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Boreal influence on English Ryazanian Bivalves

By

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With 6 text figures

ABSTRACT

In early Ryazanian times a marine embayment extended from the Southern North Sea Basin onto the East Midlands Shelf (Spilsby Basin) and slightly later also reached into the Yorkshire Basin. The sediments on the shelf are predominantly glauconitic sandstones with phosphates and sideritic clay-ironstones (upper parts of the Spilsby Sandstone and the Sandringham Sands) while those in the Yorkshire Basin are clays (lowest part of the Speeton Clay). The associated bivalve faunas are marine and show strong affinities with East Greenland and Russian Platform faunas. In south central England the ferruginous Whitchurch Sands represent restricted marine conditions and contain a bivalve fauna related in part to that of the late Portland Beds of the Upper Jurassic, although the sands are separated from these by the Lulworth Beds of late Jurassic age. In southern England the Durlston Beds are predominantly limestones and marls and contain various bivalve faunas ranging from restricted marine to freshwater facies. The near marine horizons represent transgression into the Anglo-Paris basin from the north. The more restricted and fresh-water environments are typical of European marginal facies. The various bivalve faunas reflect the fluctuating environments.

KURZFASSUNG

Im frühen Ryazanian dehnte sich eine Meeresbucht vom südlichen Nordsee-Becken bis auf den East Midland Shelf (Spilsby-Basin) aus und erreichte etwas später das Yorkshire Basin. Die Sedimente im ersteren bestehen vorwiegend aus glaukonitischen Sandsteinen mit phosphoritischen und sideritischen Toneisensteinen (oberer Teil der Spilsby Sandsteine und Sandringham Sande) während im Yorkshire Bekken Tone vorherrschen (unterer Teil des Speeton Clay). Die auftretenden Bivalven-Faunen sind marin und zeigen enge Beziehungen mit Ostgrönland und der russischen Plattform. Im südlichen Zentral-England zeigt der eisenschüssige Whitchurch Sand eingeschränkte marine Bedingungen an, die Bivalven-Fauna ist teilweise ähnlich wie die Fauna der höheren Portland Beds des Ober-Jura, obwohl sie durch die Lulworth Beds getrennt sind. In Südengland bestehen die Durlston Beds vorwiegend aus Kalken und Mergeln und enthalten vielfältige Bivalven-Faunen, die von eingeschränkt-marinen Typen an der Basis bis zu Süßwasser-Typen im oberen Teil reichen. Für den stärker marinen Anteil wird eine marine Transgression aus dem Norden in das Anglo-Französische Becken angenommen. Die nur schwach marinen und die Süßwasser-Bereiche sind typisch für die europäische Randfazies.

INTRODUCTION

The aim of this article is to review briefly the Ryazanian bivalve faunas of England. The study is based primarily on the author's own work in Eastern England, which relied in part on the important collections made by the Institute of Geological Sciences (IGS) from cut-off channels and pipe-line trenches in eastern England in the 1960's. It is supplemented by museum and literature studies of the area to the south. The stage name Ryazanian is used because it is still not possible to correlate English sequences directly with Tethys and the Berriasian stage.

Ryazanian deposition occurs in eastern and southern England, the outcrops and important localities are shown in Fig. 1. Fig. 2 shows the inter-relationship of the basins in a generalised strike section from Yorkshire to Dorset. The stratigraphic terms follow Casey (1973), Casey and Gallois

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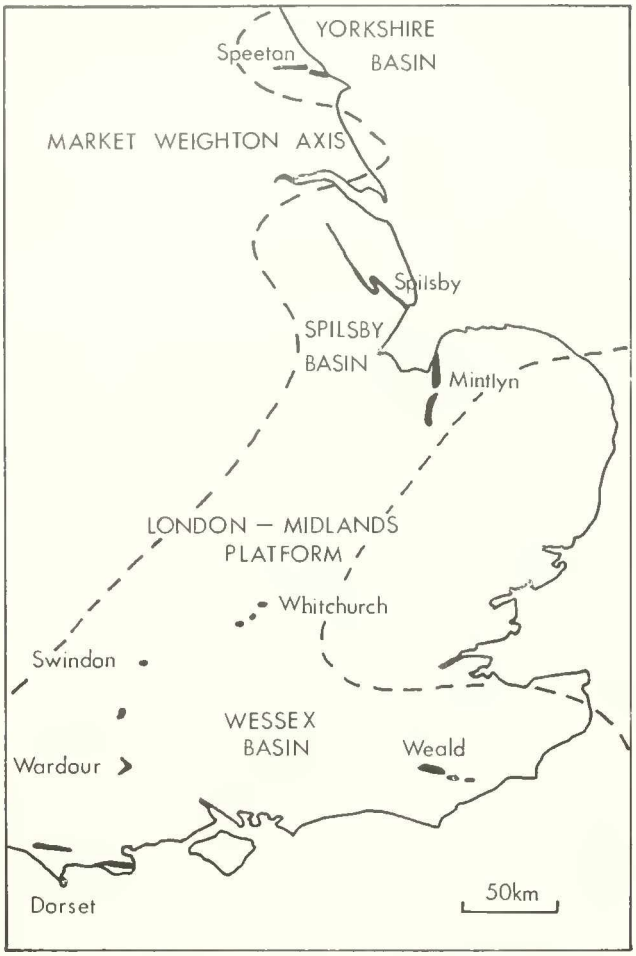


Fig. 1. Outcrop and locality map of Ryazanian strata in England, showing principal basins of deposition. Outcrop widths are exaggerated parallel to strike. Dashed line represents approximate position of shore-line.

(1973), Rawson, Curry, Dilley, Hancock, Kennedy, Neale, Wood and Worssam (1978) and Kelly and Rawson (1983 in press). North of the London-Midlands Platform clays and sandstone were deposited, predominantly fully marine (parts of the Speeton Clay, Spilsby Sandstone and Sandringham Sands Formations). To the south occur the variable salinity limestones, marls and clays of the Durlston Formation (upper part of the Purbeck Beds) ranging from restricted marine to freshwater. Casey (1963) believed that there was a basal Ryazanian transgression from the marine Spilsby Basin southwards across central England into the Wessex Basin (the northern part of the Anglo-Paris Basin). It is represented by the mid-Spilsby nodule bed in the Spilsby Basin, the Whitchurch Sands of southern central England and the Cinder Bed of the Wessex Basin. This idea is modified below. The Wessex Basin is now known to extend considerably to the south-west and it is not clear whether there may have been connection via a westerly seaway to Tethys in Ryazanian times. Fig. 3 shows the areal distribution of the principal facies in England set in a palaeogeographic reconstruction of north west Europe.

The bivalve faunas from each depositionary area are described in general terms below. Significant bivalves are described and then discussed in more detail by major taxonomic group.

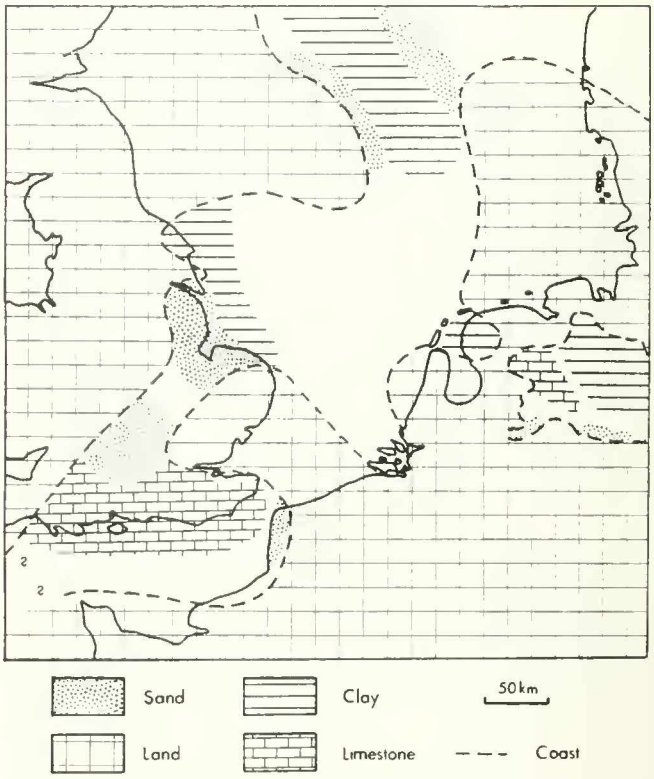


Fig. 3. Ryazanian palaeogeographic reconstruction of north-west Europe, showing distribution of principal facies.

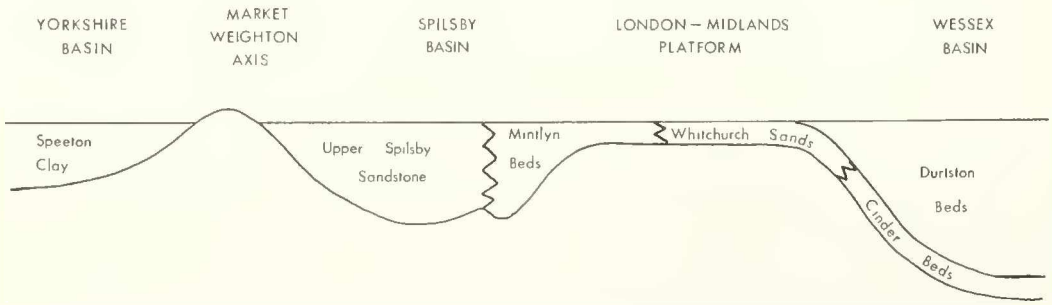


Fig. 2. Generalized strike section from Yorkshire to Dorset, showing the distribution of the various Ryazanian strata; not to scale.

Yorkshire Basin (Speeton Clay, Lower D Beds): The Yorkshire Basin represents the northerly of two Cretaceous embayments on the west side of the southern North Sea Basin, and which is bounded to the south by the Market Weighton structure which was probably emergent in Ryazanian times. The Speeton Clay is of Ryazanian to Albian age and outcrops in the classic section at Speeton on the Yorkshire coast. Only about the lowest 4 m are referred to the Ryazanian and belong to beds D8 at the base to D5 at the top (Neale 1962, 272–273; Casey 1973, 211). At the base is the Coprolite Bed which is composed of phosphatised nodules and moulds of fossils. The latter include common internal moulds of lucinids and *Grammatodon schourovskii* (Rouil. & Voss.) with valves in occlusion, together with pavloviid ammonites. The assemblage compares closely with that of the basal nodule bed of the Spilsby Sandstone in Lincolnshire and is probably of Middle Volgian age. Above this the earliest dateable macrofossils are *Acroteuthis lateralis* (Phil.) in D8 which Pinckney and Rawson (1975) regard as Ryazanian. Ammonites delete which first appear slightly higher in D7E, where late Ryazanian *Peregrinoceras* occur (Casey, 1973). It is probable that only the upper part of the Ryazanian is represented in the Lower D Beds. Neale (1968, 315) recorded *Oxytoma* and *Dicranodonta* through much of D6. I agree with his identifications of *Oxytoma*, but the records of *Dicranodonta* are *Pseudolimea*. Other elements recorded from D6 by Neale include *Lucina*, *Thracia*, *Astarte*, *Entolium* and *Pinna*. He also noted (1968, pl. 10) driftwood containing the typical flask shaped borings of bivalves referred here to the ichnogenus *Teredolites*. To these records can be added: D6A alpha, "*Lucina*" sp. (abundant in life position), ostreids including an exogyrid (one noted attached to belemnite guard), *Entolium orbiculare* (Sow.), *Plagiostoma* cf. *rigida* (Sow.); D6I, *Oxytoma* cf. *cornueliana* (d'Orb.) and *Pseudolimea arctica* Zakh.; D6H, *Stegoconcha* sp.

Neale (1968, 211) summarised his conclusions on the Lower D Beds by indicating that beds D7–6 represented a transgressive sea with slow sedimentation rate, while later in D6 there were more open circulating marine conditions with a slightly greater rate of sedimentation. The assemblage in D6A alpha is dominated by deep burrowing lucinids, but an epifauna also occurs indicating that bottom conditions were sufficiently oxygenated to support a moderately diverse assemblage. But in D5 sedimentation again dropped and the water became poorly aerated and stagnant suggesting more brackish conditions.

To the south of the Market Weighton Axis lies the Spilsby Basin which is divided into:

Northern Spilsby Basin (Upper Spilsby Sandstone): This is the northern part of the southern embayment off the west of the Southern North Sea Basin. It is bounded to the north by the Market Weighton structure and to the south it merges into the Southern Spilsby Basin. The Ryazanian is represented principally by the Upper Spilsby Sandstone, up to 11 m thick. Part of the base of the overlying Claxby Ironstone Formation is latest Ryazanian, but the faunas are not discussed here. The mid Spilsby nodule bed at the base of the Upper Spilsby Sandstone is placed in the *icenii* Zone, and the earlier Ryazanian *runctoni* and *kochi* Zones are apparently unrepresented (Casey 1973). The nodule bed does not appear to have been reworked in the way the basal Spilsby nodule bed was (Kelly, 1980), but the bivalve faunas include many late Jurassic reworked elements. The Upper Spilsby Sandstone is composed mainly of glauconitic sandstones.

Faunas occur principally in the calcite-cemented concretions, most calcarous material having been leached out of the intervening sands. Previous records of bivalves are from undifferentiated Upper and Lower Spilsby Sandstone (Woodward 1895, 293; Woods 1899–1912) where a total of about 20 species are listed. Current work indicates that there are at least 21 species from the Upper Spilsby Sandstone alone, the Lower Spilsby Sandstone having a very much richer bivalve fauna still. Dominant in the bulk of the Ryazanian sandstones is the free swimming *Entolium orbiculare*, but other significant elements of the fauna include *Maclearnia* (= *Boreionectes*) *cinctus* (Sow.), *Buchia volgensis* (Lah.) and lignite with *Teredolites* borings containing *Martesia constricta* (Phil.). The very latest Spilsby Sandstone fauna is associated with *Peregrinoceras albidum* but has not been seen in situ. It was collected by R. G. Thurrell from Biscathorpe Wold Gravel Pit and is now in the IGS. It is the best preserved assemblage in the whole of the Ryazanian of the Spilsby Basin due to the matrix being a clayey sandstone. The fauna is dominated by thick-shelled bivalves of the genera *Dicranodonta*, *Myophorella*, *Lyapinella*, *Procyprina* and *Corbicellopsis*, but also includes *Nuculoma*.

The Upper Spilsby Sandstone bivalves indicate continual normal salinity conditions. Epifaunal and infaunal elements were adapted to living in an unstable environment and therefore show that the substrate was unconsolidated and frequently reworked by currents. Only in the late Ryazanian with the incoming of clay did deposit feeders make an appearance.

Southern Spilsby Basin (Mintlyn Beds): South of the Wash up to 15 m of the Sandringham Sands are referred to the Mintlyn Beds of Ryazanian age. The full sequence of English ammonite zones of the Ryazanian was recognized by Casey (1973), although breaks in the sequence are more obvious due to the presence of phosphatic nodule beds at the base of the Ryazanian, near the top of the *kochi* Zone and in the upper part of the *Surites icenii* Zone. A preliminary listing of some of the bivalve genera was given by Casey (1961). Gallois & Morter (1980) recorded a number of Mintlyn Beds bivalves from boreholes in the Wash. The basal nodule bed of the Mintlyn Beds contains abundant moderately phosphatised *Protocardia* of the *concinna* group. The bulk of the sequence is composed of glauconitic, clayey sands in which faunas have been destroyed during compaction. However there are several horizons of sideritic clay-ironstone concretions which have produced an abundant and varied bivalve fauna usually dominated by large, thick shelled *Lyapinella*, but high in the sequence diminutive corbulids become numerically dominant. Other numerically important elements of the fauna include a globose and almost smooth *Protocardia*, *Anisocardia*,

Myophorella, *Pleuromya* and *Entolium*, the last especially in more sandy facies. Less important numerically but important stratigraphically is the inoceramid *Anopaea*.

London-Midlands Platform (Whitchurch Sands): Casey and Bristow (1964) introduced the term Whitchurch Sands for the hitherto enigmatic marine sandstones which post-dated the Lulworth Beds and predated the Aptian Lower Greensand in the area from Buckinghamshire to Wiltshire. These strata have not been seen in situ by the present author, but were stated to be a maximum of 2 m in thickness. Correlation is made with the Cinder Bed of the Wessex sequence, both units being apparently recognizable together in the Vale of Wardour. Casey and Bristow (l. c.) recorded the following taxa: *Nucula* cf. *lorioli* Cox, *Mytilus* sp., "*Gervillia*" cf. *arenaria* (Roem.), *Laevitrigonia gibbosa* (Sow.), *L. gibbosa* var. *damoniana* (Lor.), *L. wightensis* (Strand), *L.* sp. juv., *Trigonia densinoda* Eth., cf. *Corbicella pellati* Lor., *Thracia* sp., *Myrene fittoni* Casey, *M. mantelli* (Dunk.), *Eodonax* sp., *Protocardia purbeckensis* (Lor.), *P.* sp., ?"*Psammobia*" *tellinoides* J. de C. Sow., *Corbula inflexa* Roem., *C. sublaevis* Roem., *C. alata* J. de C. Sow. They did not indicate relative abundance of taxa, but there is an overwhelming domination by *Protocardia* (55%) and corbulids (40%), thus showing similarities in biofacies to parts of both the Mintlyn Beds and the Durlston Beds. But the presence of *Eodonax* and *Laevitrigonia* is reminiscent of Portland Limestone conditions. Although this is a moderately diverse assemblage of bivalves, the absence of ammonites, echinoids, brachiopods etc. suggests a restricted marine environment.

Wessex Basin (Durlston Beds): The Durlston Beds occupied most of the Wessex Basin and are generally regarded as Ryazanian (Rawson et al. 1978). The base of the Ashdown Beds of the Weald is also regarded as Ryazanian, but these strata are not discussed here. Thicknesses reach maximums of 60 and 70 m in the subsidiary basins centered on east Dorset and the Weald respectively, but thin to approximately 15 m over the Portsdown structure (Howitt 1964). Subsequent lower Cretaceous folding and erosion have destroyed much of the western area of the Durlston Beds except for the western outliers scattered along the outcrop from Dorset to Buckinghamshire. The lithologies are dominantly limestones, marls and clays. The information relating to bivalves is scattered as they have never been monographed, although lists can be compiled from the literature (e. g. Arkell 1933; 1947; Clements 1969), especially for Dorset. However Casey (1955a; b) has made important contributions to the systematic knowledge of the families Neomiodontidae and Corbiculidae which occur in the Purbeck Beds. The preservation of bivalves is commonly poor as specimens become compacted with the sediment and strongly distorted. However locally, especially in the limestone bands, preservation is good and uncrushed specimens can be obtained. Faunas from each horizon are rich in individuals but very low in diversity. Most of the remarks here will have to be confined to the type section at Durlston Bay near Swanage in Dorset because information is not yet readily available for other areas.

The base of the Durlston Beds is taken by Casey at the incoming of an oyster-rich bed, the Cinder Bed. In Durlston Bay this unit is about 3 m thick and all but a thin band near the

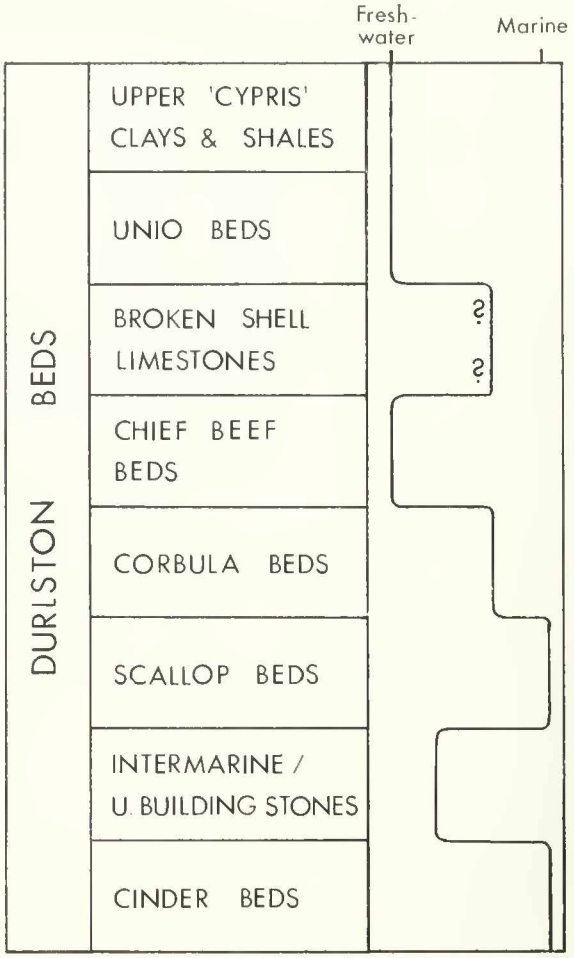


Fig. 4. Suggested salinities of the Durlston Beds in Durlston Bay, Swanage, Dorset, based on bivalves.

centre is a lumachelle composed exclusively of the predominantly disarticulated valves of *Liostrea distorta* (J. Sow.). The valves appear to be largely current sorted and ex situ. However attachment areas on many specimens indicate that other oysters were the principal sites for attachment. It should be pointed out that in the Durlston Bay sequence *Liostrea* is not restricted to the Cinder Bed, but appears in other horizons higher in the sequence, though never in anything like the same abundance. The same species also appears in the Wealden. Inland the density of *Liostrea* is reduced and diluted with, *Protocardium*, *Myrene*, *Modiolus*, *Chlamys*, and *Aguilerella* as in the Vale of Wardour. *Laevitrigonia* is present but I have not yet seen well preserved specimens. The centre of the bed in Durlston Bay is much less densily fossiliferous than the surrounding oyster lumachelle but contains a more varied assemblage including common *Protocardia major* (J. de C. Sow.), *Serpula coacervata* Blum., spines of *Hemicidaris purbeckensis* Forbes and less commonly *Modiolus* and *Laevitrigonia*. There are scattered oyster fragments, but complete valves are unusual. This clearly represents a marine assemblage though somewhat restricted in number of species. It is the most normal marine assemblage in the whole of the Purbeck Beds. It is also recognized in the Weald; for example Casey (in Worssam and Ivimey-Cook 1971, p. 33) recorded from depths of 1984–1994′ in the Warlingham borehole: *Corbula* sp., *C.* ?, "*Gervillella*" cf. *arenaria* (Roem.), *Modiolus* sp.,

Myrene fittoni Casey, *M.* cf. *fittoni*, *M. pellati* (Lor.), *M.* cf. *pellati*, *M.* sp., *Neomiodon*?, *Protocardia major* (J. de C. Sow.), *P.* cf. *major*, *P.* sp.

Above the Cinder Bed of the Durlston Bay sequence, Clements (1969, Fig. A35) has accurately logged the sequence and recorded some of the bivalve faunas. These are used below together with the author's own observations. The Intermarine Beds or Upper Building Stones contain a low diversity freshwater-dominated facies with *Neomiodon* and also *Viviparus*. But in the Scallop Beds above a restricted marine facies occurs with *Chlamys*, *Liostrea* and *Modiolus*. This again may be correlated with the Weald where Worssam and Ivimey-Cook (1971) record abundant *Corbula*, *Neomiodon* and *Modiolus* from depths of 1944–1968′ in the Warlingham Borehole. The succeeding *Corbula* Beds contain low diversity assemblages often with current-sorted *Corbula* pavements with occasional *Neomiodon* suggesting a brackish to freshwater environment. The fauna of *Unio* noted in the Chief Beef Beds indicates a definite freshwater environment. The Broken Shell Limestone is difficult to assess because of the broken and well cemented components, but possibly represents a return to more brackish conditions. The final episode of the Durlston Beds, in the *Unio* Beds and the Upper "*Cypris*" Clays and Shales, was a return to *Unio*- and *Viviparus*-dominated freshwater facies. The variation in salinities suggested for the Durlston Beds is summarised in Fig. 4. It appears that there are at least two and probably three principal marine events.

SIGNIFICANT BIVALVE GROUPS

There are several groups of bivalves which are important for discussion of correlation and of facies both within England and between England and other regions. They are discussed in turn below under family titles.

Buchiidae: Through much of the marine Boreal Realm, *Buchia* is an important element of the faunas both numerically and stratigraphically. Unfortunately in England it is rare in the Ryazanian. This is probably due to England being at the south-west of the almost landlocked Southern North Sea Basin and in close proximity to the warmer waters of the Wessex Basin. There are only five specimens known, Sedgwick Museum Cambridge (SMC) B11337-9, and British Museum, Natural History (BMNH) 81069, 81075. They were originally described by Pavlow (1896, p. 549) as *Aucella volgensis* Lahusen and came from the Spilsby Sandstone of Donington-on-Bain, Lincolnshire. Casey (1973, 204) suggested they occured in the same bed as specimens of *Surites*. Zakharov (1981) showed that *B. volgensis* appears above the base of the "Berriasian" of the Russian Platform, in the "*Chetaites sibiricus*" Zone, and continuing to the end of the Berriasian. He recorded *B. volgensis* alongside *B. uncitoides* in the central and northern parts of of the Russian Platform, but *volgensis* only in the south and south-eastern parts. The English occurences therefore compare most closely with records from the south and south-eastern parts of the Russian Platform, where part of the base of the Ryazanian is also missing. It is interesting to note that the previous appearance of *Buchia* in England was in the Middle Volgian, in the basal Spilsby nodule bed. Subsequently *B. lamplughi* (Pavlow) appeared in the Hauterivian.

Inoceramidae: Elsewhere, especially in the upper Upper Cretaceous, inoceramids are very important for correlation. The genus *Anopaea* has not yet been used, but on both the Russian Platform and in eastern England there is a similar succession of Volgian to Valanginian species from *A. sphenoidea* Geras. to *A. brachowi* (Rouil. & Voss.) (see Fig. 5). In eastern England *A. sphenoidea* occurs in the *preplicomphalus* and *lamplughi* Zones of the Spilsby Sandstone. *A. brachowi* occurs in the *lamplughi* Zone of the Spilsby Sandstone, *kochi* Zone of the Mintlyn Beds and Bed D3 of *Polyptychites*

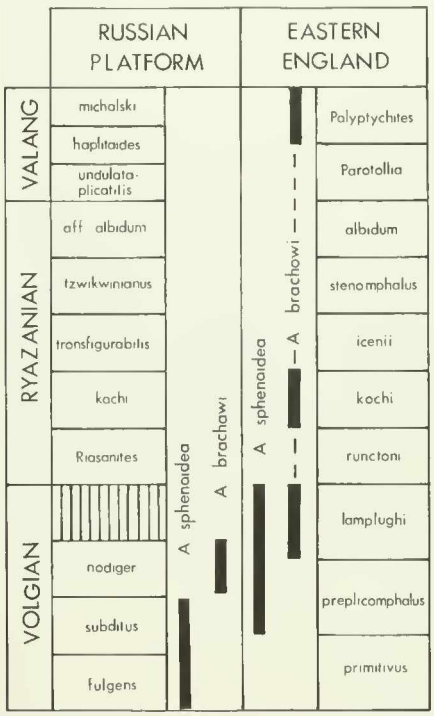


Fig. 5. Distribution of *Anopaea sphenoides* (Gerasimow) and *a. brachowi* (Rouillier) in eastern England and the Russian Platform.

Zone age in the Speeton Clay. On the Russian Platform Gerassimov (1955) described *A. sphenoidea* from the *fulgens* and *catenulatum* Zones, while *A. brachowi* only occured in the *nodiger* Zone. The discrepancy between the two ranges can be accounted for either by the ranges of the species of *Anopaea* being different between England and the Russian Platform, and the first appearance the two species is earlier on the Russian Platform; or because in England we are drawing the base of the Ryazanian lower than on the Russian Platform.

Myophorellinae: Various myophorellids occur in the Spilsby Basin including "*Trigonia ingens* Lycett" which is still under investigation. However one group, the genus *Pseudomyophorella*, has some bearing on the correlation between the Spilsby and Wessex Basins. *P. densinoda* (Ethe

RIDGE 1881) is known from only two specimens (IGS 11900, 11901) from a sandstone believed by CASEY and BRISTOW (1964, 124) to be an interdigitation of the Whitchurch Sands into the Cinder Bed of the Vale of Wardour. It is densely tuberculate, not just on the flank, but also on the area. The most closely related species is *P. tealbyensis* (LYCETT 1875) which is only known from the Upper Volgian *preplicomphalus* Zone of the Spilsby Basin, in which the ornament is much coarser. It is believed here that *P. densinoda* arose from *P. tealbyensis*.

Laevitrigoniinae: *Laevitrigonia* is particularly well known from the English Portland Beds. It also occurs rarely in the Cinder Beds, the Whitchurch Sands and there is one enigmatic specimen supposedly from an erratic pebble of Spilsby Sandstone from Norfolk. The last specimen (IGS CE3752) corresponds most closely to *L. manseli* (LYCETT) a species which is particularly common in the upper part of the Portland Limestone of Dorset. Unfortunately neither the species or the genus are known in situ from anywhere in the Spilsby Basin. However the same species is known from a well preserved mould from the Whitchurch Sands of Buckinghamshire (IGS CE 6101). *L. gibbosa* (J. SOWERBY) and *L. wightensis* (STRAND) are both recorded by CASEY and BRISTOW (1964, 123). None of the specimens that I have seen can be referred precisely to the former species which I believe occurs only near the top of the Tisbury Glauconitic Member of the Portland Limestone in the Vale of Wardour, and from a level towards the middle of the Gres des Oies in the Boulonnais of Northern France. CASEY and BRISTOW also state that the type of *L. wightensis* comes from the Whitchurch Sands near Devizes in Wiltshire. This species is very common in the Roach at the top of the Portland Limestone both on the Isle of Portland and also at Swindon in Wiltshire. A further specimen is known from Potton in Bedfordshire (SMC 85668) where it was found in the basal Lower Greensand, probably reworked from the Whitchurch Sands. It seems possible that *Laevitrigonia*, originally derived from Portland beds stock, was inhabiting the slightly brackish marine fringes of the Spilsby Basin, but not occuring with the main marine faunas in the centre of the basin. *Laevitrigonia* has not been recorded from the Russian Platform, but I now transfer the Middle Volgian species described as *T. koprinensis* GERASSIMOV (1955) to that genus.

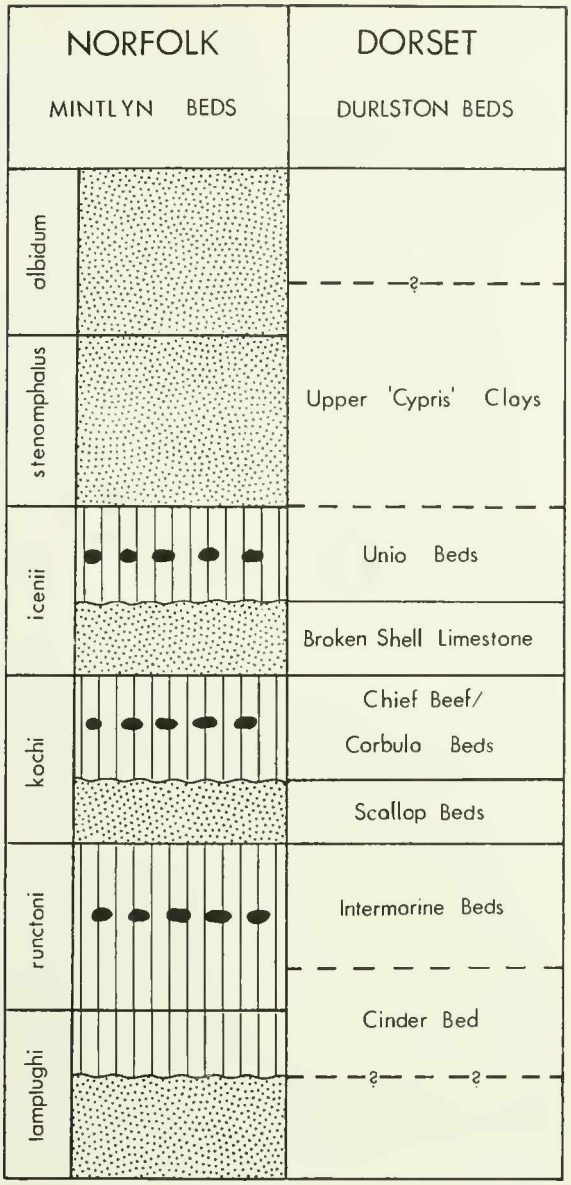
Protocardiidae: There are several distinctive protocardiids around the Jurassic Cretaceous boundary in England. The very large *Protocardia dissimilis* (J. SOWERBY) occurs in the Portland Beds only. In the Upper Volgian of the Spilsby Basin, small, inflate forms of the *P. concinna* (BUCH) group appear and become particularly abundant in the phosphatised nodule bed at the base of the Mintlyn Beds. *P. major* (J. de C. SOW.) from the Purbeck beds and from the Whitchurch Sands is extremely similar and may prove to be identical to the species of the Spilsby Basin. Above the base of the Mintlyn Beds and ranging to the top is a very globular protocardiid. It is probable that these taxa are quite strongly facies related and that their use will eventually be in the recognition of particular biofacies rather than in stratigraphic correlation.

Neomiodontidae: It is not possible here to expand further the observations of CASEY (1955a, 218), that the genera *Neomiodon* and *Myrene* occupy different habitats, the former occuring in freshwater-brackish environments, while the latter occurs in marine-brackish environments. In England both these genera are restricted to the Wessex Basin and the Midland Platform.

Corbulidae: This familiy is in need of considerable study and revision. It forms the numerically dominant bivalve in parts of the upper Mintlyn Beds, as well as being an important component of the Whitchurch Sands and of many horizons in the Durlston Beds where it is particularly abundant.

DISCUSSION

It can be seen from the above observations that correlations based on bivalves can be made in two directions. Firstly the more normal marine faunas of the Spilsby Basin provide fair comparisons with the contemporary faunas of East Greenland and the Russian Platform. In all 50 bivalve species are recorded from the Mintlyn Beds and the Upper Spilsby Sandstone. 45% of these also occur in East Greenland, 25% on the Russian Platform and 8% in the North Urals. Conversely about 60% of the Greenland, 30% of the Russian Platform and 10% of the North Urals Ryazanian bivalve species occur in England. Secondly some bivalves like *Pseudomyophorella* and *Laevitrigonia* may eventually prove useful in correlation between eastern and southern England, but in general it is extremely difficult to make any direct correlation between the Spilsby and Wessex Basins based on bivalves, because of the great facies differences between the two basins during Ryazanian times. However CASEY (1963) regarded the mid-Spilsby nodule bed as being an equivalent to the Whitchurch Sands/Cinder Bed transgression, though the more precise relationship is with the base of the *runctoni* Zone (CASEY 1973, p. 222). It has already been indicated above that correlation of events within the Wessex Basin may be feasible. It is also possible that a parallel might be drawn relating the phases of condensation in the Spilsby Basin phosphate nodule beds to the regressive periods in the sequence of the Durlston Beds. There are three phosphate nodule beds recognized in the Mintlyn Beds, which are the most complete marine Ryazanian sequence in eastern England. Each of these beds represents a time of moderate uplift of the seafloor when some winnowing took place. If the event was widespread and of a eustatic nature then it could also cause a regression within the Wessex Basin. The intervening sediments between the phosphate nodule beds represent renewed sedimentation in the Spilsby Basin and can be correlated with the more marine parts of the Durlston Beds. The situation is summarised in Fig. 6 A clear pattern of correlation can be seen between the *runctoni*, *kochi* and *icenii* Zone nodule beds and the Intermarine, Chief Beef/*Corbula* and Upper "*Cypris*" Clays respec-



tively. Thus the Cinder Bed can now be placed before the phase of condensation of the *runctoni* Zone and may even be as early as the Upper Volgian *lamplughi* Zone. The next marine horizon, the Scallop Beds, correlates with the non-phosphatised *kochi* Zone sediments. Above the Unio Beds the pattern appears to break down because the freshwater dominated Upper "*Cypris*" Clays are correlated with the normal *stenomphalus* and *albidum* Zones sediments. However the faunas of the Mintlyn Beds at these times are increasingly dominated by corbulids which appear to indicate a slightly restricted marine facies in the clay ironstones of the southern Spilsby Basin, which are probably very shallow as also indicated by the presence of abundant lignite. It must be stated that Anderson & Bazley (1971) have already indicated 19 cycles ranging from brackish to near normal marine when fully developed in the Durlston Beds of England based on ostracod evidence. Bivalves are very much larger and take much more time to become established than ostracods, therefore potentially provide a more crude stratigraphy. However the more marine ostracods may represent very temporary marine conditions, during which there was not always sufficient time for the marine bivalves to develop. Therefore when marine bivalves occur, marine conditions must have been stable for sufficient time to allow the bivalves to colonise. The three most marine levels of the Durlston Beds, based on the bivalves, i. e. the Cinder Beds, Scallop Beds and Broken Shell Beds, correspond to the more marine parts of Anderson and Bazley's Cinder Bed, Scallop and Lulworth Cycles respectively.

Whether this event correlation can also be used for correlation elsewhere in Europe remains to be seen. The nearest related area with proximity to the North Sea Basin would be the north german Lower Saxony Basin, from which Huckriede (1967) has already described fresh and brackish water bivalves in detail.

Fig. 6. Suggested correlation between the Mintlyn Beds and the Durlston Beds.

CONCLUSIONS

In the Ryazanian a mainly normal marine embayment occupied eastern England. Southern England was occupied by an enclosed embayment with marine, brackish and freshwater sediments, which maintained intermittent access to marine areas to the north through a marine strait. It can be seen clearly that the open marine fauna of the Ryazanian of England is most closely related to marine faunas of Boreal Regions and especially to those of East Greenland and the Russian Platform. Stratigraphically significant *Buchia* and *Anopaea* provide closely comparable tie lines to the ammonite correlations of Casey (1973). The bivalve faunas of the Wessex Basin, which represent variable salinity to freshwater conditions, might compare more closely with those of north Germany and other European regions.

Within England bivalve correlation cannot be made directly between the Spilsby and Wessex Basins. However the three Ryazanian condensed phosphate nodule horizons of the Spilsby Basin may be correlated with the three principal freshwater-brackish events on the Wessex Basin, thus implying a possible late Jurassic age for the Cinder Bed and Whitchurch Sand previously believed to be basal Ryazanian.

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