# THE TOARCIAN AGE OF THE UPPER PART OF THE MARLSTONE ROCK BED OF ENGLAND

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ABSTRACT. The 'Transition Bed' of Oxfordshire, Northamptonshire, and Leicestershire is the weathered or altered top of the Marlstone Rock Bed. In the top 0·05 m–0·3 m of the bed, the green ferrous minerals were oxidized to limonite, partly before deposition of overlying beds, partly recently in some areas. In another type of alteration, best seen at Harston, Leicestershire, much granular iron-pyrites was deposited in a highly irregular zone up to 0·08 m thick at the top of the bed. In these Midland counties the whole of the Tenuicostatum Zone, the basal zone of the Toarcian, is represented in the top 1–3 m of the Marlstone Rock Bed, the lower 3–6 m of which belongs to the Spinatum Zone. Regardless of the depth of weathering or alteration, *Tiltoniceras antiquum* and *Dactylioceras semicelatum* of the Semicelatum Subzone occur widely in the top 0·1 m of the bed, *D. tenuicostatum* occurs more locally at a slightly lower horizon, and lower still one *D. crosbeyi* is evidence for the Clevelandicum Subzone. Ammonites from the Semicelatum, Tenuicostatum, and Paltum Subzones occur in the Dorset coast Marlstone Rock Bed. North of Lincoln the top of the Bed is at about the top of the Spinatum Zone, while the Tenuicostatum Zone is divided between an overlying hard mudstone and higher grey shales. The change from the underlying ironstone/limestone facies to the overlying clays/shales-with-nodules facies took place at the top of the Spinatum Zone in Yorkshire, but at the top of the Tenuicostatum Zone in the Midland counties.

THE Marlstone Rock Bed is one of the most distinctive lithological horizons in the English Lias. It is typically an oolitic limestone, though the sand content becomes significant in a few places, and the ferrous iron content is high enough in two areas for it to be used as an iron-ore. The outcrop (text-fig. 1), known from numerous building-stone and iron-ore quarries in the past, extends from the Dorset coast generally north-eastwards to north of the Humber. Although it is represented immediately north of the Mendips and also at Dundry, south of Bristol, it is generally absent around and to the south of Bath. There is another gap in north Northamptonshire and south Leicestershire, where it is absent altogether or only about 0·3 m thick, owing to a combination of thin deposition and subsequent erosion. For several miles north and south of Lincoln it disappears and is represented by a layer of phosphatic pebbles and possibly some thin overlying shales. North of the Humber it thins out against the Market Weighton block, and it does not reappear farther north in Yorkshire, where equivalent beds are developed in a different facies.

Traditionally the top of the Marlstone Rock Bed was the junction between the Middle and Upper Lias, or more specifically the junction between the Spinatum and Tenuicostatum Zones (Arkell 1933, pp. 153–159; Whitehead *et al.* 1952, pp. 97, 105, 144–150). In fact the Marlstone Rock Bed was referred to a single zone, the Spinatum Zone, because in some areas it has a rich fauna of species of *Pleuroceras* (Howarth 1958, pp. ix–xi). The beds above the Marlstone Rock Bed are clays and shales in most areas, but in some parts of the Midlands the 'Transition Bed', a bed of oolitic limestone up to 0·15 m thick, is the immediately overlying bed. It was first described from the Banbury area, north Oxfordshire, and later at Tilton, Leicestershire, and contains a rich fauna of the Upper Lias ammonites *Dactylioceras* and *Tiltoniceras* '*acutum*' (Blake). It was called the Acutum Zone or hemera by Buckman (1910*b*, p. 86) and the Acutum Subzone by Arkell (1933, p. 179), and placed at the base of the Upper Lias, below the Tenuicostatum Subzone, as the lower of the two subzones of the Tenuicostatum Zone. This subzonal position of the Transition Bed has not been challenged until recently, though Spath (1942, p. 265; 1956, p. 143) did not accept the validity of this subdivision of the Tenuicostatum Zone. The identification of the horizon to which the Transition Bed belonged was made more difficult by the naming of an atypical representative of its *Dactylioceras* fauna as

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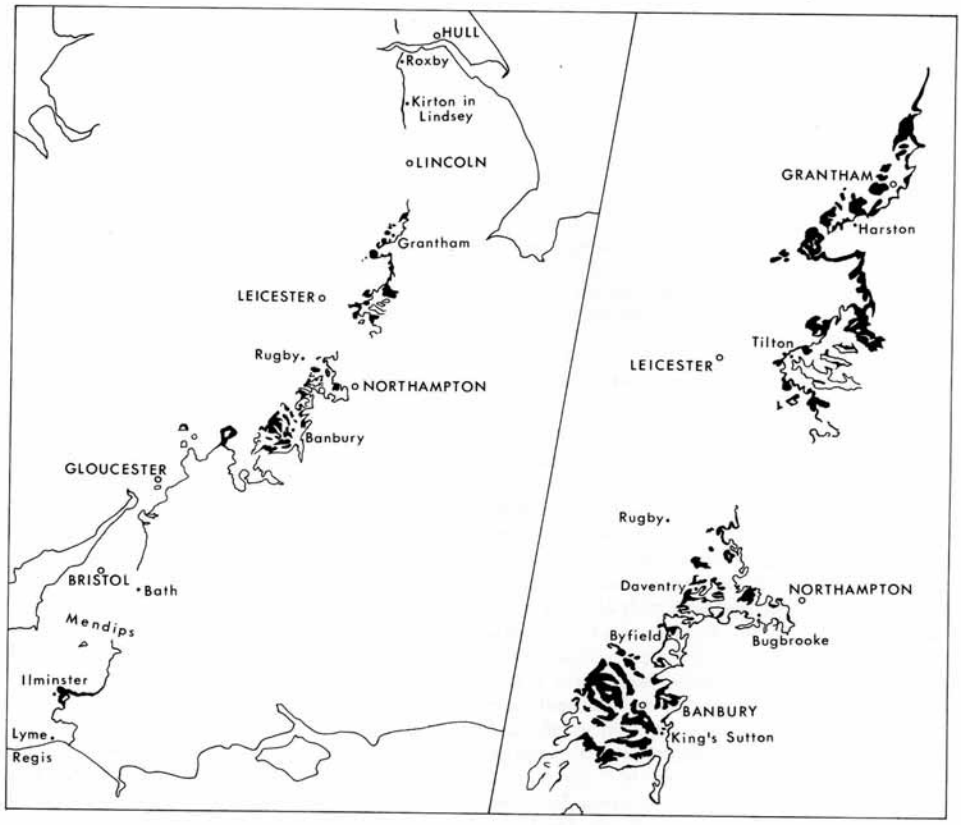
*Orthodactylites directus* Buckman (1926*a*, pl. 654), and also by the inability of anyone to find either this ammonite or *Tiltoniceras* in the Yorkshire coast Upper Lias succession. In a more recent investigation of the succession at Tilton, Hallam (1955, p. 21) discovered that *D. directum* occurred in the top 0·9 m of the Marlstone Rock Bed as well as in the Transition Bed, and suggested that it would be necessary to place the base of the Toarcian (i.e. the Upper Lias) at least 0·9 m below the top of the Marlstone Rock Bed. A more conservative view was taken by Howarth (1958, p. xi), and followed




TEXT-FIG. 1. Sketch map of the outcrop of the Marlstone Rock Bed, showing the principal localities described in the text.

later by Hallam (1967, p. 397), that it was best to retain the Middle/Upper Lias boundary at the top of the bed, because the relationships between the last *Pleuroceras* and the first *Dactylioceras* in Britain were not known at that time.

No further advance could be made until the succession of ammonites in the Tenuicostatum Zone of the Yorkshire coast was worked out. When this was done (Howarth 1973, enlarging on the collecting of the late Professor P. C. Sylvester-Bradley, whose preliminary results were published in Dean,

Donovan, and Howarth 1961, p. 476) the following sequence of ammonites, and of subzones derived from them, was established:

| Zone | Subzone | Ammonite faunas |
|---|---|---|
| *Dactylioceras tenuicostatum* | *Dactylioceras semicelatum* | *Tiltoniceras antiquum* and *Dactylioceras semicelatum* |
| | | *D. semicelatum* |
| | *D. tenuicostatum* | *D. tenuicostatum* |
| | *D. clevelandicum* | *D. clevelandicum* |
| | | *D. crosbeyi* |
| | *Protogrammoceras paltum* | *Protogrammoceras paltum* |

Abundant faunas of *Tiltoniceras* were found at the top of the Tenuicostatum Zone in Yorkshire, not at the base of the zone where the genus had always been expected before (e.g. Hallam 1967, p. 415). This alone was sufficient to suggest that the Transition Bed of the Midlands belonged to the top subzone of the Tenuicostatum Zone, and confirmation of this correlation was obtained when it was found that most of the *Dactylioceras* in that bed, to which the name *D. directum* had always been given before, were typical examples of *D. semicelatum*. In fact the populations of the latter species in the Transition Bed and in the Semicelatum Subzone of the Yorkshire coast are very similar, having almost identical ranges of variation. One end of the variation consists of evolute specimens with fine rectiradiate ribs, and Buckman gave the name *D. directum* to the most extreme example of this type from the Transition Bed.

Shortly after the Yorkshire coast Tenuicostatum Zone succession had been described, an abundant ammonite fauna was found in the top of the Marlstone Rock Bed in a quarry at Harston, north Leicestershire. The top 0·08 m of the bed contained many *D. semicelatum* and a few *Tiltoniceras*, and was clearly equivalent to the Transition Bed, though it was not developed as a distinct bed at Harston. The main discovery, however, was the presence of *D. tenuicostatum* in abundance in the next 0·05 m below, an ammonite that had hardly ever been found in the Marlstone Rock Bed before. This proved the presence of the Tenuicostatum Subzone in the bed, and further minor discoveries showed that the Clevelandicum Subzone occurred lower still in the bed.

The presence of the whole of the Tenuicostatum Zone in the Marlstone Rock Bed at Harston, and the discovery in existing museum collections of specimens of *Tiltoniceras* from Tilton preserved in green oolitic limestone typical of the Marlstone Rock Bed, led to further investigation of the Tilton Railway Cutting. It was found that, just as had been originally described by Wilson and Crick (1889), the Transition Bed is not a lithologically distinct bed, it is merely the weathered top of the Marlstone Rock Bed. There is no lithological break or disconformity that marks off a distinct bed at the top, only a highly irregular zone of oxidation of the green ferrous-iron content of the oolite to brown limonite. The Semicelatum Subzone ammonite fauna occurs in the top 0·9 m of this complete Marlstone Rock Bed (i.e. including the 'Transition Bed') at Tilton. Unfortunately there is no evidence for lower subzones of the Tenuicostatum Zone at Tilton, though there is plenty of room for them above the highest recorded *Pleuroceras* at about 3 m below the top of the Marlstone Rock Bed.

The 'Transition Bed' and its distinct ammonite fauna is also well developed in the Banbury–Byfield area of north Oxfordshire and west Northamptonshire. Although more constant in thickness, it appears possible to interpret it similarly in that area as the weathered top of the Marlstone Rock Bed, weathering that probably occurred before deposition of any overlying beds. Between north

Oxfordshire and south Somerset Tenuicostatum Zone ammonites are rarely found and the presence of the zone within the Marlstone Rock Bed has yet to be demonstrated. On the Dorset coast, however, where the Marlstone Rock Bed is very thin (0–0·6 m), ammonites are frequent and prove the presence of the Paltum, Tenuicostatum, and Semicelatum Subzones. The new stratigraphical work and ammonite collections, and reinterpretation of older collections are described in detail below.

## STRATIGRAPHICAL DESCRIPTIONS

1. *Dorset coast*. The Marlstone Rock Bed forms the lowest part of the Middle and Upper Liassic Junction Bed in the cliffs between Seatown and Eype, and has been described in detail by Buckman (1922*b*), Jackson (1922, 1926), and Howarth (1957). The bed is never more than 0·6 m thick and consists of three layers, the lithological differences and ammonite faunas of which were discussed by Howarth (1957, pp. 192–193). The lowest layer R is a coarse conglomeratic and oolitic limestone that contains many *Pleuroceras* indicative of the Apyrenum Subzone of the Spinatum Zone. The middle layer Px is a hard grey and pink limestone with scattered ooliths that contains only a few *P.* cf. *spinatum* and probably belongs to the Hawskerense Subzone. The top layer P is a brown finely oolitic limestone that contains a rich ammonite fauna. Previously (Howarth 1957, p. 193) it was said to be of Hawskerense Subzone age only, but now that the sequence within the Tenuicostatum Zone is known in Yorkshire, it is clear that layer P is a highly condensed bed that contains most horizons from the Hawskerense up to the Semicelatum Subzones. The following is a list of the ammonites that have been collected from layer P:

*Dactylioceras semicelatum* (BM C.17548, C.74719; IGS GSM 22475, 22514; SM J.44225–44226; NMW 26.135 G123), *D. tenuicostatum* (NMW 26.135 G5–8 (9 specimens), G124), *Protogrammoceras paltum* (BM 67939, C.2200, C.30769, C.68536; IGS GSM 47160–47161, 49291; SM J.44789), *Pleuroceras spinatum* (Bruguière), *P. spinatum* var. *buckmani* (Moxon), *P. yeovilense* Howarth, *P. hawskerense* (Young and Bird), *P. apyrenum* (Buckman).

These ammonites are characteristic of the Semicelatum, Tenuicostatum, Paltum, and Hawskerense Subzones, and the only horizon for which there is no evidence is the Clevelandicum Subzone. The examples of *D. semicelatum* (Pl. 81, figs. 3, 4, and Howarth 1957, pl. 17, figs. 5, 6) are typical of the species and match Yorkshire coast examples closely. The ten specimens of *D. tenuicostatum* (Pl. 82, figs. 5–8) are small and very similar to examples from near the top of the Marlstone Rock bed at Harston, Leicestershire; they all came from a layer of fine brown oolite which also contained one specimen of *D. semicelatum*, many gastropods, and a unique Terebratulid that was later described as '*Terebratula*' *reversa* Ager (1956*a*, p. 4, pl. 1, fig. 6) (possibly a *Lobothyris*). This association of fossils found in only a single block was the basis for the proposal of the layer At by Jackson (1926, p. 497) (At was derived from Buckman's hemera '*athleticum*', a term used for the Transition Bed of the Midlands that was said to contain a similar Terebratulid). However, the lithology is not different from layer P, the brachiopod has no special age significance, and the ammonites are intermediate in age between the Semicelatum and Paltum Subzones ammonites that are found in many other blocks of layer P. Therefore, there is no justification for the recognition of a separate At layer. Well-preserved specimens of *Protogrammoceras paltum* in layer P include the holotype and paratype (Buckman 1922*a*, pl. 362A; 1923*a*, pl. 362B), an example figured by Wright (1884, pl. 81, figs. 4–6), and the specific synonym *Platyharpites platypleurus* Buckman (1927*a*, pl. 698). So layer P, though never more than 0·3 m thick, contains highly condensed representatives from the Hawskerense to Semicelatum Subzones. The Marlstone Rock Bed of the Dorset coast, i.e. layers R, Px, and P, belongs to the whole of the Spinatum and Tenuicostatum Zones, so it is approximately equally divided between the Middle and Upper Lias. The next higher blocks of the Junction Bed are the layers N, O, and D, which are lateral equivalents of each other, and contain specimens of *Harpoceras exaratum*, from about the middle of the Exaratum Subzone. There are no records of *Eleganticeras* that would indicate the presence of the lower part of the Exaratum Subzone.

2. *North Dorset, Somerset, Avon, and Gloucestershire*. Northwards from the Dorset coast the Marlstone Rock Bed thickens quickly, and the term Junction Bed is now applied to the overlying sequence of clays and limestones of the Upper Lias. Both beds are very rich in ammonites in the Ilminster area of south Somerset. In the well-known Barrington succession described by Hamlet (1922), Spath (1922), and Pringle and Templeman (1922), the Marlstone Rock Bed contains many *Pleuroceras*, and is overlain by bed 1 (of Hamlet), a 0·175 m bed of 'sandy marl' which contains *D.* cf. *tenuicostatum* in addition to more examples of *Pleuroceras*. Bed 2, a 0·1 m bed of grey oolitic limestone, contains *D. semicelatum*, of which an example is figured here (Pl. 81, figs. 1, 2). The overlying bed 3 is clay containing argillaceous limestone nodules, and is of Exaratum Subzone age. So the Tenuicostatum

Zone is confined to bed 2 and part of bed 1, and these may be a local lithological variation of the Marlstone Rock Bed.

The Marlstone Rock Bed is well developed around Batcombe and Evercreech, near Shepton Mallet on the south side of the Mendips (Richardson 1906, 1909), but evidence for the presence of the Tenuicostatum Zone has not been obtained. After a gap north of the Mendips, the bed reappears north of Bath, thickens quickly, and was formerly extensively quarried along the western escarpment of the Cotswolds in Gloucestershire. There is little ammonite evidence for the age of the top of the bed. Species of *Pleuroceras* from both subzones of the Spinatum Zone are common at some localities (e.g. Alderton Hill), but data about their stratigraphical position in the Marlstone Rock Bed are lacking. There are no Tenuicostatum Zone ammonites in existing museum collections from this area. One record is intriguing, however: in an exposure of the Marlstone Rock Bed near Stow-on-the-Wold, about 25 km east of the Cotswolds escarpment, Hull (1857, pp. 19, 20) saw a 'band of deep reddish purple ironstone' 0·15 m thick at the top of the bed 'filled with good specimens of *Ammonites annulatus*'. It is likely that these were examples of *D. tenuicostatum* or *D. semicelatum* and they would show that most of the Tenuicostatum Zone was in the Rock Bed. The exposure was not extant in 1929 when Richardson (1929, p. 31) quoted the record, and the ammonites are not preserved in the Institute of Geological Sciences, so the occurrence cannot be investigated further. In the Stowell Park bore-hole, 18 km south-west of Stow-on-the-Wold, the Marlstone Rock Bed did not yield any ammonites, but 1 m of overlying shales contained *Tiltoniceras* and *Dactylioceras* of the Semicelatum Subzone. This shows that at least some of the Tenuicostatum Zone is above the Marlstone Rock Bed, though it need not be more than the upper half of the Semicelatum Subzone.

3. *Oxfordshire and Northamptonshire*. The Marlstone Rock Bed used to be extensively quarried for iron-ore and building stone over a large area between Banbury and Northampton, and details of the many former quarries can be found in Whitehead *et al.* (1952). It was in this district that the term 'Transition Bed' was first proposed by Walford (1878, p. 2) for a pale-brown oolitic and ferruginous 'marl' 0·050–0·075 m thick that forms the top of the Marlstone Rock Bed. The type area is around Banbury, and the best-known localities were quarries at Adderbury, King's Sutton, and Middleton Cheney, south and east of Banbury. Large numbers of *T. antiquum* (Wright) and *D. semicelatum* (including the holotype of *D.* '*directum*' Buckman) and many small gastropods were obtained from the Transition Bed in these quarries, and they show that the bed belongs to the Semicelatum Subzone. Arkell (1947, p. 21) proposed that the term 'Acutum Bed' (after *Tiltoniceras* '*acutum*' Blake, the holotype of which came from Adderbury) should supercede Transition Bed in the north Oxfordshire area, but this change of name has not been adopted by other authors ('Acutus Subzone' had been used earlier by Walford (1899, p. 33)). This lithology and 0·050–0·075 m thickness is fairly constant over the whole of north Oxfordshire and west Northamptonshire as far north as Daventry. At Iron Cross Farm, Byfield, the last locality at which it was well exposed (Howarth 1978, p. 240), it forms the upwards continuation of the Marlstone Rock Bed, with which it has a sharp and irregular junction. The Transition Bed appears to be the altered top of the Marlstone Rock Bed, alteration that is mainly oxidation and leaching of the green ferrous iron, and which probably took place before deposition of the overlying Abnormal Fish Bed. The latter is separated by a parting from the top of the Transition Bed, and is of mid and upper Exaratum Subzone age (Howarth 1978, p. 241).

In areas further east, and especially around Milton and Bugbrooke west of Northampton, a series of beds up to 0·35 m thick has been referred to the Transition Bed (Thompson 1889, 1892). This is due to the inclusion of an overlying sandy or shaly clay that does not contain the characteristic Transition Bed ammonites or gastropods. The age of the clay is not accurately known, but it may bridge the small disconformity that occurs everywhere else between the Transition Bed and the Abnormal Fish Bed, and it should not be included in the Transition Bed. At Bugbrooke Thompson (1892, p. 337) said that the Transition Bed was not present as a distinct bed, but was nevertheless clearly shown by the altered character of the top of the Marlstone Rock Bed which contained the Transition Bed fossils. Thus it appears that throughout the area the Transition Bed is the altered top of the Marlstone Rock Bed, alteration which probably took place before deposition of the overlying beds.

Evidence for the subzonal age of the remainder of the Marlstone Rock Bed is meagre in this area. Only one specimen of *D. tenuicostatum* has been found (Pl. 82, figs. 3, 4), at Rothersthorpe, 5 km south-west of Northampton, from an unrecorded horizon, but judging from the grey-green finely oolitic matrix, probably from immediately below the altered top of the Marlstone Rock Bed. This ammonite is evidence for the Tenuicostatum Subzone, but there are no ammonites to prove the presence of lower subzones. The majority of the Marlstone Rock Bed belongs to the Spinatum Zone and the characteristic brachiopods *Tetrarhynchia tetrahedra* and *Lobothyris punctata* are abundant except at the extreme top. *Pleuroceras* is rare in Northamptonshire: a few *P. spinatum* have been found and at least one *P. apyrenum* is known, but their horizons are not recorded. The Middle/Upper Lias junction occurs near the top of the Marlstone Rock Bed, probably within the top 0·25 m.

4. *Tilton, Leicestershire.* The well-known section at Tilton Railway Cutting (SK 762055) was first described by Wilson and Crick (1889) and there is a good photograph of it in its original state in Fox-Strangways (1903, p. 30, pl. 2). Wilson and Crick saw the Marlstone Rock Bed soon after it was uncovered below a thickness of up to 9 m of Upper Lias shales and it had been little affected by recent subaerial weathering. The 'Transition Bed' was described as a flaggy limestone 0·15–0·23 m thick containing a distinctive fauna, especially the ammonite *Tiltoniceras*, even though they said that 'it possesses the mineral characters of and is welded to the top of the Marlstone Rock Bed' (Wilson and Crick 1889, p. 297). Woodward (1893, p. 236) repeated this interpretation of the Transition Bed, but Whitehead *et al.* (1952, p. 135) made no mention of a Transition Bed at Tilton, nor anywhere in the surrounding area. The railway section was again described by Hallam (1955; 1968, p. 208) who recognized the 0·15–0·23 m Transition Bed, and observed that it lapped 'over minor irregularities at the top of the ironstone' and 'rested non-sequentially on the ironstone'. The lithology of the Transition Bed has been described as a pale-brown or cream finely oolitic limestone, sometimes flaggy, and sometimes passing up into sandy marl. *Tiltoniceras* preserved in such brown oolitic limestone is very common, but many others also occur preserved in the deep-green oolitic ironstone that is typical of the Marlstone Rock Bed at Tilton. Hallam (1955, p. 21) explained the latter by saying that the genus occurred rarely in the ironstone immediately below the Transition Bed.

Examination of the Tilton Railway Cutting exposures in recent years shows that the Transition Bed does not exist as a separate bed. It is the weathered top of the Marlstone Rock Bed, in which the siderite and chamosite of the deep green oolitic limestone are oxidized to limonite; partial decalcification gives it a friable, granular texture, which has been described as sandy, though the bed is not arenaceous. The depth of weathering varies greatly between 0·01 m and 0·25 m below the top surface, and the lowest extent is marked by an undulating thin sheet of brown limonite. Many specimens of *T. antiquum* (Wright), *D. semicelatum* (Pl. 81, figs. 5, 6) and *Gibbirhynchia tiltonensis* Ager, and many small gastropods (Wilson and Crick 1889, pp. 298–305, pl. 9) occur in the top 0·2 m of the Marlstone Rock Bed. Whether they occur preserved in deep-green ironstone or pale-brown oolitic limestone depends entirely on how deeply the weathering has penetrated at any particular point. Several fine examples of *Tiltoniceras* preserved in green ironstone were obtained from only 0·025 m below the top, but most of the green specimens occur lower down. In some specimens that are orientated approximately vertically in the bed, the upper half of the ammonite is pale brown and the lower half deep green. Weathering also penetrates deeply down some of the vertical joints and can convert fossils much lower down into pale-brown friable limestone. In a few places horizontal bedding planes lead to greater penetration of weathering, and rarely the whole of the top 0·2 m is affected giving the appearance of a distinct lithological bed at the top of the ironstone. Such beds fade out rapidly laterally, and the usual state is dark-green Marlstone Rock Bed weathered brown to a highly variable depth.

*D. semicelatum* is commonest in the top 0·2 m, but unlike *Tiltoniceras* it also occurs lower down to depths of 0·9 m below the top of the ironstone. This is the amount of the Marlstone Rock Bed that must be referred to the Semicelatum Subzone. No Upper Lias ammonites belonging to lower subzones occur at Tilton. The only Pleuroceras found *in situ* is a specimen of *P.* cf. *hawskerense* (Young and Bird) 3·0 m below the top of the Marlstone Rock Bed, and it indicates the Hawskerense Subzone of the Spinatum Zone. The brachiopods *Tetrarhynchia tetrahedra* (J. Sowerby) and *L. punctata* (J. Sowerby) range higher in the ironstone, the last ones being about 1·2 m below the top (Hallam 1955, p. 20). These two are usually held to be good indicators of the Spinatum Zone in England, but there are rare records from the Upper Lias, the genus *Tetrarhynchia* ranges up into the Bajocian (Ager 1956*b*, p. 3), and *T. tetrahedra* occurs in the Upper Lias, Bifrons Zone, in Spain (Hallam 1972, p. 408). So in the absence of ammonites, it does not seem safe to take the highest occurrence of these brachiopods as unequivocal evidence of the Spinatum Zone. The evidence available at present suggests that the Spinatum/Tenuicostatum Zone boundary occurs between 1 m and 3 m below the top of the Marlstone Rock Bed at Tilton. There is room in this thickness for condensed representatives of the three lower subzones of the Tenuicostatum Zone, and a disconformity need not be postulated to explain their absence. There is also no lithological evidence for such a disconformity.

The beds above the Marlstone Rock Bed are clays and shales with a few thin beds of limestone or limestone nodules. The basal 2·8 m belongs to the Exaratum Subzone, and uncrushed examples of *Harpoceras elegans* (J. Sowerby) and *H. serpentinum* (Schlotheim) occur at about the 2 m level. These indicate the top part of the Exaratum Subzone, and the absence of *H. exaratum* suggests that the non-sequence between the top of the Marlstone Rock Bed and the shales represents at least the lower half of the Exaratum Subzone. All the higher shales up to the top of the cutting belong to the Falciferum Subzone and contain the index ammonite commonly throughout. The following is a summary of the section exposed in the Tilton Railway Cutting (SK 762055), Leicestershire:

Zone and subzone of *Harpoceras falciferum*

Grey shale, with two rows of small limestone nodules about 0·5 m and 0·6 m below the top. *H. falciferum* . . . . . 5·50 m
Grey clay containing large calcite ooliths. *H. falciferum*, *Phylloceras heterophyllum* (J. Sowerby) . 0·70 m

Subzone of *Harpoceras exaratum*

Grey clay, oolitic. Large specimens of *H. serpentinum* (Schlotheim) . . . . . 0·80 m
Grey oolitic limestone. *H. elegans* (J. Sowerby) (BM C.80481–80483) and *H. serpentinum* common (BM C.80484–80485), and many *Dactylioceras* sp. indet. . . . . 0·20 m
Grey shales, paper shales, and clays. *H. serpentinum* in top 0·5 m . . . . . 1·80 m

Zones of *Dactylioceras tenuicostatum* and *Pleuroceras spinatum*

Marlstone Rock Bed:

a. Ironstone. Dark-green finely oolitic limestone, containing chamosite and siderite, weathered brown to an irregular depth, and sometimes more deeply along joints and bedding planes. *Tiltoniceras antiquum* (Wright) (BM C.10265–10267, C.41733, C.48753–48757, C.80242–80276, C.80470–80480) and *D. semicelatum* (BM C.36186–36188, C.49766, C.80277–80282, C.80466–80469) are abundant in the top 0·2 m and 0·9 m respectively and indicate the Semicelatum Subzone; *P.* cf. *hawskerense* (Young and Bird) (BM C.73686) occurs at the bottom and indicates the Hawskerense Subzone . . . . . 3·0 m
b. Green oolitic limestone, containing numerous specimens of *Tetrarhynchia tetrahedra* and *Lobothyris punctata*, and many bivalves (band B of Hallam 1955, p. 18) . . . . . 0·45 m
c. Sandrock. Green massive calcareous sandstone . . . . . 1·4 m
d. Calcareous sandstone as bed c, but with many nests of the brachiopods *T. tetrahedra* and *L. punctata* (band A of Hallam 1955, p. 18) . . . . . 0·3 m
e. Sandrock, as bed c . . . . . 0·75 m

Other exposures of the Marlstone Rock Bed in the Tilton area were in iron-ore quarries, where the bed had been less deeply buried than in the railway cutting. Consequently the top of the bed had been more strongly weathered. Of those described by Whitehead *et al.* (1952) and Hallam (1955, 1968), few now remain. One that can still be seen is the old quarry 1·3 km east of Tilton (SK 756056), where the top 0·2 m of the Marlstone Rock Bed is highly weathered into a pale-brown oolitic limestone that contains *Tiltoniceras antiquum* and *Dactylioceras semicelatum*. Other quarries, now obscured, were similar, and it is thought that the 'Transition Bed' is, in all cases, the weathered top of the Marlstone Rock Bed.

5. *Grantham area, north Leicestershire and south Lincolnshire*. Two quarries working the Marlstone Rock Bed as iron-ore existed, until closed down and filled in in 1975, at Harston, 12 km south-west of Grantham. Here the top of the Marlstone Rock Bed contains more Dactylioceratidae than any other exposure of the bed in England, and it is the most important section for dating the Upper Lias part of the bed. A section for the Upper Lias shales above the bed was given in Hallam (1968, p. 210), but a more detailed description is now given, so that the position of the disconformities can be established. Section at Harston Quarry (SK 843305), 1·5 km south-south-east of Harston:

Zone and subzone of *Harpoceras falciferum*

Clay. Impressions of *H. falciferum* and *Dactylioceras* sp. indet. . . . . 2·00 m
Brown rubbly limestone, oolitic or pisolitic in places. *H. falciferum* . . . . . 0·20 m

Subzone of *Harpoceras exaratum*

Grey shale . . . . . 1·20 m
Scattered flat nodules of blue limestone, weathered red-brown and white. *H. elegans* (J. Sowerby) abundant, *Dactylioceras anguiforme* Buckman abundant, *Nodicoeloceras crassoides* (Simpson), *Phylloceras heterophyllum* (J. Sowerby), *Coelodiscus minutus* (Schübler) . . . . . 0·10 m
Grey shale . . . . . *c.* 10·00 m
Grey calcareous clay, forming a hard massive bed. A few limestone nodules occur in a row at the top. Large specimens of *H. elegans*, *H. serpentinum* (Schlotheim) and *Hildaites murleyi* (Moxon) . . 1·30 m
Shale, with a row of 0·025 m thick flat limestone nodules at the top. *H. serpentinum*, *H. elegans* . . 0·05 m
Scattered lenticles of coarse sandstone, cross-bedded, with many granules of iron pyrites and some small pebbles. Much shell debris broken into small fragments. Fragments of *Harpoceras* (?*H.* cf. *exaratum*) . . . . . 0–0·05 m

Zone of *Dactylioceras tenuicostatum*

Marlstone Rock Bed:

a. Pale-brown limestone, consisting of numerous calcite ooliths and minute shell fragments in a calcareous matrix; the top 0·05 m contains patches of crystalline calcite and occasional pebbles of brown limestone; the lower half becomes green-coloured, more coarsely oolitic, with chamosite and siderite, and much recrystallized calcite; the top 0·025–0·080 m is full of fine granules of iron-pyrites and is grey-green in colour; its very uneven lower boundary is marked by a solid line of iron-pyrites, and the bed below is pale brown with only a few granules of iron-pyrites . . . 1·20 m

Subzone of *Dactylioceras semicelatum*

The top 0·08 m contains *Tiltoniceras antiquum* (Wright) (BM C.80237–80241), *D. semicelatum* common (BM C.80169, C.80171–80235), *Acrocoelites vulgaris* (Young and Bird), *Gibbirhynchia* sp. and gastropods.

Subzone of *Dactylioceras tenuicostatum*

Between 0·08 m and 0·13 m below the top *D. tenuicostatum* is abundant (BM C.80099–80168) and *Gibbirhynchia* sp. occurs.

Subzone of *Dactylioceras clevelandicum*

0·23 m below the top one specimen of *D. crosbeyi* (Simpson) (BM C.80170) was found.

Zone of *Pleuroceras spinatum*

b. Deep-green oolitic limestone, with much chamosite and siderite, and many bands of recrystallized calcite. Abundant *Tetrarhynchia tetrahedra* and *Lobothyris punctata* in nests. One *Pleuroceras* cf. *spinatum* (Bruguière) 0·25 m below the top, and several other specimens not *in situ* . . . 3·00 m

This quarry contained one of the best sections of the Marlstone Rock Bed for demonstrating that the top part that contains *Tiltoniceras* is a typical part of the bed that has been diagenetically altered. The alteration is due to pyritization from the top surface downwards. It consisted of the deposition of a large amount of fine granular iron-pyrites, which penetrated to a depth varying between 0·025 m and 0·080 m and the very uneven lower boundary is marked by a thin sheet of solid iron-pyrites. *Tiltoniceras* and *D. semicelatum* (Pl. 81, figs. 10, 11; Pl. 82, figs. 11, 12) occur in the top 0·080 m, so some of the Semicelatum Subzone is in the pyritized part and some in the unaltered part below. Most ammonites lie parallel to the bedding plane, but a few are at a high angle and occasionally the lower boundary of pyritization has reached half down an ammonite. There is no lithological break or change other than the pyritization, except for a few pebbles just below the top surface.

*D. tenuicostatum* (Pl. 82, figs. 1, 2, 9, 10) occurs in abundance between 0·08 m and 0·13 m below the top of the Bed, and this is the extent of the Tenuicostatum Subzone, which is below the pyritized zone. A single *D. crosbeyi* 0·23 m below the top is evidence for the presence of the Clevelandicum Subzone. There are no ammonites to prove the presence of the Paltum Subzone, but there is plenty of room for it between 0·25 m and 1·2 m below the top of the Bed. Marlstone Rock Bed division b of the above section is a natural downward continuation of the upper part where it becomes richer in iron, and several specimens of *Pleuroceras* occur of the Spinatum Zone.

The whole of the Tenuicostatum Zone is in the top 1·2 m of the Marlstone Rock Bed at Harston, and there are no major lithological discontinuities within that part of the bed. The main disconformity is at the top of the bed where the lithology changes to shale facies, and the bottom one-third of the Exaratum Subzone is missing (because of the absence of *Eleganticeras*). The middle third of that subzone is represented only by the lenticles of sandstone that contain *Harpoceras*, and continuous deposition starts only in the upper third of the subzone where more than 11 m of shales contain *H. elegans* and *H. serpentinum*.

At Denton Park Quarry (SK 856316), 1·5 km north-east of Harston Quarry, a similar succession was seen at the top of the Marlstone Rock Bed, though ammonites were much less common. The top 0·03–0·08 m of the bed contains much granular iron-pyrites as at Harston, but it is more of a shell bed containing a great number of broken bivalve shells and large numbers of the belemnite *Acrocoelites vulgaris* (Young and Bird). A few fragments of large specimens of *Tiltoniceras* were also seen. The lower non-pyritized part of the bed is similar to that at Harston, but Tenuicostatum Subzone ammonites were not found.

6. *North Lincolnshire and south Humberside*. North of Grantham the Marlstone Rock Bed thins steadily and disappears altogether before Lincoln. At Lincoln the Spinatum Zone is absent or is represented by a bed of

phosphatic pebbles (Trueman 1918; Howarth 1958, p. xii, bed 11), but there is no ammonite evidence for the presence of the zone nor for the lowest three subzones of the Tenuicostatum Zone. The presence of the Semicelatum Subzone is shown, however, by specimens of *T. antiquum* (Trueman Coll., Nottingham University, and BM C.48429–48432) in the top 0·15 m of the 0·60 m of overlying shales (Howarth 1958, p. xi, bed 12). *D. semicelatum* also occurs in these shales, and probably in the shales of bed 14 above.

The Marlstone Rock Bed reappears north of Lincoln and it was well exposed in recent years in quarries at Kirton in Lindsey (Howarth and Rawson 1965) and Roxby (Penny and Rawson 1969, pp. 194–197). The distribution of ammonites in the Upper Lias shales was poorly known in these quarries, and better records have been obtained from boreholes in the same area. Most information came from boreholes near Worlaby, 8 km east of Roxby, where many specimens of *T. antiquum* occurred in shales between 4 m and 5·7 m above the Marlstone Rock Bed (Richardson 1979). The following succession for part of the Middle and Upper Lias in this area incorporates details of the Kirton in Lindsey Quarry (Howarth and Rawson 1965, pp. 262–263), the north end of the Roxby Quarry (Penny and Rawson 1969, p. 196), and some records from the Worlaby boreholes. Thicknesses and lithology show little variation, though the rows of doggers are more obvious in the quarries, especially at Kirton in Lindsey. The ammonite distribution is the same, and records from all three places are included.

Subzone of *Harpoceras exaratum*

Shale, with two rows of doggers and a band of limestone. Beds 25–29 at Kirton in Lindsey; bed 29, a row of doggers 0·13 m from the top, contains many *H. elegans* (J. Sowerby); bed 27, a bed of limestone 1·2 m from the top, contains *H.* cf. *exaratum* (Young and Bird); bed 25 is a row of doggers at the base . . . . . 4·60 m

Subzone of *Dactylioceras semicelatum*

Shale, close-bedded, but sandy in basal 0·3 m. Beds 23 and 24 at Kirton in Lindsey. Many crushed *Tiltoniceras antiquum* (Wright), sometimes in shell beds, through most of the thickness . . 3·50 m

Shale, with scattered limestone nodules, especially near the base. Crushed *D. semicelatum* in the shales in the borehole, and well-preserved solid specimens in the basal nodules at Roxby . . 1·70 m

Subzone of *Dactylioceras tenuicostatum*

Shale. A few *D.* cf. *tenuicostatum* . . . . . 1·30 m

Subzones of *Dactylioceras tenuicostatum* (part), *D. clevelandicum*, and *Protogrammoceras paltum*

Hard, pale-grey, calcareous mudstone, silty and micaceous, with some phosphatic and calcareous nodules. Bed 21 at Kirton in Lindsey. Many well-preserved ammonites and belemnites: *D. tenuicostatum* and *D. clevelandicum* common; one large *P. paltum* (Buckman) known from Roxby . . . . . 0·40–1·10 m

Zone of *Pleuroceras spinatum*

Marlstone Rock Bed. Green oolitic limestone. Rare *Pleuroceras* cf. *hawskerense* (Young and Bird) (level unknown). Many brachiopods . . . . . 3·00 m

The Dactylioceratidae that were recorded previously (Howarth and Rawson 1965, p. 262) in bed 21 at Kirton in Lindsey have been reassessed in the light of the succession of species now known in the Yorkshire coast Grey Shales (Howarth 1973). *Dactylioceras tenuicostatum* and *D. clevelandicum* are both present, and with the single large *Protogrammoceras paltum* at Roxby, they show that the Paltum, Clevelandicum, and part of the Tenuicostatum Subzones are present in that bed. *D. tenuicostatum* also occurs in the shales above, and then *D. semicelatum* and *Tiltoniceras antiquum* occur higher up. So it can be shown that the Tenuicostatum Zone lies wholly above the Marlstone Rock Bed in the area north of Lincoln. Approximately the lower half of the zone is condensed in a bed up to 1·1 m thick, but unlike the 'Transition Bed' of Oxfordshire to Leicestershire, it is a calcified silty mudstone significantly different in lithology from the Marlstone Rock Bed. The upper half of the zone occurs in shales 6·5 m thick that resemble the Grey Shales of the Yorkshire coast in thickness and lithology, except for the absence of pyritized doggers.

## SYSTEMATIC DESCRIPTIONS

### Family DACTYLIOCERATIDAE Hyatt, 1867
### Genus DACTYLIOCERAS Hyatt, 1867
### Subgenus ORTHODACTYLITES Buckman, 1926
### *Dactylioceras* (*Orthodactylites*) *semicelatum* (Simpson)

Plates 80, 81; Plate 82, figs. 11, 12; text-figs. 2, 3

1819 *Ammonites annulatus* J. Sowerby, p. 41, pl. 222, figs. 1, 2 (*non* figs. 3–5) (*non Ammonites annulatus* Schlotheim, 1813).
1843 *Ammonites semicelatus* Simpson, p. 20.
1855 *Ammonites semicelatus* Simpson, p. 50.
1884 *Ammonites semicelatus* Simpson, p. 81.
1911*a* *Dactylioceras semicelatum* (Simpson); Buckman, pl. 31.
1926*a* *Orthodactylites directus* Buckman, pl. 654.
1927*a* *Kryptodactylites semicelatus* (Simpson); Buckman, pl. 31A.
1927*a* *Orthodactylites mitis* Buckman, pl. 738.
1957 *Dactylioceras directum* (Buckman); Howarth, p. 197, pl. 17, figs. 5, 6.
1957 *Dactylioceras semicelatum* (Simpson) and spp.; Maubeuge, figs. 1–3, ?18–21, 41, 42, 44, ?46, 47, 48, ?49, ?58, ?59 (1), 59 (2).
1957 *Dactylioceras pseudocrassoides* Maubeuge, p. 201, pl. 13, fig. 28.
1957 *Dactylioceras densicostatum* Maubeuge, p. 202, pl. 13, fig. 29.
1960 *Dactylioceras* sp. indet.; Hoffmann and Martin, p. 114, pl. 9, fig. 5; pl. 10, figs. 2*a*, 2*b*.
1968 *Dactylioceras* cf. *toxophorum* (Buckman); Hoffmann, p. 4, pl. 2, figs. 3, 4; pl. 3, fig. 1.
1968 *Dactylioceras* (*Orthodactylites*) *semicelatum* (Simpson); Hoffmann, p. 6, pl. 2, figs. 1, 2.
1968 *Dactylioceras* (*Orthodactylites*) *eikenbergi* Hoffmann, p. 8, pl. 1, fig. 2.
1968 *Dactylioceras* (*Orthodactylites*) *wunnenbergi* Hoffmann, p. 7, pl. 1, fig. 1.
1968 *Dactylioceras ernsti* Lehmann, p. 46, pl. 17, figs. 5, 6; pl. 19, figs. 2, 4.
1971 *Dactylioceras* (*Orthodactylites*) *anguinum* (Reinecke); Pinna and Levi-Setti, p. 90, pl. 2, figs. 1, 2, 5.
1971 *Dactylioceras* (*Orthodactylites*) *semicelatum* (Simpson); Pinna and Levi-Setti, p. 90, pl. 2, figs. 3, 4, 15.
1973 *Dactylioceras* (*Orthodactylites*) *semicelatum* (Simpson); Howarth, p. 262, pl. 6, fig. 1; pl. 7, figs. 1, 2; pl. 8, figs. 1–4; pl. 9, figs. 1–3.

*Occurrence.* Dorset coast: Marlstone Rock Bed layer P, fairly frequent; Somerset: bed 2 (Hamlet 1922) at Barrington, Ilminster, about four specimens known; north Oxfordshire and Northamptonshire: abundant in the top of the Marlstone Rock Bed at many localities from south and east of Banbury to Byfield, Daventry, and Northampton; Leicestershire: abundant in the top of the Marlstone Rock Bed in the Tilton area and common at Harston; Lincoln: shales of beds 12 and 14 (Howarth 1958, p. xi); north Lincolnshire and south Humberside: shales 2·3–4·0 m above the Marlstone Rock Bed at Kirton in Lindsey and Roxby.

*Discussion.* The occurrence of *Dactylioceras* (*Orthodactylites*) *semicelatum* in the Grey Shales Formation of the Yorkshire coast has already been described in detail by Howarth (1973, p. 262), and

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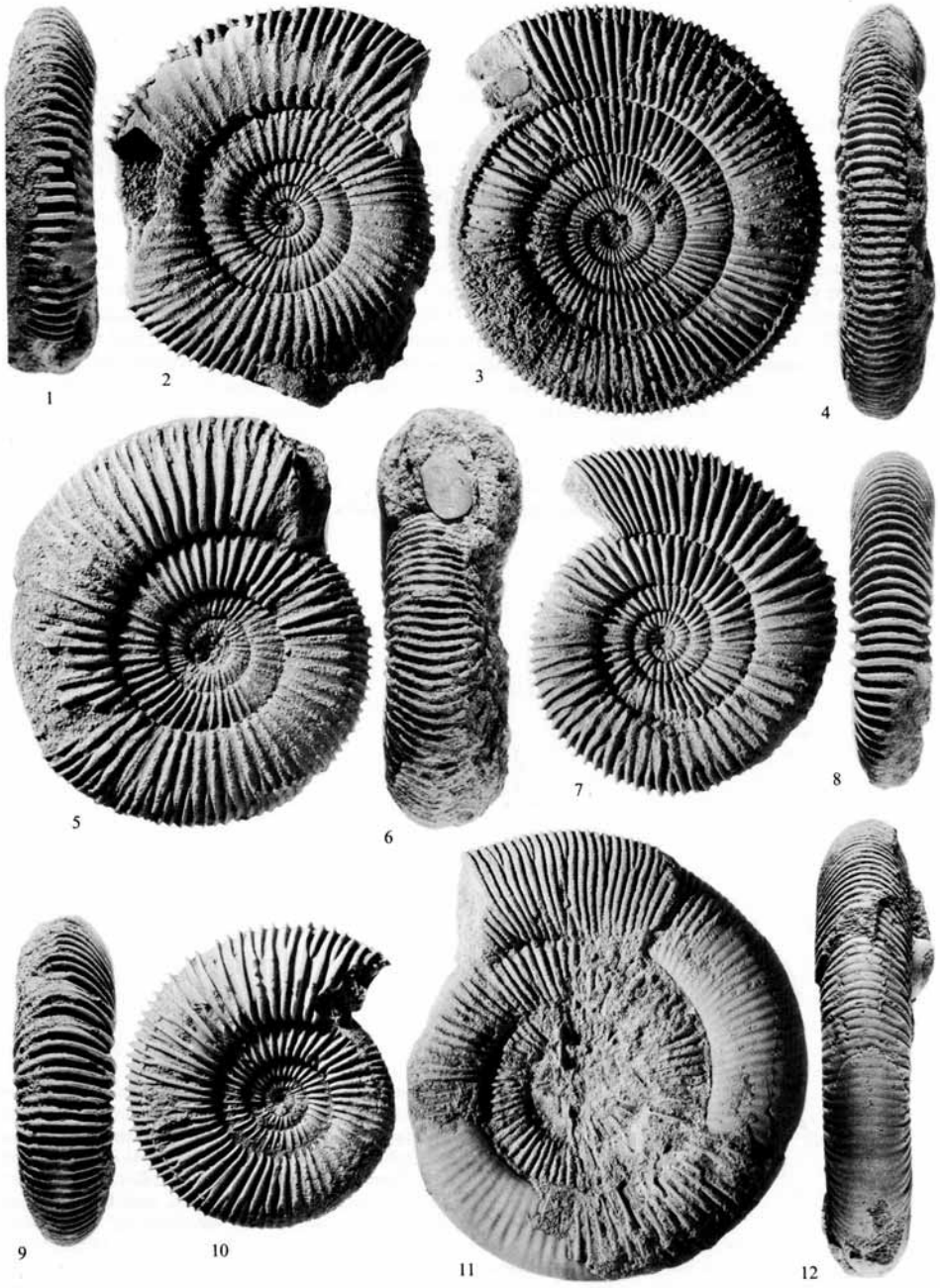
EXPLANATION OF PLATE 80

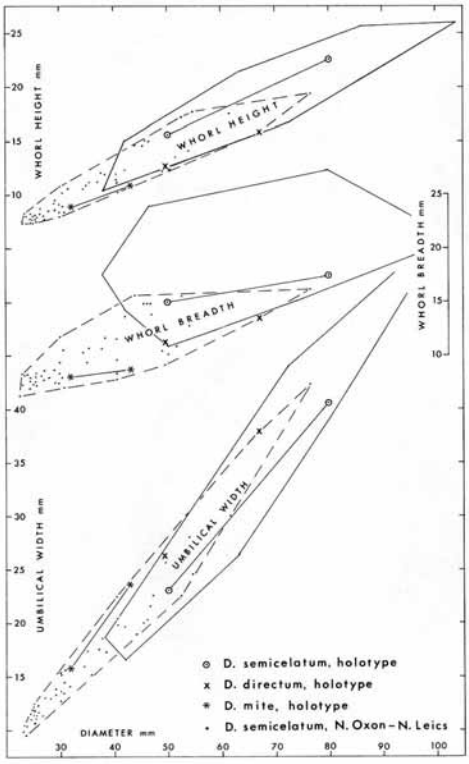
Figs. 1–12. *Dactylioceras* (*Orthodactylites*) *semicelatum* (Simpson). All from top 0·1 m of the Marlstone Rock Bed ('Transition Bed'), Semicelatum Subzone, Tenuicostatum Zone, of the Banbury area, Northamptonshire. 1, 2, 5, 6, King's Sutton, 6 km SE of Banbury, BM C.67697, C.67376. 3, 4, Middleton Cheney, 4 km ENE of Banbury, originally figured Buckman (1926*a*, pl. 654) as holotype of *Orthodactylites directus*, IGS GSM 47847. 7, 8, Adderbury, 6 km SSE of Banbury, IGS GSM 22566. 9, 10, Chipping Warden, 10 km NE of Banbury, BM C.67388. 11, 12, Copredy, 6 km north of Banbury, originally figured J. Sowerby (1819, p. 41, pl. 222, fig. 1), paralectotype of *Ammonites annulatus*, BM C.40125. All figures × 1.




HOWARTH, ammonite *Dactylioceras*

reference should be made to that paper for an account of the type specimen, the diagnosis and the general description of the species. Outside Yorkshire, the commonest occurrence is in the topmost part of the Marlstone Rock Bed (the 'Transition Bed') in Northamptonshire and Leicestershire. The name *Orthodactylites directus* Buckman (1926*a*, pl. 654) has always been used for these examples previously (including Howarth 1973, pp. 266–267). However, analysis of the west Northamptonshire fauna shows that it agrees closely with the Yorkshire fauna of *D.* (*O.*) *semicelatum* in all characters. Whorl dimensions and rib-density are expressed graphically in text-figs. 2 and 3, where it can be seen that there are no significant differences from the Yorkshire fauna, and that the Yorkshire holotype occupies an approximately central position within the variation of the Northamptonshire fauna. An average specimen from the Marlstone Rock Bed of Northamptonshire is figured in Plate 80, figs. 1, 2, an example with higher whorls and more rectiradiate ribs in Plate 80, figs. 5, 6, and a more involute example with higher whorls in Plate 80, figs. 9, 10. Text-figs 2 and 3 also show that the holotype of *D. directum* (Pl. 80, figs. 3, 4) is an extreme form being more evolute, more compressed, and more finely ribbed than most Northamptonshire specimens. Nevertheless, it does fall within the range of variation of the population, and it matches some Yorkshire specimens closely (e.g. Howarth 1973, pl. 8, fig. 1), so the specific name *directum* should be placed in synonymy with *semicelatum*.

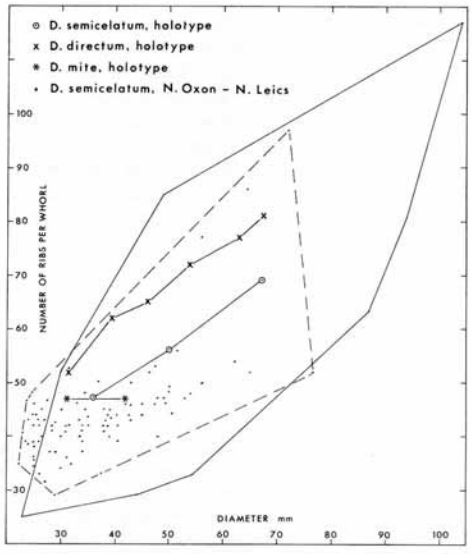
The only west Northamptonshire specimen that is more finely ribbed is one of the paralectotypes of *Ammonites annulatus* J. Sowerby (1819, pl. 222, fig. 1). Previously (Howarth 1973, p. 262) it was determined as *D.* (*O.*) *tenuicostatum*, but, although it is evolute and finely ribbed (Pl. 80, figs. 11, 12), it has the characteristic compressed oval (not near-circular) whorls and prorsiradiate ribs of *D.* (*O.*)




TEXT-FIG. 2. Scatter diagrams of whorl dimensions (whorl height, whorl breadth, and umbilical width, plotted against diameter) for fifty-nine specimens of *Dactylioceras* (*Orthodactylites*) *semicelatum* (Simpson) from the top of the Marlstone Rock Bed in north Oxfordshire, Northamptonshire, and Leicestershire. The dashed lines are the envelopes of these points, while the solid lines are the envelopes of the scatter diagrams of the Yorkshire coast population of the same species (from Howarth 1973, p. 259, fig. 5).

*semicelatum* and is matched closely by several specimens from bed 30 in Yorkshire (e.g. Howarth 1973, pl. 8, figs. 1, 2, and BM C.77304). Another west Northamptonshire specimen was made the holotype of *O. mitis* Buckman (1927*a*, pl. 738): it also is not typical of the Northamptonshire fauna, being more evolute than most specimens and it has flat whorl sides and widely spaced ribs near the aperture (text-figs. 2, 3; Pl. 81, figs. 7–9). It is an incomplete immature specimen 44 mm diameter, and it is matched very closely by two specimens from bed 28 in Yorkshire and by some from Harston, Leicestershire (e.g. Pl. 82, figs. 11, 12). These are only another form in the variation of the species, with a different combination of characters, being evolute with fewer ribs, and *O. mitis* should also be placed in synonymy with *D.* (*O.*) *semicelatum*. A larger west Northamptonshire example with similar widely spaced ribs is figured in Plate 80, figs. 7, 8. It is one of the few complete adults that are known from the Marlstone Rock Bed, and has a mouth border at 55 mm diameter. A specimen from Tilton, Leicestershire (C.80278), has a mouth border at 54 mm diameter, and two other Northamptonshire and Harston specimens are 97 and 99 mm diameter at their adult mouth borders respectively. This 54–99 mm range compares with an adult diameter range of 75–120 mm for the Yorkshire coast fauna. A typical example from the top 0·1 m of the Marlstone Rock Bed at Tilton is figured in Plate 81, figs. 5, 6. Two small and indifferently preserved Dorset coast specimens were figured previously (Howarth 1957, p. 197, pl. 17, figs. 5, 6); a large, better preserved example is figured in Plate 81, figs. 3, 4, which is a typical involute specimen with the high, oval whorls of the species. At Barrington, Somerset, specimens occur in a bed about 0·2 m above the Marlstone Rock Bed, and the best one is figured in Plate 81, figs. 1, 2.

The only occurrence of *D.* (*O.*) *semicelatum* outside Britain that was not dealt with in the Yorkshire coast paper (Howarth 1973) consists of those specimens in north-west Germany described as *D. ernsti* by Lehmann (1968, p. 46, pl. 17, figs. 5, 6; pl. 19, figs. 2, 4; also figured by Hoffmann 1968) and smaller specimens figured by Hoffmann and Martin (1960). These show all the usual characters of *D.* (*O.*) *semicelatum*, and the holotype of *D. ernsti* has whorl proportions and rib-density that are close to the average of the Yorkshire and Northamptonshire populations. All the north-west German specimens come from the Semicelatum Subzone, and *D. ernsti* is considered to be a synonym of *D.* (*O.*) *semicelatum*.




TEXT-FIG. 3. Scatter diagram of number of ribs per whorl for seventy-one specimens of *Dactylioceras* (*Orthodactylites*) *semicelatum* (Simpson) from the top of the Marlstone Rock Bed in north Oxfordshire, Northamptonshire, and Leicestershire. The dashed line is the envelope of these points; the solid line is the envelope of the scatter diagram of the Yorkshire coast population of the same species (from Howarth 1973, p. 261, fig. 6).

*Dactylioceras* (*Orthodactylites*) *tenuicostatum* (Young and Bird)

Plate 82, figs. 1–10, 13, 14

1822 *Ammonites tenuicostatus* Young and Bird, p. 247, pl. 12, fig. 8.
1828 *Ammonites annulatus* Sowerby; Young and Bird, p. 253, pl. 12, fig. 11.
1884 *Stephanoceras annulatum* (J. Sowerby); Wright, p. 475, pl. 84, figs. 7, 8.
1920*a* *Dactylioceras tenuicostatum* (Young and Bird); Buckman, pl. 157.
1927*a* *Tenuidactylites tenuicostatus* (Young and Bird); Buckman, pl. 157A.
1933 *Dactylioceras tenuicostatum* (Young and Bird); Arkell, pl. 32, fig. 6.
1956 *Dactylioceras tenuicostatum* (Young and Bird); Arkell, pl. 33, fig. 6.
1957 *Dactylioceras tenuicostatum* (Young and Bird); Maubeuge, p. 208, figs. ?41, 42, 43.
1961 *Dactylioceras tenuicostatum* (Young and Bird); Dean, Donovan, and Howarth, pl. 72, fig. 1.
1973 *Dactylioceras* (*Orthodactylites*) *tenuicostatum* (Young and Bird); Howarth, p. 258, pl. 5, figs. 1, 2; pl. 6, figs. 2, 3.

*Occurrence*. Dorset coast: Marlstone Rock Bed layer P, uncommon; Somerset: bed 1 (Hamlet 1922) at Barrington, Ilminster, poorly preserved crushed specimens; Northamptonshire: Rothersthorpe, one specimen; Leicestershire: 0·08–0·13 m below the top of the Marlstone Rock Bed at Harston, abundant; north Lincolnshire and south Humberside: hard mudstone and 1 m of shales above the Marlstone Rock Bed at Kirton in Lindsey and Roxby, common.

*Discussion*. A full account of the type specimen, diagnosis, and the Yorkshire coast fauna is found in Howarth (1973, pp. 258–262). Outside Yorkshire, *D. tenuicostatum* is much less widely distributed than *D. semicelatum*, and the only substantial collection from the Marlstone Rock Bed was that obtained from Harston, Leicestershire. About seventy specimens were collected, all of them immature and less than 60 mm maximum diameter. Most have part of their body chambers preserved but they are incomplete, and no adult specimens, indicated by constricted mouth borders or approximated final suture-lines, were found. All have the typical rounded whorl section and fine ribs of *D. tenuicostatum*. An immature of average size is figured in Plate 82, figs. 9, 10, and the largest of 58 mm diameter in Plate 82, figs. 1, 2. The top part of the Marlstone Rock Bed at Harston is highly condensed, and although the main occurrence of *D. semicelatum* is higher up, a few specimens of the latter species are found at the same level as the highest *D. tenuicostatum*. Specimens of *D. semicelatum* are always separable by their higher whorls, oval whorl section, more widely spaced ribs, and by the considerably thicker whorls in some individuals.

A single well-preserved specimen has already been referred to (p. 641) from the top of the Marlstone Rock Bed at Rothersthorpe, 5 km south-west of Northampton (Pl. 82, figs. 3, 4). It is immature, 46 mm diameter, and has a body chamber one whorl long. About ten examples of *D. tenuicostatum* are known from layer P of the Marlstone Rock Bed on the Dorset coast. Again they are all immature or inner whorls of less than about 60 mm diameter, and two of the best specimens are figured in Plate 82, figs. 5–8. In north Lincolnshire the species occurs in the hard mudstone that overlies the Marlstone Rock Bed, and one of the more complete, though small, specimens is figured in Plate 82, figs. 13, 14.

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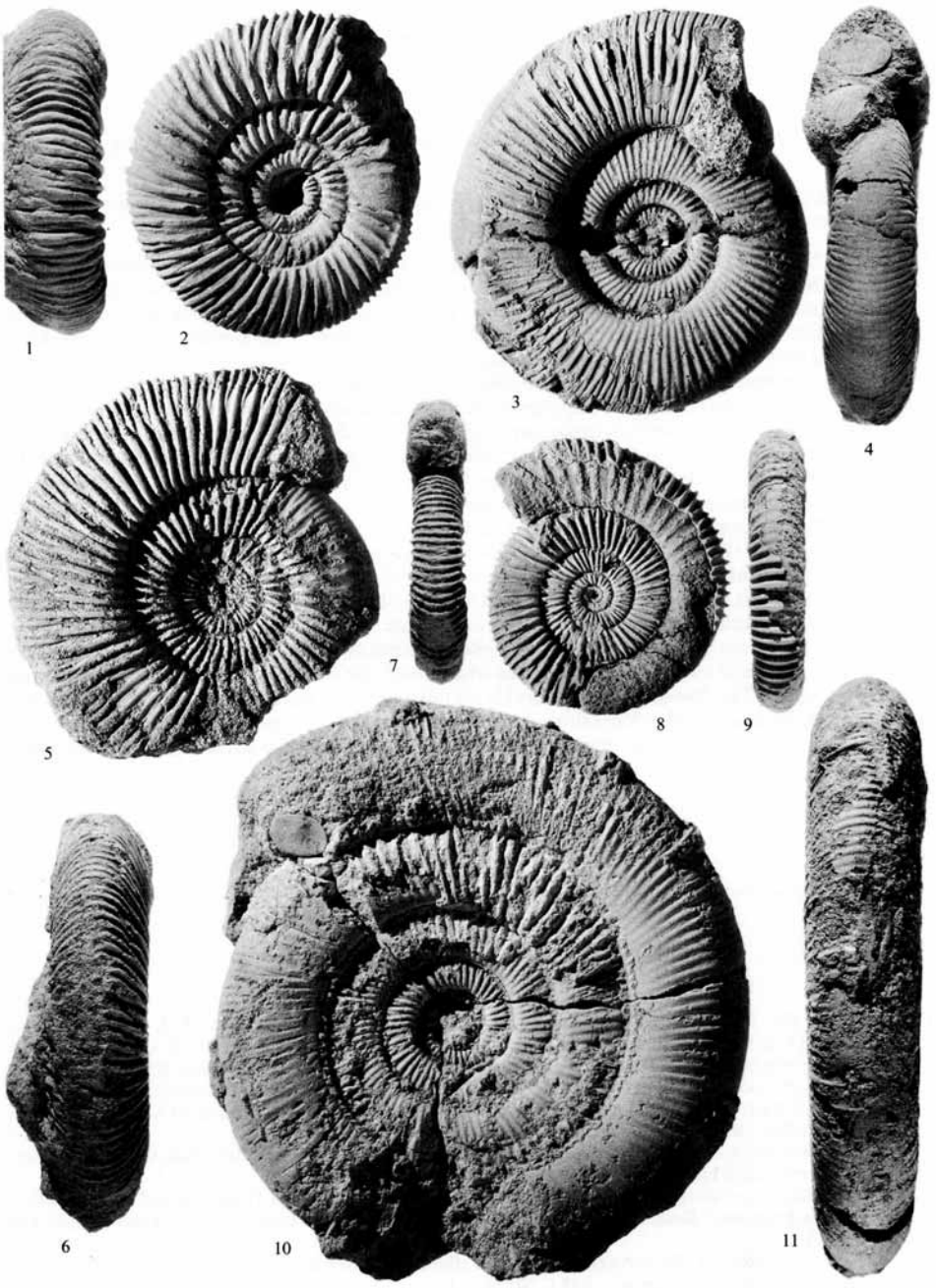
EXPLANATION OF PLATE 81

Figs. 1–11. *Dactylioceras* (*Orthodactylites*) *semicelatum* (Simpson). 1, 2, bed 2 (Hamlet 1922), 0·2 m above Marlstone Rock Bed, Barrington Quarry, near Ilminster, Somerset, IGS GSM 31612. 3, 4, Marlstone Rock Bed layer P, Seatown, Dorset, BM C.17548. 5, 6, Marlstone Rock Bed, top 0·1 m, Tilton Railway Cutting, Leicestershire, BM C.80277. 7–9, top of Marlstone Rock Bed ('Transition Bed'), Byfield, Northamptonshire, originally figured Buckman (1927*a*, pl. 738) as holotype of *Orthodactylites mitis*, IGS GSM 38384. 10, 11, Marlstone Rock Bed, 0·08 m below top, Harston Quarry, north Leicestershire, BM C.80169. All figures × 1.




HOWARTH, ammonite *Dactylioceras*

*Dactylioceras* (*Orthodactylites*) *clevelandicum* Howarth

Plate 82, figs. 15, 16

1973 *Dactylioceras* (*Orthodactylites*) *clevelandicum* Howarth, pp. 257–258, pl. 3, figs. 1–3; pl. 4, figs. 1, 2; pl. 5, fig. 3.

*Occurrence*. About eight specimens known in bed 21 at Kirton in Lindsey, north Lincolnshire, and an equivalent horizon in the near-by Worlaby borehole.

*Discussion*. The most difficult problem in describing the Tenuicostatum Zone Dactylioceratidae that occur in the Marlstone Rock Bed area in England is the identification of the well-preserved specimens in the hard mudstone and the calcareous nodules (bed 21) that overlie the Rock Bed at Kirton in Lindsey, north of Lincoln. Specimens, though well preserved, are not very numerous, and considered on their own they could be a condensed mixture of *D. semicelatum*, *D. tenuicostatum*, and *D. clevelandicum*. Some limit to the age range can be obtained, however, from the ammonites in the overlying beds, for crushed *Dactylioceras* that appear to be *D. tenuicostatum* occur in the overlying 1·3 m of shale, then *D. semicelatum* appears in the next higher 1·7 m of shale, and unmistakable specimens of *Tiltoniceras* occur in the next 3·5 m. These ammonites are in the correct stratigraphical sequence for the Tenuicostatum and Semicelatum Subzones. So it is probable that only the lower part of the Tenuicostatum Subzone, together with lower horizons, occurs in the hard mudstone. This mudstone, and especially the calcareous nodules within it, contains a number of small or fragmentary specimens of *D. tenuicostatum* (Pl. 82, figs. 13, 14), and also a small collection of larger and better-preserved individuals that are identified with *D. clevelandicum*. One of the best specimens from the mudstone at Kirton in Lindsey is figured in Plate 82, figs. 15, 16. Although it is like *D. semicelatum* in some respects, it has rectiradiate ribs, not the prorsiradiate ribs of compressed specimens of *D. semicelatum*. Nor does it have the typical oval whorl section of the latter species. Other examples in this bed have a range of variation from rounded whorls with fine ribs, to depressed whorls with coarse ribs and tubercles. The few that are measurable all fall within the ranges for whorl dimensions and rib-density measured for the Yorkshire coast population of *D. clevelandicum* (Howarth 1973, pp. 259, 261). No examples of this species have been found anywhere else in the Marlstone Rock Bed area.

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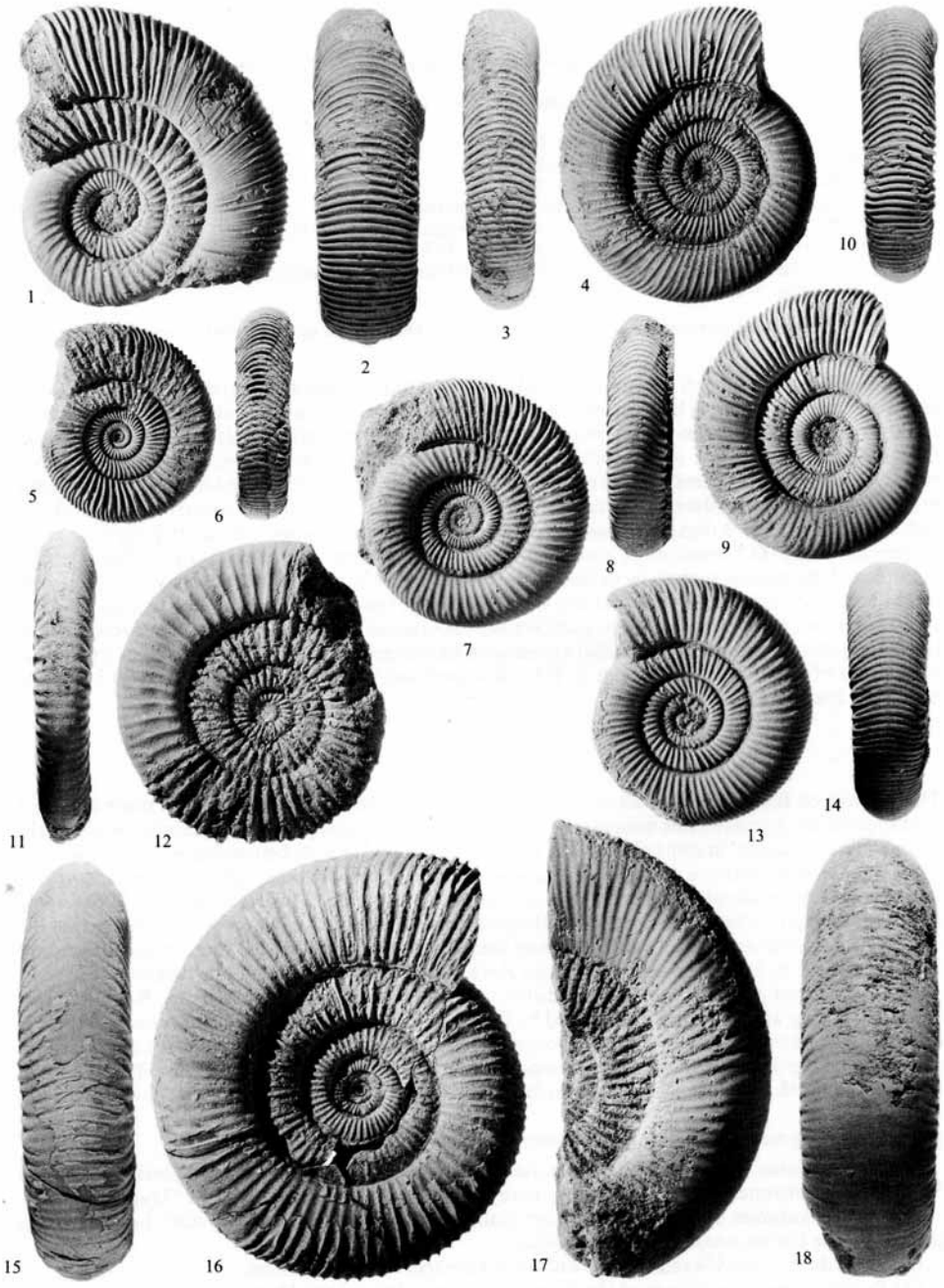
EXPLANATION OF PLATE 82

Figs. 1–10, 13, 14. *Dactylioceras* (*Orthodactylites*) *tenuicostatum* (Young and Bird). 1, 2, 9, 10, Marlstone Rock Bed, 0·1 m below top, Harston Quarry, north Leicestershire, BM C.80122, 80100. 3, 4, Marlstone Rock Bed, immediately below 'Transition Bed', Rothersthorpe, 5 km SW of Northampton, BM C.82051. 5–8, Marlstone Rock Bed layer P, Doghouse Cliff, Seatown, Dorset, NMW 26.135 G124 and G5.2. 13, 14, bed 21 (Howarth and Rawson 1965), 0·3 m above Marlstone Rock Bed, quarry 2 km north of Kirton in Lindsey, north Lincolnshire, BM C.73560. All figures × 1.

Figs. 11, 12. *Dactylioceras* (*Orthodactylites*) *semicelatum* (Simpson). Marlstone Rock Bed, 0·08 m below top, Harston quarry, north Leicestershire, BM C.80173, × 1.

Figs. 15, 16. *Dactylioceras* (*Orthodactylites*) *clevelandicum* Howarth. Bed 21 (Howarth and Rawson 1965), 0·3 m above Marlstone Rock Bed, quarry 2 km north of Kirton in Lindsey, north Lincolnshire, BM C.73561, × 1.

Figs. 17, 18. *Dactylioceras* (*Orthodactylites*) *crosbeyi* (Simpson). Marlstone Rock Bed, 0·23 m below top, Harston quarry, north Leicestershire, BM C.80170, × 1.




HOWARTH, ammonite *Dactylioceras*

*Dactylioceras* (*Orthodactylites*) *crosbeyi* (Simpson)

Plate 82, figs. 17, 18

1843 *Ammonites crosbeyi* Simpson, p. 22.
1855 *Ammonites crosbeyi* Simpson, p. 58.
1884 *Ammonites crosbeyi* Simpson, p. 90.
1912*a* *Coeloceras crosbeyi* (Simpson); Buckman, pl. 60.
?1957 *Dactylioceras pseudosemicelatum* Maubeuge, p. 193, pl. 3, fig. 6.
?1957 *Dactylioceras podagrosum* Maubeuge, p. 193, pl. 4, fig. 7.
1973 *Dactylioceras* (*Orthodactylites*) *crosbeyi* (Simpson); Howarth, p. 255, pl. 1, figs. 2–4; pl. 2, figs. 1–4.

*Occurrence*. North Leicestershire: 0·23 m below the top of the Marlstone Rock Bed, Harston quarry, one specimen.

*Discussion*. This broken half ammonite is about 74 mm diameter, and the final one-third of a whorl is probably body-chamber. It has relatively high and broad whorls that are about one-quarter involute, and the whorl section has an evenly rounded venter. The preservation is mainly as an internal cast, so the ribbing is of very low relief, and consists of prorsiradiate primary ribs, about half of which bifurcate at the ventro-lateral edge. The ribs on the venter swing slightly more forwards, and only the slightest traces of ventro-lateral tubercles are present. At 74 mm diameter the whorl height is 21·5 mm and the breadth is 21·0 mm, and these whorl dimensions agree well with those of Yorkshire coast specimens of *D.* (*O.*) *crosbeyi*. It compares well with the more compressed, more finely ribbed examples of the species such as were figured by Howarth (1973, pl. 1, fig. 2; pl. 2, fig. 2). The whorl height and the amount of overlap of the whorls are both too large for *D.* (*O.*) *clevelandicum*. The specimen occurs 0·1 m below a rich population of *D.* (*O.*) *tenuicostatum* in the Marlstone Rock Bed at Harston, a stratigraphical position that agrees with its occurrence in Yorkshire. No trace was found at Harston of the intervening species *D.* (*O.*) *clevelandicum*. No other examples of *D.* (*O.*) *crosbeyi* have been found outside Yorkshire.

## CONCLUSIONS

The 'Transition Bed' is the weathered or altered top of the Marlstone Rock Bed. The main change is oxidation of the green ferrous minerals to limonite, and associated partial decalcification leaves the bed crumbly or 'sandy' in some places. The weathering occurred partly before deposition of the overlying beds in some areas, e.g. Banbury and west Northamptonshire, though at Tilton most of the weathering is more recent. Another type of alteration that took place before deposition of overlying beds, was the pyritization of the bed in the Harston area, Leicestershire. There is no evidence that the bed is otherwise mineralogically different from the Marlstone Rock Bed, and there is no sedimentary discontinuity at its base. The term Marlstone Rock Bed should be applied to the whole of the bed.

In south Dorset and from north Oxfordshire to south Lincolnshire the Marlstone Rock Bed was deposited during all the period represented by the Spinatum and Tenuicostatum Zones, and there is no lithological division between the two zones. The ammonite faunas at the boundary are poor, but generally the top 1–3 m belongs to the Tenuicostatum Zone and the bottom 3–6 m to the Spinatum Zone. From north Somerset to south Oxfordshire there is no ammonite evidence for the age of the top of the bed.

The following ammonite faunas have been found in the Marlstone Rock Bed:

(*a*) *Dactylioceras semicelatum* (*D. directum* is a synonym) and *Tiltoniceras antiquum* of the Semicelatum Subzone. This is abundant at many localities and is the fauna of the 'Transition Bed'.

(*b*) *D. tenuicostatum* of the Tenuicostatum Subzone. Abundant only at Harston, Leicestershire, present on the Dorset coast, and rare elsewhere.

(*c*) *D. crosbeyi* of the Clevelandicum Subzone. One specimen at Harston.

(*d*) *Protogrammoceras paltum* of the Paltum Subzone. Only on the Dorset coast.

(*e*) *Pleuroceras* spp. of the Spinatum Zone. Abundant in Dorset, Somerset, and Gloucestershire. Much rarer from Oxfordshire to north Humberside, but sufficient are known to show that both the Apyrenum and Hawskerense Subzones are present.

From north of Lincoln to north Humberside deposition of the Marlstone Rock Bed stopped at the end of the Spinatum Zone, and ammonites of all four subzones of the Tenuicostatum Zone occur in an overlying, lithologically distinct, hard mudstone and in shales above. The latter are similar to the Grey Shales Formation of the Yorkshire coast.

The change from the lower, regressive ironstone/limestone facies to the upper transgressive clays/shales-with-nodules facies (Hallam 1967, pp. 431–440) did not occur simultaneously in Britain. In Yorkshire it occurred at the top of the Spinatum Zone at the Upper Pliensbachian/Toarcian (i.e. Middle/Upper Lias) boundary, but from Dorset to south of Lincoln it occurred at the top of the Tenuicostatum Zone. In a small transitionary area between north of Lincoln and Market Weighton the change took place in the middle of the Tenuicostatum Subzone. The extent of the time disparity for the facies change may be judged from the fact that 14 m of Grey Shales Formation on the Yorkshire coast were being deposited while 1–3 m of Marlstone Rock Bed was being deposited in England south of Lincoln.

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