OSTRACODA FROM THE UNDERBARROW, KIRKBY MOOR AND SCOUT HILL FLAGS (SILURIAN) NEAR KENDAL, WESTMORLAND

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ABSTRACT. The fauna collected from the rocks previously referred to the Kirkby Moor Flags, permits their subdivision and correlation with the succession at Ludlow and with the Baltic sequence. In this the ostracodes play an important role. They are here described and their value in correlation is illustrated. A new genus, *Huttoniella*, and a new species, *Neobeyrichia confluens*, are described.

OSTRACODES occurring in the 'Kirkby Moor Flags' have previously received little attention. Sedgwick and McCoy 1855 identified *Beyrichia Kloedeni* McCoy, the presence of which is again referred to by the Geological Survey (Aveline and Hughes 1872; Aveline, Hughes, and Tiddeman 1872; Aveline, Hughes, and Strahan 1888). No further identifications of ostracodes were made until the work of Llewellyn, published in a paper by Furness, Llewellyn, Norman, and Rickards 1967, when the occurrence of *Beyrichia lauensis* Kiesow was noted from the Longsleddale area, to the north of the area under consideration.

The present work is the result of the revision of the faunal stratigraphy of the rocks succeeding the Bannisdale Slates in the type area of the Kirkby Moor Flags. Particular attention has been paid to the ostracodes in view of their stratigraphical importance. In conjunction with this, especially in regard to those apparently indicating a Downtonian age, the author collected and described ostracodes from the Ludlow area (Shaw 1969).

STRATIGRAPHY

The classification of the strata succeeding the Bannisdale Slates by the author is comparable with that outlined by Sedgwick (1842, 1845, 1852, and 1859) and by the Geological Survey in 1872 and 1888. By the systematic collecting and identification of the fauna the stratigraphical and faunal divisions have been made with greater definition.

Four faunal divisions have been recognized: the Lower and Upper Underbarrow Flags, the Kirkby Moor Flags, and the Scout Hill Flags. The Lower Underbarrow Flags correlate with the Upper Leintwardinian stage; the Upper Underbarrow and Kirkby Moor Flags are of Whitcliffian age, and the Scout Hill Flags are Downtonian.

Lithologically the succession forms two main units, a finer, rather ill-sorted, closely laminated group, of silt grade comprising the Lower and Upper Underbarrow Flags and a series of tough, well-sorted silts forming the upper two faunal divisions. The Scout Hill Flags additionally include 500 ft of red, laminated silts.

The important fossils in each of the four divisions may be tabulated:

Scout Hill Flags	*Frostiella groenvalliana.*
Kirkby Moor Flags	*Acastella prima, Homalonotus knighti, Neobeyricha confluens.*

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Upper Underbarrow Flags	*Acastella prima*, *Neobeyrichia confluens*.
Lower Underbarrow Flags	*Atrypa reticularis*, *Chonetes lepisma*, *Chonetoida grayi*, *Neobeyrichia lauensis*, *Neobeyrichia nutans*, *Nodibeyrichia scissa*, *Encrinurus stubblefieldi*, *Lapworthura miltoni*.

At the base of the Upper Underbarrow Flags there is a marked decline in the variety of species, this despite the lack of any visible lithological change. In contrast to this trend is an increase in the abundance of certain species, particularly but not exclusively, at the advent of the Kirkby Moor–Scout Hill Flag lithology. Among the brachiopods this is seen especially in *Protochonetes ludloviensis* and *Salopina lunata*. The gastropods behave similarly above the base of the Kirkby Moor Flags with *Cyclonema carinata*, *Naticopsis glaucinoides*, and *Holopella cingulata* becoming especially abundant. The lamellibranchs, relatively rare in both variety and abundance in the lower parts of the succession, diversify considerably in the Kirkby Moor Flags.

Details of the fauna from each division and its classification into assemblages have been included in another paper (Shaw 1971).

SYSTEMATIC DESCRIPTIONS

There are important limitations on the systematic value of the fauna occurring in this succession. Chief among these are their mode of occurrence and preservation.

In the Kirby Moor Flags and the Scout Hill Flags fossils are preserved almost exclusively in lenses set in well-sorted silts. The lenses are calcareous but induration of the quartz grains, which form the bulk of the detrital material, is such that fresh, unweathered samples yield good specimens only after patient effort with a mounted needle.

Weathered samples, although yielding more abundant specimens, have their limitations. In this condition the sediment is extremely friable and fossils are preserved only as internal and external moulds. These are usually coated with limonite, which, depending on the amount, either preserves or completely obliterates the ornament. In addition, due to the relatively coarse grain size (compared with the relief of the ornament), preservation of the ornament, in moulds lacking a thin film of limonite, is always poor.

As a result of these problems, the identification of the fossils often relies on occasional samples in which the preservation is unusually good with additional information being supplied by the abundant less well-preserved specimens. From the samples collected, however, details of the ostracode fauna in the succession can be gained and useful material for purposes of correlation is available.

Techniques used in the study of the ostracodes varies with the nature of the rock. In the weathered samples it was found useful to make rubber casts of the external moulds. These, due to the friable nature of the rock, yielded variable results. To some extent it was possible to recement the rock before applying the rubber solution by impregnating the specimen with a weak solution of Perspex in chloroform.

A fairly successful method of handling the unweathered rock is to roast it for a short time and then quench in cold water. This has the effect of weakening the rock such that fracture will occur around rather than across the specimens.

Specimens from the two divisions of the Underbarrow Flags are more easily studied. They occur as diffuse lenses or isolated specimens in unsorted silt whose clay fraction is high. Thus, although specimens are usually weathered and fossils are preserved as moulds, the ornament is clearly imprinted in the sediment and excellent casts are easily made recording all observable details of the ornament without damaging the specimens.

The photographic method used was that described by Martinsson 1962 and magnesium oxide was used to coat the specimens. Illumination is from the north-west unless this is prevented by the configuration of the rock enclosing the specimen. The terminology used in the descriptions is that of Martinsson 1962.

In all references to localities and strata from which the described and illustrated ostracodes were found their mode of occurrence is similar. Details of this information can adequately be furnished at this point.

The successions through the Lower and Upper Underbarrow Flags are lithologically monotonous and the mode of occurrence of the fossils is similarly uniform. There is a general scatter of fossils throughout the sediment but a tendency to concentration approaching lens-like accumulations exists often associated with slightly better sorted silt.

In the Kirkby Moor and Scout Hill Flags the sediments again form a monotonous sequence in this case of well-sorted silts. The fossils are almost exclusively restricted in their occurrence to calcite enriched lenses, within or occasionally at the base of these silt members.

In all four divisions the clearest guide to fossil localities is by way of grid reference and stating which of the divisions the material comes from. Unfortunately there can be no clearer guide by reference to the localities relationship to obvious lithological, sedimentary, or other geological marker as these do not occur.

The abundances of the fossils are stated as the percentage of fossiliferous localities, in each division, yielding each species.

Order PALAEOCOPIDA Henningsmoen 1953
Suborder BEYRICHICOPINA Scott 1961
Superfamily BEYRICHIACEA Matthew 1886
Family BEYRICHIIDAE Matthew 1886
Subfamily AMPHITOXODONTIDINAE Martinsson 1962
Genus HEMSIELLA Martinsson 1962

Hemsiella maccoyiana (Jones 1855)

Plate 109, figs. 1–4

1855 *Beyrichia maccoyiana* Jones, p. 88, pl. 5, fig. 14.
1962 *Hemsiella maccoyiana* (Jones); Martinsson, fig. 2B.

Remarks. This is a highly distinctive species, characterized particularly by a syllobium which possesses a depressed area isolating the remainder of the syllobium from a marked cuspidal portion. This depressed area is also responsible for the formation of a lunate roll on the posterior face of the syllobium. The lobes bear a characteristic reticulate ornamentation and are weakly connected ventrally. The velum is rather flat, with strongly developed tubules and distinct cross fibres. The heteromorph has the same syllobial depression, is similarly ornamented, and has a large crumina with a striate ornamentation.

Occurrence. H. maccoyiana is found in the Upper Underbarrow Flags (< 5%), throughout the Kirkby Moor Flags (48%), and in the Scout Hill Flags (59%). It is identified in the Łeba 1 core (Martinsson 1964) and in two of the Polish cores described by Witwicka (1967).

Genus HUTTONIELLA gen. nov.

Derivation of name. Feminine diminutive of Latin *Huttonius*, associated with, or, inhabitant of, Old Hutton near Kendal.

Type species. Huttoniella contracta n. sp.

Diagnosis. Hinge straight, shorter than maximum length of slightly amplete valve, ventral margin smoothly curved. Lobal connections extremely weak. Preadductoral lobe narrow in the tecnomorphic valves, and very narrow in the heteromorphs. Lobal

ornamentation finely reticulate, which in the heteromorphic valves is stretched to a striate type. Velum narrow, straight, with tubules and lacks a denticulate margin. In the heteromorph the velum is considerably reduced.

Remarks. While the new genus clearly belongs to the Amphitoxotidinae it differs from all other described genera. In view of the cruminal and lobal morphology, however, it is probably related to the *Cryptopholobus-Lophoctonella* part of the subfamily.

Huttoniella contracta sp. nov.

Plate 109, figs. 5, 6

Derivation of name. From the Latin *contractus*, narrow, referring to the narrowness of the preadductoral lobe.

Holotype. Left valve, Plate 109, fig. 5.

Type Stratum and Type Locality. Kirkby Moor Flags, about ½ mile S. of Old Hutton, Kendal, Westmorland (G.R. 5642 8774).

Diagnosis. As for genus.

Description. Hinge straight and shorter than the maximum length of the valve. Syllobium weakly connected to the preadductoral lobe which is narrow. Anterior lobe broad but barely connected with the preadductoral lobe. All lobes have a well-developed reticulate ornamentation. Small tubercles occur on the posteroventral part of the anterior lobe, and the posterodorsal part of the syllobium. Velum narrow, strongly tubulose and with a non-denticulate border. Subvelar field narrow, limited ventrally by a marginal frill.

The heteromorph, apart from the addition of a large crumina, shows considerable differences from the tecnomorph. Syllobium large but rather narrow, preadductoral lobe very narrow, anterior lobe largely absorbed into the crumina. Ornamentation of lobes stretched from reticulate in the tecnomorph to a striate type in the heteromorph. Velum considerably modified in the heteromorph into a thick rolled marginal structure extending only as a very weak feature half way across the crumina.

Dimensions. Hinge length and sulcal height in microns:

Tecnomorph	710–490,	850–610.
Heteromorph	1090–730,	1170–820.

Occurrence. Kirkby Moor Flags (33%) and Scout Hill Flags (29%) around Kendal.

EXPLANATION OF PLATE 109

Figs. 1–4. *Hemsiella maccoyiana* (Jones). 1, right valve, GSM Zl9029, Scout Hill Flags, G.R. 5378 8389. 2, internal mould of left valve, GSM Zl9030, Kirkby Moor Flags, G.R. 5854 9396. 3, left heteromorph valve, GSM Zl9032, Kirkby Moor Flags, G.R. 5537 9340. 4, internal mould of right heteromorph valve, Kirkby Moor Flags, GSM Zl9030, G.R. 5854 9396.

Figs. 5, 6. *Huttoniella contracta* gen. et sp. nov. Kirkby Moor Flags. 5, holotype, left valve, GSM Zl9033, G.R. 5642 8774. 6, left heteromorph valve, GSM Zl9052, G.R. 5549 8449.

Figs. 7, 8. *Macrypsilon salterianum* (Jones), Kirkby Moor Flags, G.R. 5544 8267. 7, right heteromorph valve, GSM Zl9055. 8, right valve, GSM Zl9054.

All figures ×40.

Genus LOPHOCTONELLA Martinsson 1962

Lophoctonella cf. *scanensis* (Kolmodin 1869)

Plate 110, figs. 1–6

1869 *Beyrichia scanensis* Kolmodin, p. 19, fig. 11.
1962 *Lophoctonella scanensis* (Kolmodin); Martinsson, figs. 6A–C.

Description. Hinge straight, shorter than maximum valve length. Valve preplete, margin smoothly curved. Lobation well developed. Syllobium connected weakly to preadductoral lobe, anterior lobe separate. All three lobes ornamented by a cristal loop; that on the syllobium $2\frac{1}{2}$–3 times the width of the limbs of the loop; preadductoral loop narrower, being equal in width to the limbs; that on the anterior lobe very narrow, the field between the limbs only just being discernible. Lobes reach but do not extend beyond the hinge. Velum broad, fairly flat-lying dorsally, upturned to near vertical anteriorly, strongly developed tubules each with two denticulations.

The morphology of the heteromorph is strikingly different from that of the tecnomorph. In addition to the large crumina set over the deep anteroventral depression, the velum has weakly developed tubules without denticulations and is considerably thicker. Syllobium divided into a cuspidal part extending beyond the hinge line and a relatively raised ventral part. Neither part bears a cristal loop, but the ventral part is ornamented by randomly distributed tubercles. Preadductoral lobe partially absorbed into the crumina, dorsally it bears a small but well-marked cristal loop. Anterior lobe relatively small, unornamented, projects beyond the hinge line. Crumina ornamented by a striate pattern. The velum reaches much of the way across the crumina; below it is a toric ridge.

Remarks. This species differs from the type species *L. angustilaqueata* Martinsson in the small size of the cristal loop on the preadductoral lobe in the heteromorph and the presence of a cristal loop on the anterior lobe in the tecnomorph. The velum also differs. It does not rise anteriorly into a strongly elevated comb-like structure and lacks the denticulations on the margin in the heteromorph. The specimens from the Lake District show many characters in common with *L. scanensis*, especially in the disposition of the lobes, nature of the velum and ornamentation of the crumina, but differ to some degree in the lobal ornamentation. The heteromorph illustrated by Martinsson (1962, fig. 122B) shows only a very weak indication of a cristal loop on the dorsal face of the preadductoral lobe, and lacks the tuberculation on the ventral part of the syllobium. No cristal loop is seen on the anterior lobe of a tecnomorph figured by Martinsson (1962, fig. 6C).

Occurrence. This species is recorded throughout the succession in the Kendal area: Lower Underbarrow Flags (6%), Upper Underbarrow Flags (< 5%), Kirkby Moor Flags (46%), Scout Hill Flags (59%). There is no apparent change in its form, though this is difficult to confirm from the generally poor preservation.

Genus MACRYPSILON Martinsson 1962

Macrypsilon salterianum (Jones 1855)

Plate 109, figs. 7, 8

1855 *Beyrichia salteriana* Jones, p. 89, pl. 5, fig. 15*a*.
1962 *Macrypsilon salterianum* (Jones); Martinsson, fig. 2D.

Remarks. The tecnomorphic valves are characterized by the occurrence of narrow sulci which isolate the lobes and join ventrally to give a Y-shape. The lobes are full and well rounded, with a very fine reticulate ornamentation. There is characteristically a slight swelling at the dorsal end of the adductoral sulcus. The velum is narrow and weakly tubulose. In the heteromorph, the crumina is large. The syllobium has a tendency to deflate posteriorly, with a lip or rim marking its posterodorsal extremity.

Occurrence. This species occurs in the upper part of the Kirkby Moor Flags (8%) and in the Scout Hill Flags (12%). It is not a common species but is regarded as characteristic of these beds. It is a species characteristic of strata of high Ludlovian and Downtonian age, being recorded from the Baltic in erratic blocks by Martinsson (1962), from the Stonehouse Formation, Nova Scotia (Copeland 1964) and from the Chlapowo core, Poland (Witwicka 1967) in addition to the above-mentioned Lake District occurrence.

Subfamily BEYRICHIINAE Matthew 1886
Genus NEOBEYRICHIA Henningsmoen 1954

Neobeyrichia confluens sp. nov.

Plate 111, figs. 1–5

Derivation of name. Latin *confluens*, flowing together of two rivers, referring to the merging of the ventral lobule of the syllobium and the velum.

Holotype. Right tecnomorphic valve. Plate 111, figs. 2 and 4.

Type Stratum and Type Locality. Kirkby Moor Flags, about ½ mile S. of Old Hutton, Kendal, Westmorland (G.R. 5642 8774).

Diagnosis. Ventral lobule of syllobium merges with the velum. Velum lacks tuberculate margin. Syllobial groove shallow. Surface ornamentation weak.

Description. Hinge straight, valves slightly preplete. Syllobium divided by a shallow groove. Ventral lobule of syllobium merges with velum and is weakly connected with the preadductoral lobe. Preadductoral lobe narrow, straight, and reaches the hinge line. Anterior lobe slightly arcuate and isolated from the other lobes by a deep anteroventral depression. Velum well developed, but rather narrow, lacks tuberculate ornamentation on its margin. Undersurface of velum shows a marked toric ridge with evidence of two weaker ridges above.

Heteromorph has a relatively small crumina. Syllobium strongly divided by a groove. Lobes ornamented by irregularly distributed small tubercles which also occur on posterior part of velum.

EXPLANATION OF PLATE 110

Figs. 1–6. *Lophoctonella* cf. *scanensis* (Kolmodin). 1, left heteromorph valve, GSM Zl9035, Kirkby Moor Flags, G.R. 5642 8774. 2, right valve (rubber cast), GSM Zl9053, Scout Hill Flags, G.R. 5987 8104. 3, left heteromorph valve, GSM Zl9036, Kirkby Moor Flags, G.R. 5642 8774. 4, left valve, GSM Zl9036, Kirkby Moor Flags, G.R. 5642 8774. 5, left heteromorph valve showing details of cruminal ornamentation, GSM Zl9038, Kirkby Moor Flags, G.R. 5642 8774. 6, ventral view of 1, showing trace of velum across crumina.

All figures ×40.

Dimensions. Hinge length and sulcal height in microns:
Tecnomorph 740–540, 1050–790, 1620–1080, 1970–1430.
Heteromorph 1970–1370.

Remarks. The ontogeny of this species is interesting. In the smallest specimens in which the shell is preserved, the margin of the velum is ornamented by a number of fine spines. In the smaller specimens the syllobium is undivided. The division is introduced and becomes increasingly incised in successive instars.

The species is closely related to *Neobeyrichia lauensis*, but is clearly distinguished by the confluence of the ventral lobule of the syllobium with the velum, the lack of tubercles ornamenting the margin of the velum, the lack of surface ornamentation on the lobes, the relative weakness of the syllobial groove, and the extension of the preadductoral lobe to the hinge-line. Stratigraphically, *Neobeyrichia confluens* appears to succeed the *lauensis* form of the genus.

Occurrence. N. confluens is a common species in the Upper Underbarrow (16%) and Kirkby Moor Flags (49%). It is recorded only as a single specimen in the Lower Underbarrow Flags and is rarely encountered in the lowest beds of the Scout Hill Flags (< 5%).

Neobeyrichia lauensis (Kiesow 1888)

Plate 111, fig. 6

1888 *Beyrichia lauensis* Kiesow, p. 8, pl. 2, figs. 1, 2.
1962 *Neobeyrichia* (*Neobeyrichia*) *lauensis* (Kiesow); Martinsson, p. 318, figs. 10, 177, 178.

Remarks. The species is distinguished by a well-marked differentiation of the syllobium into a shorter dorsal lobule and a longer ventral one. The latter is connected by a weak col to the preadductoral lobe which does not reach the hinge-line. The surface is ornamented by small evenly distributed granules with a number of superimposed small tubercles. The velum is highly distinctive, being thick and with a number of large tubercles along its ventral margin. In these characters it is readily distinguished from *Neobeyrichia confluens* sp. nov.

Occurrence. N. lauensis is characteristic of the Upper Leintwardine Beds of the Welsh Borderland, where, in association with the brachiopod *Chonetoidea grayi* it is regarded as definitive of the Upper Leintwardinian age. *N. lauensis* is common in the Lower Underbarrow Flags (31%) and there occurs together with *C. grayi*. The range of this ostracode in the Lake District strata extends beyond the extinction of its Upper Leintwardinian suite of fossils into the Upper Underbarrow Flags (45%) and occurs with *N. confluens*. *N. lauensis* is also described from the 'Hemse' Beds of Gotland (Martinsson 1967) and is recorded in the succeeding Eke Beds (Martinsson 1962).

Neobeyrichia nutans (Kiesow 1888)

Plate 112, fig. 3

1888 *Beyrichia buchiana* var. *nutans* Kiesow, p. 7, pl. 1, figs. 11–14.
1962 *Neobeyrichia* (*Neobeyrichia*) *nutans* (Kiesow); Martinsson, p. 321, figs. 40B, 179.

Remarks. The syllobium is broad and divided into a dorsal cusp, a median lobule and a ventral lobule by two furrows. The ventral lobule is connected to the preadductoral

lobe. The anterior lobe is isolated and projects beyond the hinge line. The velum is thick with two rows of small spines. The cruminal ornamentation is distinctive, there being a striate area ventromarginally with the remainder covered by small elongate tubercles.

Occurrence. This species is characteristic of the Lower Underbarrow Flags where it occurs fairly commonly (9%). In the 'Hemse' Beds of Gotland, Martinsson (1967) regards it, together with *Hammariella pulchrivelata*, as part of the ostracode fauna preceding the *N. lauensis–N. scissa* association. If this is the case then its range in the Lake District succession is somewhat extended.

Neobeyrichia torosa (Jones 1855)

Plate 111, figs. 7, 8

1855 *Beyrichia kloedeni* var. *torosa* Jones, p. 167, pl. 6, figs. 10–12.

Description. Hinge straight, slightly shorter than the maximum length of valve. Ventral margin smooth and valve preplete. Syllobium fairly narrow, divided by a groove into a shorter cuspidal part and a longer ventral part. Connection of syllobium with preadductoral lobe weak. Preadductoral lobe knob-like, not reaching the dorsal margin. Anterior lobe isolated, developed into a pronounced cusp dorsally. Syllobium and anterior lobes marked by extension dorsally of cusps into long hollow spines. Lobes ornamented by fairly large tubercles. Tendency for ventral part of anterior lobe to be separated from cuspidal part. This is not a clearly defined feature, but evidently illustrates the approach of the species to the genus *Nodibeyrichia*.

Velum well developed, with a large number of long slender spines.

No heteromorph of this species has been encountered in the limited amount of Lake District material.

Remarks. Specimens of *Neobeyrichia torosa* collected from the Whitcliffe Beds show some variations on the Lake District material. Although the bulk of the specimens are closely comparable a number of Welsh Borderland individuals develop a node on the ventral part of the syllobium.

Occurrence. Neobeyrichia torosa is recorded from the Lower Underbarrow Flags (< 5%), the Kirkby Moor Flags (< 5%), and the Scout Hill Flags (10%) in the Lake District succession but occurs only rarely. It is a common fossil in the Ludlow area ranging from the Lower Leintwardinian to the top of the Whitcliffian. It is not recorded outside this country.

EXPLANATION OF PLATE 111

Figs. 1–5. *Neobeyrichia confluens* sp. nov. Kirkby Moor Flags. 1, right valve, GSM Zl9039, G.R. 5642 8774, ×40. 2, ventral view of fig. 4 showing subvelar field, ×30. 3, left valve, GSM Zl9040, G.R. 5642 8774, ×40. 4, holotype, right valve, GSM Zl9041, ×30. 5, left heteromorph valve, GSM Zl9059, G.R. 6051 8688, ×30.

Fig. 6. *Neobeyrichia lauensis* (Kiesow). Right valve (rubber cast), GSM Zl9060, Upper Underbarrow Flags, G.R. 6030 8902, ×30.

Figs. 7, 8. *Neobeyrichia torosa* (Jones). Scout Hill Flags, G.R. 5696 8283. 7, right valve (rubber cast), GSM Zl9066, ×30. 8, left valve, internal mould, GSM Zl9066, ×35.

Genus NODIBEYRICHIA Henningsmoen 1954

Nodibeyrichia scissa Martinsson 1962

Plate 112, figs. 1, 2

1962 *Neobeyrichia (Nodibeyrichia) scissa* Martinsson, p. 323, fig. 180.

Remarks. This species is distinguished by the division of a fairly broad syllobium into cuspidal, median, and ventral lobules. The ventral lobule is connected weakly to the preadductoral lobe which fails to reach the hinge line. The anterior lobe is particularly distinctive being divided by an oblique sulcus into an anteroventral and dorsal lobule. The sulcus does not completely divide the anterior lobe, but reaches the greater part of the way across it. The velum is quite thick and bears some evidence of the occurrence of small spines. The ventral surface of the velum is ornamented by a toric ridge. No heteromorphic specimens of this species have yet been identified from Lake District material.

In these characters it closely resembles the type material described and figured by Martinsson (1962, pp. 323 and 324, fig. 180). Slight differences may be noted in the ornamentation which in the type material occurs as a fairly coarse tuberculation of the syllobium. This has not been noted in the Lake District material.

Occurrence. In Gotland, *Nodibeyrichia scissa* occurs in the 'Hemse' Beds where Martinsson (1967, p. 371) regards it, in association with *Neobeyrichia lauensis*, as part of a fauna which correlates with the Leintwardinian. *N. scissa* is characteristic of the Lower Underbarrow Flags, though it is not very common (13%). *N.* cf. *scissa* is reported to occur in the Upper Leintwardine Beds near Leintwardine (Martinsson 1967, p. 371).

Subfamily KLOEDENIINAE Ulrich and Bassler 1923
Genus FROSTIELLA Martinsson 1963

Frostiella groenvalliana Martinsson 1963

Plate 113, figs. 1–5, 7

1963 *Frostiella groenvalliana* Martinsson, p. 29, figs. 7c, 8, 14–17.

Description. Hinge straight, shorter than the maximum length of valve, outline of the valve rounded, and preplete. Lobes quite strongly defined; anterior lobe and syllobium are connected ventrally by a ventral lobal body; preadductoral lobe connected to this by a shallow col. Ornamentation generally lacking, but shell pitted. Preadductoral lobe bears a cristal loop which extends down its dorsal face. Within this loop there is some evidence of striate ornamentation.

Heteromorph distinguished by swelling of the anteroventral part of ventral lobal body. Striate area occurs between velar ridge and margin of valve.

Remarks. The relationship of these specimens to *F. groenvalliana* is fairly clear. There are, however, some differences including an increased tumidity of the lobation and the striate area on the ventral face of the crumina is rather broad. In these characters, an approach to *F. lebiensis* Martinsson is seen.

Occurrence. F. groenvalliana is definitive of the Scout Hill Flags of the Lake District succession (51%). It is also recorded from Bed 4 at Oved-Ramsåsa, and in the Downton Castle Sandstone group. This species therefore, is seen to be indicative of strata of Downtonian age.

Superfamily DREPANELLACEA Ulrich and Bassler 1923
Family AECHMINIDAE Bouček 1936
Genus AECHMINA Jones and Holl 1869

Aechmina sp.

Plate 112, fig. 5

Remarks. Specimens are rare and usually poorly preserved. Those which have been found do not permit specific identification. The shape of the valve is more quadrate than that of *A. cuspidata* Jones and Holl (1869), which is rounded and extended posteriorly. In shape it more closely resembles *A. molengraaffi* Botke (1916). Unfortunately the spine in the Kirkby Moor Flag material is not well preserved. In all cases it is broken off near the base. It is clear, however, that it is rather narrower than that of *A. molengraaffi*.

Occurrence. Aechmina sp. has been found only in the Kirkby Moor Flags where it is rare (< 5%).

Superfamily HOLLINACEA Swartz 1936
Family ?HOLLINIDAE Swartz 1936

Gen. *A* sp.

Plate 112, figs. 6, 7

Description. Hinge straight, shorter than maximum length of valve. Slightly amplete. Shallow adductoral sulcus extends from middle of hinge to a pit in centre of valve. Right valve slightly smaller than left. Surface lacks lobes and ornamentation. Some specimens, particularly the internal moulds, show the presence of a small preadductoral lobe. Velum forms a weak shelf. Marginal frill present.

Remarks. The above description permits the possible assignment of the fossil to the family Hollinidae. Its relationship to the members of that family is unknown so the present material is referred to as gen. *A* sp.

Occurrence. This material has been recorded from the Upper Underbarrow Flags (< 5%), the Kirkby Moor Flags (9%) and the Scout Hill Flags (13%).

EXPLANATION OF PLATE 112

Figs. 1, 2. *Nodibeyrichia scissa* Martinsson. Lower Underbarrow Flags, G.R. 4703 9043, ×40. Rubber casts of left valves. 1, GSM Zl9064; 2, GSM Zl9065.

Fig. 3. *Neobeyrichia nutans* (Kiesow), rubber cast of left valve, GSM Zl9062, Lower Underbarrow Flags, G.R. 4703 9043, ×30.

Fig. 4. *Amygdalella* sp., right valve, GSM Zl9046, Kirkby Moor Flags, G.R. 5642 8774, ×40.

Fig. 5. *Aechmina* sp., internal mould of left valve, GSM Zl9077, Kirkby Moor Flags, G.R. 5824 8500, ×40.

Figs. 6, 7. Genus *A* sp., Kirkby Moor Flags, G.R. 5642 8774, ×40. 6, right valve; 7, ventral view of same, GSM Zl9043.

Figs. 8–10. *Cavellina circulata* Neckaja, Kirkby Moor Flags, G.R. 5642 8774, ×40. 8, right valve, GSM Zl9047; 9, left valve overlapped by right, same specimen; 10, dorsal view of same specimen.

Superfamily PRIMITIOPSACEA Swartz 1936
Family PRIMITIOPSIDAE Swartz 1936
Subfamily LEIOCYAMINAE Martinsson 1956
Genus AMYGDALELLA Martinsson 1956

Amygdalella sp.

Plate 112, fig. 4

Remarks. Only one unweathered specimen of this genus has been found. Moulds are more common and the identification of a specimen with the shell intact permits their tentative assignment to the genus *Amygdalella*. The chief character the valve displays is the straight hinge line which is overhung by the dorsal part of the valve. It is roughly symmetrical but there is an indication that a dimorphic pouch is present at the posterior end of the valve. In these characters the specimen clearly belongs to the genus *Amygdalella*.

Occurrence. The above specimen is described from the lower part of the Kirkby Moor Flags, Old Hutton, near Kendal. It has not been identified in strata other than Kirkby Moor Flags (< 5%).

Suborder METACOPINA Sylvester-Bradley 1961
Superfamily HEALDIACEA Harlton 1933
Family CAVELLINIDAE Egorov 1950
Genus CAVELLINA Coryell 1928

Cavellina circulata Neckaja 1958

Plate 112, figs. 8–10

1958 *Cavellina circulata* Neckaja, p. 360.

Remarks. The right valve is large and overlaps the left valve. The shell is strongly arched dorsally especially towards the anterior end. The right valve is slightly pointed anteriorally but posteriorally is more truncated. The surface of the valve is smooth except for a shallow groove running along ventral margin of left valve. Internals show a slight sulcation and a muscle spot.

Occurrence. Underbarrow Flags (< 5%), Kirkby Moor Flags (47%), and Scout Hill Flags (41%) in the Kendal area. It is common in both the Kirkby Moor and Scout Hill Flags. Witwicka (1967) reports the species from the Lebork, Weyherowo, and Clapowo cores in Poland. The type material comes from the 'Ludlovian' of the U.S.S.R.

Family BAIRDIOCYPRIDIDAE Shaver 1961
Genus CYTHERELLINA Jones and Holl 1869

Cytherellina siliqua (Jones 1855)

Plate 113, fig. 6

1855 *Beyrichia siliqua* Jones, p. 90, pl. 5, fig. 22.

Remarks. This species is oval, elongate, rounded at the hinge, and straight along the ventral margin. The surface of the shell is smooth and unornamented. Internally the shells are thickened in two areas extending from the dorsal to the ventral margin.

Occurrence. *C. siliqua* extends throughout the Underbarrow Flags (7 and 19%), the Kirkby Moor Flags (52%) and the Scout Hill Flags (36%).

Cytherellina cf. *siliqua*

Plate 113, fig. 8

Remarks. No externals of this form have been found but the internal moulds are highly characteristic. The general shape of the valves is the same as in *C. siliqua* but the internal sulcation is markedly different. The valves are not traversed by two sulcae but at the anterior end a step or shelf occurs pointing anteriorally.

The relationships of this species are unknown. Its general form is very much that of *C. siliqua* but in the quite striking differences internally it is distinct from that species. However, for lack of abundant good material with which fully to understand this species, it must be referred to *C.* cf. *siliqua*.

Occurrence. It is not found in the Underbarrow Flags and is rather rare in the Kirkby Moor Flags and the Scout Hill Flags.

STRATIGRAPHICAL VALUE OF THE OSTRACODES

In text-fig. 1 the stratigraphical distribution of the ostracodes in the Lake District succession is illustrated. While it is clear that a number of the species extend through the whole succession, there are a number of species which are useful in the division of the Lake District succession and in correlation both within this country and abroad.

(*a*) *Lower Underbarrow Flags*. The ostracode fauna is characterized by the occurrence of *Neobeyrichia nutans*, *N. lauensis*, and *Nodibeyrichia scissa*. *N. nutans* and *N. scissa* are confined to these beds, while *N. lauensis* continues into the Upper Underbarrow Flags.

The macro- and micro-fauna identified from the Lower Underbarrow Flags indicates an Upper Leintwardinian age when compared with the faunal lists of Holland, Lawson and Walmsley 1963. The part played in this by the ostracodes is the common occurrence of *N. lauensis*, in particular, and the tentative identification of *N. scissa* (Martinsson 1967).

When the Lower Underbarrow Flag association, *N. lauensis*, *N. scissa*, and *N. nutans* is compared with the successive ostracode faunas identified by Martinsson (1967) in Gotland, a useful correlation may be made. He identifies as Leintwardinian a *N. lauensis–N. scissa* association. The Lower Underbarrow Flags as indicated above additionally include *N. nutans*. This species, according to the faunas determined on Gotland (Martinsson 1967), is included in an assemblage somewhat older than the *lauensis–scissa* fauna; in Martinsson's Fig. 2 it is drawn extending down into the upper part of the

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EXPLANATION OF PLATE 113

Figs. 1–5, 7. *Frostiella groenvalliana* Martinsson, Scout Hill Flags. 1, right valve, internal mould, GSM Zl9068, G.R. 5585 8307, ×40. 2, right valve, GSM Zl9072, G.R. 6027 7958, ×40. 3, right heteromorph valve, GSM Zl9073, G.R. 6027 7958, ×40. 4, dorsal view of fig. 3, showing cristal loop on preadductoral lobe, ×40. 5, ventral view of fig. 3, showing ornamentation on ventral face of crumina, ×40. 7, left heteromorph valve, internal mould, GSM Zl9074, G.R. 6027 7958, ×30.

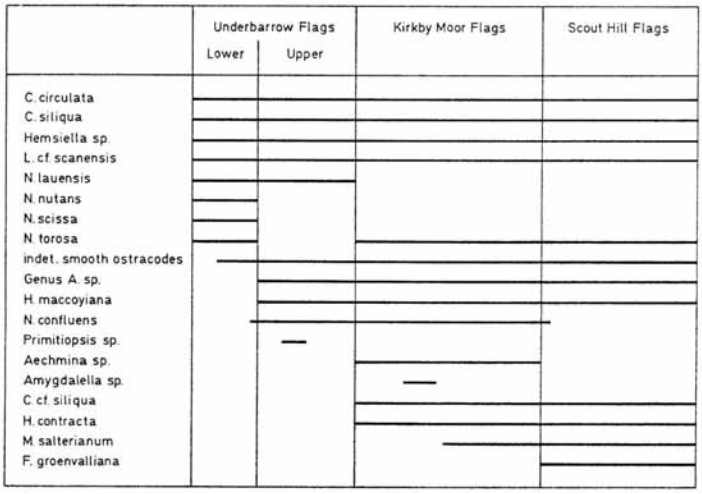
Fig. 6. *Cytherellina siliqua* (Jones), left valve, internal mould, GSM Zl9076, Kirkby Moor Flags, G.R. 5434 9501, ×40.

Fig. 8. *Cytherellina* cf. *siliqua* (Jones), left valve, internal mould, GSM Zl9031, Kirkby Moor Flags, G.R. 5854 9396, ×40.

Bringewoodian stage. It is evident, therefore, that in the Lake District succession its range is probably extended.

The other species occurring in the Lower Underbarrow Flags are long-ranging extending through the remainder of the succession, with the exception of *N. torosa*, which has not been found in the Upper Underbarrow Flags.

(*b*) *Upper Underbarrow Flags*. The Upper Underbarrow Flags are the lithological continuation of the Lower Underbarrow Flags, but are also the lateral equivalent of part of the Kirkby Moor Flags, the base of the Kirkby Moor Flags being diachronous from north-west to south-east. They are marked by the loss of *N. nutans* and *N. scissa*. *N. lauensis* might have been expected to be lost at this point but its continuation into strata of Whitcliffian age indicates an extended range in the Lake District. In support of this contention is the addition of some species which characterize the Kirkby Moor Flags.



TEXT-FIG. 1. Stratigraphical distribution of ostracodes.

The most significant ostracodes occurring in the Upper Underbarrow Flags are *Hemsiella maccoyiana* and *Neobeyrichia confluens*, whose association is characteristic of the Kirkby Moor Flags. They illustrate the faunal change occurring at the Upper Leintwardinian–Whitcliffian boundary in the Lake District.

As mentioned above the Upper Underbarrow Flags, in addition to including these new species, retains *N. lauensis*. It is important, however, in such circumstances to regard more highly the appearance of new forms into succession rather than the continued occurrence of older species.

(*c*) *Kirkby Moor Flags*. The Kirkby Moor Flags are a lithologically distinct division. They mark the influx of thick units of well-sorted silts in which the fauna occurs in discrete lenses of restricted vertical and lateral extent; outside these lenses fossils do not normally occur.

This distinctive lithological sub-division is marked by the appearance of species of ostracodes new to the Lake District succession. The more important include *Huttoniella contracta* and *Macrypsilon salterianum*. The species particularly common in this division is *N. confluens*. As mentioned above in the discussion of the Upper Underbarrow Flags, these contain *N. confluens* which is important in demonstrating faunally the lateral equivalence of the Upper Underbarrow Flags and the lower part of the Kirkby Moor Flags. In addition this species is occasionally found in the lowest horizons of the Scout Hill Flags. However, in the overwhelming number of cases, the existence of *N. confluens* is indicative of Lake District strata which correlate with the Whitcliffian stage.

The identification of *H. contracta* is significant not only from the point of view of its value in correlation but that it also emphasizes the progressive faunal changes occurring through the succession since its appearance in the succession is at the commencement of the Kirkby Moor Flags.

In correlation the ostracode fauna of the Kirkby Moor Flags is rather problematical. It does not readily fall into the ostracode faunal succession identified in Gotland by Martinsson (1967) and its correlation with the type succession at Ludlow is restricted by the general lack of variation of ostracode species occurring there. Martinsson (1967, pp. 374–376) has recognized two ostracode faunas which he correlates with the Whitcliffian. These are the *Cryptolopholobus–Juviella–Neobeyrichia regnans* fauna and the *Hemsiella maccoyiana–Neobeyrichia regnans* fauna. None of the species characteristic of the first of these faunas has been identified in the Kirkby Moor Flags. The second fauna, however, is more promising, since *H. maccoyiana* has been recognized and this is regarded as a diagnostic element in the Baltic. In addition *Macrypsilon salterianum* and *Amygdalella* sp. occur and, although rare, are important in that they constitute a part of the *H. maccoyiana–N. regnans* assemblage.

It is clear that the correlation of these Whitcliffian Kirkby Moor Flags with the faunas of Gotland is rather difficult. At present there is a lack of species in common to both the Lake District and Gotland to suggest a firm correlation. Lake District species unknown from Gotland include *Huttoniella contracta*, *Neobeyrichia confluens*, and *N. torosa*. It appears that during the Whitcliffian conditions had diverged sufficiently for the faunal provinces to develop relatively independently.

The ostracodes yielded by the Whitcliffian of the type area near Ludlow are rather few in variety. They include species of *Hemsiella*, *Neobeyrichia torosa*, *Lophoctonella* sp., *Cytherellina siliqua*, and a number of smooth indeterminate forms. It is clear from this faunal list that more work is required on the Whitcliffian ostracodes until which time it may only be stated that correlation of the Upper Underbarrow Flags and Kirkby Moor Flags, on the basis of ostracodes alone, is tenuous. Using the macro- and the micro-fauna together, however, this correlation may be made. The basis for the correlation is in having demonstrated the existence of strata of Upper Leintwardinian age below (the Lower Underbarrow Flags) and the occurrence of rocks of Downtonian age (the Scout Hill Flags) above. The strata which lie between must therefore be Whitcliffian. This is essentially the argument upon which the type Whitcliffian was erected since no fossil found in that stage identified it as such. The Upper Leintwardine/Whitcliffe boundary is clearly documented at the loss of a readily recognizable assemblage. This is precisely the faunal change occurring at the upper limit of the Lower Underbarrow Flags with the exception of the extension of *N. lauensis* through the Upper Underbarrow Flags. The upper limit of the Kirkby Moor Flags is defined at the appearance of *Frostiella groenvalliana*, an important member of the fauna succeeding the Ludlow Bone Bed.

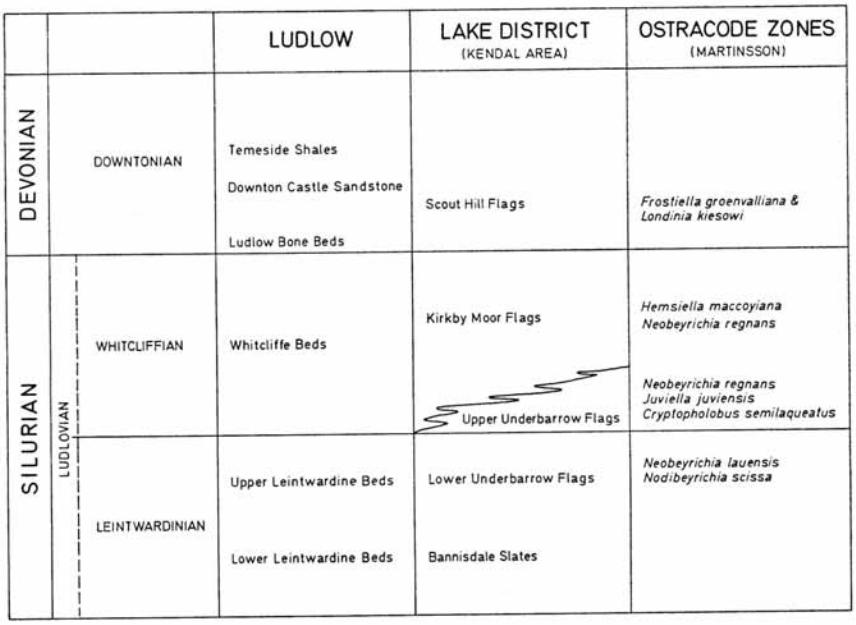
It is on this evidence that a correlation is made between the Upper Underbarrow and Kirkby Moor Flags and the Whitcliffian *Neobeyrichia confluens* and the trilobite *Acastella prima* form a diagnostic association in the Lake District but are of no value in correlation with the Welsh Borderland where neither occurs and a definitive assemblage is badly needed.

(*d*) *Scout Hill Flags*. The commencement of the Scout Hill Flags is not marked by dramatic changes in the ostracode fauna. As mentioned above *Neobeyrichia confluens* is lost at the base of this division, being found only on very rare instances in the lowest beds. The most marked change is in the gain of *Frostiella groenvalliana*. This is a particularly valuable ostracode as a means of correlation and is an easily recognizable species. At Ludlow, *Frostiella groenvalliana*, appears above the Bone Bed, together with *Londinia arisaigensis*. The latter is closely related to *Londinia kiesowi* which together with the former is regarded as a Downtonian assemblage (Martinsson 1963, 1964, and 1967). *Frostiella groenvalliana* appears in the Lake District for the first time in the Scout Hill Flags, which, by this token, may be regarded as Downtonian age.

The Scout Hill Flags can be correlated with the type Siluro-Devonian succession at Ludlow. There, above the base of the Ludlow Bone Bed, *F. groenvalliana* and *Londinia arisaigensis* are introduced into the succession (Shaw 1969) at the commencement of the Downtonian. This clearly correlates with similar faunal changes at the base of the Stonehouse Formation (Nova Scotia) and in the Baltic area. In the vicinity of Llandeilo, south of Ludlow, the Long Quarry Beds which are considered to be Downtonian (Potter and Price 1965) contain *Frostiella groenvalliana* which, as in the Scout Hill Flags, occurs in the absence of *Londinia*.

The value of this horizon, i.e. the introduction of *Frostiella* and *Londinia* of the *arisaigensis–kiesowi*

type into the succession is of considerable importance in that it permits a ready correlation of strata with the Siluro-Devonian boundary near Ludlow. In addition it has been shown that this horizon can be correlated with some accuracy using both ostracodes and trilobites with the graptolite sequence recorded on the Continent (Shaw 1969). The results of the correlation demonstrate the equivalence of the Ludlow Bone Bed horizon approximately with the $e\beta1$–$e\beta2$ boundary of the sequence in Bohemia. With present information the closest this correlation may be made is with the *Monograptus ultimus* zone, though no doubt with further research into the faunas both of the type section at Ludlow and of the continental sections this correlation could be rendered more precise and will continue to provide the correct and most workable horizon for the Siluro-Devonian boundary.



TEXT-FIG. 2. Correlation table for the Lake District succession near Kendal.

CONCLUSIONS

1. The ostracodes of the Lake District succession, although rather difficult to use systematically, yield important and useful results for the division of the succession and its correlation.

2. The Lower Underbarrow Flags and the Scout Hill Flags yield faunas which can be correlated with the ostracode faunas on Gotland which Martinsson (1967) correlates with the Leintwardinian and the Downtonian respectively.

3. The Upper Underbarrow Flags and the Kirkby Moor Flags are less easily correlated directly with Martinsson's ostracode faunas. There is some evidence, however, that the upper part of the Kirkby Moor Flags correlates with the upper of the two ostracode faunas which Martinsson correlates with the Whitcliffian.

4. The Upper Underbarrow Flags and the Kirkby Moor Flags contain two new species of ostracode, *Huttoniella contracta* and *Neobeyrichia confluens*. The former extends through the Scout Hill Flags but the latter is characteristic of the lower beds.

5. The presence of *Frostiella groenvalliana*, defining the Scout Hill Flags, demonstrates the existence of strata of Downtonian age in the Lake District. This was suggested in the early history of the study of Lake District geology although it was not then supported by fossil evidence (Marshall 1839; Sedgwick 1845, 1852, and 1859; Aveline, Hughes, and Tiddeman 1872; and Aveline, Hughes, and Strahan 1888).

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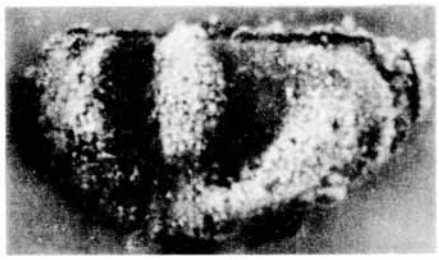

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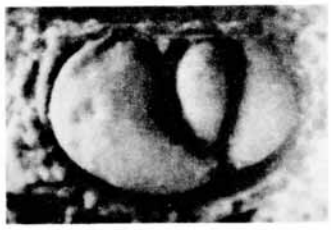

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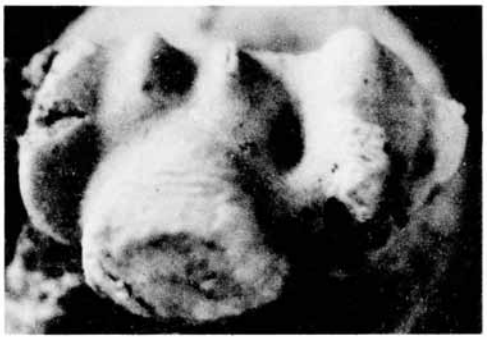

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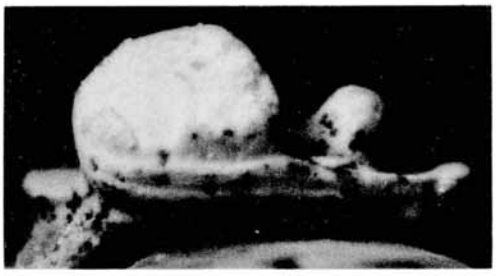

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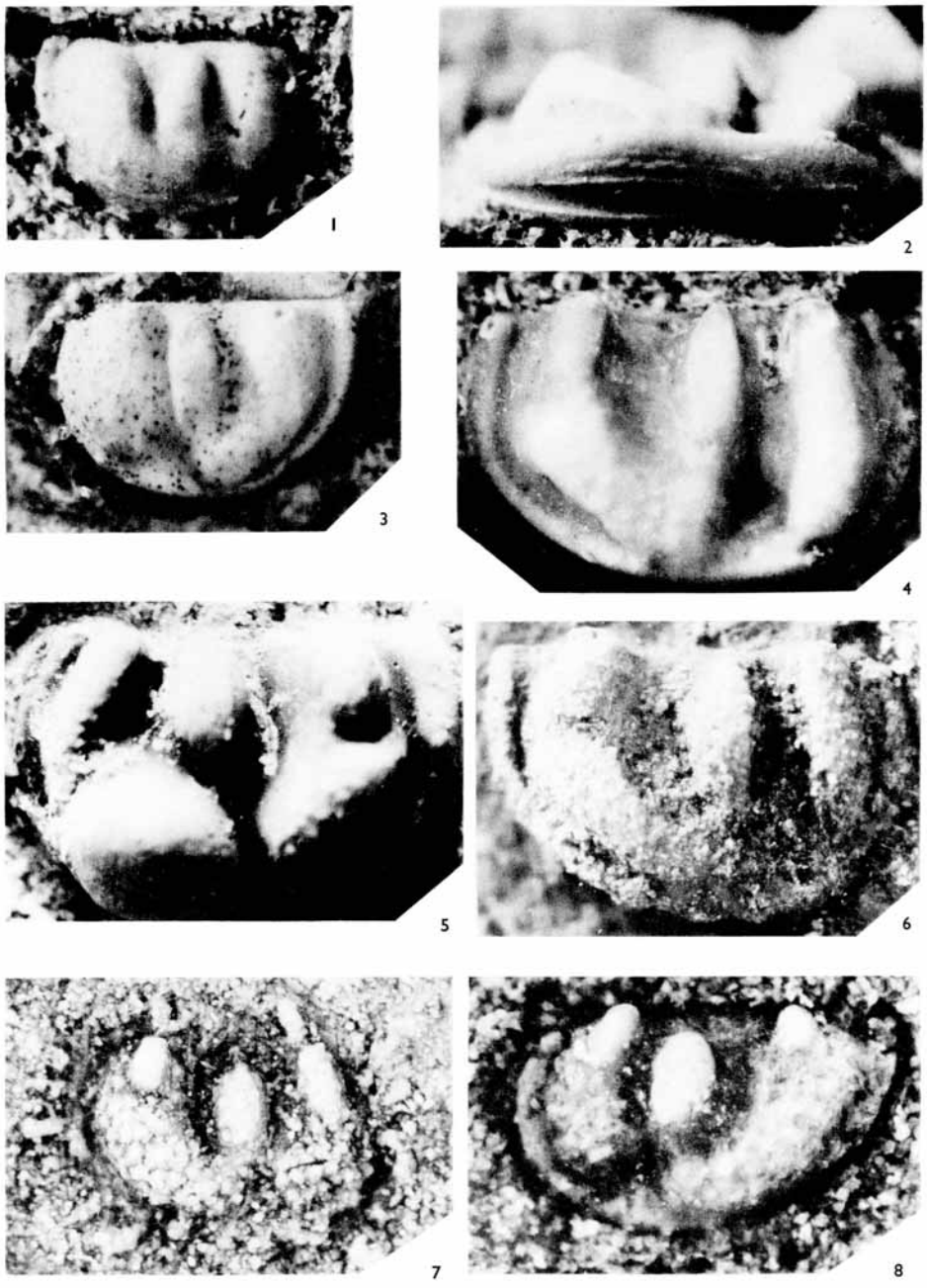

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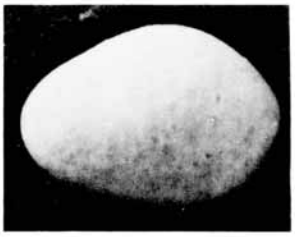

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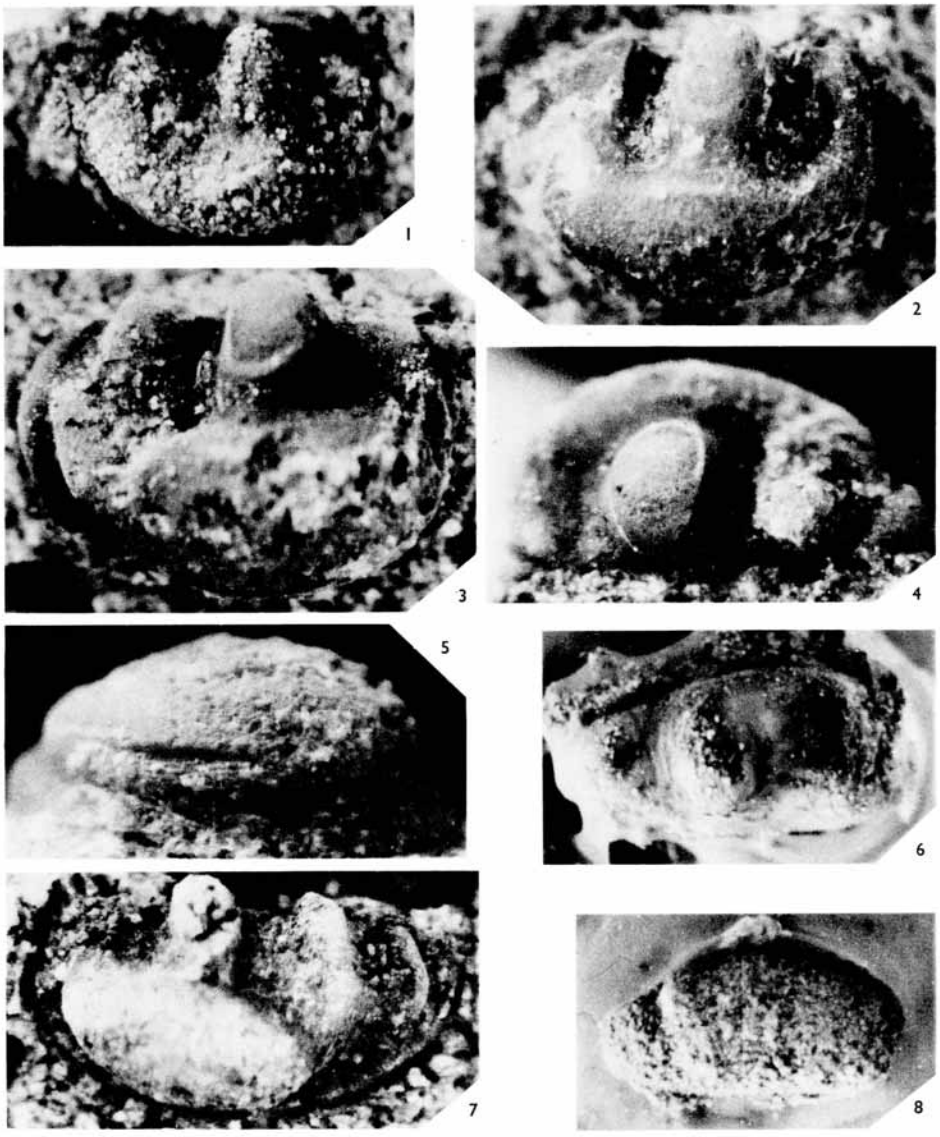

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