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THE LYME REGIS BOREHOLE, DORSET - PALYNOLOGY OF THE MERCIA MUDSTONE, PENARTH AND LIAS GROUPS (UPPER TRIASSIC -LOWER JURASSIC.

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The Lyme Regis Borehole was drilled in 1901 but remains the only one in Devon and Dorset that has been cored through the lower part of the Lias Group, the Penarth Group and most of the Mercia Mudstone Group. Samples from 24 of the 50 levels from which core is extant have been examined for palynomorphs. Carnian (early Late Triassic) miospores from 287 m below the top of the Mercia ; Mudstone Group are the lowest such occurrence in the region, and may be only 100m above the top of the Anisian (early Mid Triassic) Otter Sandstone Formation of the Sherwood Sandstone Group. The Blue Anchor Formation, at the top of the Mercia Mudstone Group, yielded Norian(?) and Rhaetian (Late Triassic) miospores associated with acritarchs and foraminifer remains which give, 20.22 m below the top of the formation, the first indication of a transgression that resulted in the widespread establishment of marine conditions by the end of Triassic times. The Penarth Group has yielded Rhaetian palynomorph associations which are comparable with those documented from the group elsewhere in the British Isles and comprise miospores, dinoflagellate cysts and acritarchs. Palynomorph assemblages recovered from the Lias Group are dominated by conifer pollen.

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INTRODUCTION

The Lyme Regis Borehole was drilled in 1901 (Jukes-Browne, 1902) at a site [SY 336 930] on the Lias Group outcrop immediately north of Lyme Regis (Figure 1). It remains the only borehole in Devon and Dorset in which a substantial thickness of the Mercia Mudstone Group, together with the succeeding Penarth Group and lower part of the Lias Group, was cored. Remains of the core representing a total of 50 levels in the borehole are held in museums at Dorchester, Exeter, Lyme Regis, Taunton and Torquay and in the collections of the British Geological Survey at Keyworth. Warrington and Scrivener (1980) presented a revision of the lithostratigraphy of the section proved in the borehole, based upon this extant core material and on the driller's record and other accounts. Material from 24 of the horizons represented amongst the museum collections has been processed and the residues examined for palynomorphs (see Appendix for sample details). Material from 10 of the horizons sampled is held in more than one of the repositories but the remainder are not replicated in this manner.

PALYNOLOGICAL RESULTS

Mercia Mudstone Group - undivided

Only two levels in the undivided Mercia Mudstone Group, below the Blue Anchor Formation, proved productive.

A small assemblage of the following miospores was recovered from 328.27 m (relative abundances are expressed as % based upon a count of 100 specimens from preparation MPA 25621):

Alisporites sp.	1.0%
Camerosporites secatus Leschik emend. Scheuring 1978	12.0%
?Duplicisporites granulatus Leschik emend. Scheuring 1970	7.0%
Ellipsovelatisporites plicatus Klaus 1960	2.0%
?Labiisporites granulatus Leschik 1956	1.0%
Lycospora sp.	1.0%
Ovalipollis cultus Scheuring emend. Scheuring 1978	2.0%
Ovalipollis pseudoalatus (Thiergart) Schuurman 1976	21.0%
indeterminate non-taeniate bisaccate pollen	53.0%

A rich assemblage of the following miospores was recovered from 309.98 m (relative abundances are expressed as % based upon a count of 200 specimens from preparation MPA 24948):

Camerosporites secatus	23.5%
Duplicisporites dispertitus (Leschik) Klaus 1960	1.5%
Duplicisporites granulatus	14.5%
Duplicisporites verrucosus Leschik emend. Scheuring 1978	0.5%
Ellipsovelatisporites plicatus	6.5%
?Enzonalasporites vigens Leschik 1955	0.5%
Haberkornia gudati Scheuring 1978	1.0%
?Kuglerina meieri Scheuring 1978	0.5%
Ovalipollis pseudoalatus	2.0%
?Protodiploxypinus sp.	0.5%
?Vallasporites ignacii Leschik 1955	1.0%
indeterminate circumpolles	7.0%
indeterminate non-taeniate bisaccate pollen	41.0%

The above assemblages are indicative of a Camian (early Late Triassic) age; a specimen of *Lycospora* from 328.27 m is assessed as reworked from deposits of Carboniferous age.

In relation to the lithostratigraphy of the borehole (Warrington and Scrivener, 1980), preparations MPA 25621 and 24948 are from 287.53 and 269.24 m respectively below the top of the Mercia Mudstone Group and about 65 and 48 m respectively below a unit of mudstones with arenaceous intercalations that is probably equivalent to the Weston Mouth Sandstone Member which is exposed on the south Devon coast, some 18 km to the west-south-west (Warrington and Scrivener, 1980). A sample from 42 m below that member in the coastal outcrop (Warrington, 1971) yielded an assemblage similar to those recovered from the borehole samples. The borehole samples and that from outcrop are from beds in or close below a unit of colour-banded mudstones. The assemblages recovered from the borehole are, however, from lower in the group than the lowest obtained from the coastal exposures. The biostratigraphic control in the borehole extends to some 23 m lower in the group than in the outcrop and a Carnian age is now recognized down to a level which may be as little as 100 m above the base of the group. The group overlies the Otter Sandstone Formation (Sherwood Sandstone Group) which is assessed as Anisian (early Mid Triassic) in age, on the basis of vertebrate faunas (Benton *et al.,* 1994).

The miospores reported here from the Mercia Mudstone Group represent a parent flora of gymnosperms, principally conifers.

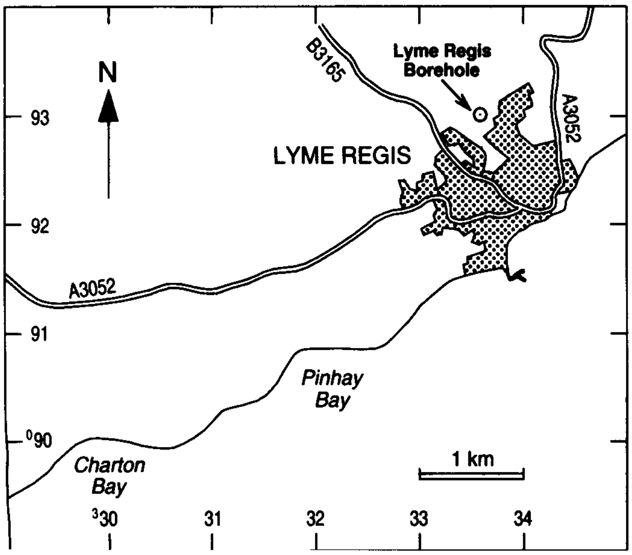

Figure 1. Location map; topography based upon Ordnance Survey mapping.

Mercia Mudstone Group - Blue Anchor Formation

Four levels (64.62, 60.96, 52.43 and 47.55 m depth) in the Blue Anchor Formation, at the top of the Mercia Mudstone Group, have yielded palynomorphs. The lowest and highest levels yielded only possible remains of bisaccate pollen and a solitary specimen of *Ricciisporites tuberculatus* Lundblad 1954 respectively (Figure 2). Preparations from 60.96 and 52.43 m yielded rather sparse palynomorph assemblages which are dominated by miospores, principally the circumpolles *Classopollis* spp., but include organic-walled microplankton (OWM), principally acritarchs *(Micrhystridium* spp., Figure 2). The miospore association from 60.96 m is more varied than that from 52.43 m and includes a few specimens of *Carnisporites anteriscus* Morbey 1975, *Chasmatosporites apertus* (Rogalska) Nilsson 1958, *Gliscopollis meyeriana* (Klaus) Venkatachala 1966, *Kraeuselisporites reissingeri* (Harris) Morbey 1975 and *Porcellispora longdonensis* (Clarke) Scheuring emend. Morbey 1975, together with possible examples *of Ovalipollis pseudoalatus, Quadraeculina anellaeformis* Maljavkina 1949 and *Ricciisporites tuberculatus;* several of these taxa were also recovered from the overlying Penarth Group (Figure 2). The preparation from 60.96 m includes test linings of foraminifera and a possible specimen of the dinoflagellate cyst *Rhaetogonyaulax rhaetica* (Sarjeant) Loeblich & Loeblich emend. Below 1987; tasmanitid algae were recorded from 52.43 m.

The assemblages from the Blue Anchor Formation are indicative of a Norian? to Rhaetian (Late Triassic) age; the presence of possible specimens of *Quadraeculina anellaeformis* may favour the younger (Rhaetian) age. The possible presence of *Rhaetogonyaulax rhaetica* suggests a level within the Rr dinoflagellate cyst Biozone of Woollam and Riding (1983). The presence of OWM and remains of foraminifera indicates that subaqueous environments of marine origin existed at the time of deposition of beds 20.22 and 11.69 m below the top of the formation. The miospore associations reflect a parent flora dominated by gymnosperms, including members of the Cheirolepidaceae which produced *Classopollis-type* pollen (Alvin, 1982). The existence of bryophytes is indicated by the presence of the spore *Porcellispora longdonensis* which, together with sporadic fern spores, indicates that damp environments existed on the contemporary land areas.

The palynomorph assemblages recovered from the Blue Anchor Formation in the Lyme Regis Borehole have similarities with those reported by Orbell (1973) from the upper 9 m of the formation at outcrop in Charton Bay [SY 29 89] (Figure 1) and farther west, near Culverhole [SY 270 894] (Warrington, 1971). The borehole assemblages, like those from outcrop, include OWM and foraminifer remains but are from lower levels in the formation and therefore indicate the existence of a marine influence at a lower stratigraphic level than that noted by Warrington (1971) and Orbell (1973).

Penarth Group

All the levels sampled in the Penarth Group yielded palynomorph assemblages comprising miospores, OWM and, in some cases, foraminifer test linings (Figure 2).

Assemblages from the Westbury Formation include taxa observed in those from the Blue Anchor Formation but are richer and more diverse; they are dominated by OWM, principally the dinoflagellate cyst *Rhaetogonyaulax rhaetica* (Figure 2). The diversity of the miospore and OWM associations increases upwards through the formation, from 38.71 to 31.39 m depth.

The miospore associations are dominated by circumpolles pollen *(Classopollis* spp.), *Ovalipollis pseudoalatus, Rhaetipollis germanicus* Schulz 1967 and *Ricciisporites tuberculatus.* Also present are small numbers of spores, including *Acanthotriletes varius* Nilsson 1958, *Cingulizonates rhaeticus* (Reinhardt) Schulz 1967, *Deltoidospora* spp., *Kraeuselisporites reissingeri, Leptolepidites argenteaeformis* (Bolkhovitina) Morbey 1975, *Microreticulatisporites fuscus(Nilsson) Morbey* 1975, monosulcate pollen *(Chasmatosporites magnolioides (Erdtman) Nilsson 1958),* taeniate bisaccate pollen *(Lunatisporites rhaeticus* (Schulz) Warrington 1974) and other pollen, including bisaccates *(Alisporites* spp., *Quadraeculina anellaeformis* and *Vesicaspora fuscus* (Pautsch) Morbey 1975), *Tsugaepollenites? pseudomassulae* (Mädler) Morbey 1975 and small numbers of the circumpolles *Geopollis zwolinskae(Lund)* Brenner 1986, *Gliscopollis meyeriana* and *Granuloperculatipollis rudis* Venkatachala & Góczán emend. Morbey 1975. These associations become slightly more diverse upwards through the formation (Figure 2).

The OWM associations are dominated by dinoflagellate cysts, principally *Rhaetogonyaulax rhaetica* and, particularly at 34.75 m, *Dapcodinium priscum* Evitt emend. Below 1987; *?Beaumontella caminuspina* (Wall) Below 1987, *B. langii (Wall)* Below 1987 and *?Valvaeodinium koessenium* (Morbey) Below 1987 also occur in small numbers, mainly in the most diverse association, from 34.75 m depth (Figure 2). Acanthomorph acritarchs *(Micrhystridium* spp.), the netromorph acritarch *Cymatiosphaera polypartita* Morbey 1975, the polygonomorph acritarch *Veryhachium* sp. and tasmanitid algae occur sporadically and foraminifer test linings are also present (Figure 2).

Contrasting palynomorph assemblages have been recovered from the lower and upper parts of the Lilstock Formation (Figure 2). A diverse assemblage from the lower part of the Cotham Member (30.48 m depth) is dominated by OWM and is comparable with those from the underlying Westbury Formation; others, from higher in the Cotham Member (29.26 m depth) and from the overlying Langport Member (24.38 and 23.17 m depth), are considerably less diverse and are dominated by miospores (Figure 2).

The lowest assemblage from the Cotham Member includes most of the miospore taxa present in those froth the Westbury Formation but is more diverse, a feature which reflects a continuation of the upward increase in diversity noted in that formation (Figure 2). Taxa which appear in this assemblage include *Abietineaepollenites dunrobinensis* Couper 1958, *Carnisporites* spp., *Convolutispora microrugulata* Schulz 1967, *?Lycopodiacidites rugulatus* (Couper) Schulz 1967 and ?*Todisporites* spp.. The change of the assemblages

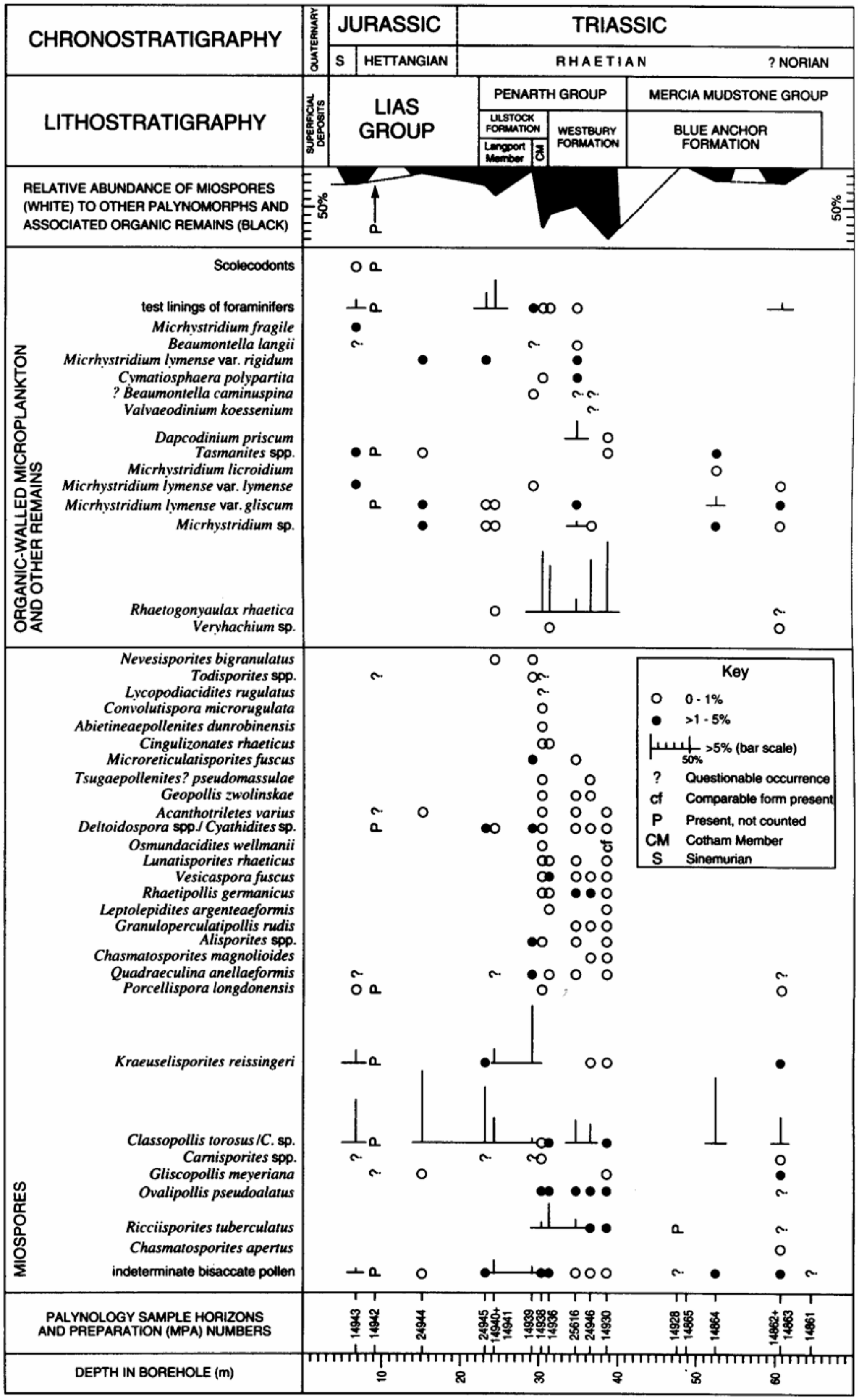

Figure 2. Distribution and relative abundances of palynomorphs and associated organic remains in preparations from the Blue Anchor Formation (Mercia Mudstone Group), Penarth Group and Lias Group of the Lyme Regis Borehole. Relative abundances are based upon counts of 200 specimens, except in preparations MPA 14862/14863 (total - 150 specimens), MPA 14940/14941 (total - 135 specimens) and MPA 24945 (100 specimens). Preparations are held in the palynology collections at the British Geological Survey, Keyworth, and are registered in the MPA series.

which occurs above this level (30.48 m depth) is largely a result of the disappearance of many of the miospore taxa, including *Cingulizonates rbaeticus, Convolutispora microrugulata, Geopollis zwolinskae, Lunatisporites rhaeticus, Ovalipollis pseudoalatus, Rhaetipollis germanicus, Ricciisporites tuberculatus* and *Tsugaepollenites? pseudomassulae,* present lower in the succession. The associated OWM are largely dinoflagellate cysts *(Rhaetogonyaulax rhaetica);* sporadic acritarchs *(Micrhystridium lymense* var. *rigidum* Wall 1965) and test linings of foraminifera are also present (Figure 2).

The assemblage from the upper part of the Cotham Member is dominated by miospores; a few acanthomorph acritarchs *(Micrhystridium lymense* var. *lymense* Wall 1965), possible dinoflagellate cysts *(?Beaumontella langii)* and foraminifer test linings are also present (Figure 2). The miospore association is dominated by spores, principally *Kraeuselisporites reissingeri,* and though lacking most of the taxa noted lower in the succession, includes *Nevesisporites bigranulatus* (Levet-Carette) Morbey 1975, which was not recorded below this level (Figure 2).

Assemblages from the upper part of the overlying Langport Member are also dominated by miospores, *principally Classopollis* spp. and smaller numbers of *Kraeuselisporites reissingeri* and bisaccate pollen; other miospore taxa are extremely scarce (Figure 2). The sparse OWM associations from the Langport Member are dominated by acanthomorph acritarchs *(Micrhystridium* spp.); a solitary specimen of the dinoflagellate *cyst Rhaetogonyaulax rhaetica* occurred at 24.38 m depth. Preparations from the member include relatively large numbers of foraminifer test linings (Figure 2).

The Penarth Group palynomorph assemblages are Rhaetian (late Late Triassic) in age. This is indicated by the presence of *Quadraeculina anellaeformis* and *Tsugaepollenites? pseudomassulae* in association with *Ovalipollis pseudoalatus, Rhaetipollis germanicus* and *Ricciisporites tuberculatus.* The presence of *Rhaetogonyaulax rhaetica* indicates a level within the Rr dinoflagellate cyst Biozone of Woollam and Riding (1983). Subaqueous environments of marine origin are indicated by the presence of OWM and foraminifer remains. The change from OWM associations dominated by dinoflagellate cysts, in the Westbury Formation, to ones dominated by acanthomorph acritarchs higher in the group, and the parallel increase in the relative abundance of foraminifer test linings (Figure 2), reflects a change in environment, from partly enclosed nearshore water bodies, such as lagoons, to more open-sea conditions, during deposition of the group. The miospore associations originate from a parent flora dominated by gymnosperms but the increase in diversity which occurs within the lower part of the group reflects an increasing contribution from other plants, including ferns. The presence of the bryophyte spore *Porcellispora longdonensis* in the Gotham Member indicates that damp environments existed on the contemporary land areas.

The palynomorph assemblages recovered from the Penarth Group in Lyme Regis Borehole are comparable with those recorded by Orbell (1973) from an outcrop of the group at Charton Bay [SY 29 89] (Figure 1). Orbell *(op. cit.)* presented palynological results from part of the Westbury Formation and from the Langport Member; the upper beds of the Westbury Formation, together with the Cotham Member and the basal part of the Langport Member, were obscured and not sampled.

Lias Group

Assemblages from the Lias Group are dominated by miospores, principally *Classopollis* spp.; other miospores are, with the exception *of Kraeuselisporites reissingeri,* extremely scarce (Figure 2). The OWM associations from this group are dominated by acanthomorph acritarchs *(Micrhystridium* spp.) but include sporadic tasmanitid algae and possible specimens of the dinoflagellate cyst *Beaumontella langii;* small numbers of foraminifer test linings and scolecodonts are also present (Figure 2).

In Britain the base of the Jurassic is placed at the level at which ammonites of the genus *Psiloceras* first appear (Cope *et al.,* 1980; Warrington *et al.,* 1980). This level has not been established in the Lyme Regis Borehole as there are no known records of ammonites from that borehole. However, in the coastal section exposed between Pinhay Bay and Lyme Regis (Figure 1), *Psiloceras* appears in bed H25 of Lang (1924), at a level about 2.5 m above the top of the Penarth Group (Callomon and Cope, 1995). The lowest palynomorph assemblage from the Lias Group in the Lyme Regis Borehole is from about 7 m above the base of the group and, therefore, about 4.5 m above the base of the Jurassic. Comparison of the borehole section and the zonal thicknesses recorded from the coastal outcrops (Hesselbo and Jenkyns, 1995) suggests that the palynomorph assemblages from 15.24 and 9.14 m depth are from the Hettangian *liasicus* and *angulata* zones respectively, and that the highest assemblage (6.71 m depth) may be from the top of the *angulata* Zone or the base of the Sinemurian *bucklandi* Zone.

Deposition in open marine environments is indicated by the OWM, which are predominantly acanthomorph acritarchs *(Micrhystridium),* and the associated remains of foraminifera. The miospore associations reflect a parent flora dominated by gymnosperms, including members of the Cheirolepidaceae which produced *Classopollis-type* pollen. The scarcity of other miospores may reflect a decline in other plant groups, including ferns, a decrease in the size of the contemporary land areas, or an increase in the distance from land, or a combination of these factors. A palynological study of the Lias Group exposed in the Dorset coast sections (Wall, 1965) recorded similar palynomorph assemblages and successions to those recovered from the Lyme Regis Borehole samples.

SUMMARY AND CONCLUSIONS

Palynomorph assemblages from core samples from the Lyme Regis Borehole allow dating of parts of the Mercia Mudstone Group succession together with the succeeding Penarth Group. The results augment those obtained by previous palynological studies of this succession from exposures on the south Devon coast.

Carnian (early Late Triassic) miospores occur in the undivided Mercia Mudstone Group succession at 287.53 and 269.24 m below the top of the group. The assemblages are comparable with those recovered from beds below the Weston Mouth Sandstone Member on the south Devon coast. The lowest is, however, about 23 m below the lowest horizon at which Carnian palynomorphs were previously known to occur in this area and may be as little as 100 m above the base of the Mercia Mudstone Group which overlies the Anisian (early Middle Triassic) Otter Sandstone Formation of the Sherwood Sandstone Group.

A Norian? or Rhaetian age is indicated for the Blue Anchor Formation, at the top of the Mercia Mudstone Group, and the succeeding Penarth Group is latest Triassic (Rhaetian) in age.

There is no palynological evidence for the position of the base of the Jurassic which is placed, by comparison with outcrop sections near Lyme Regis, about 2.5 m above the base of the Lias Group. The lowest beds of that group are, therefore, assigned a latest Triassic (Rhaetian) age.

The palynomorph assemblages from the undivided Mercia Mudstone Group comprise only gymnosperm pollen, of land plant origin. In the Blue Anchor Formation, at the top of that group, miospores derived from land plants are associated with OWM and foraminifer remains, the lowest occurrence of which, 20.22 m below the top of the formation, is the first indication of the onset of a transgression that resulted in the establishment of marine conditions over much of Britain by the end of Triassic times. The development of marine environments, with a change from partly enclosed to open-sea conditions, is reflected in changes observed in successive associations of OWM and other remains from the Blue Anchor Formation and the succeeding Penarth and Lias groups.

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APPENDIX: SAMPLE DETAILS

Preparation number (MPA: result (+/-)	*Depth in borehole (m / ft)*	*Source* and collection number*	*Lithostratigraphic unit (Group: Formation: Member)*
14943+	6.71 (22)	BGS: B.774	Lias
14942+	9.14 (30)	BGS: B.775	"
24944+	15.24 (50)	Dor: 0.1361	"
24945+	23.17 (76)	Dor: G.1362	Penarth:Lilstock:Langport
14940+	24.38 (80)	Torquay	" " "
14941+	" " "	BGS: B.776	" " "
14939+	29.26 (96)	Exeter	" " :Cotham
25615-	" " "	Lyme: L.585	" " "
14937+	30.48 (100)	Torquay.	" " "
14938+	" " "	BGS: B.778	" " "
14936+	31.39 (103)	BGS: B.777	Penarth:Westbury
14932+	34.75 (114)	Torquay	" "
14933+	" " "	Taunton	" "
14934+	" " "	BGS: B.779	" "
14935+	" " "	Exeter	" "
25616+	" " "	Lyme: L.586	" "
14931+	36.58 (120)	BGS: B.780	" "
24946+	" " "	Dor: G.1360	" "
14930+	38.71 (127)	Torquay	" "
14928+	47.55 (156)	Taunton	Mercia:Mudstone:Blue Anchor
14929-	" " "	Torquay	" "
24947-	" " "	Dor: 0.1359	" "
25617-	" " "	Lyme: L.587	" "
14865-	48.77 (160)	BGS: B.781	" "
14864+	52.43 (172)	Torquay	" "
14862+	60.96 (200)	BGS: B.782	" "
14863+	" " "	Torquay	" "
14861+	64.62 (212)	Torquay	" "
25618-	137.16 (450)	Lyme: L.588	Mercia Mudstone (undivided)
14837-	259.08 (850)	BGS: B.785	" "
14835-	263.04 (863)	Torquay	" "
14836-	" " "	BGS: B.786	" "
14832+	309.98 (1017)	BGS: B.787	" "
14833+	" " "	Taunton	" "
14834-	" " "	Torquay	" "
24948+	" " "	Dor: G.1356	" "
25619-	" " "	Lyme: L.594	" "
14769-	320.04 (1050)	Torquay	" "
14770-	" " "	BGS: B.788	" "
14771-	" " "	Exeter	" "
25620-	" " "	Lyme: L.595	" "
14768-	320.35 (1051)	Taunton	" "
25621+	328.57 (1077)	Lyme: L.601	" "
14767-	369.72 (1213)	Torquay	" "

*(*BGS-British Geological Survey; Dor - Dorset County Museum, Dorchester; Exeter - Royal Albert Memorial Museum; Lyme - Lyme Regis (Philpott) Museum; Taunton - Somerset County Museums Service; Torquay - Torquay Natural History Society Museum. Specimen depths (feet) are from museum registers or specimen labels. Lithostratigraphic terms are from the interpretation of the borehole by Warrington and Scrivener (1980) and with only one exception correspond with the lithostratigraphic attribution given by museum sources; specimen Dor. 1362 is assigned to the Lias Group in museum records but is here placed, on the basis of its depth (23.17m), at the top of the underlying Penarth Group. Preparation (MPA) numbers are those assigned to palynological samples and slides registered and curated in the MPA series at BGS, Keyworth).*