce zones of Dorset and eastern England (Neale & Kilenyi, 1961; Kilenyi, 1969; Wilkinson, 1983a). There is a questionable record of the genus in the Oxfordian, although this is based on juvenile specimens (Whatley, 1965 MS). Males have not yet been recognised.

Mandelstamia (Mandelstamia) nikolaevi Kolpenskaya, 1993

Pl.20, Fig. 2,5

1979 *Mandelstamia ventrocornuta* Sharapova; Fuller & Lord, 51-54, pl.52, figs.1-3, pl.54, figs1-5.

1993 *Mandelstamia nikolaevi* Kolpenskaya: 84, pl.8, figs.8-9.

Diagnosis. Ovate outline. Anterior margin broadly rounded, posterior margin acutely rounded. Dorsal margin almost straight, the posterior cardinal angle is well marked. Ventral margin subparallel, but convex postero-ventrally to merge with the posterior. A small, but pronounced swelling postero-ventrally may overhang the margin slightly. The lateral surface is ornamented by coarse, rounded to angular reticulation, showing concentric disposition with the posterior and anterior margins. The fossae are no more than 0.045mm in diameter. The muri may form weak vertically disposed ribs in the anterior and ventral part of the valve.

Remarks. This species differs from *M. percostata* (Lyubimova, 1960, p.103, pl.10, fig.5), a Kimmeridgian species from south western Siberia, in the postero-ventral swelling and from *M. (M.) ventrocornuta* in the shape of the posterior and the large reticulation. Externally it bears some similarity to *M. reticulata*, but that species has only a very weak postero-ventral swelling and is longer compared to its height.

Mandelstamia (Mandelstamia) rectilinea Malz, 1958

Pl.20. fig.8,11

- 1958 *Mandelstamia rectilinea* Malz:38-39, pl. 11, figs. 58-63; text-fig. 4.
1961 *Mandelstamia rectilinea* Malz; Neale & Kilenyi, 440-441, pl. 71, figs. 1-4,6.
1961 *Mandelstamia triebeli* Kilenyi; in Neale & Kilenyi, 442-443, pl. 71, figs., 5,9-10,14-15.
1969 *Mandelstamia (Mandelstamia) rectilinea* Malz; Kilenyi, 133, pl.29, figs. 1-6; text-figs. 4a-b.
1969 *Mandelstamia (Mandelstamia) triebeli* Kilenyi; Kilenyi, 133-134, pl. 29, figs. 9-10; text-figs. 4c-d, 5k.
1976 *Mandelstamia rectilinea* Malz; Bielecka, Blaszyk & Styk, 232, pl.18, fig.7.
1978 *Mandelstamia rectilinea* Malz; Kilenyi, 278, pl.8, figs, 7-10.
1982 *Mandelstamia rectilinea* Malz; Wilkinson, pl.1, figs. 2-3.
1983a *Mandelstamia rectilinea* Malz; Wilkinson, pl.1, figs. 8-9.
1985 *Mandelstamia rectilinea* Malz, Dépêche, pl.33, fig.2.
1987 *Mandelstamia rectilinea* Malz; Ahmed, 269, figs. 2 (5-7).
1994 *Mandelstamia (Mandelstamia) rectilinea* Malz; Witte & Lissenberg, 20-21, pl. 4, figs. 23-27.

Diagnosis. Females subovate, tapering posteriorly; dorsal margin straight and ventral margin convex. Reticulate laterally. Males angular, dorsal margin straight, ventral margin sinuous. Primary and secondary reticulation, particularly in the posterior half.

Remarks. The strong dimorphism has caused some confusion. It ranges throughout the Upper Oxfordian (Whatley, 1965, MS; Wilkinson, 1982) and into the Lower Kimmeridgian of Dorset (Eudoxus Zone) and eastern England (Baylei to early Autissiodorensis zones, Beds KC1-33) (Malz, 1958; Neale & Kilenyi, 1961; Kilenyi, 1969, 1978; Christensen & Kilenyi, 1970; Wilkinson 1983a). In the southern North Sea it ranges up to the late Mutabilis Zone (Bed KC22) (Cox *et al.*, 1987) and throughout the Lower Kimmeridgian of the Dutch Sector (Witte & Lissenberg, 1994). Christensen (1970) also recorded the species from the Børglum Formation of Denmark. The species migrated through the Danish trough into the Polish Trough where it has been recorded in the Lower Kimmeridgian (Bielecka, Blaszyk & Styk (1976).

Subgenus *Xeromandelstamia* Beutler & Gründel, 1963

Subgenotype. *Mandelstamia (Xeromandelstamia) sexti* Neale, 1961

Mandelstamia (Xeromandelstamia) sexti Neale, 1961

Pl.20 Fig.16

1961 *Mandelstamia sexti* Neale: in Neale & Kilenyi, 446--447, text-figs. 2-3.

1962 *Mandelstamia sexti* Neale; Neale, 453, pl. 12, figs. 24-31.

1978 *Mandelstamia sexti* Neale; Neale, 336, pl.2, fig. 14, table 1.

1988 *Mandelstamia sexti* Neale; Hengreen *et al.*, 758, pl.2, fig. 1.

1994 *Mandelstamia (Xeromandelstamia) sexti* Neale; Witte & Lissenberg, 21, Pl.10, Figs. 12-18.

Diagnosis. Females acutely rounded posteriorly, coarsely punctate to reticulate with rounded fossae and slightly sulcate. Laterally swollen postero-ventrally. Males quadrate with fine primary and secondary reticulation in the posterior part and coarse, rounded to angular fossae in the anterior part of the lateral surface.

Remarks. Recorded from the Ryazanian of the Speeton Clay and from the basal Valanginian of Lincolnshire, eastern England (Wilkinson, 1988, MS) and eastern part of the Netherlands (Witte & Lissenberg, 1994).

Mandelstamia (Xeromandelstamia) maculata Kilenyi, 1961

Pl.20, Fig.7,10

1961 *Mandelstamia maculata* Kilenyi: in Neale & Kilenyi, 444-446, pl. 71, figs. 19-25.

1969 *Mandelstamia (Xeromandelstamia) maculata* Kilenyi; Kilenyi, 135-136, pl. 29, fig. 33; text-figs. 4e-f.

1978 *Mandelstamia (Xeromandelstamia) maculata* Kilenyi; Kilenyi, 278, pl.8, figs. 11-12.

1983a *Mandelstamia (Xeromandelstamia) maculata* Kilenyi; Wilkinson, pl.2, figs.9-10.

Diagnosis. An elongate and ovate species of *Mandelstamia (Xeromandelstamia)* with, in the female, an acute, but broadly rounded posterior and a well marked postero-ventral swelling. The male has an obliquely upturned postero-ventral margin which merges into a broadly rounded, but slightly truncated posterior. The ventral margin of the male is concave, but does not bear the postero-ventral swelling. The lateral surface is reticulate, with rounded to slightly angular fossae, in the female.

Fine primary and secondary reticulation on the lateral surface of the male, particularly in the posterior part.

Remarks. This species closely resembles *M. (M.) reticulata* externally, but can be differentiated by the ventral concavity and the obliquely upturned postero-ventral margin of the males, the acutely rounded posterior of the female and, when visible, the merodont hinge. It lacks the tumidity of *M. (X.) tumida*.

The species has been recorded from the Scitulus and Wheatleyensis zones in Dorset (Kilenyi, 1978), but in eastern England has been recorded only from the higher zone (Bed KC40 to the lower part of KC42) and in the base of the Hudlestoni Zone (upper part of Bed KC42) (Wilkinson, 1983a,b).

Mandelstamia (Xeromandelstamia) tumida Christensen & Kilenyi, 1994

Pl.20 Fig.9,12

1961 *Mandelstamia* sp.1 Kilenyi: in Neale & Kilenyi, 446, pl. 71, figs. 7-8, 13.

1969 *Mandelstamia (Xeromandelstamia)* sp.1 Kilenyi; Kilenyi, 136, pl.29, figs. 7-8.

1970 *Mandelstamia (Xeromandelstamia) tumida* Christensen & Kilenyi: 52-53, pl.3, figs. 3a-f, pl.4, figs.1a-d.

1994 *Mandelstamia (Xeromandelstamia) tumida* Christensen & Kilenyi; Witte & Lissenberg, 21-22, pl.5, figs.8-16.

Diagnosis. A strongly dimorphic species of *Mandelstamia (Xeromandelstamia)* with postero-dorsal swelling particularly conspicuous in the females and juveniles, and a lesser tumidity in the postero-ventral area. Reticulate with rounded fossae and secondary reticulation in the males.

Remarks. The species has been recorded from the Upper Kimmeridgian and Lower Portlandian of the Dutch Sector of the Central North Sea Graben (Witte & Lissenberg, 1994) and thus has a younger range than those of Dorset (*Pectinatus* Zone) (Kilenyi, 1969; Christensen & Kilenyi, 1970) and eastern England (Late Hudlestoni and *Pectinatus*) (Wilkinson, 1983a,b). In the Denmark it has been recorded in the 'mid' and late Kimmeridgian (Börglum and Fredrikshavn formations) (Christensen & Kilenyi, 1970).

Notes on other species

Mandelstamia ignobilis Lyubimova(1955) was recovered from the Lower Volgian (*Virgatus* Zone) of Russia. This small, ovate species is somewhat obliquely downturned postero-dorsally with sub-parallel ventral and dorsal margins and

ornamented by subconcentric reticulation. The hinge is not described, but this species does not fit within *Mandelstamia*, but is a species of *Dicrorygma* Poag, 1962.

A group of species from south western Siberia have been referred to *Mandelstamia*. They have not been examined in detail for the present paper, but the following observations are made. Several species are clearly not members of the genus under consideration: *Mandelstamia furtiva* Lyubimova, *M. complacida* Kazmina, *M. (?) infida* Kazmina, *M. ordinataformis* Lyubimova, *M. (?) posterotuberculata* Mandelstam & Lyubimova, *M. quadriformis* Mandelstam & Lyubimova, *M. emendata* Lyubimova, *M. aspera* Mandelstam & Lyubimova, *M. ordinata* Mandelstam & Kazmina, *M. vulgata* Mandelstam & Kazmina and *M. dorsospina* Mandelstam & Kazmina. Two species require further examination before relationships can be determined, *Mandelstamia homesta* Mandelstam & Lyubimova and *M. conspicua* Kazmina. The only species in south western Siberia that can be placed in *Mandelstamia* with confidence are: *Mandelstamia ventrocornuta* (from the Oxfordian) and *M. percostata* (from the Kimmeridgian).

Mandelstamia grekoffi Bate (1975) from the mid to late Kimmeridgian of Tanzania, has an elongate, compressed carapace, tapering towards the posterior, and reticulate lateral surface. The inner margin is very narrow and although it possesses a lophodont hinge and a weak mid ventral concavity, it appears to have little in common with *Mandelstamia sensu stricto*.

Three species from the late Jurassic of Germany, by original designation, *Limnocythere brevispina* Steghaus (1951), *Limnocythere inflata* Steghaus (1951) and *Limnocythere fragilis* Martin (1940), have recently been placed into *Mandelstamia*. Morkhoven (1962) pointed out that they did not fit comfortably in this position. Christensen & Kilenyi (1970, p.31) placed *L. inflata* in *Mandelstamia* (but without comment) and Schudack (1994) considered all three to be of that genus. Nothing is known about the internal morphology of these taxa, but externally they show more resemblance to genera such as *Fabenella* or *Sternbergella* than *Mandelstamia* and do not belong here.

"*Limnocythere?* sp. (netzskulptiert)" Klingler, Malz & Martin (1962), may fall within the definition of *Mandelstamia*, but the inadequate illustration and lack of description prevents assignment with any certainty.

Leptocythere? of Triebel (1941, pl.7, figs. 71-72) from the "Dogger" of a borehole at Rodewald, Germany, might be a member of *Mandelstamia*, although the internal details are unknown.

Mandelstamia bathonica Ware & Whatley, described from the Bathonian Forest Marble of Oxfordshire, differs markedly in outline, ornamentation and in the sexual dimorphism of *Mandelstamia* and is only questionably assigned to the genus here. *Mandelstamia(?) pusilla* Ware & Whatley from the Bathonian Forest Marble of Oxfordshire differs in outline and the sexual dimorphism is less pronounced than other species of the genus. It does not fall within *Mandelstamia* as understood by the present authors.

Finally, a group of heavily ornamented species from the Late Jurassic have been assigned to this genus: *Mandelstamia horrida* Wilkinson (1983) from the Upper Kimmeridge Clay and *Mandelstamia immanensis* Witte & Lissenberg (1994) from the Lower to Middle Oxfordian deposits of the Dutch sector of the Southern North Sea Basin. These species are considered to be *Rectocythere*.

6. Conclusions

Mandelstamia is a long ranging genus with its origins in the Triassic. The earliest *Mandelstamia* (*Mandelstamia*) is known from the Aalenian, but the subgenus reaches its maximum diversity in the Late Oxfordian to Late Kimmeridgian (i.e. Middle Volgian) on the muddy sea floor the open shelf waters. The genus did not thrive in the higher energy conditions in which more arenaceous deposits accumulated. It is particularly numerous in the North Sea Basin, in the Timan-Pechora Basin and on the Russian Platform. In both areas the maritime influence and the open connections to the north delayed the influence of the climatic changes, caused by the northward movement of the arid climatic belt during the later part of the Jurassic. However, this, together with other physical pressures

associated with oxygenation/dysaerobia, oscillations in sea level and restrictions of the maritime conditions, controlled its distribution and led to its eventual extinction.

The evolutionary change from *Mandelstamia* (*Mandelstamia*) to *Mandelstamia* (*Xeromandelstamia*) was not seen in the Russian Province, where the former subgenus continued through to the early Cretaceous. However, during the late Kimmeridgian to early Cretaceous in northwestern Europe, *Mandelstamia* (*Mandelstamia*) disappeared to be replaced by *Mandelstamia* (*Xeromandelstamia*).

Mandelstamia disappeared from the record during the early Valanginian, but the subfamily continued through to the mid-Cretaceous in the genus *Dolocythere*.

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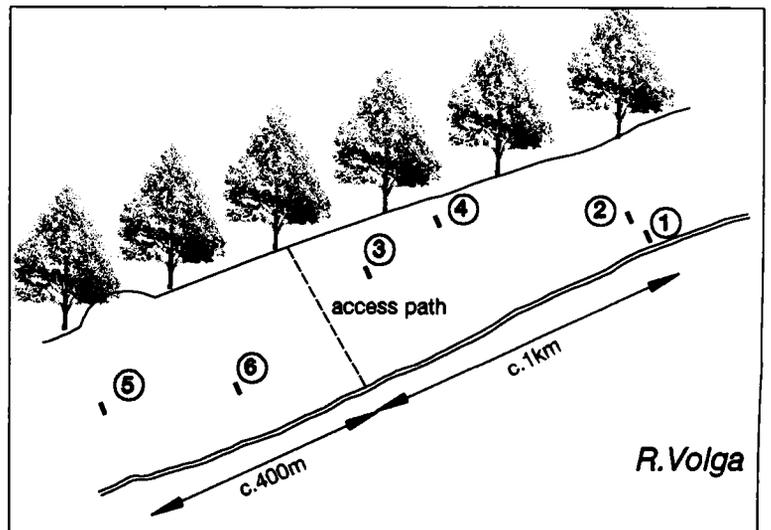
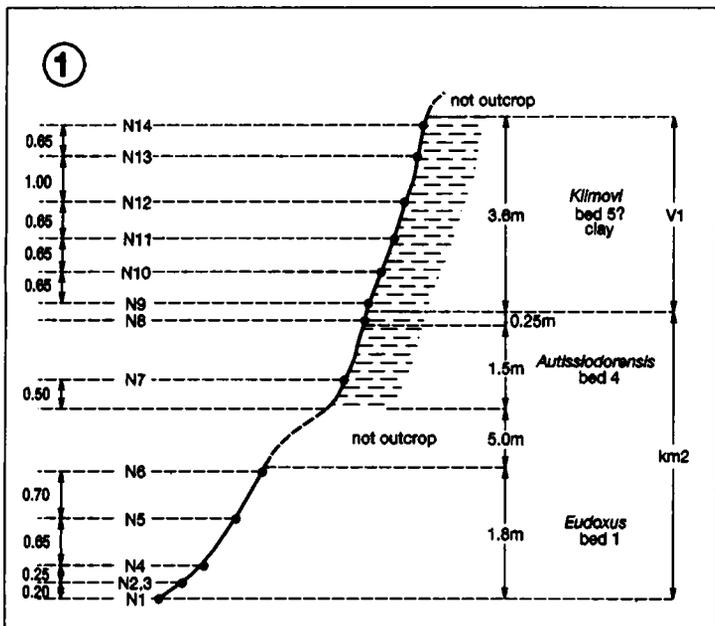
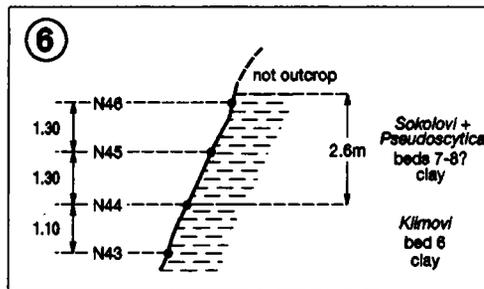
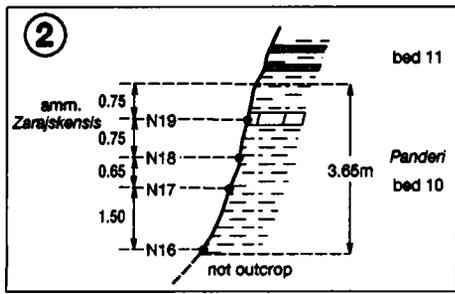
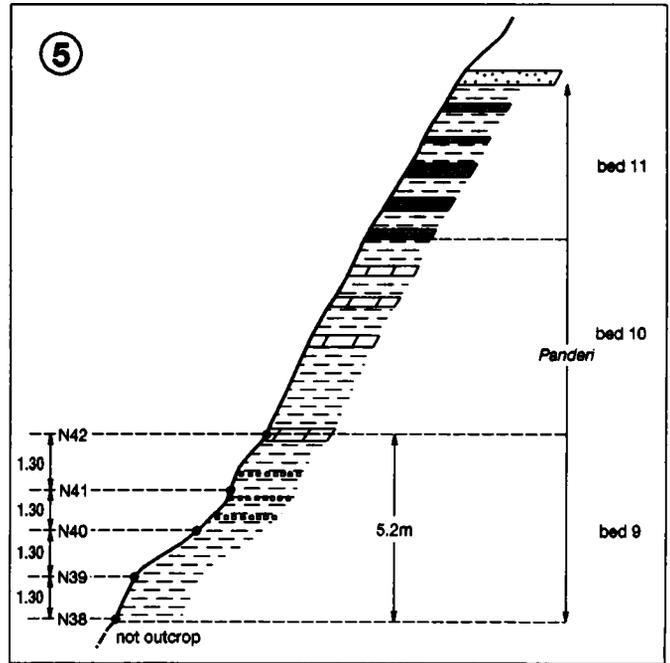
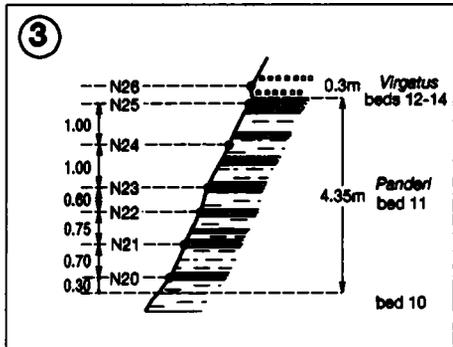
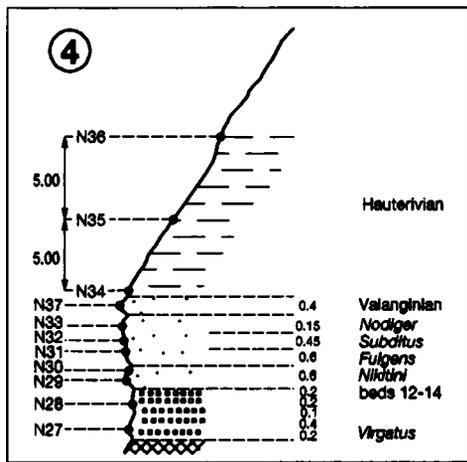
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**APPENDIX V. SAMPLES FROM GORODICHSHE REGISTERED
AT THE B.G.S., KEYWORTH
(Right Bank of the River Volga, 25km north of Ulyanovsk)**

Field no.	Sample no.	Sample position	Bed	Zone/Subzone
1	MPA42782	Upper Kimmeridgian		Eudoxus
2	MPA42783			
3	MPA42784			
4	MPA42785			
5	MPA42786			
6	MPA42787			
7	MPA42788			Autissiodorensis
8	MPA42789			
9	MPA42790	Lower Kimmeridgian		Klimovi
10	MPA42791			
11	MPA42792			
12	MPA42793			
13	MPA42794			
14	MPA42795			
16	MPA42796			
17	MPA42797	Middle Volgian		Panderi
18	MPA42798			
19	MPA42799			
20	MPA42800	Middle Volgian		Panderi
21	MPA42801			
22	MPA42802			
23	MPA42803			
24	MPA42804			
25	MPA42805			
26	MPA42806			
27	MPA42807			Virgatus
28	MPA42808			
29	MPA42809			
30	MPA42810			Nikitini
31	MPA42811			
32	MPA42812	Upper Volgian		Fulgens
33	MPA42813			Subditus
34	MPA42814			Nodiger
35	MPA42815	Lower Cretaceous		Hauterivian
36	MPA42816			
37	MPA42817			
38	MPA42818			Valanginian
39	MPA42819	Middle Volgian		Pavlovi/Panderi
40	MPA42820			
41	MPA42821			
42	MPA42822			
43	MPA42823			Pavlovi/Zarajskensis
44	MPA42824	Lower Volgian		Klimovi
45	MPA42825			Sokolovi
46	MPA42826			Pseudoscythica
47	MPA42827			
48	MPA42828			
51	MPA42829			
52	MPA42830			

Text-fig. 34

The Stratigraphy of the Volgian stratotype area of the Russian Platform as exposed in Summer 1995 together with the position of samples held at BGS, Keyworth (see Appendix V).



**APPENDIX VI. SAMPLES FROM THE DORSET COASTAL
SECTION
REGISTERED AT THE B.G.S., KEYWORTH**

Field No.	Sample No. (MPA)	Locality details
1	42038	0.5m below base of The Flats Stone Bed
2	42039	3.5m above top of The Flats Stone Bed
3	42040	7.5m above top of The Flats Stone Bed
4	42041	0.5m below base of Washing Ledge Stone Bed
5	42042	4.0m above top of Washing Ledge Stone Bed
6	42043	5.0m above top of Washing Ledge Stone Bed
7	42044	11.6m below base of Maple Ledge Stone Bed
8	42045	7.5m below base of Maple Ledge Stone Bed
9	42046	0.8m below base of Maple Ledge Stone Bed
10	42047	4.0m above top of Maple Ledge Stone Bed
11	42048	10.2m above top of Maple Ledge Stone Bed
12	42049	11.7m above top of Maple Ledge Stone Bed
13	42050	9m below base of Blake's Bed 42
14	42051	3.8m below base of Blake's Bed 42
15	42052	0.6m below base of Blake's Bed 42
16	42053	2.4m above top of Blake's Bed 42
17	42054	6.2m above top of Blake's Bed 42
18	42055	9.4m below base of Yellow Ledge Stone Bed
19	42056	4.9m below base of Yellow Ledge Stone Bed
20	42057	2.5m below base of Yellow Ledge Stone Bed
21	42058	0.9m above top of Yellow Ledge Stone Bed
22	42059	4.8m above top of Yellow Ledge Stone Bed
23	42060	8.7m above top of Yellow Ledge Stone Bed
24	42061	12.2m above top of Yellow Ledge Stone Bed
25	42062	14.7m above top of Yellow Ledge Stone Bed
26	42063	0.7m above top of Cattle Ledge Stone Bed
27	42064	4.4m above top of Cattle Ledge Stone Bed
28	42065	3.4m below base of Grey Ledge Stone Bed
29	42066	immediately above Grey Ledge Stone Bed
30	42067	4.3m above top of Grey Ledge Stone Bed
31	42068	8.5m above top of Grey Ledge Stone Bed
32	42069	11.3m below base of Rope Lake Stone Bed
42	42070	1.2m above top of Basalt Stone Bed
43	42071	5.2m above top of Basalt Stone Bed
44	42072	8.7m above top of Basalt Stone Bed
45	42073	5.1m below base of White Stone Bed
46	42074	0.8m below base of White Stone Bed
47	42075	2.2m above top of White Stone Bed
48	42076	3.3m below base of Middle Stone Bed
49	42077	0.1m above top of Middle Stone Bed
50	42078	4.0m above top of Middle Stone Bed
51	42079	1.8m below base of Fresh Water Steps Stone Bed
52	42080	1.6m above top of Fresh Water Steps Stone Bed
53	42081	5.6m above top of Fresh Water Steps Stone Bed
54	42082	10.2m above top of Fresh Water Steps Stone Bed
55	42083	13.7m above top of Fresh Water Steps Stone Bed
56	42084	17.6m above top of Fresh Water Steps Stone Bed
57	42085	22.0m above top of Fresh Water Steps Stone Bed
58	42086	26.0m above top of Fresh Water Steps Stone Bed

59	42087	30.0m above top of Fresh Water Steps Stone Bed
60	42088	34.0m above top of Fresh Water Steps Stone Bed
61	42089	37.5m above top of Fresh Water Steps Stone Bed
62	42090	41.4m above top of Fresh Water Steps Stone Bed
63	42091	20.1m below base of Rotunda Nodules
64	42092	16.1m below base of Rotunda Nodules
65	42093	12.2m below base of Rotunda Nodules
66	42094	8.2m below base of Rotunda Nodules
67	42095	4.2m below base of Rotunda Nodules
68	42096	0.1m below base of Rotunda Nodules
69	42097	0.15m above top of Rotunda Nodules
70	42098	8.0m above top of Rotunda Nodules
100	42099	6.0m below base of the Massive Bed
101	42100	2.0m below base of the Massive Bed
102	42101	0.3m below base of the Massive Bed
197	42102	8.5m below prominent siltstone rib
198	42103	6.75m below prominent siltstone rib
199	42104	3.75m below prominent siltstone rib
200	42105	immediately above prominent siltstone rib
201	42106	4.0m above prominent siltstone rib
202	42107	8.0m above prominent siltstone rib
203	42108	12.0m above prominent siltstone rib
204	42109	16.0m above prominent siltstone rib
205	42110	18.0m above prominent siltstone rib