NOTES ON SILURIAN STRATIGRAPHY AND CORRELATION IN THE OSLO DISTRICT

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Studies of shelly and graptolite faunas from selected sections in the Silurian of the Oslo district allow correlations to be made with the standard sequences of Britain to a finer degree than has hitherto been attempted; particular attention is paid to beds of Middle Llandovery to early Wenlock age. Some of the 'Stages' and 'Zones' established by Kiær (1908) are shown to be diachronous.

Two graptolites are described, one *(Monoclimacis vomerina vikensis)* as a new subspecies, and the other (Monograptus sp. A) as a species of uncertain affinity.

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The Silurian rocks of southern Norway are particularly well known through the work of Johan Kiær who in 1908 published an exhaustive memoir on the stratigraphy, based on detailed mapping and analysis of the faunas. Kiær established a number of 'Stages' and 'Zones' throughout the area as an extension and refinement of the nomenclature proposed earlier by Kjerulf (1857) for the whole of the Lower Palaeozoic, and he was able to make broad correlations with the type Silurian sequences of Great Britain. Thus Stages 6 and 7 were correlated with the Lower and Upper Llandovery, Stage 8 with the Wenlock and Stage 9 with the Ludlow. The extent and detail of Kiær's work were such that it has stood ever since as the standard reference on the Silurian of Norway with very little or no subsequent modification or revision. The successions and correlations now accepted throughout the area have been summarized in tabular form by Henningsmoen (1960a, Pl. 7) and the same author has briefly reviewed the history of stratigraphical studies within the Lower Palaeozoic (Henningsmoen 1960b, pp. 5–7).

Since the publication of Kiær's paper, British Silurian stratigraphy and palaeontology has been subjected to a good deal of revision and refinement. In the shelly facies of the Llandovery Series detailed mapping has led to the recognition of thirteen stratigraphical divisions (Jones 1925, 1949; Williams 1953) and the use of diagnostic faunal elements such as evolving lineages of the brachiopods *Stricklandia* (Williams 1951) and *Eocoelia* (Ziegler 1966),

now allows these divisions to be correlated with confidence over a wide area (Ziegler, Cocks & McKerrow 1968). Studies on Wenlock shelly faunas are in progress as a preliminary to a revision of the Wenlock stratigraphy (Bassett 1970), while in the Ludlow Series four Stages are now correlated throughout the Welsh Borderland, based on the nine litho- and biostratigraphical divisions recognised in the type area of the Ludlow anticline (Holland, Lawson & Walmsley 1963). Similarly, in the British basin facies the sequence and composition of graptolite faunas are now known in far more detail than was available to Kiær in 1908. The definitive monograph of Elles & Wood was not completed until 1918 and it was this that formed the basis for modern graptolite studies. Recent revisions and amendments to this work allow a detailed zonal scheme to be recognised and correlated over a wide area within the Llandovery, Wenlock and Ludlow Series (e.g. Rickards 1965, 1967, 1969b, 1970).

During a visit by one of the authors (M. G. B.) to some of the Silurian sections around Oslo in the summer of 1969, it became clear that a number of horizons contain well preserved shelly faunas including many of the diagnostic elements used in the refined dating of the British Silurian. This was confirmed by a detailed examination of the extensive collections in Paleontologisk Museum, Oslo, including Kiær's collection, which allows his original identifications to be checked and emended where necessary. In some cases the initial conclusions reached were supported or modified by a preliminary study of graptolite faunas which occur at various horizons throughout the succession. Subsequently the graptolites have been studied in detail by the other author (R.B.R). The results of these studies allow a number of horizons to be correlated with the standard British sequences to a finer degree than has hitherto been attempted. This account is not intended to be an exhaustive re-survey of the whole of the Silurian around Oslo, but rather a series of notes on the correlation indicated at certain levels, with particular reference to beds of Middle Llandovery to early Wenlock age. The conclusions suggest, however, that other parts of the succession are in need of up to date interpretation based on modern faunal studies.

Three separate areas are considered; the first, on the island of Malmøya at the northern end of Bunnefjorden, is in the eastern facies development (Henningsmoen 1960a, p. 146); the second is in the intermediate facies developed in the Asker-Bærum district west of Oslo at the head of Oslofjorden, and the third is around Ringerike some 25 km to the north-west of Oslo in the western facies. The succession is discussed separately in each area since some of Kiær's original 'Stages' can be shown to vary slightly in age in the different sections examined.

Specimens referred to in the text are housed in Paleontologisk Museum, Oslo (PMO), the National Museum of Wales, Cardiff (NMW) and the Sedgwick Museum, Cambridge University (SM).

Malmøya

The sequence on Malmøya ranges from Stage 5b at the base to 8d at the top. Only the beds between 6bβ and 8b inclusive will be considered here, but it is worth noting that within the lower beds the base of the Silurian is drawn at the base of the sandy shales and limestones of 6aα, which contain the graptolite *Climacograptus normalis* Lapworth on the neighbouring island of Ormøya (Spjeldnaes 1957, p. 365).

6bβ is a richly fossiliferous unit of shales and limestones from which the following brachiopod species have been identified: – *Protatrypa malmoeyensis* Boucot, Johnson & Staton, *Eoplectodonta duplicata* (J. de C. Sowerby), *Meifodia ovalis ovalis* Williams, *Leptaena valentia* Cocks and *Eostrophonella* sp. This assemblage suggests a correlation with the Middle Llandovery (B) of Britain. At Llandovery itself *M. ovalis ovalis* is confined to the B_2 and B_3 beds (Williams 1951, p. 109 and table on p. 130), while *L. valentia* has been described only from the Middle Llandovery of Woodland Point, Ayrshire, Scotland (Cocks 1968, pp. 307–308). The remainder of the assemblage is consistent with a Middle Llandovery age although Boucot et al. (1964, p. 810) considered *P. malmoeyensis* to be of Lower Llandovery age when originally describing it from its type horizon in the 6b beds of Malmøya.

The overlying beds of 6cα are again richly fossiliferous, with abundant specimens of *Stricklandia lens* (J. de C. Sowerby) aff. *intermedia* Williams. *Eoplectodonta duplicata, Protatrypa malmoeyensis* and *Plectatrypa* sp. also occur. The presence of *S. lens* aff. *intermedia* is again indicative of a Middle Llandovery (B_{1-3}) age (Williams 1951, p. 101 and table on p. 129); however, all the specimens examined from Malmøya appear to be late forms of *S. lens intermedia* since they have fairly wide inner plates in the cardinalia, approaching those of *S. lens progressa* which occurs in the early Upper Llandovery (C_{1-2}) beds of the Llandovery district. The Malmøya specimens are therefore probably of latest Middle Llandovery age, but could also be considered to belong to the earliest Upper Llandovery. The Middle Llandovery and earliest Upper Llandovery span the *gregarius, convolutus* and *sedgwickii* graptolite zones (Ziegler et al. 1968, Fig. 2; Fig. 1 of this paper).

Stricklandia lens also occurs in Stage 6cβ but it is less common than in 6cα and the material examined does not allow subspecific determination. However, *S. lens* occurs only in beds of pre–C_5 age, and since 6cβ overlies beds of probable latest Middle Llandovery age it can be dated as C_{1-4}. Stages 7a to 7c contain few definitive faunal elements. In 7a *Pentamerus borealis* (Eichwald) is fairly common while in 7bα and 7bβ this species is replaced by *P. oblongus* J. de C. Sowerby. The presence of *Pentamerus* in all three units indicates a pre–C_5 age but there is no firm evidence for a lower age limit; the superposition of 7a-b on 6cβ, however, suggests a middle Upper Llandovery age, probably within the range of C_{3-4}. Stage 7c consists of a sequence of thin shales with thick bedded, nodular limestones, the unit being referred to

collectively as the Crinoid shale and limestone. Despite the large faunal list given by Kiær (1908, p. 159), few fossils can now be collected apart from numerous long crinoid stems. St. Joseph (1938, pp. 290–291) records that in these beds on Malmøya *Pentameroides* 'is hardly ever found', but if one accepts this as a record that it does occur, then it indicates a lower age limit of C_5 (see Ziegler et al. 1968, Fig. 2). An upper age limit of C_6 (uppermost Llandovery) for Stage 7c is proved by the presence of basal Wenlock graptolites in the overlying beds of Stage 8a.

Stages 8a–b on Malmøya are made up of black graptolitic shales which are very well exposed in the bay of Skinnerbukta on the west side of the island. The following fauna has been identified in material collected by M.G.B. from the lowest beds (8aα):– *Monoclimacis vomerina vomerina* (Nicholson), *M. vomerina vikensis* subsp. nov., *Cyrtograptus* ex gr. *centrifugus* (Bouček), *Monograptus flexuosus* Tullberg and *M. priodon* (Bronn). The identification of the 8aβ fauna is based on specimens in Kiær's collection in Paleontologisk Museum and includes the following species:– *Cyrtograptus bohemicus* (Bouček), *C.* ex gr. *murchisoni* Carruthers, *Monoclimacis vomerina* cf. *vomerina, M. vomerina vikensis, Monograptus priodon* and *M. flexuosus*. In addition there is a large number of specimens in the same collection, from undifferentiated beds in 8a, which contain the above mentioned species together with specimens of *Retiolites geinitzianus geinitzianus* (Barrande) and *Barrandeograptus pulchellus* (Tullberg). All three assemblages refer Stage 8a definitely to pre-*riccartonensis* Zone lowest Wenlock. There is, however, a problem of differentiating the *centrifugus* and *murchisoni* Zones within these collections. The common presence of *Cyrtograptus* ex gr. *centrifugus* in the 8aα fauna and of *C.* ex gr. *murchisoni* in 8aβ suggests that both zones are present. Kiær's specimens of *R. g. geinitzianus* are probably from 8aα since it was the only horizon from which it was recorded by him (Kiær 1908, p. 165). *R. g. geinitzianus* does not occur above the *centrifugus* Zone as recognized in Britain (Rickards 1967, 1969), although Teller (1969) records it from the *murchisoni* Zone of Poland. In the absence of more detailed stratigraphical information the other recorded species could be assigned to either the *centrifugus* or *murchisoni* Zones. It is interesting to note that Kiær (*op. cit.*, pp. 165–168) recorded *Monograptus crenulatus* Törnquist from both 8aα and 8aβ, an identification which would suggest the presence of the uppermost Llandovery *crenulata* Zone. However, at least one specimen collected and identified by Kiær as *M. crenulata* (PMO 43654) is re-identified here as *Monoclimacis vomerina ?vomerina* and it seems likely that any other specimens should be similarly re-identified.

Within the collections examined from Paleontologisk Museum there are also a number of specimens, supposedly from Stage 8a, which contain possible anomalies. Firstly, the slabs PMO 43870–78 are of a different lithology to the rest and yield numerous specimens of a single monograptoid species which may be referable to a Llandovery species obtained by the authors elsewhere (see below, under the description of *Monograptus* sp. A.). These spe-

cimens were collected by Kjerulf in 1863 and may not be from the 8a beds as mapped by Kiær; clearly the section needs a more detailed re-examination in order to locate the horizon of this species. Secondly, the slab PMO 70737 collected by L. Størmer in 1953, contains specimens of *Monoclimacis flumendosae* (Gortani) and *Monograptus flemingii* (Salter) proving a middle Wenlock age (*rigidus* to *ellesae* Zones); this specimen almost certainly came from Stage 8b, providing an upper age limit for that division. The highest beds of the Malmøya succession (Stages 8c-d) have not been re-examined.

Asker-Bærum

In the Asker-Bærum district to the west of Oslo the Silurian sequence extends from Stage 6a*α* to 9g. The faunas of Stages 6, 7, and 8 are closely comparable with those of the same part of the sequence on Malmøya, but Stages 8a-c contain a few additional elements that are worthy of comment. These beds have been examined in sections around Gjettum and Sandvika. The highest beds in the area (Stages 8d and 9a-g) have not been studied.

Kiær's collection contains numerous graptolites from Stage 8a, of which the following species have been identified:– *Monoclimacis vomerina* s.l., *M. vomerina vikensis, M. griestoniensis* (Nicol.) s.l., *Retiolites geinitzianus geinitzianus, Monograptus priodon* and *Pristiograptus* aff. *watneyae* Rickards. In the absence of robust cyrtograptids this assemblage could technically be of highest Llandovery (*crenulata* Zone) or basal Wenlock (*centrifugus* Zone) age. The latter alternative is more strongly suggested by the close comparison of the bulk of the fauna with that of the 8a beds of Malmøya; the additional elements *P.* aff. *watneyae* (PMO 53773) and *M. griestoniensis* s.l. (PMO 53772) support this conclusion as both species are associated in the *centrifugus* Zone of Northern England (Rickards 1965, Fig. 1). Stage 8b also contains graptolites, but less commonly than in 8a. A single specimen, collected by M.G.B. (NMW 69.142.G11) from the upper half of 8b in the railway cutting approximately 300 m WNW of Gjettum station, belongs to *Monoclimacis* cf. *linnarssoni* (Tullberg). *M. linnarssoni* is a high Llandovery to lowest Wenlock species and is not known with certainty from above the *centrifugus* Zone. This zone may thus extend from 8a into the upper half of 8b, though the presence of *M.* cf. *linnarssoni* in 8b perhaps supports the alternative suggestion discussed above that the 8a fauna is partly of latest Llandovery age.

Collections from Stage 8c have been made both from above the 8b beds in the railway cutting near Gjettum station and from the section on Dugnadsveien approximately 350 m NW of the station. In both sections the beds consist of mudstones with thin bands of limestone and contain a fairly rich shelly fauna including the brachiopods *Eocoelia angelini* (Lindström), *Protochonetes* sp., *Resserella* sp. and *Atrypa reticularis* (Linnaeus). The presence of *Eocoelia* is extremely useful since stages in the evolving lineage of this genus are

now used widely in the correlation of the Upper Llandovery and early Wenlock (Ziegler 1966; Ziegler, Cocks & McKerrow 1968). *E. angelini* was not recorded by Ziegler *(op. cit.)* who described *E. sulcata* (Prouty) as the end-member of the *Eocoelia* lineage from beds of latest Llandovery (C_6) and early Wenlock age. Bassett & Cocks (in prep.) discuss the possible conspecificity of *E. angelini* and *E. sulcata* and conclude that typical specimens of *angelini* represent a further evolutionary stage and are hence slightly younger than typical *sulcata* as described by Ziegler. The type specimens of *E. angelini* are from the Högklint beds of Gotland which belong in the *riccartonensis* Zone of the Wenlock (Bassett & Cocks *op. cit.);* the Norwegian 8c specimens are at the same stage of development and are thus considered here to be of probable *riccartonensis* Zone age. [Note that Ziegler (*op. cit.*, p. 538) recorded *E. sulcata* as being 'abundant in Stage 8a-b Gjettum Station, Bærum'. Correspondence with Dr. Ziegler indicates that this record is based on collections from the same road section on Dugnadsveien as that mentioned above. There is no doubt, however, that the *Eocoelia*-bearing beds at this locality are in Stage 8c since they are overlain within a few metres by the thick bedded limestones of 8d and since they contain the typical 8c fauna as listed by Kiær (1908, p. 361), from his 'Zone with *Chonetes* sp.' All specimens of *Eocoelia* examined from this locality are identified here as *E. angelini*.]

Ringerike

In the Ringerike district the sequence has been studied from Stage 7a to Stage 9a inclusive. The sections exposed on the mainland around Vik are relatively straightforward, but there are marked anomalies in some of the faunas examined from the islands of Storøya and Geitøya in Tyrifjorden and from Bragsøya in Steinsfjorden.

To the west of Vik the beds of Stage 7a contain abundant specimens of *Pentamerus borealis* while in 7b this species is replaced by *P. oblongus*. In both cases the presence of *Pentamerus* is indicative of a pre-C_5 (Upper Llandovery) age (Ziegler et al. 1968, Fig. 2). Stage 7cα consists of predominantly red crinoid bearing shales with no diagnostic faunal elements. On the mainland the succeeding beds of Stage 7cβ are poorly exposed, but there are well preserved shelly faunas in Kiær's collection from this division on Storøya, including the peninsula of Purkøya at the south-western tip of the island. These faunas include *Pentameroides* cf. *gotlandicus* (Lebedev) and *Costistricklandia lirata lirata* (J. de C. Sowerby). Both genera are known only from beds of C_5 or younger age (Ziegler et al., *op. cit.*). *C. lirata lirata* is confined to beds of C_6 age on Gotland and to C_6 and early Wenlock in Britain. Kiær (1908, p. 65) also records the distinctive coral *Palaeocyclus porpita* (Linnaeus) in association with this fauna, but there are no specimens in his collections. The presence of *P. porpita* would strengthen a correlation of Stage 7cβ with the C_6 beds of the Upper Llandovery.

Stage 8a is well exposed near Løkken along the road from Kroksund to Vik. Specimens in Paleontologisk Museum contain the graptolites *Monograptus priodon* and *Monoclimacis* sp., while other material provided for the authors by Dr. J. H. McD. Whitaker yields *Monoclimacis vomerina vikensis, Monograptus priodon, Retiolites* sp. *(?geinitzianus), Pristiograptus* ex gr. *dubius* (Suess) and robust cyrtograptids *(?C.* ex. gr. *centrifugus)* from the same Stage. The beds can therefore be assigned with some confidence to the pre-*riccartonensis* Zone Wenlock. The middle and upper beds of 8a also contain brachiopods of which *Atrypa reticularis* (Linnaeus) and *Cyrtia exporrecta* (Wahlenberg) are the most common.

The fauna of Stage 8b, as examined from Storøya, Geitøya and Bragsøya, contains a number of interesting and anomalous elements. In all three cases *Palaeocyclus porpita* occurs commonly and on Bragsøya it is associated rarely with *Costistricklandia lirata lirata* (e.g. PMO 21751). Graptolites from the same beds on Bragsøya include *Monograptus priodon, Monoclimacis* sp. and *Retiolites geinitzianus,* while *M. priodon* has also been identified from Storøya. The presence of *P. porpita* and its association with *C. lirata lirata* strongly suggests a correlation with the C_6 beds of the topmost Llandovery since both elements are associated over a wide area at that horizon, e.g. in Britain and Gotland (Lower Visby Marl). The graptolite fauna, though not diagnostic in itself, is consistent with a C_6 age. Thus this 8b fauna appears to be slightly older than that of the 8a beds on the mainland and of approximately the same age as, or very slightly younger than, the 7cβ fauna from Storøya discussed above. These apparently anomalous relationships cannot be explained satisfactorily without a more detailed facies and faunal analysis of the relevant sections, a task that is outside the scope of this account. The excellence of the almost continuous exposure throughout these sections makes it extremely unlikely that there is hitherto undetected strike faulting or folding either within the sequences on the islands or between the islands and the mainland. It may be that some of the 'diagnostic' faunal elements such as *Palaeocyclus, Costistricklandia* and *Pentameroides* span a wider time range in the calcareous beds of this area than in the essentially clastic environments of the British Upper Llandovery, but what seems most likely is that some of the limestone units used by Kiær as marker horizons are strongly diachronous and exhibit complex facies relationships.

The faunas from the highest beds of Stage 8 (8c and 8d) do not allow an age determination to be made as a check on that suggested above for the underlying beds of 8b, but there is some support from the succeeding beds of Stage 9a. Kiær (1908, p. 93) refers to 9a as being of earliest Ludlow age; – when comparing the Norwegian and British successions, however, he (1908, p. 551) correlates 9a with the Wenlock limestone (cf. also Henningsmoen 1954, p. 67; 1960a, pl. 7). However, on Bragsøya, Storøya, and Geitøya Stage 9a contains abundant *Eocoelia angelini* at the same stage of development as those recorded earlier (p. 251) from Stage 8c of Asker-Bærum and considered to be of probable lower Wenlock (*riccartonensis* Zone) age. Stage

9a on the islands may therefore also be of lower Wenlock age, a conclusion which adds weight to the postulated late Llandovery age for 8b. The alternative to this correlation is that the *Eocoelia* lineage represented by *E. angelini* extends into much younger beds in the limestone environments of Ringerike than in clastic environments elsewhere; this, however, seems unlikely in view of the fact that the type horizon of *E. angelini* is in similar limestones of the Högklint beds of Gotland, known to be of *riccartonensis* Zone age (Bassett & Cocks, in prep.).

Conclusions

The suggested correlations of the beds examined in the Malmøya, Asker-Bærum and Ringerike districts are summarized in Fig. 1. In addition on the anomalous relationships suggested at Ringerike it is also apparent that some of Kiær's 'Stages' exhibit marked diachronism when traced throughout the Oslo district; in Fig. 1 this diachronism is particularly well illustrated with reference to the beds of 8b. At Ringerike, correlation of 9a with an early Wenlock horizon supports the recent evidence provided by vertebrate faunas to suggest that the whole of Stage 9 is of Wenlock age (e.g. see Heintz 1969, pp. 23–25).

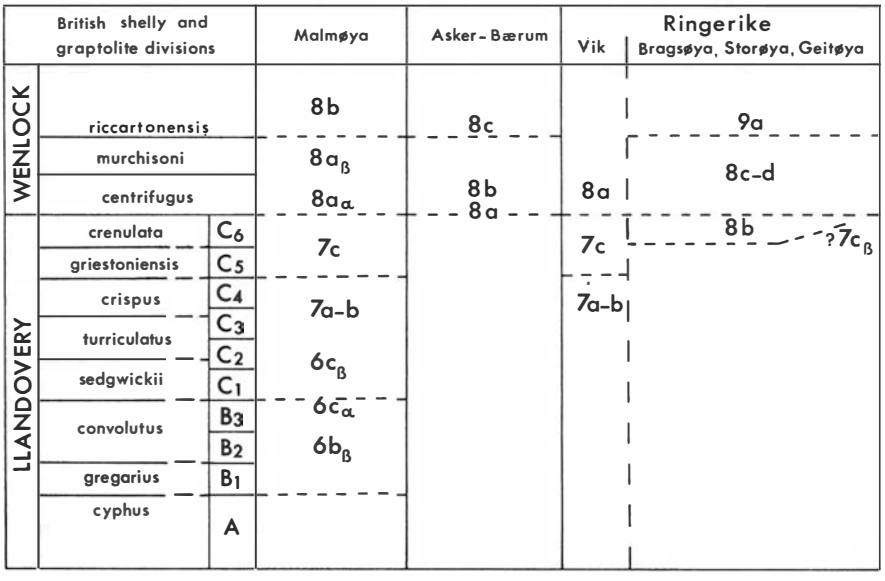

Fig. 1. Correlation of selected horizons in the Silurian of the Oslo district with the British succession (the correlation of the British shelly and graptolite divisions is modified after Ziegler et al. 1968, Fig. 2).

Systematic descriptions

Class GRAPTOLITHINA Bronn, 1846
Order GRAPTOLOIDEA Lapworth, 1875
Suborder MONOGRAPTINA Lapworth, 1880
Family MONOGRAPTIDAE Lapworth, 1873

Genus *Monoclimacis* Frech, 1897

Diagnosis
Rhabdosome often long and more or less straight though slight curvature is common proximally and rarer distally; ventral wall of each thecae subsequent to thl has a distinct excavation which contains the apertural region of the preceding thecae; apertural region often everted, sometimes strongly; excavation often hooded by an outgrowth of microfusellar tissue from the geniculum, or possibly by strong retroversion of the dorsal margin of the preceding theca.

Remarks
Urbanek (1958) showed the presence of a hook of microfusellar tissue in Ludlow representatives of the genus. This structure has recently been found in Wenlock representatives of the genus, e.g. *Monoclimacis flumendosae* (Gortani) from Co. Galway, Eire (Trinity College, Dublin No. 8121). However, there is no doubt that some early Wenlock species, such as *M. vomerina vikensis* subsp. nov. described below, exhibit very strong thecal evertion perhaps to the extent that the dorsal thecal margin becomes retroverted and itself contributes to the hooded appearance. Such a structure is not unexpected and is in accord with the relationship between *Monoclimacis* and *Monograptus* s.s. suggested by Rickards (1969a, pp. 308–309).

Monoclimacis vomerina vikensis subsp. nov.

Figs. 2A, B
Holotype: – SM A75311, well preserved specimen in moderate relief, preserved in pyrite, from 180 m SE of Garntangen, Vik, Ringerike district, grid ref. 72186084. Collected by Dr. J. H. McD. Whitaker (University of Leicester).

Horizon of holotype: – According to Dr. Whitaker the shales are near the base of the Wenlock Series (upper part of Kiær's Stage 8a). Associated with the holotype are numerous specimens of the same species, numerous specimens of *Monograptus priodon* Bronn, and rare specimens of *Retiolites* sp. (*?geinitzianus*) and *Pristiograptus* ex gr. *dubius* (Suess).

Material: – Numerous well preserved specimens in the University of Leicester, Paleontologisk Museum, Oslo and the National Museum of Wales.

Other localities and horizons: – Sandvika, Stage 8a-b; ?Bærum, Stage 8a; ?Malmøya, Stage 8aβ; Malmøya, Stage 8aα.

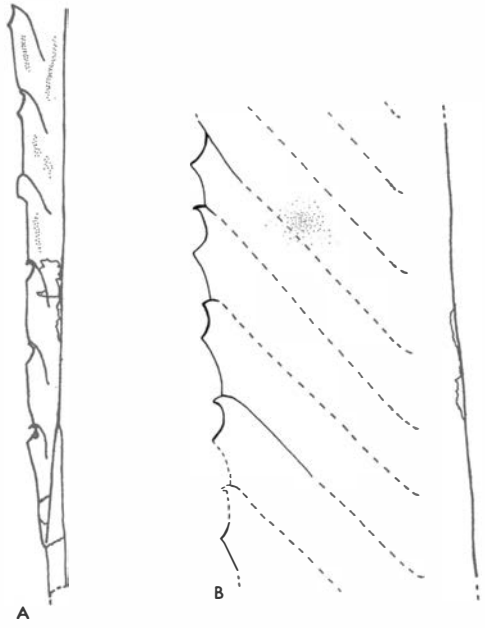

Fig. 2.
A. *Monoclimacis vomerina vikensis* subsp. nov., Holotype, SM A75311, proximal end of a specimen in relief, upper part of 8a, 180 m SE of Garntangen, Ringerike (Grid Ref. 72186084) × 10.
B. *Monoclimacis vomerina vikensis* subsp. nov., NMW 69.142. G1, portion of distal part of a flattened rhabdosome, 8aα, south side of Skinnerbukta on west side of Malmøya. × 70.

Diagnosis: – Rhabdosome very long, distally broad, over 3 mm dorso-ventral width; proximally slender with thorn-like aspect; sicula 2 mm in length, reaching to level of aperture of thl; thecal spacing 10 in 10 mm proximally to 8 in 10 mm distally.

Description: – The rhabdosome is probably of great length although the present collection consists of fragments up to eight centimetres long. No distal fragments have been seen in the Vik material but the other localities have yielded fragments with a dorso-ventral width (flattened) of up to 3.30 mm.

The dorso-ventral width (in relief) at the level of thl is of the order of 0.4 mm, and thereafter the rhabdosome widens gradually to the maximum width, achieved at a suggested distance of about 30 cm from the sicula. The thecal spacing changes equally gradually from 10 in 10 mm for the first 20–40 mm to 8 in 10 mm at the distal extremity of the rhabdosome.

The sicula has a length of 2 mm and the position of its apex is usually at the level of the aperture of thl. Less commonly the apex is fractionally above or below the aperture of thl. Thl originates 0.50–0.60 mm above the sicular aperture, and has a length of 1.40–1.50 mm. Subsequent thecae are 2 mm in length at a distance of 30 mm from the sicula, and most distally are almost 4 mm long. Thecal overlap changes from ⅓ at the proximal end to $^4/_5$ distally.

Throughout the length of the rhabdosome the thecal apertures are strongly everted. It is difficult to determine whether the thecal hoods are genicular hoods of microfusellar tissue, or reflect genuine retroversion of the dorsal thecal wall. The latter possibility seems the more likely (Figs. 2A,B), particu-

larly in view of the abnormal hook developed on th4 of the holotype (Fig. 2A). The thickened rim present on the thecal apertures of most specimens also supports this interpretation.

Thecal excavations occupy, at the most, $^1/_4$ of the dorso-ventral width, and usually rather less. In sub-apertural views, however, the excavations may appear to be rather more than $^1/_4$ the dorso-ventral width. Distally the geniculum becomes less sharp and in the most distal, elongate thecae may be barely detectable except in sub-apertural views.

Remarks: – *M. vomerina vikensis* subsp. nov. is very closely related to *M. vomerina basilica* (Lapworth) and the two are probably geographical subspecies since they occur at exactly the same horizon (lowest Wenlock) in association with the same species of graptolites. The differences between the two forms are slight but constant. Thus the Norwegian form has a long sicula (2 mm) in contrast to the diminutive sicula of *M. v. basilica* (1.20–1.40 usually, rarely 1.50 mm). The position of the apex of the sicula is the same in both subspecies, and may be contrasted with that of *M. v. vomerina* in which the 1.5–2.0 mm long sicula is midway between the apertures of th1 and th2. The whole thorn-like proximal end of *M. vomerina vikensis* recalls that of *M. v. basilica,* yet it widens even more gradually to its eventually robust distal dimensions. The change to distal lower thecal spacing values is also slower in the Norwegian subspecies. Thecal overlap of the distal thecae is probably less in Lapworth's subspecies.

The British representatives of the genus *Monoclimacis* are at present being revised by one of us (R. B. R.) and the above information concerning *M. v. basilica* (Lapworth) is taken from this revision rather than from the sketchy description of Elles and Wood (1911, p. 411). It is because of this lack of published information concerning the Lapworth subspecies that we doubt the supposed conspecificity, suggested by some workers of *M. v. basilica* (Lapworth) and *Monoclimacis hemipristis* (Meneghini).

Genus *Monograptus* Geinitz, 1852

Monograptus sp. A

Figs. 3C, D

Material: – Eighteen flattened, well-preserved specimens on slabs PMO 43870–78 of Paleontologisk Museum, Oslo.

Localities and horizon: – Malmøya, supposedly from Stage 8a, but most of the specimens in collections undoubtedly from 8a indicate a low Wenlock horizon, whilst *Monograptus* sp. A may possibly indicate a Llandovery age (see below). The lithology of the slabs with *Monograptus* sp. A is slightly different from the other shale slabs, whilst another indication of a 'mixed' collection is provided by slab PMO 70737 which has a middle Wenlock assemblage (see discussion, p. 251).

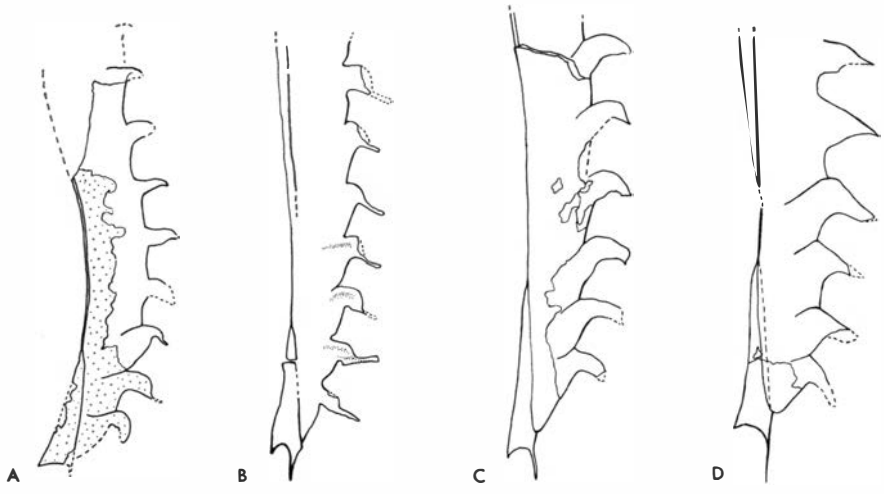

Fig. 3.

A. *?Monograptus* sp. A, specimen on the same slab (Birmingham University 1571) as the specimen of *M. galaensis* Lapworth figured by Elles & Wood, 1911, Fig. 281a, Meigle Quarry, Selkirkshire, Scotland.
B. *?Monograptus* sp. A, Institute of Geological Sciences (Leeds) RS6579, occurring with *M. galaensis* Lapworth, Cross Fell, Northern England.
C. *Monograptus* sp. A, PMO 43871, 8a, Malmøya.
D. *Monograptus* sp. A, PMO 43872, 8a, Malmøya.
All figures × 10.

Description: – The rhabdosome has a length of at least 35 mm and achieves a maximum dorso-ventral width (flattened) of 2.0 mm. However, there appears to be some tectonic deformation of the specimens, some seemingly rather narrow and others broader. The majority of specimens are narrower than 2.0 mm distally.

The proximal end exhibits a stiff dorsal curvature involving the first 5 mm of the rhabdosome, and largely contributed to by a very prominent sicula. The sicula has a length of 2.0–2.8 mm (excluding virgella) and reaches to well above the level of th2, and often to the level of th3. In consequence the proximal end is robust, the dorso-ventral width at the level of th2 (excluding processes) varying from 0.90–1.1 mm. The dorso-ventral width at the level of th7 is 1.50–1.70 mm. The true nature of the thecal hooks is not easily ascertained. There is a suggestion on some specimens that the hooks may consist of paired lappets, but the preservation is not sufficiently good to be certain. In profile the hooks are large, prominent, occupy approximately $^1/_3$ of the dorso-ventral width, and become less retroverted and more beak-like distally. Thecal spacing varies from 10–15 in 10 mm, the higher values obtaining proximally.

Remarks: – *Monograptus* sp. A is a distinctive form, probably as yet unnamed, having the proximal dimensions usually found in Wenlock representatives

of *Monograptus* s.s. The closest of the latter group is probably *M. riccartonensis* Lapworth, to which *Monograptus* sp. A bears a superficial resemblance particularly with respect to the curvature of the proximal end. *Monograptus* sp. A is, however, more robust on all counts including size and position of the sicula.

One of us (R. B. R.) has obtained Llandovery specimens associated with *Monoclimacis galaensis* (Lapworth) which agree in most respects with *Monograptus* sp. A. These specimens are from probable *turriculatus* Zone (Llandovery) strata of the Cross Fell Inlier, Northern England, and Meigle Quarry, Southern Scotland. In both cases the specimens (Figs. 3A,B herein) are associated with *M. galaensis*. The dimensions of the British specimens are as follows: Cross Fell material, sicula 2.0 mm reaching between th2 and th3; thecal spacing 15 in 10 mm proximally; dorso-ventral width at th2, 1.0 mm; dorso-ventral width at th7, 1.4 mm approximately; Meigle Quarry material, sicula 2 mm reaching almost to th3; thecal spacing 15 in 10 mm proximally.

The main differences appear to be in the form of the thecal hook, although this is unfortunately only seen well preserved in the Cross Fell material (Fig. 3B). Here the thecae are seen to possess a distinct, laterally-directed apertural process. Such processes would not be visible on the Meigle Quarry and Norwegian specimens. There is a distinct resemblance between the thecal profiles of the Meigle Quarry and Norwegian specimens, and in particular between their distal thecae.

The possibility exists, therefore, that the Norwegian *Monograptus* sp. A is of Llandovery age. Until the structure of the thecal hook is better understood it is not considered wise to describe the form as a new species. There is a small number of relatively robust *Monograptus* s.s. described from the Llandovery rocks *(M. pandus, M. mcoyi)* but these are ill-defined species with which comparison is impossible at present.

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