Read at the Annual Conference of the Ussher Society, January 1995

THE LATE TRIASSIC - EARLY JURASSIC SUCCESSION AT SELWORTHY, WEST SOMERSET, ENGLAND.

G. WARRINGTON, H. C. IVIMEY-COOK, R.A. EDWARDS AND A. WHITTAKER

Warrington, G., Ivimey-Cook, H.C., Edwards, R.A and Whittaker, A. The Late Triassic-Early Jurassic succession at Selworthy, west Somerset, England. *Proceedings of the Ussher Society,* **8,** 426-432.

An outcrop of Mesozoic rocks between Minehead and Porlock, west Somerset, is largely fault-bounded and surrounded by Devonian rocks; it includes a west-north-west to east-south-east-trending outlier of Penarth Group and Lias Group rocks that is the most westerly occurrence of those deposits onshore in England. The outlier is 3 km long and up to 0.6 km wide. The Penarth Group includes the Westbury and Lilstock formations, but is thinner than in the nearest comparable sections which occur to the east, between Blue Anchor and St Audrie's Bay on the west Somerset coast. The Lias Group includes a Hettangian succession which may be over 60 m thick; Early Sinemurian beds may be present but are unproven. Small differences in lithofacies between the Penarth Group and the lower *angulata* Zone in the outlier and their correlatives in the Blue Anchor - St Audrie's Bay area suggest that the former area was closer to the margin of deposition.

G. Warrington and A. Whittaker, British Geological Survey, Kingsley Dunham Centre, Keyworth, Nottingham NG12 5GG H.C. Ivimey-Cook, Bramleys, 6 Lodwells Orchard, North Curry, Taunton TA3 6DX Somerset
R.A. Edwards, British Geological Survey, St Just, 30 Pennsylvania Road, Exeter EX4 6BX

INTRODUCTION

The most westerly occurrence of Triassic and Jurassic rocks onshore in England lies in west Somerset, in an area extending eastwards from Porlock to Tivington and south-eastwards, through the Wootton Courtenay area, to east of Timberscombe (Figure 1). The Mesozoic succession here is contiguous to the north-west with that present offshore in Porlock Bay and the Bristol Channel, but elsewhere is surrounded by Middle Devonian rocks, principally the Hangman Sandstone Formation. The Mesozoic rocks are faulted against the Palaeozoic along the northern and eastern sides of the onshore occurrence; both faulted and unconformable relationships are seen along the southern margin.

The Lias Group here was first noted by Homer (1816, p. 379) as "a small insulated patch of the lyas strata", and the underlying Penarth Group was first recorded, as the "Rhaetic Series", by Etheridge (1872). Thomas (1940) provided an account of the lower part of the post-Hercynian succession, comprising beds now assigned to the Mercia Mudstone Group (Triassic) and the underlying Luccombe Breccia, the age of which is uncertain. Other, mostly brief, notices of parts of the Mesozoic succession hereabouts have been given by de la Beche (1846), Champernowne and Ussher (1879), Ussher (1890), Woodward (1893), Richardson (1911), and Laming (1968). New information on the highest part of the Mercia Mudstone Group, the Blue Anchor Formation, together with the overlying Penarth and Lias groups, was provided by two cored boreholes drilled by the Geological Survey on the Lias outcrop in 1973 (BGS, 1974). The most recent account of the outlier is by Whittaker (1976), who gave a brief description of the Lias Group succession proved by these boreholes and the available exposures, and noted that it comprises offshore facies and may have been displaced vertically by as much as 320 m, relative to occurrences of correlative beds offshore in the Bristol Channel.

Further stratigraphic information is now available, following the completion of the survey of the Minehead (1:50 000-scale geological sheet 278) district by the British Geological Survey. The present account combines a summary of the results of this survey, based upon 1:10 000-scale geological mapping by R.A. Edwards, with the lithostratigraphic record of the boreholes, by A. Whittaker, and biostratigraphic studies, mainly of the borehole sections, by H.C. Ivimey-Cook (macrofossils) and G. Warrington (palynomorphs).

STRATIGRAPHY AND OUTCROP DISTRIBUTION

The Mesozoic succession in the Selworthy area comprises the following units:

- Lias Group
- Penarth Group
  - Lilstock Formation
    - Langport Member
    - Cotham Member
  - Westbury Formation
- Mercia Mudstone Group
  - Blue Anchor Formation
  - un-named red-beds

The lower part of the Mercia Mudstone Group lacks evidence of age in this area and is not dealt with in this account, which is concerned with the proven Late Triassic and Early Jurassic beds, from the Blue Anchor Formation upwards, in the above succession. These beds dip northwards, towards a west-north-west to east-south-east-trending faulted contact with the Hangman Sandstone Formation. The strike parallels that contact, and younger beds crop out progressively toward the north-north-east.

The upper beds of the Mercia Mudstone Group have been mapped for some 5 km, from Tivington north-westwards to between Porlock and Bossington (Figure 1), but are obscured by superficial deposits in parts of this area. The group continues north-westwards, beneath superficial deposits, to the offshore area in Porlock Bay, on the south side of the Bristol Channel. The Blue Anchor Formation has been mapped for about 3.5 km along the northern side of the outcrop of the group, from near Venniford Cross to Allerford (Figure 1). The outcrop of this formation broadens from about 60 m in the east to about 170 m in the west; it is obscured by superficial deposits around Holnicote and Brandish Street, and may continue north-westwards from Allerford, beneath superficial deposits, towards Bossington and Porlock Bay. Dips in the formation vary from 10° to the north-north-east near Allerford, to 18° to the north in the area south of Selworthy.

The Penarth Group outcrop lies immediately north of that of the Blue Anchor Formation; it has been mapped over a slightly shorter distance (about 3 km), from Tivington to near Allerford, and varies from 20 to 60 m in width (Figure 1). The outcrop is terminated at the north-west, between Brandish Street andAllerford, at a north-west to

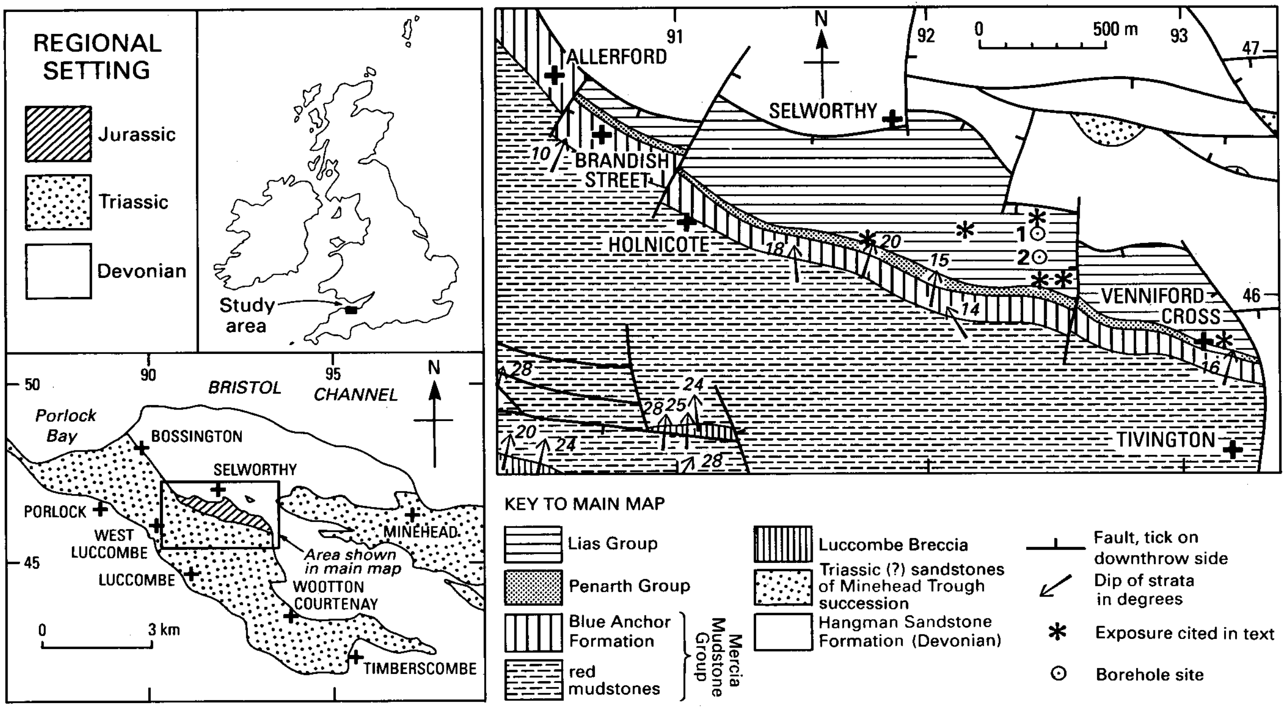

Figure 1. Location and geology of the Penarth Group and Lias Group outlier at Selworthy, west Somerset. Geological lines from BGS 1:10 000-scale mapping, by permission of the Director, BGS; topography based upon Ordnance Survey mapping.

south-south-east-trending fault. A dip of 15° to the north was recorded south of Selworthy, at the boundary with the overlying Lias Group.

The Lias Group outcrop lies immediately north of that of the Penarth Group and has been mapped over a similar distance, from Tivington to near Allerford (Figure 1). The outcrop, which is obscured by superficial deposits near Brandish Street and south-west of Selworthy, is about 550 m wide south of Selworthy, and narrows to both the south-east and the north-west (Figure 1). Dips of 16° and 20° to the north were recorded from the lower part of the group, at Venniford Cross and south of Selworthy respectively.

Stratigraphic details

There are few exposures of the Blue Anchor Formation, or of the Penarth and Lias groups, in the Selworthy area. The following descriptions are based upon the two cored boreholes (Selworthy No.1 and No.2, Figures 1, 2), drilled by the Geological Survey about 0.75 km south-east of Selworthy in 1973 (BGS, 1974; Whittaker, 1976), and upon recent biostratigraphical studies of those boreholes and a very limited amount of outcrop material. Thicknesses based upon the borehole sections have been corrected for a dip of 15° but remain approximate, because of the fractured condition of parts of the core.

Mercia Mudstone Group

The beds between 35.61 and 51.44 m in Selworthy No.2 Borehole [SS 9244 4618] were formerly assigned to the 'Grey Marl and Tea Green Marl' (BGS, 1974), a unit now incorporated in the Blue Anchor Formation (Warrington et al., 1980); they overlie a fault zone (51.44 and 52.02-52.22 m), which contains red-brown mudstones and fractured Devonian sandstones (Hangman Sandstone Formation) (Figure 2). The upper boundary of the Blue Anchor Formation was originally placed at 35.61 m (BGS, 1974), within a unit of dark grey and black mudstones of Westbury Formation type. It is now considered more appropriate to place the boundary lower, at the base of those mudstones (37.62 m, Figures 2, 3). This is supported by a comparison of the palynomorph succession from the borehole (Figure 3) with that from the Blue Anchor Formation and succeeding Westbury Formation exposed some 18 km to the east-south-east, at St Audrie's Bay [ST 104 431] (Warrington, 1974, 1981, 1983; Warrington and Whittaker, 1984). The beds between 37.62 m and the fault zone comprise grey to grey-green and grey mudstones, many with silt laminae, and siltstones; veins of anhydrite occur in the lower 7.6 m.

The corrected thickness of the incomplete sequence in the borehole is about 13.41 m; calculations based upon the dip and outcrop width suggest that the formation may be at least 25 m thick in the Selworthy area. The beds proved in Selworthy No: 2 Borehole are, therefore, equivalent to the higher part of the formation exposed at St Audrie's Bay; the correlatives of the lower part are cut out by the fault encountered in the borehole.

No macrofossils have been recovered from the formation in the Selworthy area, but samples from the No.2 Borehole yielded rich palynomorph assemblages (Figure 3), comparable with those documented from the formation on the west Somerset coast (Warrington and Whittaker, 1984). Most of the assemblages comprise only miospores (spores and pollen of land plants), but some include sporadic organic-walled microplankton (acritarchs and dinoflagellate cysts) and other remains (foraminifer test linings) indicative of marine environments. The miospore associations are dominated by pollen of the circumpolles group (*Classopollis, Geopollis, Granuloperculatipollis and Gliscopollis*) and *Ovalipollis pseudoalatus* (Thiergart) Schuurman 1976, but include small numbers of bisaccate and monosulcate pollen and trilete spores. The diversity of the associations increases upwards through the formation. Acritarchs (*Micrhystridium*) appear about 8 m below the top of the formation. The dinoflagellate cyst *Rhaetogonyaulax rhaetica* (Sarjeant) Loeblich and Loeblich emend. Harland, Morbey and Sarjeant 1975, occurs in the highest 2 m of the sequence here assigned to the Blue Anchor Formation. Its relative abundance at that level is comparable with that in the Williton Member, at the top 'of the formation at St Audrie's Bay (Warrington, 1981; Warrington and Whittaker, 1984), and is considerably lower than that recorded from the succeeding 2 m of beds, which were formerly assigned to the Blue Anchor Formation (BGS, 1974) but are here included within the overlying Westbury Formation (Figures 2, 3). The presence of *Quadraeculina anellaeformis* Maljavkina 1949 and *Tsugaepollenites?*

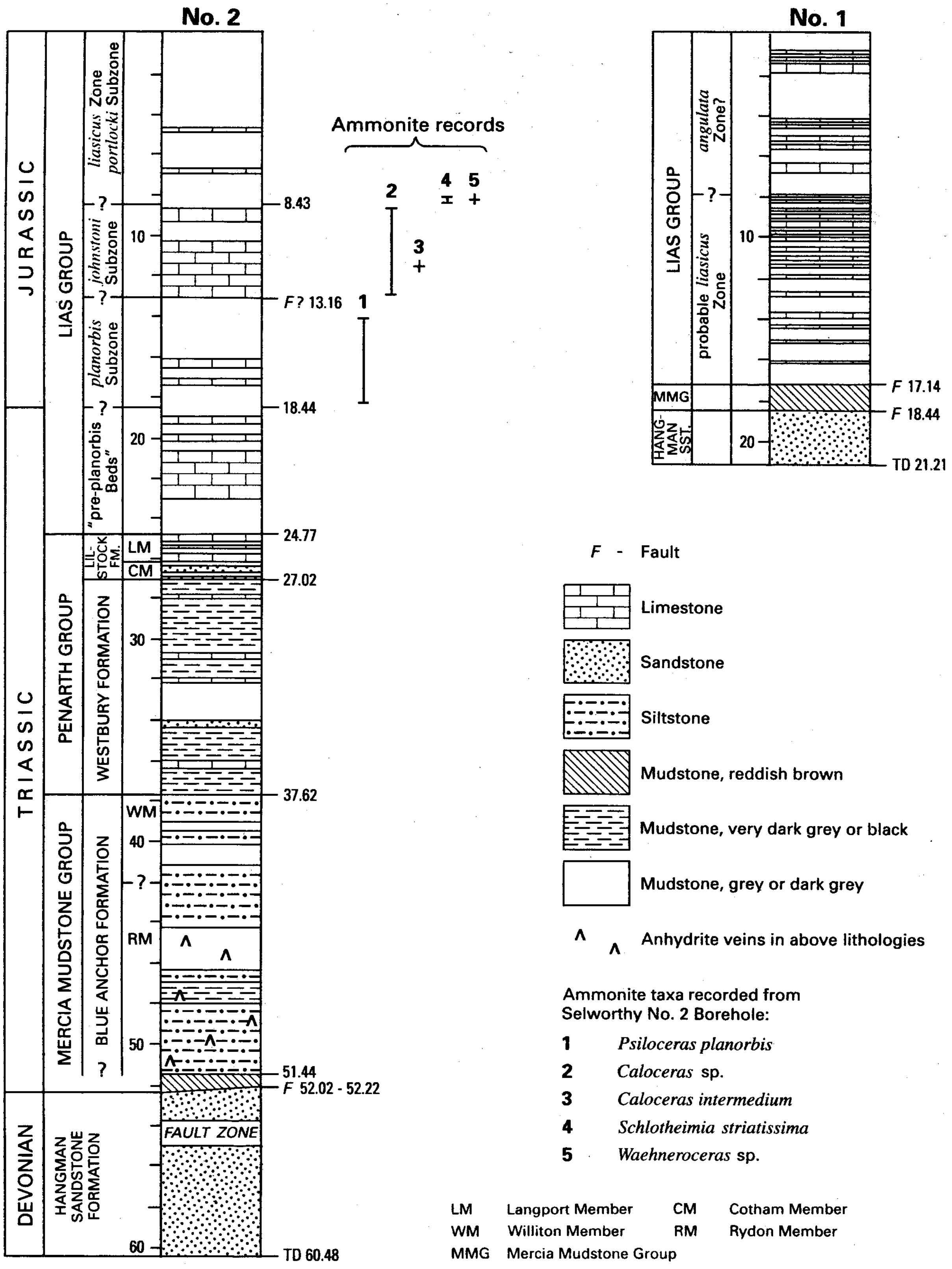

Figure 2. Graphic logs of the Selworthy boreholes, with distribution of ammonites recorded from No. 2 Borehole. Scales and depths in metres.

pseudomassulae (Madler) Morbey 1975 in the miospore associations is indicative of a Rhaetian age for the part of the Blue Anchor Formation proved in Selworthy No.2 Borehole; this is supported, in the upper part of the section, by the presence of *Rhaetogonyaulax rhaetica*, the index fossil of the Rr dinoflagellate cyst biozone (Woollam and Riding 1983), of Rhaetian age.

Penarth Group

The beds between 24.77 and 35.61 m in Selworthy No.2 Borehole were assigned to the Rhaetic, including White Lias' (BGS, 1974). The base of this unit, now termed the Penarth Group (Warrington *et al*., 1980), is considered to lie at 37.62 m (Figures 2, 3). The corrected thickness of the group here (about 12.46 m) is some 4.2 m less than that present at outcrop at St Audrie's Bay (Whittaker and Green, 1983; Warrington *et al*., 1994).

The Westbury Formation (about 27.02 to 37.62 m), consists largely of non-calcareous, medium to dark grey mudstones and silty mudstones, with some thin limestones and silty, pyritic and sandy limestones, and sandstones; the corrected thickness is about 10.28 m. The following macrofauna has been recovered:

Gastropod:	*'Natica' oppelii Moore*
Bivalves:	*Cardinia sp., Chlamys valoniensis* (Defrance), *Dimyopsis intusstriata* (Emmrich), *Eotrapezium concentricum* (Moore), *Lyriomyophoria postera* (Quenstedt), *Modiolus'* sodburiensis Vaughan, Protocardia rhaetica (Merian), Rhaetavicula contorta (Portlock)
Fish:	Lissodus sp., and indeterminate remains.

Rich palynomorph assemblages, comprising miospores and organic-walled microplankton, were recovered (Figure 3). The miospore associations are mostly dominated by *Classopollis torosus* (Reissinger) Balme 1957 and *Ovalipollis pseudoalatus*, though *Rhaetipollis germanicus* Schulz 1967 and *Ricciisporites tuherculatus* Lundblad 1964 are prominent components in some; the associations increase in diversity upwards through the formation. Assemblages from beds close above the revised base of the formation contain relatively large numbers of *Rhaetogonyaulax rhaetica*, and this dinoflagellate cyst dominates some assemblages from the upper part of the formation (Figure 3). The palynomorph associations are comparable with those documented from sections of the Westbury Formation elsewhere in the region (Warrington, 1974, *in* Waters and Lawrence, 1987), and are indicative of a Rhaetian (late Late Triassic) age.

The Lilstock Formation (about 24.77 to about 27.02 m) comprises grey to green, fine grained sandstones with grey limestone and grey and green-grey calcareous mudstone interbeds (Gotham Member), overlain by limestones and silty calcareous mudstones (Langport Member). The corrected thickness is about 2.18 m.

No bivalves were recovered from this formation, but sporadic ostracods occur in the basal part of the Langport Member. Palynomorph assemblages from the lower (Gotham Member) part of the formation (Figure 3, preparations MPA 37457, 37458) are similar to those recovered from the upper part of the Westbury Formation, and include a high proportion of dinoflagellate cysts (*Rhaetogonyaulax rhaetica*). An assemblage from the Langport Member (Figure 3, preparation MPA 37456) is slightly less diverse; it includes acritarchs and dinoflagellate cysts but is dominated by miospores, principally *Classopollis torosus, Gltscopollis meyeriana* (Klaus) Venkatachala 1966 and bisaccate pollen. The assemblages are indicative of a Rhaetian age.

Lias Group

The corrected thickness of the partial Lias Group sequence in Selworthy No.2 Borehole, where it was proved from surface to about 24.77 m, is about 24.03 m; a thin weathered zone is present at the top.

The sequence comprises alternating grey, calcareous mudstones and silty mudstones, with thin beds of micritic and silty limestones; mudstones predominate (Figure 2).

The lowest beds (about 6.14 m thick) of the Lias Group, below the level of the appearance of the ammonite *Psiloceras* at about 18.44 m, comprise the 'pre-planorbis Beds' (Figure 2). These have yielded a sparse macrofauna, including the bivalves *Liostrea hisingeri* (Nilsson), *Modiolus minimus* J. Sowerby, *Protocardia rhaetica*, and *Pteromya tatei* (Richardson and Tutcher), and spines of diademopsid echinoids, and are assigned a Rhaetian age. Palynomorph assemblages from these beds are less diverse than those from the Penarth Group and are dominated by the pollen *Gliscopollis meyeriana* (Figure 3). These beds were formerly worked in a number of small pits south of Selworthy where a section [SS 9179 4622] shows about 2.5 m of mudstones and interbedded limestones which have also yielded the above fauna.

The base of the Hettangian Stage, at the base of the *Psiloceras planorbis* Zone, is located at about 18.44 m, at the lowest occurrence of ammonites of the genus *Psiloceras*. Within the Hettangian sequence, the *planorbis* Subzone of the *P. planorbis* Zone is proved by occurrences of *Psiloceras planorbis* (J. de C. Sowerby) between 14.20 and 18.44 m (Figure 2). Exposures [SS 9246 4612 and 9256 4613] of these beds have been recorded near the southern margin of the Lias Group outcrop, south of the Selworthy No.2 Borehole site, and farther east, near Venniford Cross [c. SS 932 458] (Whittaker, 1976). Palynomorph assemblages from the *planorbis* Subzone are comparable with those from the underlying beds in the Lias Group; there is no change in the palynomorph succession at the level, based upon ammonites, which is taken as the base of the Jurassic (Figure 3).

The presence of the succeeding *johnstoni* Subzone of the *P. planorbis* Zone in Selworthy No.2 Borehole is indicated by the occurrence of *Caloceras intermedium* (Portlock) at 11.66 m, and of *Caloceras* sp.? between 8.73 and 13.10 m (Figure 2). On the basis of an association of juvenile, finely ribbed, but poorly preserved schlotheimiids, referred to *Schlotheimia striatissima* (Quenstedt), between 8.13 and 8.43 m, with a more coarsely ribbed ammonite referred to *Waehneroceras* at 8.33 m, the base of the *Alsatites liasicus* Zone is placed at 8.43 min Selworthy No.2 Borehole (Figure 2). Similar finely ribbed schlotheimiids sp. juv., have been recovered from probable *liasicus* Zone beds near Kilve, on the west Somerset coast, and from beds low in that zone, at 106.97 m, in Twyning Borehole, Worcestershire (BGS records, unpublished).

Over 16.5 m of beds higher in the Lias Group were proved in the Selworthy No.1 Borehole [SS 9244 4630] (Figures 1, 2), which was sited 120 m north of Selworthy No.2 (BGS, 1974; Whittaker, 1976). The age of these beds, though not satisfactorily indicated by material from the borehole, was considered by Whittaker (1976) to be *liasicus* Zone, possibly extending into the *Schlotheimia angulata* Zone in the upper 4.5 m. Whittaker (1976) regarded an exposure [SS 9216 4632], some 250 m along the strike to the west of the borehole, as being in beds of *angulata* Zone age, on the basis of a record of *Schlotheimia*?, this specimen is now considered to be S. cf. *extranodosa* (Waehner), indicating a probable early *angulata* Zone age. Slightly higher beds, exposed at a locality [SS 9243 4633] about 30 m north of the Selworthy No.1 Borehole site, contain the brachiopod *Calcirhynchia calcaria* S. S. Buckman, which Whittaker (1976) reasoned, by comparison with its occurrence in the succession exposed on the west Somerset coast, indicated a level high in the *angulata* Zone or even within the basal (*conybeari*) subzone of the Early Sinemurian *Arietites bucklandi* Zone. Though, on this basis, the presence of the *angulata* Zone appeared reasonably certain, beds of post-*angulata* Zone age remained unproven. Sinemurian deposits are now considered not to occur immediately north of the Selworthy No.1 Borehole site (see below), but may be present immediately south of Selworthy, around' [SS 920 466], at the northern margin of the broadest part of the outcrop (Figure 1).

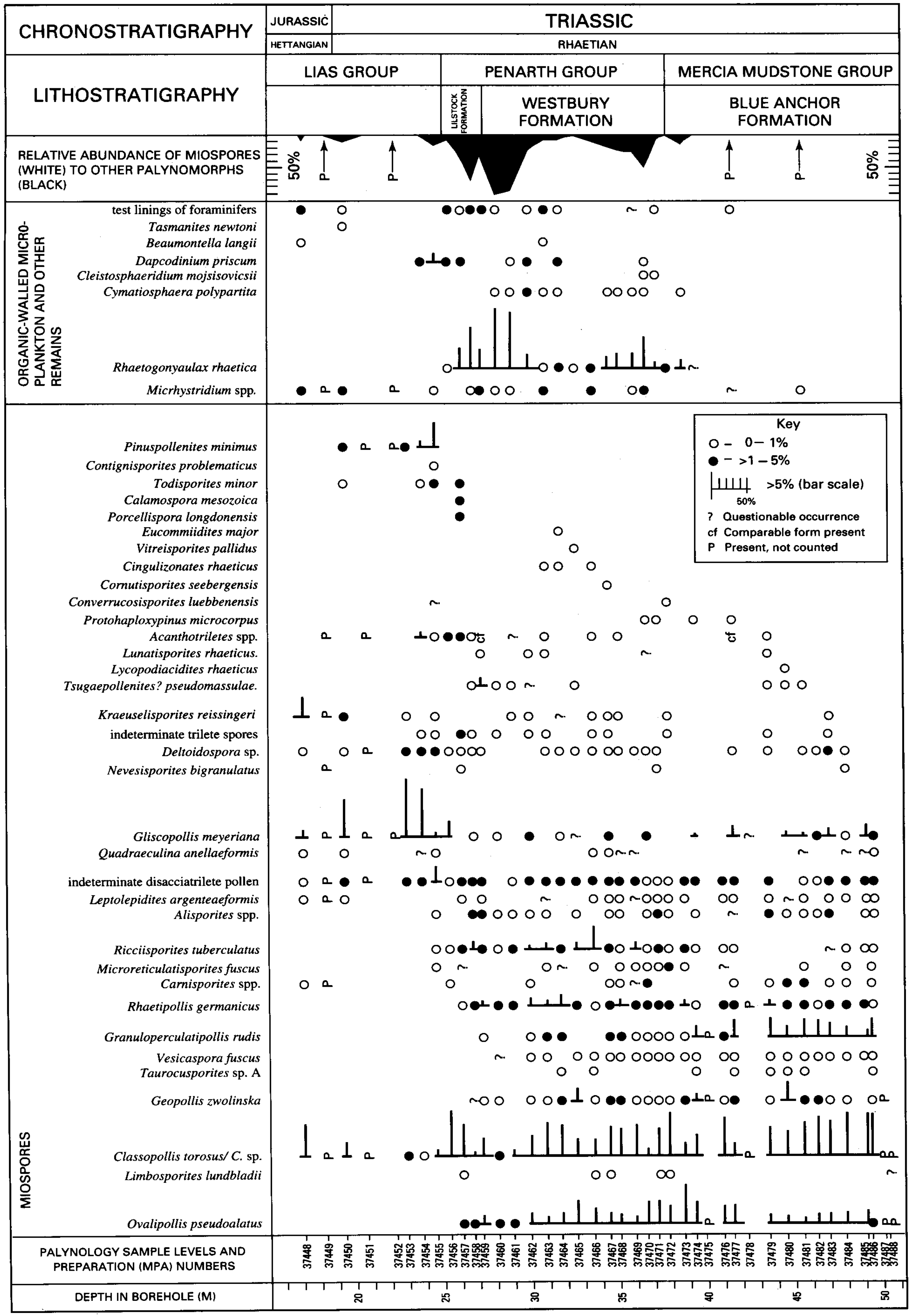

Figure 3. Stratigraphic distribution and relative abundances of palynomorphs in the Blue Anchor Formation, Penarth Group and basal Lias Group succession, Selworthy No. 2 Borehole. Relative abundances expressed as percentages based upon counts of 200 specimens. Preparations are held in the palynology collections at BGS, Keyworth.

COMPARISON AND CORRELATION

The eastern end of the Selworthy outlier of the Penarth and Lias groups is 10 km west-north-west of the nearest outcrops of those beds on the west Somerset coast, at Blue Anchor [ST 038 436]. The succession known from the Selworthy boreholes is here compared with that documented from coastal exposures between Blue Anchor and St Audrie's Bay, 7 km farther east (Whittaker and Green, 1983).

The Blue Anchor Formation is 31.18 m thick at St Audrie's Bay. The formation was not fully proved in Selworthy No.2 Borehole, where it is in faulted contact with older beds, but calculations based upon dip and outcrop width suggest that the full thickness there may be some 6 m less than on the coast. In the coastal sections, the formation has been divided into the Rydon Member and overlying Williton Member (Mayall, 1981). The highest 4 m of the formation in Selworthy No.2 Borehole has microfloral and microfaunal characters comparable with those shown by the Williton Member, and similarly indicative of marine depositional environments. That member appears, therefore, to persist westwards to the Selworthy area where it may be slightly thicker than at Blue Anchor, suggesting a continuation of the gradual westerly thickening noted by Mayall (1981) between St Audrie's Bay and Blue Anchor.

The Penarth Group is about 12.46 m thick at Selworthy, compared with nearly 17 m at St Audrie's Bay (Whittaker and Green, 1983; Warrington *et al*., 1994). This appreciable westerly thinning affects the Westbury and Lilstock formations equally and may be accompanied by a slight change in facies; in the Selworthy area both formations contain slightly thicker limestone beds and are slightly more arenaceous in character than in the coastal sections.

Though the Lias Group sequence in the Selworthy borehole cores was badly fractured, the distribution of limestone beds in that sequence (Figure 2) allows broad comparison with the outcrop sections documented by Whittaker and Green (1983). The thickness of the 'pre-planorbis Beds' at St Audrie's Bay is now reduced to about 5.3 m, following the discovery (Hodges, 1994) of *Psiloceras* in Bed 8 of Whittaker and Green (1983). The greater thickness recorded at Selworthy (about 6.14 m) may reflect collection failure in poor core. The *planorbis* Subzone is, however, proved, from 14.20 to 18.44 m, within a lithological sequence similar to that of beds 8 to 28 of Whittaker and Green (1983), in which it occurs in the coastal sections. This similarity suggests that the level assigned to the base of the subzone in the borehole may be slightly too high, and that the subzone may extend up to 13.16 m, where limestones overlie mudstones, possibly with a faulted contact. Between that level and the top of the succeeding *johnstoni* Subzone, placed at 8.43 m, the succession is lithologically comparable with that of beds 29 to 42 of Whittaker and Green (1983), in which the *johnstoni* subzone occurs in the coastal sections. The sequence assigned to the *liasicus* Zone in Selworthy No.2 Borehole is lithologically comparable with that, extending upwards above bed 42 of Whittaker and Green (1983), in which the zone occurs in the coastal sections.

The possibility that the higher part of the *liasicus* Zone is represented in the Selworthy No.1 Borehole section is, in the absence of clear biostratigraphic evidence, supported by a comparison of the lithological characters of that section with those on the coast. The distribution of limestone beds below 8 m in the borehole is closely comparable with that in the bed 68 to 79 sequence in the coastal sections, which is of similar thickness and is assigned to the upper (*laqueus*) subzone of the *liasicus* Zone. Up to 8 m of beds in the borehole may, therefore, belong to the *angulata* Zone; however, limestones are more numerous in this sequence than in the possible correlative sequence (beds 80 to 90 of Whittaker and Green, 1983) of the coastal sections. The higher part of the *angulata* Zone (beds 91 to 145 of Whittaker and Green (1983) is some 30 m thick in the coastal sections; it is unlikely that this, or a greater, thickness of beds occur between Selworthy No.1 Borehole and the site, only 30 m farther north, with the brachiopod (*Calcirhynchia calcaria*) upon which Whittaker (1976) based a suggestion of the presence of beds as young as the *conybeari* Subzone (*bucklandi* Zone, Early Sinemurian). It is, therefore, likely that the outcrop to the north of the Selworthy No.1 site contains only beds of *angulata* Zone age.

SUMMARY AND CONCLUSIONS

In comparison with that exposed on the west Somerset coast between St Audrie's Bay and Blue Anchor, the Selworthy succession appears to show the following differences:

a. the Blue Anchor Formation may be slightly thinner but includes a slightly thicker Williton Member.

b. The Penarth Group is thinner, includes thicker limestone beds, and is slightly more arenaceous.

c. the combined thickness of the 'pre-planorbis Beds' and beds assigned to the *planorbis* Zone is slightly greater than in the coastal sections.

d. the lower part of the *angulata* Zone contains more limestone beds than in the coastal sections.

The thickness of the Penarth Group at Selworthy indicates that the rate of subsidence there was lower in Rhaetian times than in the area east of Blue Anchor; this factor may also have been operative during deposition of the Blue Anchor Formation and older Mercia Mudstone Group beds. In contrast, units in the Lias Group appear to be slightly thicker than in the coastal sections east of Blue Anchor, indicating a slightly greater rate of subsidence in the Selworthy area during latest Rhaetian and Hettangian times. Comparison of the thickness of the Lias Group beds in the Selworthy boreholes with their correlatives in the coastal sections suggests that the Selworthy succession, up to the level of the youngest beds proved in the No.1 Borehole, is likely to be at least 60 m thick. The full thickness of the Lias Group preserved in the outlier is, however, unknown.

There is no clear indication of the extent to which the Mesozoic deposits preserved in the Selworthy area formerly extended across the Devonian rocks of westernmost Somerset and north Devon. On the north side of the Bristol Channel, sections in Glamorgan, South Wales, show the margin of Late Triassic and Early Jurassic sedimentation; there, the passage from offshore to littoral or marginal facies takes place very close to the depositional margin (Waters and Lawrence, 1987; Wilson *et al*., 1990). The slightly more arenaceous character, and the presence of thicker limestones, the thinner Penarth Group sequence at Selworthy may thus reflect proximity to a marginal facies zone of Rhaetian age. e apparent westerly increase in the proportion of limestone in lower *angulata* Zone beds in Somerset may reflect a lateral passage similar to that seen in correlative sequences on the north side of the Bristol Channel, where limestones increase in abundance westwards and become dominant adjacent to a zone of Early Jurassic proximal nearshore deposits.

ACKNOWLEDGEMENTS

The authors are grateful to Drs J. N. Carney and G. K. Lott, of the British Geological Survey, Keyworth, who kindly read and made helpful comments upon an initial draft of this account. The illustrations were prepared by staff of the Publication Services Group at the British Geological Survey, Keyworth. The contribution is published with the approval of the Director, British Geological Survey (N.E.R.C.).

REFERENCES

BGS. 1974. IGS boreholes 1973. Report of the Institute of Geological Sciences **74/7**. HMSO, London.

CHAMPERNOWNE, A. and USSHER, W. A. E. 1879. Notes on the structure of the Palaeozoic districts of west Somerset. *Quarterly Journal of the Geological Society of London*, **35**, 532-548.

DE LA BECHE, H. T. 1846. On the formation of the rocks of South Wales and south western England. *Memoirs of the Geological Survey of Great Britain*, **1,** 1-296.

ETHERIDGE, R. 1872. Notes upon the physical structure of the Watchett area, and the relation of the secondary rocks to the Devonian series of west Somerset. *Proceedings of the Cotteswold Naturalists' Field Club*, **6**, 35-47.

HODGES, P. 1994. The base of the Jurassic System: new data on the first appearance of *Psiloceras planorbis* in southwest Britain. *Geological Magazine*, **131,** 841-844.

HORNER, L. 1816. Sketch of the geology of the south-western part of Somersetshire. *Transactions of the Geological Society of London*, **3**, 338-384.

LAMING, D. J. C. 1968. New Red Sandstone stratigraphy in Devon and west Somerset. *Proceedings of the Ussher Society*, **2**, 23-25.

MAYALL, M. J.1981. The Late Triassic Blue Anchor Formation and the initial Rhaetian marine transgression in south-west Britain. *Geological Magazine*, **118,** 377-384.

RICHARDSON, L. 1911. The Rhaetic and contiguous deposits of west, mid, and part of east Somerset. *Quarterly Journal of the Geological Society of London*, **67**, 1-74.

THOMAS, A. N. 1940. The Triassic rocks of north-west Somerset. *Proceedings of the Geologists' Association*, **51**, 1-43.

USSHER, W. A. E. 1890. The Triassic rocks of west Somerset and the Devonian rocks on their borders. *Proceedings of the Somersetshire Archaeological and Natural History Society*, **35**, 1-36.

WARRINGTON, G. 1974. Studies in the palynological biostratigraphy of the British Trias. I. Reference sections in west Lancashire and north Somerset. *Review of Palaeobotany and Palynology*, **17,** 133-147.

WARRINGTON, G. 1981. The indigenous micropalaeontology of British Triassic shelf sea deposits. In: *Microfossils from Recent and fossil shelf seas*. Eds: J. W. NEALE and M. D. BRASIER, Ellis Horwood, Chichester, 61-70.

WARRINGTON, G. 1983. Mesozoic micropalaeontological studies. In: WHITTAKER, A. and GREEN, G. W. (q.v.), 131-132.

WARRINGTON, G., AUDLEY-CHARLES, M. G., ELLIOT, R. E., EVANS, W.B., IVIMEY-COOK, H. C., KENT, P. E., ROBINSON, P. L., SHOTTON, F. W. and TAYLOR, F. M. 1980. A correlation of Triassic rocks in the British Isles. *Geological Society of London, Special Report* **13**.

WARRINGTON, G. and WHITTAKER, A. 1984. The Blue Anchor Formation (late Triassic) in Somerset. *Proceedings of the flasher Society*, **6**, 100-107.

WARRINGTON, G., COPE, J. C. W. and IVIMEY-COOK, H. C. 1994. St Audrie's Bay, Somerset, England: a candidate Global Stratotype Section and Point for the base of the Jurassic System. *Geological Magazine*, **131,** 191-200.

WATERS, R. A. and LAWRENCE, D. J. D. 1987. Geology of the South Wales Coalfield, Part III, the country around Cardiff, 3rd edition. *Memoirs of the British Geological Survey,* (*Street 263*). HMSO, London.

WHITTAKER, A. 1976. Notes on the Lias outlier near Selworthy, west Somerset. *Proceedings of the Ussher Society*, **3**, 355-359.

WHITTAKER, A. and GREEN, G. W. 1983. Geology of the country around Weston-super-Mare. *Memoirs of the British Geological Survey*, (*Sheet 279, with parts of sheets 263 and 295*). HMSO, London.

WILSON, D., DAVIES, J. R., FLETCHER, C. J. N. and SMITH, M. 1990. Geology of the South Wales Coalfield, Part VI, the country around Bridgend, 2nd edition. *Memoirs of the British Geological Survey* (*Sheet 262*). HMSO, London.

WOODWARD, H. B. 1893. The Jurassic rocks of Britain. The Lias of England and Wales (Yorkshire excepted). *Memoirs of the Geological Survey of the United Kingdom*.

WOOLLAM, R. and RIDING, J. B. 1983. Dinoflagellate cyst zonation of the English Jurassic. *Report of the Institute of Geological Sciences* **83/2.**