Late Caradoc – early Ashgill trilobite distribution in the central Oslo Region, Norway

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Detailed collections from profiles in the Upper Chasmops Limestone (Oslo-Asker) and Solvang Formation (Ringerike) have yielded a total trilobite fauna of 45 taxa. The stratigraphical distribution of these is presented in the form of faunal logs which show a progressive immigration of forms and increase in diversity. The effect of this is emphasised by a major fauna shift at the base of overlying shales which are markedly diachronous westwards from Oslo. The trilobite fauna provides the best available means of correlation so far with standard British late Caradoc and early Ashgill shelly assemblages.

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Since the early 1800’s, the richly fossiliferous Lower Palaeozoic rocks in the neighbourhood of Oslo have yielded large collections, among them those from the Ordovician Chasmops Beds. The latter formed the basis for a research project started in 1948 by the late Professor Leif Størmer (Størmer 1953) which aimed at describing the various fossil groups and refining interregional correlation. In that project the geographical area for study was widened to include what Størmer (1953:51) defined as the Oslo Region. In order to describe the total fauna, a group of specialists was invited to cooperate and, by 1977, 27 publications had appeared containing descriptions of some of the major fossil groups. The bulk of material used for these studies, however, was mainly from collections at Paleontologisk museum, Oslo, and others of ‘bag-stratigraphical’ type (Jaanusson 1976: 302), and little or no information was presented as to the spatial distribution of taxa within units.

With this in mind, one of us (D.L.B.) decided to make detailed collections from several profiles in the Oslo-Asker area with a view to describing trilobite (and other) distributions. With the help of cand. real. J. Fredrik Bockelie and a number of students, sites were chosen and detailed collections made at Bygdøy (Oslo) and Fornebu (Bærum), while Bockelie alone took Raudskjer (Asker) (Fig. 1). All sites offer profiles through the Upper Chasmops Limestone, the most fossiliferous unit, and the subject of this account. The profiles, together with beds on Terneholmen (Asker), were recollected at various intervals between 1968-1970 and, apart from Terneholmen, were also recollected by Gunnbjørg Qvale (Qvale 1977) in her search for ostracodes. In the meantime Owen had started a study on the trilobite faunas from equivalent beds in Ringerike and Hadeland in the north west of the Oslo Region (Owen 1977, 1978, 1979) and his data on trilobite distribution in these areas, together with that subsequently assembled jointly from the Oslo area, are presented here. A monograph of the Upper Chasmops Limestone trilobites which is to form another part of this joint study will appear later.

Fig. 1. Map showing the localities in the Oslo-Asker district referred to herein with the location of the measured profiles (p) indicated. The Lower Palaeozoic succession is tightly folded with a regional strike of 060.
Fig. 2. The distribution of trilobites in the Upper Chasmops Limestone on A. Bygdøy and B. Fornebu. Metre intervals in the sections measured from either the top (Bygdøy) or base (Fornebu) of the Chasmops beds and samples in Paleontologisk museum, Oslo from each profile are documented in terms of these datum lines. Most trilobite occurrences are illustrated as bars representing 10 cm of the section and no break is shown between bars from successive horizons. In cases where the sample locations are less precise, they are illustrated as dashed lines between the known limits of collection. Vertical lines represent the range of each species in the Upper Chasmops Limestone and when extended below the lowest sample indicate their occurrence in the underlying Upper Chasmops Shale. In the case of the Fornebu profile most of this unit is not exposed (Toni 1975, fig. 1). The highest part of the Upper Chasmops Limestone may be missing in the Bygdøy profile. *Aphanurus thorslundi* Bruton and *Platylichas laxatus* (McCoy) are known from old collections from the Upper Chasmops Limestone on Bygdøy and Fornebu respectively, but were not present in the samples on which this study is largely based.
Trilobite distribution in Oslo Region

In most instances, sample weights varied from large (2-5 kgs) for limestones, to much smaller samples (50 gs) for shales. There is thus a sample size bias but the intervening shales are devoid of trilobites and have a restricted fauna of isolated bryozoa (*Diplotrypa*), many in growth position, and scattered pockets of brachiopods often distorted and cleaved. Each limestone sample was crushed in the laboratory using a rock-jaw hydraulic cutter and reduced to a size of about 5 cm or less. Pieces were there after carefully searched under the microscope, all fossil fragments ringed, and where possible identified and separated according to fossil group. In sorting the ostracodes, many of the smaller trilobites were recognised at the same time; this proved especially valuable.

Articulated specimens of trilobites were rare in the samples, the majority being represented by disarticulated elements. In many cases exuviae were recognised and at certain horizons specimens of *Stenopareia* made up coquinas. Exuviae found in very fossiliferous pockets on the soles of limestone beds showed exoskeletal parts slightly displaced or not scattered far, while other examples lay at all angles to the bedding and had clearly drifted or been transported in suspension to their present site. For these reasons we have not attempted any quantification of the trilobite fauna.

Jaanusson (1976) demonstrated that the number of specimens of a species per sample size as well as the number of samples in relation to the stratigraphical thickness studied have a profound effect on resultant faunal logs of the type presented here (Figs. 2 to 5). However, we consider the size and frequency of the samples under study to be sufficient for most forms to be recovered at any given horizon and that the data presented give a reasonably accurate picture of trilobite distribution. Nevertheless, we are aware of the fact that our samples are probably not large enough to guarantee the presence of forms which even now are known only from a few specimens, among many thousands collected and identified.

**Sampling**

Each profile in the Oslo-Asker region was carefully measured from a fixed point either at the exposed top of the succession or at the base, and bulk sampling made to the nearest 30 cms or, in

**Stratigraphy**

A revised lithostratigraphical scheme for the Chasmops Beds in the Oslo-Asker area will be described elsewhere. Reasons for dispensing with the hitherto used numerical classification of ‘etasjer’ have already been presented by Owen.
(1978, 1979), who has introduced new lithostratigraphical terms for equivalent strata in Ringerike and Hadeland. These are followed here. For the Oslo-Asker Region, we have followed Størmer (1953:65) in taking as the base of the Upper Chasmops Limestone the conspicuous nodular pyrite band which occurs at the transition between the dominant shale sequence containing ellipsoidal nodules of the Upper Chasmops Shale, and the succeeding nodular to well-bedded limestones and subordinate shale succession (Brøgger 1887, Toni 1975). This pyrite band is an excellent marker horizon in the Oslo-Asker area and can be recognised in all our...
Trilobite distributions

In an unpublished study based entirely on museum collections, Owen (1977, fig. 42) listed the trilobite species occurring in the Upper Chasmps Limestone and found a marked increase in the total number of forms westwards from Oslo through Bærum to Asker. Although based on "bag-stratigraphical" samples, the data confirm the overall geographical distribution of species shown by the present work (Fig. 6), but it is now possible to assess the relative stratigraphical distribution of these taxa over the whole area. Our study has revealed 8 new species and 13 other taxa not previously recorded from Norway. Where precise horizon details are available on labels of studied museum specimens, these correspond well with the levels.
known from the measured sections as do co-occurrences of taxa on the same hand specimen. Two genera *Carrickia* sp. (one specimen) and *Primaspis* sp. (two specimens) occurring in the museum collections have not been identified in new collections. Both are from the uppermost bed of the Upper Chasmops Limestone on Skjærholmen and occur with other forms which, however, are found in our collections.

Fig. 6 shows the order of appearance of species and their relative stratigraphical ranges. The scaling of the relative positions of first appearances is based largely on stratigraphical thicknesses in the measured sections (Figs. 2 to 5). However, this assumes a similar and constant deposition rate over the whole area along with subsequent uniform compaction, especially of the shale horizons. Lacking reliable data on these factors, this approach at best gives only a close approximation to a time scale, the degree of accuracy of which can be judged from the following examples.

In Oslo-Asker, *Ampyxella aculeata* and *Ampyxina?* sp. first occur either together or within no more than 1 m of each other in each profile. Both are restricted to the highest exposed limestone bed (11.8 m above base) on Bygdøy and the uppermost bed further east on Nakholmen. The two forms first occur at 9.8 m above the base of the Fornebu profile and within 60 cm, 11.9–12.5 m above the base on east Raudskjer. This similarity in height above the base of each profile suggests that the first occurrence of these species is broadly synchronous throughout the whole area. Furthermore, all but two of the forms restricted to localities west of Fornebu first appear above this level. Similarly, *Tretaspis ceriodes* (s. 1.), *Decybele gracilis*, *Illaenus (Parillaenus) aff. fallax*, and *Stygina minor* occur only in the uppermost part of the Upper Chasmops Limestone on Kalvøya and Østøya whilst forms known only from further west occur above the first appearance of these species.

Størmer (1953:68) noted that the upper part of the Upper Chasmops Limestone in Asker is younger than in Oslo. Thus *Tretaspis ceriodes* occurs in the uppermost horizons in the western part of Bærum and in Asker, but further east is known only in the lower part of the overlying Lower Tretaspis Shale in a dark limestone 0.85–1.02 m above the Upper Chasmops Limestone.
Owen (1979) argues that this diachronism of the base of the shale unit is seen also in Ringerike to the north west, where limestones and shales of the Høgberg Member of the Solvang Formation on Frognsøya are younger than the Solvang Formation at Norderhov and the Upper Chasmops Limestone in Asker. The uppermost part of the Norderhov profile (Fig. 5) contains a very similar trilobite fauna, including *T. ceriodes*, to that of the upper beds on Raudskjer (Fig. 4).

The Solvang Formation in Hadeland (Owen 1978) contains a trilobite succession similar to that found at Norderhov and in Asker, but lack of sufficiently complete profiles in Hadeland prevents us illustrating this distribution in the way we have done for the Oslo-Asker and Ringerike sections.

### Interpretation of trilobite distribution

A survey of the underlying Upper Chasmops Shale shows this unit to have a fairly restricted trilobite fauna including *Broeggerolithus discors* (Angelin, 1854) known only in Oslo but not in Bærum or Asker. Others such as *Chasmops extensa*, *Harpidella* (s.l.) sp. A, *Remopleurides* sp. A, and *Stenopareia glaber* are less restricted and persist into the Upper Chasmops Limestone where they all have long vertical ranges.

The distribution of species within the Upper Chasmops Limestone and the Solvang Formation indicates a gradual incoming of species, the later stages of which were accompanied by the initiation of dominantly shale deposition to the east. The diachronous base of these shales marks a very pronounced faunal change and thus the largely carbonate-restricted fauna of the upper parts of the limestone units shows a progressive westward increase in endemicity. As this change is approximately at right angles to the regional strike it is not necessary to produce a palinspastic reconstruction in order to appreciate the scale of these lateral changes. Few trilobites from the Upper Chasmops Limestone and Solvang Formation are known from the overlying, and partly coeval, shale units which in Oslo-Asker and Ringerike have a fairly low-diversity fauna dominated by members of the *Tretaspis seticornis* group (of Ingham 1970) and species of *Flexicalymene*, *Decoroproetus*, and *Primaspis*.

Most species at any one time were probably distributed throughout the area of dominantly limestone deposition. This distribution may have been somewhat patchy. Thus *Calyptaulax aff. norvegicus* and *Harpidella* (s.l.) sp. A are not known from Bygdøy but occur in all other Oslo-Asker profiles described here. A few of the older species are known only from the east or west of the Oslo-Asker district. *Pseudosphaelexochus bulbosus* and *Decoroproetus* sp. A are known from the lower part of the Upper Chasmops Limestone in the Raudskjer profile but not from further east. Similarly *Carrickia* sp. and *Primaspis* sp. are known from Oslo in the east but not Bærum or Asker. All these forms are known from only a few specimens and no significance is attached to their presently known distributions.

The distribution of species of *Flexicalymene*, however, reflects some major ecological control, possibly depth, in the Oslo-Asker district. *F. scabustula* occurs at various horizons in the Bygdøy profile and the limited amount of available information suggests the same is true on Nakholmen. At Fornebu to the west, it is known only from the middle part of the Upper Chasmops Limestone. The species is not known further west where the closely related *F. jemtlandica* occurs in the upper part of the unit in Bærum and Asker and also in the Solvang Formation at Norderhov. The lower part of the stratigraphical range of *F. jemtlandica* slightly overlaps with the range of *F. scabustula*. Some form of ecological control at the generic level is shown by the distribution of *Illaenus* and *Stenopareia*. *I. (Parillaenus) fallax* and *S. glaber* coexist in the Upper Chasmops Shale but only the latter persists into the succeeding Upper Chasmops Limestone where it is abundant throughout most of the unit in all areas. At the top of the unit on Østoya, Raudskjer and Terneholmen and in the Solvang Formation at Norderhov and on Frognsøya, *S. glaber* is displaced by *I. (Parillaenus) aff. fallax* and the two appear to be mutually exclusive at this level. Both genera coexist again in younger units.

Jaanusson (1976) distinguished two types of faunal changes:

*Faunal shifts* associated with changes in local physical conditions such as lithofacies, and

*immigrations* from outside the region induced by large-scale environmental changes such as temperature.

He acknowledged that there is not always a clear distinction between these types of change.
and that in considering Ordovician successions in the Balto-Scandinavian region, the uncertainty has been compounded by insufficient data on geographical and vertical ranges of taxa. This is still true, and, in view of such uncertainties, Jaanusson used the term faunal shift for all the changes he described in Middle Ordovician benthonic faunas which are demonstrably associated with lithological changes. The abrupt change in the trilobite fauna associated with the change to dominantly shale deposition at the top of the Upper Chasmops Limestone and Solvang Formation, is clearly a faunal shift. The available evidence suggests that no such shift in the trilobite fauna occurred at the base of the Upper Chasmops Limestone.

Faunal changes described as immigrations by Jaanusson are characterized by the appearance of forms not known from older strata in the Balto-Scandinavian region and such changes are not associated with distinct lithological changes. The gradual incoming of trilobite species seen in the Upper Chasmops Limestone and Solvang Formation almost certainly represents an immigration in Jaanusson’s sense. All the species and most of the genera whose first appearance in the Upper Chasmops Limestone and Solvang Formation lies above the bases of these units (Fig. 6) are not known from lower horizons in the Oslo Region. Moreover, the available evidence suggests that the same is true for the whole Balto-Scandinavian region. Three of the new genera (Ampyxina?, Carrickia, and Tretaspis) are known only from earlier horizons in association with North American faunas.

Remarks on correlation
Correlation between areas in the Balto-Scandinavian region is still hampered by faunas elsewhere being in need of modern documentation and description. Nevertheless among trilobites described by Thorslund (1940) from the Upper Chasmops Limestone in the autochthonous sequence in Jemtland, Sweden, the following forms are the same as Norwegian species: Tretaspis ceriodes (Angelin, 1854), Triarthrus linnarssoni Thorslund, 1940 and probably Flexicalymene scabustula Siveter, 1977?, Stenopareia ‘avus’, and Ampyxella aculeata (Angelin, 1854). Pseudosphaerexochus tværnessi Thorslund, 1940 is closely related to the Norwegian form P. bulbosus.

Dean (1960, 1963a) has commented on the strong similarity between trilobite faunas in the Upper Chasmops Limestone with those of the Actonian and Onnian stages in the type Caradoc succession of Salop (Shropshire), England. This similarity applies to both the generic and specific association. The following species from the type Actonian (A) and Onnian (O) stages occur in the Upper Chasmops Limestone in Oslo-Asker and the Solvang Formation at Norderhov, Ringerike, or are closely related to forms which do occur there:

- Ampyxella edgelli (Reed, 1932) (A & O)
- Calyptaulax actionensis Dean, 1961 (A)
- Chasmops extensa (Boeck, 1838) (A & O)
- Lonchodomas pennatus (LaTouche, 1884) (A & O)
- Platylласhas laxatus (McCoy, 1846) (A & O)
- Tretaspis ceriodes (Angelin) favus Dean, 1963a (A & O)
- Remopleurella burmeisteri (Bancroft, 1949) (O)

Species of Flexicalymene from the Norwegian units are likewise closely related to those assigned to Onnicalymene from Salop by Dean (1962, see Siveter 1977). The genus Gravicalymene Shirley, 1936 occurs in the type Actonian and Onnian but its niche in the Upper Chasmops Limestone fauna was occupied probably by Prianocheilus Rouault, 1847.

The range of Tretaspis ceriodes favus in Salop may be slightly different from that given by Dean (1963a), who described the subspecies from just above and below the Actonian-Onnian boundary in the banks of the River Onny and from supposed Actonian strata near Cardington. Specimens collected by one of us (A.W.O.) from the latter locality are associated with Onnia gracilis (Bancroft, 1929), the supposed index fossil for the middle part of the Onnian Stage. Species of Onnia are a characteristic feature of Onnian assemblages in Salop and northern England (Dean 1960, 1962, 1963a, Ingham 1966, 1974) but the genus is unknown in Scandinavia (Owen in Hughes, Ingham & Addison 1975:597).

The olenid Triarthrus linnarssoni Thorslund, 1940 described by Dean (1963) from the uppermost part of the Onnian Stage, is not known from the Upper Chasmops Limestone, but we have identified it (= Triarthrus cf. skutensis of Nikolaisen 1965) together with Tretaspis ceriodes (sensu lato) in the lowest part of the Lower Tretaspis Shale on Nakholmen, Oslo.

The faunal distribution data presented herein...
help further to explain the relationship between the younger parts of the succession in Oslo-
Asker and Ringerike. Previously Kier (1921) and
Størmer (1953:87) believed, on the basis of the succession of *Tretaspis* species, that in Ringe-
rike the occurrence of *T. kiaeri* Størmer, 1930
indicated a hiatus in Oslo-Asker where it is
absent. Owen (1979) argued that the fauna of the
*T. kiaeri*-bearing Høgberg Member of the Sol-
vang Formation on Frognsyta (essentially ‘4bø’
of Størmer) simply represents a later phase in the
immigration of largely limestone-restricted
species than is seen in the Upper Chasmops
Limestone. The correlation of the Høgberg
Member with the standard British succession
has been discussed by Dean (1971: 14, 47-48),
Brøgger (1975: 712), and Owen (1979). The latter
has shown that it is probably lowest Pusgillian in
age because it contains *S. seticornis seticornis*
(Hisinger, 1840). Members of this group (sensu
Ingham 1970) succeed *T. cerioides* without over-
lap and independently of lithology in Scan-
dinavia and Britain. In the case of the lat-
ter, they occur at the Onnian-Pusgillian (i.e.

Also occurring in the Høgberg Member and
confirming its age are *Phillipsinella preclara*,
known also from the highest part of the Pusgillian
at Cross Fell (Brøggen 1976), and *Pseudosphaer-
exochus densigranulatus* Nikolaisen, 1965 which
is the same as *P. aff. tectus* of Ingham (1974)
from Pusgillian horizons at Cross Fell and in the
Cautley area.

In the absence of graptolites from the Upper
Chasmops Limestone no precise correlation can
be made with the standard British graptolite
sequence. Nevertheless the trilobite faunas de-
tailed here provide the best available means of
correlation so far with British late Caradoc and
Ashgill shelly assemblages and hopefully this
may be refined further when results of other
groups, among them the brachiopods currently
being studied by Dr. M. G. Bassett, are made
known.

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