ARTICULATED ECHINOIDS FROM THE BASAL BLUE LIAS FORMATION (LOWER JURASSIC) NEAR WATCHET, SOMERSET, ENGLAND

K. PAGE 1 AND C.R.C. PAUL 2


Common, small, crushed Diademopsis tests with associated spines occur in the Lower Jurassic, lowermost Blue Lias Formation near Watchet, Somerset. Almost all come from a 5–10 cm shale interval in the top of Whittaker and Green’s bed 14 in the lower part of the Planorbis Chronozone (Hettangian) with a few specimens also recorded from Bed 18. The associated assemblage includes Psiloceras ex grp planorbis (Sowerby), the bivalves Modiolus minimus (J. Sowerby) and Armingella?, a plurioluminal Isocrinus angulatus (Fraas), a decapod crustacean and rare plant fragments. Echinoid remains include teeth and hemipyramids from the jaw apparatus, as well as ambulacral and interambulacral plates with associated spines. All plates derive from the pedinoid echinoid, Diademopsis. Several examples appear to have been fragmented before burial, suggesting they were subjected to predation, but burial was soon after death due to the presence of attached spines associated with the tests of most individuals. Diademopsis tests with associated spines are also known from the basal Blue Lias in south-east Devon (Pinhay Bay and Tolcis Quarry). The horizons in Pinhay Bay (Lang’s beds H1, H3 and H6) are, however, slightly lower in the Blue Lias succession as they occur below the first occurrence of ammonites in bed H25, at levels corresponding to the Tilmanni Chronozone and probably also the terminal Triassic.

INTRODUCTION

Articulated echinoids have long been known from the lower part of the Lower Lias Group of Devon and Dorset (Hettangian-Lower Sinemurian, Lower Jurassic), but seem to have been less frequently recorded from the West Somerset coast. For example, De La Beche (1826, p. 28, pl. 4, fig. 5) briefly described and illustrated a partial test with a few associated spines of an unidentified echinoid from the ‘lias marl’ of Dorset. From De La Beche’s illustration, the specimen appears to be a cidaroid. Broderip (1837) described ‘Cidaris bechei’ Broderip from Lyme Regis, Dorset and suggested it might be the same species as that figured by De La Beche (1826). Wright (1855) described ‘Hemipedina bechei’ and ‘H. bowierbanki’ Wright, from the Blue Lias Formation of Devon and later (1861) added ‘H. tomesii’ Wright. Wright (1857–1878) also monographed all the then known Jurassic echinoids and described several species from the Blue Lias Formation of Devon. Fraser and Lewis (2010) figured specimens from the Natural History Museum London, reported to be from the Blue Lias Formation of the Lyme Regis area, including Procidaris edwardsii (Wright), ‘Cidaris’ sp., Diademopsis bowierbanki (Wright) and D. beberti (Agassiz and Desor), but all lack precise stratigraphical information.

Most recently Smith (2015) has thoroughly described and illustrated the British Jurassic regular echinoids recorded from the Lower Lias Group. He recognized four species, three cidaroids and one pedinoid, all of which are known from the Blue Lias Formation in Devon and Dorset (Hettangian to Lower Sinemurian, as reviewed by Page, 2002), but only a single example of Couvelardicidaris sp. from the Upper Hettangian of Cockhill Quarry, Emborough, Somerset (Smith, 2015, p. 11).

These records suggest that, remarkably, few articulated echinoids have been recorded from the considerably more extensive exposures of the Blue Lias Formation on the West Somerset coast, although ‘echinoid fragments’ were noted by Whittaker and Green (1983) in their comprehensive memoir on the area (for instance in their Bed 22 of the Blue Lias Formation in Doniford Bay, near Watchet). One of us (KNP) has also noted concentrations of echinoid spines at several levels in the Liassicus Chronozone (as noted in Weedon et al. 2017, p. 21) with occasional isolated spines at other levels. Nevertheless, although Warrington et al. (1994) reported the sea urchin Diademopsis from the Late Triassic, Lisstock Formation in St Audrie’s Bay, we are unaware of any report in the literature of specifically identified sea urchins from the overlying Blue Lias Formation of the coastal area.

It is, therefore, appropriate to document a recently identified occurrence of partially complete and partially articulated examples of Diademopsis from low in the Blue Lias Formation at Helwell Bay, Somerset (Figs 1, 2), as noted briefly by Weedon et al. (2017, p. 20). Most of the new specimens come from a 5–10 cm shale interval in the upper part of Whittaker and Green’s bed 14, with a few specimens being recorded from Bed
Currently held in Plymouth University.

Regis, registration numbers LYMPH 2017/30.1–20. Others are specimens have been deposited in the Philpot Museum, Lyme Regis, southern England. Most of the figured

gave a full synonymy of all four species known from the Blue

Psiloceras foreground is Bed 8, the lowest level to yield ammonites (Fig. 2).

Hettangian (Bloos and Page 2000; Weedon the Planorbis Subchronozone and Chronozone of the lower Hettangian (Sinemurian) of southern England. The differences detected here between the present specimens and the recent description of D. serialis (Smith, 2015, pp. 59–60) also appear to be due to size differences and imply that all the current specimens are juveniles.

**Genus Diademopsis Desor, 1855**

**Diagnosis:** Pedinids with relatively wide interambulacral plates that have a central primary tubercle flanked by smaller secondary tubercles on adradial and interradial sides. Apical disc only loosely connected to the corona (Smith, 2015, p. 57).

**Diademopsis serialis** (Agassiz, 1838): for synonymy see Smith (2015, p. 58).

**Diagnosis:** A species of Diademopsis with pore pairs arranged uniserially throughout (no phyllodes adorally). Ambulacral tubercles relatively large, occupying most of each triad at the ambitus and leaving room for only a narrow per-radial zig-zag row of granules and small secondary tubercles. Secondary interambulacral tubercles absent in individuals smaller than 14 mm diameter; small flanking secondary tubercles present on subamittal interambulacral plates of individuals from 14 to about 24 mm test diameter, and two sub-equal tubercles present on ambital and subambital plates from individuals of 24 to 34 mm test diameter. Largest individuals with primary tubercles flanked by two slightly smaller secondary tubercles on ambital plates. (Smith, 2015, p. 58)

**Description:** The smallest examples appear to have more or less complete tests, but have lost most of their spines (Fig. 3a, b). LYMPH 2017/30.3 and 2017/30.7 both appear to be complete, but are only 6.7 mm in test diameter (Figs 5d, 4). The largest tests (e.g., LYMPH 2017/30.1 and 2017/30.12) only reach about 11 mm test diameter and are slightly incomplete peripherally (Fig. 3c). Fragments of larger examples occur, but nothing as large as the 30–35 mm diameter recorded by Smith (2015, p. 59). Ambulacra are much less than half the width of interambulacra. Specimen LYMPH 2017/30.15 has ambulacra 5.0 mm wide (Figs 3d, 4). The interambulacra are straight and on the aboral surface the ambital plates. (Smith, 2015, p. 58)

**Description:** The smallest examples appear to have more or less complete tests, but have lost most of their spines (Fig. 3a, b). LYMPH 2017/30.3 and 2017/30.7 both appear to be complete, but are only 6.7 mm in test diameter (Figs 5d, 4). The largest tests (e.g., LYMPH 2017/30.1 and 2017/30.12) only reach about 11 mm test diameter and are slightly incomplete peripherally (Fig. 3c). Fragments of larger examples occur, but nothing as large as the 30–35 mm diameter recorded by Smith (2015, p. 59). Ambulacra are much less than half the width of interambulacra. Specimen LYMPH 2017/30.15 has ambulacra 5.0 mm wide (Figs 3d, 4). The interambulacra are straight and on the aboral surface the ambital plates. (Smith, 2015, p. 58)

18. Both faunas fall within the planorbis Biohorizon (Hn5) of the Planorbis Subchronozone and Chronozone of the lower Hettangian (Bloos and Page 2000; Weeden et al. 2017).

The systematics utilized here follow Smith (2015), who also gave a full synonymy of all four species known from the Blue Lias Formation in southern England. Most of the figured specimens have been deposited in the Philpot Museum, Lyme Regis, registration numbers LYMPH 2017/30.1–20. Others are currently held in Plymouth University.

**SYSTEMATIC PALEONTOLOGY**

There is nothing about the echinoid remains from Watchet to suggest that more than one species is present. On this assumption, the presence of a grooved tooth indicates that they are either cidaroid or pedinoid echinoids (Smith, 1981). The three known contemporary cidaroids (Smith, 2015) all have perforate, crenulate primary spine bosses on their interambulacral plates set in a more or less equant areola. Furthermore Couvelardicidaris has highly ornamented spines, covered in granules. The Watchet specimens have smooth, perforate primary spine bosses and long, unornamented, slender spines. They most closely resemble the pedinoid sea urchin Diademopsis Desor, 1855. In his monograph, Wright (1857–78) accepted three species of Diademopsis from the British Hettangian and Sinemurian, but Smith (2015, p. 60) suggested that they were largely based on growth differences and assigned them all to D. serialis (Agassiz, 1838) which is known from the Late Triassic to Early Jurassic (Sinemurian) of southern England. The differences detected here between the present specimens and the recent description of D. serialis (Smith, 2015, pp. 59–60) also appear to be due to size differences and imply that all the current specimens are juveniles.

**Genus Diademopsis Desor, 1855**

**Diagnosis:** Pedinids with relatively wide interambulacral plates that have a central primary tubercle flanked by smaller secondary tubercles on adradial and interradial sides. Apical disc only loosely connected to the corona (Smith, 2015, p. 57).

**Diademopsis serialis** (Agassiz, 1838): for synonymy see Smith (2015, p. 58).

**Diagnosis:** A species of Diademopsis with pore pairs arranged uniserially throughout (no phyllodes adorally). Ambulacral tubercles relatively large, occupying most of each triad at the ambitus and leaving room for only a narrow per-radial zig-zag row of granules and small secondary tubercles. Secondary interambulacral tubercles absent in individuals smaller than 14 mm diameter; small flanking secondary tubercles present on subamittal interambulacral plates of individuals from 14 to about 24 mm test diameter, and two sub-equal tubercles present on ambital and subambital plates from individuals of 24 to 34 mm test diameter. Largest individuals with primary tubercles flanked by two slightly smaller secondary tubercles on ambital plates. (Smith, 2015, p. 58)

**Description:** The smallest examples appear to have more or less complete tests, but have lost most of their spines (Fig. 3a, b). LYMPH 2017/30.3 and 2017/30.7 both appear to be complete, but are only 6.7 mm in test diameter (Figs 5d, 4). The largest tests (e.g., LYMPH 2017/30.1 and 2017/30.12) only reach about 11 mm test diameter and are slightly incomplete peripherally (Fig. 3c). Fragments of larger examples occur, but nothing as large as the 30–35 mm diameter recorded by Smith (2015, p. 59). Ambulacra are much less than half the width of interambulacra. Specimen LYMPH 2017/30.15 has ambulacra 5.0 mm wide (Figs 3d, 4). The interambulacra are straight and on the aboral surface the ambital plates. (Smith, 2015, p. 58)

**Description:** The smallest examples appear to have more or less complete tests, but have lost most of their spines (Fig. 3a, b). LYMPH 2017/30.3 and 2017/30.7 both appear to be complete, but are only 6.7 mm in test diameter (Figs 5d, 4). The largest tests (e.g., LYMPH 2017/30.1 and 2017/30.12) only reach about 11 mm test diameter and are slightly incomplete peripherally (Fig. 3c). Fragments of larger examples occur, but nothing as large as the 30–35 mm diameter recorded by Smith (2015, p. 59). Ambulacra are much less than half the width of interambulacra. Specimen LYMPH 2017/30.15 has ambulacra 5.0 mm wide (Figs 3d, 4). The interambulacra are straight and on the aboral surface the pore-pairs are aligned. They are arranged in triads, but the only indications of this arrangement are the primary spine bosses, which occur alternately on every third ambulacral plate (Fig. 4b). All ambulacral plates reach the per-radial suture (Fig. 4b). The outer pore of each pair is slightly larger and a little below the inner pore (Fig. 4a, b).

Interambulacra are much broader than ambulacra with plates reaching 2.5 mm wide by 1.0 mm high (LYMPH 2017/30.13). Primary spine bosses are perforate and smooth (Fig. 4c). Spines about equal or slightly exceed the test diameter and are very slender (e.g., Fig. 3c, e). Spine bosses are perforate and not crenulate when well preserved.

Hemipyramids and one tooth from the Aristotle’s lantern are preserved on some slabs. The tooth (Fig. 5a) is concave and...
Articulated echinoids from the basal Blue Lias Formation (Lower Jurassic) near Watchet, Somerset, England

Figure 3. Articulated specimens of Diademopsis from Bed 14 of the Blue Lias Formation, Watchet, Somerset (a-e) and an unknown horizon at Lyme Regis (f). (a) LYMPH 2017/30.3 A small, nearly complete test of Diademopsis; (b) LYMPH 2017/30.7 Another small, nearly complete test of Diademopsis with associated spines; (c) LYMPH 2017/30.1 A damaged test of Diademopsis about 11 mm across with associated spines the longest of which just exceeds the test diameter; (d) LYMPH 2017/30.15. Three fragments of articulated test of Diademopsis with an associated spine. The external surface (upper right) shows prominent perforated spine bosses in interambulacral plates (cf. Fig. 4c). The other two pieces show the internal surface of test plates: (e) a cluster of six specimens of Diademopsis with associated spines (Plymouth University). (f) A complete crushed Diademopsis from the Blue Lias Formation, near Lyme Regis, Dorset. LYMPH 1973.3. Scale bars = 3 mm (a), 5 mm (b-d) and 10 mm (e, f). All specimens coated with ammonium chloride. In this and subsequent figures, all the Watchet specimens originate from the bed 14 in Fig. 2.
sharply pointed. One isolated hemipyramid (LYMPH 2017/30.13, Fig. 5b) is 2.75 mm maximum height by 1.3 mm maximum width. LYMPH 2017/30.9 preserves a pair of hemipyramids still articulated and shows that the foramen magnum is a V-shaped cleft (Fig. 5c). The pair of hemipyramids is 1.65 mm high by 0.8 mm wide with an aboral cleft 0.35 mm deep.

**DISCUSSION**

Echinoderms typically have complex multi-element skeletons; their taphonomy is similarly complex. Donovan (1991) provided a review for echinoderms in general and Smith (1984, chapter 2) for echinoids in particular. Irregular echinoids evolved after the basal Jurassic, so Hettangian sea urchins were all regular echinoids. In living regular echinoids the sutures between plates are the strongest parts of the corona because they are bound together by numerous collagen fibres. Damage during life often results in breaks across plates, rather than separation of plates along sutures. The latter only occurs after the collagen fibres have decayed. Knowledge of modern echinoid taphonomy sometimes comes from chance events (e.g., Greenstein, 1989) and of fossil taphonomy from chance discoveries (e.g., Bloos, 1973). However, Kidwell and Baumiller (1990) investigated disintegration of regular echinoids experimentally. They concluded that temperature and decay of collagen fibres controlled the speed of break up, whereas presence or absence of oxygen made little difference. Decay at 30°C resulted in more than a tenfold increase in rate of disintegration in a tumble mill compared with decay at 11°C. Furthermore, Kidwell and Baumiller (1990, p. 252) concluded that collagen fibres decayed effectively in a few days at 30°C, but took more than four weeks at 11°C. When the sea urchins were left to decay undisturbed the first loss was of pedicellariae and spines, followed by disintegration of the peristomial and periproctal membranes and then loss of the lantern. Kidwell and Baumiller (1990) recognized seven stages in the disintegration of tumbled specimens (Table 1).

**Figure 4.** Camera lucida drawings of ambulacral and interambulacral plates of Diademopsis from the basal Blue Lias Formation near Watchet, Somerset. (a) LYMPH 2017/30.15 showing adjacent ambulacral and interambulacral plates near the apical disc. (b) Ambulacral and (c) two isolated interambulacral plates of LYMPH 2017/30.10.

**Figure 5.** Stereophotos of echinoderms from the Lower Lias, Helwell Bay, Somerset. (a) An isolated concave tooth from Diademopsis, specimen LYMPH 2017/30.10. (b) An isolated hemipyramid from the jaw apparatus of Diademopsis, LYMPH 2017/30.14. (c) Stereophotos of an isolated pair of hemipyramids of Diademopsis LYMPH 2017/30.9. (d) Stereophotos of a pluricolumnal of Isocrinus angulatus? LYMPH 2017/30.14, with a single cirral ossicle still attached to the nodal (bottom right). Scale bars = 0.5 mm (a), 1 mm (b-d). All specimens coated with ammonium chloride.
Table 1. Stages of disarticulation of the regular echinoid Strongylocentrotus (After Kidwell and Baumiller, 1990, p. 250)

<table>
<thead>
<tr>
<th>Stage</th>
<th>Characterization</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Loss of &lt;50 % spines</td>
</tr>
<tr>
<td>2</td>
<td>Loss of &gt;50 % spines</td>
</tr>
<tr>
<td>3</td>
<td>Loss of oral and aboral membranes</td>
</tr>
<tr>
<td>4</td>
<td>Loss of lantern, which has disintegrated</td>
</tr>
<tr>
<td>5</td>
<td>Douglas fractured</td>
</tr>
<tr>
<td>6</td>
<td>Corona broken into large pieces</td>
</tr>
<tr>
<td>7</td>
<td>Corona broken into small fragments or dissociated plates</td>
</tr>
</tbody>
</table>

The taphonomy of the specimens from near Watchet differs from examples from the Blue Lias near Lyme Regis, Dorset (Fig. 3f). The latter appear to have been killed by rapid burial, as they are crushed but otherwise complete and well preserved. They also mainly occur in marls. In contrast, the specimens from Somerset are preserved in relatively hard and laminated organic-rich shale and are often damaged. Although spines are associated with most specimens, many spines are missing and those that remain are often separated slightly from the test plates. It is distinctly possible that the present specimens had been subjected to predation and/or scavenging before final burial since they combine Kidwell and Baumiller’s (1990) stages 2 and 6 (Table 1). They were completely buried shortly but not immediately after death, as indicated by the disarticulation of most examples. Furthermore, the disarticulation seems unlikely to have been caused by mechanical damage in such fine-grained sediment. In contrast, Paul (1997, p. 197) recorded small test fragments of the cystoid Echinospaerites from the Upper Ordovician, Balclatchie Conglomerate of Penwhapple Burn, near Girvan, Scotland, which Tripp (1980, p. 125) had concluded were pulverized by slumping of the coarse-grained conglomerate. Bloos (1973, p. 8) concluded that specimens of Diademaposis from the Hettangian of Württemberg, Germany were subject to pulses of sedimentation. He even estimated the time between such pulses at 4–5 weeks by comparing the preservation of the lower and upper surfaces of examples that were only partially buried initially with known decay rates of the modern regular echinoid Echinus (Schäfer, 1962, p. 118).

Unless the supposed predators or scavengers removed the specimens from their living environment and deposited them elsewhere, we assume that the echinoids lived more or less where they are now buried, as only a few show features which would clearly indicate transport (e.g., alignment of spines and disarticulation). The rarer specimens from Bed 18, however, seem to show more disarticulation and alignment, so conditions might have been less calm. Figure 3f shows a cluster of six examples, all more or less the same size. They appear to represent a cohort from the same spat fall.

Certainly many in situ echinoids are known from the basal Blue Lias Formation near Lyme Regis (see Smith, 2015, pl. 1; Figure 3f herein) and must have moved around on the sea floor despite the fine-grained nature of the sediment. Their morphology, however, is poorly adapted to life on soft substrates, as tube feet would get no grip on loose mud and the spines are long and sharply pointed. It is impossible not to conclude, therefore, that despite the fine-grained nature of the sediment, locally the ‘Blue Lias’ sea floor must have been firm, because if the substrate had been soft and soupy the sea urchins would have sunk into it. In addition, as the echinoids are likely to have grazed an algal film, either the substrate was firm enough to grow such a film, or they were grazing algal films on shells on the seabed, for instance ammonites. The associated fauna and flora may provide some additional clues as the environment and the single decapod crustacean observed, a possible Coleita, is a potential scavenger. The abundant, well-preserved, but crushed, aragonitic ammonite shells (all Psiloceras ex grp planorbis (Sowerby)), could provide another possible scavenger, or simply a substrate for algal growth. Interestingly, encrusting serpulids, apparently mainly on the upper surface confirm that the at least some of the ammonite shells were resident on the sea floor for a significant period of time. However, there is no clear evidence of bioturbation, as would be expected on a stable oxygenated sea floor, suggesting that the sediment itself remained sufficiently anoxic that not even dysoxerotic Chondrites could become established. Specimen LYMPH 2017/30.14 includes a crinoid pluricolumnal consisting of a nodal and eight internodals (Fig. 5d) typical of Isocrinus angulatus (Fraas). Simms and Jeram (2007) recorded this species (as Isocrinus sp. nov.) from the Early Hettangian of Waterloo Bay, Lorne, Northern Ireland (Simms, personal communication, June, 2017; see also Landon et al., 2017, p. 368), but it was regarded as a synonym of I. psilonoti (Quenstedt) in Simms (1989). All known isocrinids are benthic (Simms, 1986). The associated bivalves are also films on shells on the seabed, for instance ammonites. The environment of the specimens from near Watchet differs certainly many from the basal Blue Lias Formation (Lower Jurassic) near Watchet, Somerset, England as specifically identifiable echinoids are generally rather rare. However, at many horizons spines are not. Clearly the nature of the seabed was frequently firm enough for echinoids to settle and thrive, and rather than representing an exception, Beds 14 and 18 may actually provide a much more typical view of benthic Blue Lias life.

ACKNOWLEDGEMENTS

Professor S.K. Donovan kindly provided a copy of a relevant reference (Bloos, 1973). Dr M. J. Simms provided useful cheirozoan on the identity of the crinoid pluricolumnal preserved with the sea urchins described herein. Comments from two reviewers and editor helped improve the final manuscript.

REFERENCES


benthic
K. Page and C.R.C. Paul


