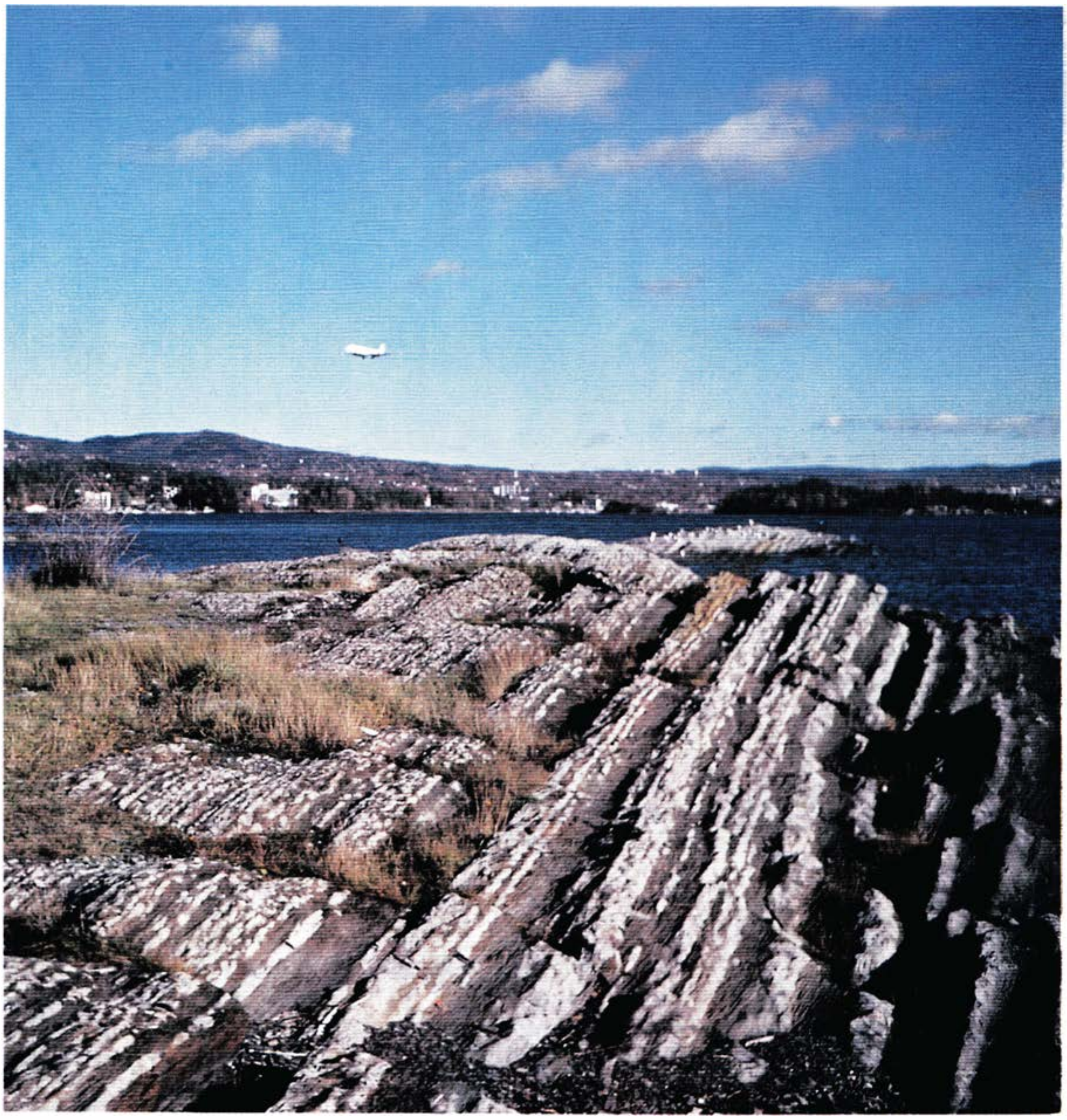
NORGES GEOLOGISKE UNDERSØKELSE

THE ORDOVICIAN SUCCESSIONS OF THE OSLO REGION, NORWAY

Alan W. Owen, David L. Bruton,
J. Fredrik Bockelie & Tove G. Bockelie

Special Publication 4



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Cover illustration: View northeast across Lysakerfjorden below Fornebu airport, Bærum. In foreground, hypostratotype section of Frognerkilen Formation with dark shales of Arnestad Formation below. In the middle ground, the islands of Killingen and Bygdøy, stratotype section of Huk Formation. In background, the city of Oslo and the Permian igneous rocks of Vettakollen and Holmenkollen on the left. Photo – D. L. Bruton.

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The Ordovician successions of the Oslo Region, Norway.

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The Ordovician successions of the Oslo Region are subdivided in terms of a modern lithostratigraphical scheme. Twenty-nine formations are defined; some of which are subdivided into stratigraphical or geographical members. Type localities (including hypostratotypes) are designated and many illustrated by measured sections. Provisional correlations with the standard British and the Baltic chronostratigraphical schemes are made but highlight the lack of good biostratigraphical controls at several levels. The Tremadoc to Llanvirn lithostratigraphy shows considerable uniformity over the Oslo Region but the remainder of the Ordovician shows some marked lithofacies contrasts between, and even within, districts.

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Contents

Introduction

During the past two decades a wealth of information on the stratigraphy of the Ordovician rocks of the Oslo Region has been presented in degree theses and in published form. Many of these works point to the need for a comprehensive, modern lithostratigraphical scheme to be applied to the region. The existing 'etasje' nomenclature established almost exclusively in the Oslo-Asker district (Kjerulf 1857; Brøgger 1882, 1887; Kiær 1897, 1902) was essentially lithostratigraphically based. Subsequently this scheme was imposed on successions elsewhere in the region, commonly on faunal grounds only and a chronostratigraphical usage, both implicit and explicit, has developed (Henningsmoen 1961, 1982). Many of the recent studies involving detailed mapping and faunal work have demonstrated that a chronostratigraphical etasje nomenclature is at best imprecise and commonly inapplicable outside, and in some cases within, Oslo-Asker. The same conclusion was reached by workers on the Silurian of the region and a stratigraphical revision similar to the present work has been produced (Worsley et al. 1983). We therefore advocate the complete replacement of the etasje system and propose the purely lithostratigraphical scheme outlined below. This is the result of our own field observations and a consideration of the detailed studies produced by other workers. We have tried to conserve existing stratigraphical names which conform to modern usage wherever possible. Some units have had to be redefined in the light of recent work and many of the terms used here are new.

The present study was initiated in 1979 when it was intended that the order of authorship should be alphabetical and various works (e.g. Owen 1981, Wandås 1984) referred (prematurely) to 'Bockelie et al.'. However, pressure of work has prevented two of us (JFB and TGB) from playing as full a role in the project as was intended and consequently the authorship order has been essentially reversed. The first two authors therefore accept a greater share of criticism for any errors or inadequacies that might appear in the paper. Moreover, the delays in completing the present work have resulted in the new formation names for the Arenig to Ashgill succession in Oslo-Asker being published without detailed definition by one of us (Owen 1981, 1987) as a necessary framework for descriptions of the trilobite faunas. These units are formally defined herein.

Setting

The Oslo Region was defined by Størmer (1953 pp.51-53, Fig. 1) to comprise eleven districts in a NNE-SSW trending strip of southern Norway some 220km long and 40-70km wide (Fig. 1). Its present lateral limits are essentially those of a Permian graben (Dons & Larsen 1978) but during the early Palaeozoic it was a cratonic basin (Størmer 1967, Ramberg 1976, Bockelie 1978, Worsley et al. 1983). The Cambrian to Silurian succession is considerably thicker, more complete and with a greater siliciclastic content than is seen in contemporaneous platform sequences elsewhere on the Baltic Craton (Bruton et al. 1985). The nappes and obduction slices of the Scandinavian Caledonides did not have a significant effect on sedimentation in the region until the mid-Silurian although geochemical evidence suggests a subtle and increasing input from the advancing nappes from the Middle Ordovician onwards (Bjørlykke 1974, Bruton et al. 1985, Bruton & Harper 1988).

The Lower Palaeozoic successions are preserved within the various districts of the Oslo Region along with Precambrian gneisses and Permian igneous rocks (Fig. 1). In some districts Carboniferous and Lower Permian sedimentary rocks underlie Permian lavas (Henningsmoen 1978, Olaussen 1981). The Lower Palaeozoic rocks of the southern districts, Skien-Langesund and Eiker-Sandsvær are gently tilted but those of the rest of the region show varying degrees of folding and faulting. The northernmost part of the Mjøsa area, Ringsaker, at the northern end of the Oslo Region, has a Lower Palaeozoic succession which overlies a thick sequence of late Precambrian sediments. The whole succession here has been thrust southwards at least 150km and forms part of the Osen-Røa Nappe Complex (Nystuen 1981, 1982, 1987). The Ordovician successions of the rest of the region are also considered to be only parautochthonous with décollement zones situated at the base of, or within, the Cambrian Alum Shales (Ramberg & Bockelie 1981; Harper & Owen 1983; Bockelie & Nystuen 1985; Morley 1986, 1987). Extensive thrusting is also present locally at higher stratigraphical levels (Harper & Owen 1983).

The Ordovician rocks of the region largely comprise alternating shale (or mudstone) and limestone units (see Bjørlykke 1973, 1974a, 1974b; Henningsmoen 1974 and Möller & Kvingan 1988 for discussions of the possible origins of the limestones). Sandstones are rare, except in the uppermost Ordovician and volcanic rocks are restricted to bentonite horizons in the Middle Ordovician of Oslo-Asker (Hagemann & Spjeldnæs 1955).

History of Research

Summaries of the first century of systematic studies on the Ordovician successions of the Oslo Region up to the early 1950's have been given by Størmer (1953) and Henningsmoen (1982). It is sufficient to note here that the stratigraphical contributions of Kjerulf (1857), Brøgger (1882, 1887) and Kiær (1897, 1902, 1908) provided the foundation on which all subsequent work was based and the field observations of these workers are as relevant and useful today as they were then. The 'Middle Ordovician of the Oslo Region' project

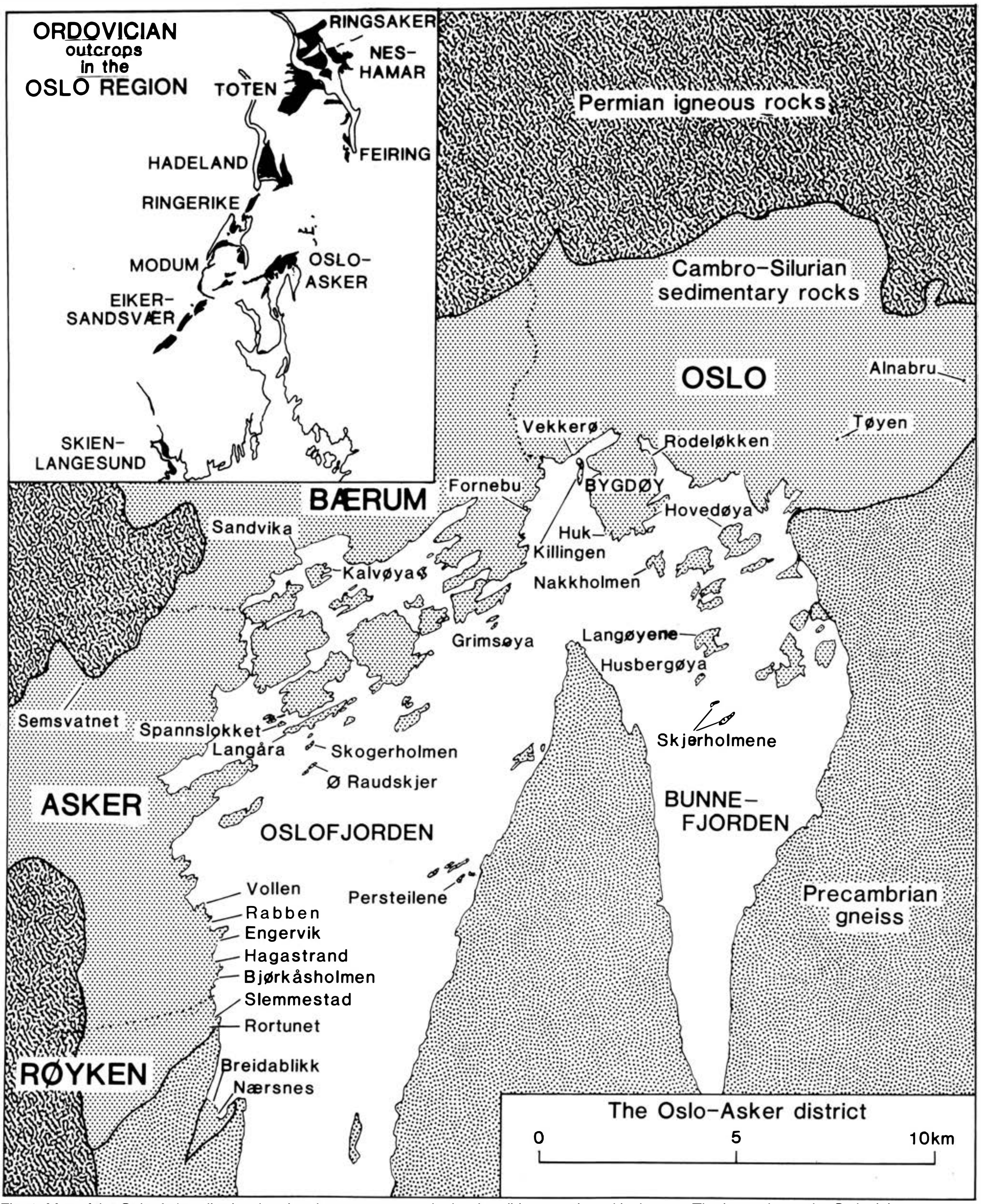

Fig. 1. Map of the Oslo-Asker district showing the stratotype and other localities mentioned in the text. The inset shows the Ordovician outcrops in the districts of the Oslo Region defined by Størmer (1953).

initiated by Størmer in 1953 has attracted works by international specialists in a variety of fields and these are published in Norsk Geologisk Tidsskrift (see Bruton & Williams 1982, pp.215-216 for a list of the first 30 contributions to this series). The Lower and Upper Ordovician have received proportionally less attention until recent years partly as a result of the focus provided by Størmer's project.

The Ordovician faunas of the Oslo Region have received considerable, if patchy, interest over the years. Thus whilst the trilobites, brachiopods and echinoderms are now fairly well known, much remains to be done on, for example, the molluscs. Published sedimentological and especially petrographic work on the Ordovician successions is comparatively rare. With the exception of geochemical studies (Bjørlykke 1974) and facies analyses (Seilacher & Meischner 1964) of the Lower Palaeozoic succession as a whole, the only major published studies have been on the uppermost Ordovician of the Oslo-Asker district (e.g. Brenchley & Newall 1975, 1977, 1980; Brenchley et al. 1979) and on Late Caradoc carbonate units in the northern and southern extremities of the region (Harland 1980, 1981, 1981a; Opalinski & Harland 1981). Largely unpublished sedimentological studies include those of Fjelldal (1966), Skaar (1972), Lervik (1969), Hanken (1974), Rønning (1979), Harwood (1985), Kvingan (1986) and Heath (1989).

Approach Adopted

The present paper provides a definition of the Ordovician formations (and in some instances, members) of the Oslo Region in terms of stratotype development and gross variation seen in other outcrops. A recommendation from the Norwegian Stratigraphical Committee that units be defined by basal stratotypes is adopted as are other procedures outlined in their recent nomenclatorial rules (Nystuen 1986, 1989). Measured sections for newly defined units or at least their basal stratotypes are given and reference made to previously published sections wherever possible. Hypostratotypes are designated to show the geographical variation and extent of many formations. Terms previously ascribed to a unit are also summarized but as many of there were never precisely defined there is not always a precise equivalence in these synonymies. Wherever possible, names and spellings used on the present 1:50,000 topographical maps are used in constructing formation names and this has entailed some minor changes in the spelling of some existing terms. A policy of *nomen conservatum* might have been preferable for the spelling of established names which differ from the spelling on more recent maps but the adopted policy is the result of firm recommendations from the Norwegian Stratigraphical Committee. The expression of the unit names in Norwegian is given at the beginning of each section. Where the systematic variation in thickness of a unit is known, this is given in the section in its definition. Where only local thicknesses are known, they are listed under a separate heading and give at least an impression of geographical variation.

We have not formally assigned the Ordovician formations to groups although Kjerulf (1857; see Størmer 1953 p.47) did so essentially for Oslo-Asker (a scheme being modified by Naterstad et al. in press) as did Owen (1978) for the Middle and Upper Ordovician of Hadeland. Such grouping of units is best done in conjunction with either detailed mapping of an overall assessment of sedimentation.* The scheme proposed here is a basic framework which is essential at the present time in order to accommodate the considerable biostratigraphical data which are accumulating. These will ultimately provide a much firmer basis for chronostratigraphical correlation with the established British and Baltic standards. Impetus for this also comes from the IUGS Balto-Scandia Ordovician Chronostratigraphy Working Group established in 1983 and from the need for modern lithostratigraphical terms to be used on maps currently being compiled by Norges Geologiske Undersøkelse. An environmental interpretation of the litho- and biofacies is not undertaken here but will form part of later detailed studies once the time equivalence of parts of the succession is better known.

The Tremadoc to Llanvirn lithostratigraphy shows considerable uniformity over the Oslo Region and, indeed, the Tremadoc and lower Arenig formation names can be applied over much of the Baltic area (e.g. Jaanusson 1982, Fig. 4). From the Llandeilo onwards, marked differences in lithofacies between districts are developed (Plate 1) and the organization of the paper reflects this. A brief summary of the Ordovician succession in each district is also given. The grid references of all the localities mentioned in the text are listed in the appendix and locations in Oslo-Asker are also shown in Fig. 1.

* Cand. Real. Johan Naterstad, pers. comm. 15/3/1990, informs us that in connection with the publication of the new map sheet Asker (Naterstad et al. in press), the Røyken Group will include the shales and continuous limestone units from the Middle Cambrian (Alum Shale Formation) up to and including the Ordovician Huk Formation, and the Oslo Group will cover the succeeding nodular limestone, shale and sandstone formations to the base of the Silurian. The Røyken and Oslo groups together with those to be defined for the Silurian are assigned to the Oslofjord Supergroup.

Stratigraphy

ALUM SHALE FORMATION (Alunskiferformasjonen)

Discussion. The Alum Shale Formation can be recognised over a large portion of Baltoscandia both in the platform sequences and the Caledonian nappes. It extends from the Middle Cambrian to lowest Ordovician and ranges in thickness from about twenty to almost a hundred metres and has been the subject of detailed reviews by Martinsson (1974) and Andersson et al. (1985). The formation has yet to be formally defined and this is beyond the scope of the present work. It is composed largely of black, organic rich shales, which give a black streak, together with discontinuous beds and concretions, some several cubic metres in size, of dark bituminous limestone ('stinkstone'). The shales have a very low $CaCO_3$ content and are enriched in a variety of trace elements including uranium, vanadium, molybdenum and nickel (Bjørlykke 1974, Andersson et al. 1985, Berry et al. 1986).

Although at the time of writing an international stratotype for the base of the Ordovician System has yet to be selected, it will almost certainly lie at a point equivalent to a level within the uppermost part of the Alum Shale. Bruton et al. (1982, 1988), have suggested that this level may be at the first appearance of the olenid trilobite *Boeckaspis hirsuta* in the section at Nærsnes, Røyken, south of Asker. The level approximates to the base of what has historically been termed the Dictyonema Shale (Strand & Henningsmoen 1960, Henningsmoen 1973) but this is a purely biostratigraphical unit and it lies in a uniform sedimentary sequence of Alum Shale. 'Dictyonema Shale' has been described from many parts of Scandinavia and the Baltic area (see Erdtmann 1982, Jaanusson 1982, Jaanusson & Mutvei 1982, Karis 1982, Henningsmoen 1973).

Near the top of the Alum Shale Formation in Oslo Asker is a 15-40cm thick black, planar limestone (the 'Platypeltoides incipiens Limestone' - see Henningsmoen 1973 p.431 for discussion). It is well exposed in a road cutting near the Rortunet Shopping Centre in Røyken (Fig. 2) where it is overlain by up to 6cm of black shale with a black streak, identical to that of the underlying shales and then a 12-20cm black planar limestone. At the top of this is a prominent pyrite horizon forming the base of the succeeding 6.5m of blocky dark grey shales which have a black streak in the lower half metre above which the streak becomes progressively paler up succession. In an unpublished thesis, Gjessing (1976) assigned the 'Platypeltoides Limestone' (his Vækerø Member) and the overlying shales with a black streak to the Alum Shale Formation. He termed the shales with a white streak the Breidablikk Shale Member of the Nærsnes Formation within which he also included the Ceratopyge Limestone as a second member (our Bjørkåsholmen Formation, see below). The use of the name Vækerø was most unfortunate as in an earlier thesis Fjelldal (1966) had defined a Vækerø Formation which comprised the Ceratopyge Limestone and overlying Vestfossen

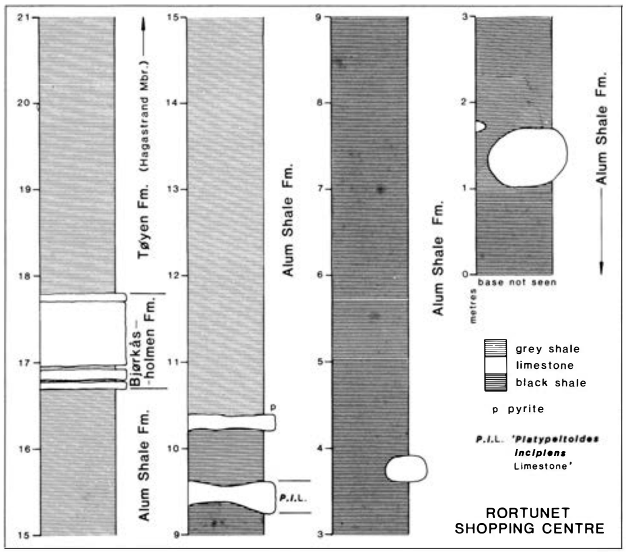

Fig. 2. Measured section of the road section near the Rortunet Shopping Centre, Røyken (NM 835280), from the Upper Alum Shale Formation through the Bjørkåsholmen Formation into the lower part of the Tøyen Formation.

Member (see below). Most of Gjessing's measured sections are incomplete, faulted or contain igneous intrusions. Moreover, his approach differed markedly from the traditional inclusion of all the beds between the base of the 'Platypeltoides Limestone' and the base of the 'Ceratopyge Limestone' as the 'Ceratopyge shales' (see Henningsmoen 1973, p.431). As the shales immediately above the 'Platypeltoides Limestone' are indistinguishable from those underlying it we include the whole sequence up to the base of the 'Ceratopyge Limestone' in the Alum Shale Formation. However, the 'Platypeltoides Limestone' marks an important faunal change (Henningsmoen *op. cit*) and is a useful informal unit. It is present throughout Oslo-Asker and also at Vikersund (Wandås 1982, p.136). It may be absent from Eiker-Sandsvær as indicated by work on borehole cores by Gjessing (1976) and outcrop mapping by Gjessing (1976) and Cadow (1985) although Brøgger (1882 pp.28-29, text-fig. 1) suggested that a 30cm horizon of nodules at Vestfossen may represent this limestone. The 'Platypeltoides Limestone' contains the trilobites *Platypeltoides incipiens, Ceratopyge forficula, Peltocare norvegica* and species of *Conophrys, Orometopus* and *Apatokephalus* (see Størmer 1920, Henningsmoen 1973, Gjessing 1976). The overlying shales are poorly fossiliferous but have yielded *C. forficula,* and the graptolites *Bryograptus ramosus, Kiaerograptus kiaeri* and *Triograptus* (Spjeldnæs 1985). Gjessing (1976, pp.112, 114) collected a large fauna from a limestone nodule in the shales at Killingen. This comprised *C. forficula, Euloma ornatum, Conophrys pusilla, Høypermecaspis inflecta, Parabolinella limitis, Asaphellus sp.,* agnostids, *Broeggeria salteri, Conotreta sp.* and *Orbithele ceratopygarum.* These faunas indicate a late Tremadoc age. Equivalent beds are largely absent from mainland Sweden (but see Karis 1982, p.55 for the allochthon in Jämtland) but are well known from the island of Øland where the 1.7-2.7m thick 'Ceratopyge Shale' is poorly fossiliferous but contains a fauna similar to that in Norway (see Tjernvik in Magnusson 1956, Jaanusson & Mutvei 1982, pp.4-5).

BJØRKÅSHOLMEN FORMATION (Bjørkåsholmformasjonen)

(New name)

(Previously termed: 3aα, Der Ceratopygen kalk, Ceratopygekalk, Ceratopyge Limestone).

Main Lithology. Limestone (Bjørkåsholmen Limestone, Bjørkåsholmkalken)

Basal Stratotype. Oslo-Asker: Bjørkåsholmen (Fig. 3) (NM 844 294).

Hypostratotypes. Oslo-Asker: Hagastrand (Fig. 4) (NM 842 297), and Vekkerø (Fig. 5) (NM 925 432). Ringerike: Haug skole (NM 734 717). Eiker-Sandsvær: Hals (NM 486 230). Vikersund: Øvre Øren Farm (NM 556 444).

Thickness variation. Oslo-Asker: Bjørkåsholmen (1.2m), Rortunet Shopping Centre (1m), Vekkerø (1m), Hagastrand (1.2m), Engervik (Fig. 6) (1.2m). Ringerike: Haug Skole (1.05m). Eiker-Sandsvær.Krekling (0.6m). Modum (Vikersund): Øvre Øren Farm (1.3m).

Definition. The base of the Bjørkåsholmen Formation is an abrupt change from the dark grey shales of the underlying Alum Shale Formation to pale weathering nodular limestone. The lower part comprises pale grey, irregularly bedded limestones with thin intercalations of shale. These limestones contain dark concretions at the base along with pale limestone clasts up to about 2cm long. The shales are locally graptolitic. At the Rortunet Shopping Centre the succeeding 74cm is composed of a single bed of grey limestone and is overlain by an 8cm 'glauconitic' (but see Bjørlykke 1974, p.13) limestone bed but at other localities (e.g. Bjørkåsholmen and Hagastrand) shales are developed in the uppermost part of the 'main'

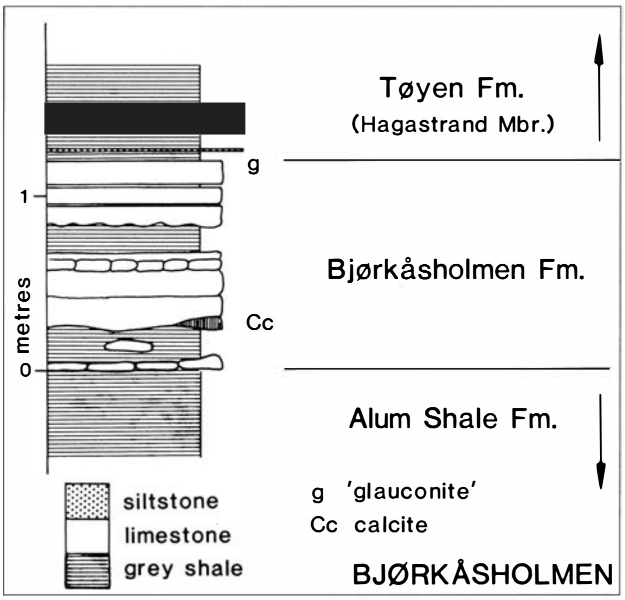

Fig. 3. Measured section through the basal stratotype of the Bjørkåsholmen Formation and its contiguous formations at Bjørkåsholmen, near Slemmestad, Asker (NM 844294).

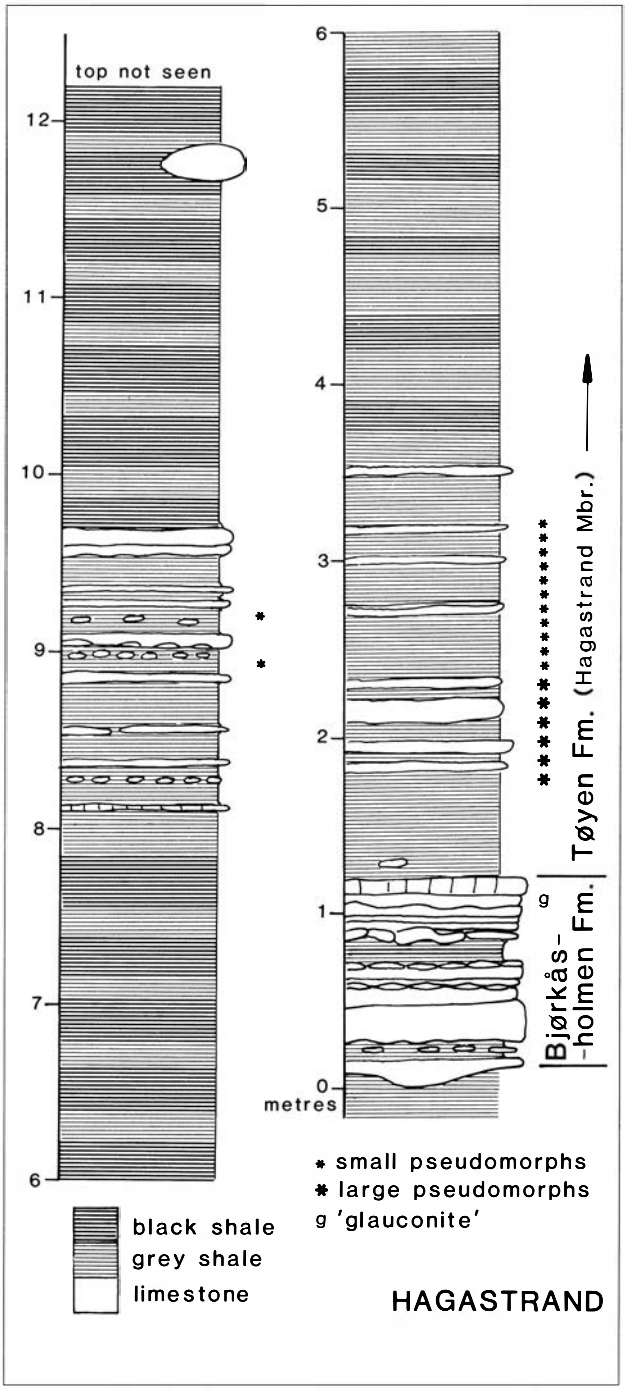

Fig. 4. Measured section through the hypostratotype of the Bjørkåsholmen Formation and the neostratotype of the Tøyen Formation at Hagastrand, Asker (NM 842297). Note that the calcareous beds in the lower 2m of the Tøyen Formation weather rusty red but are poorly differentiated from the grey shales in less weathered parts of the section.

(thick) limestone and beneath the 'glauconitic' limestone (e.g. see Fjelldal 1966, Fig. 30 and Figs. 3, 4 herein). A detailed petrological study of the formation in Oslo-Asker and Eiker-Sandsvær was given by Fjelldal in an unpublished thesis (1966).

Age. The diverse shelly fauna of the Bjørkåsholmen Formation in the Oslo Region was listed and discussed by Brøgger (1882, pp.16-17; 1898). Some

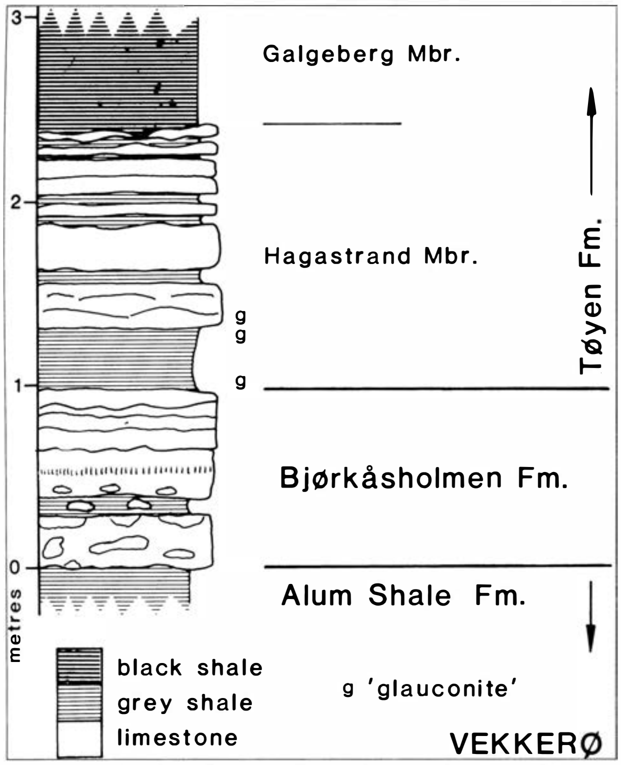

Fig. 5. Measured section through the hypostratotype of the Bjørkåsholmen Formation and the overlying Tøyen Formation at Vekkerø, Oslo (NM 925432). The development of limestones in the Hagastrand Member of the Tøyen Formation is the 'Vestfossen Member' of Fjelldal (1966, see also Erdtmann 1965).

trilobite species have been redescribed more recently by Størmer (1940) and Henningsmoen (1959); the latter also providing a list of the whole trilobite fauna. The trilobites constitute the *Euloma-Niobe* fauna of Brøgger (1898 - see also Henningsmoen 1973) which is also present in the uppermost part of the Alum Shale Formation and is characteristic of the latest Tremadoc.

The Bjørkåsholmen Formation is widely developed in Sweden where Tjernvik (1956) discussed its fauna and distribution. Characteristic trilobites include *Ceratopyge forficula, Triarthrus angelini, Euloma ornatum, Apatokephalus serratus* and *Niobe insignis*. Other elements of the fauna include cephalopods, gastropods, echinoderms, brachiopods and bryozoans.

TØYEN FORMATION (Tøyenformasjonen)
(Erdtmann 1965)

(Previously termed: 3b, Phyllograptusskifer, under Didymograptusskifer, Untere Graptolithschiefer, Unteren Didymograptusschiefer, Der Phyllograptusschiefer, Lower Didymograptus Shale, Phyllograptus Shale).

Main Lithology. Black and grey shale (Tøyen Shale, Tøyenskiferen).

Neostratotype. Oslo-Asker: Hagastrand, (Fig. 4) (NM 842 297).

Thickness variation. Oslo-Asker: Engervik (20.53m), Tøyen (19.75m). Eiker-Sandsvær: Hals (?min 4.29m), absent in south of district. Modum (Vikersund): 7.5m Øvre Øren Farm (7.5m). Ringerike: Løkenåsen (~20m). Hadeland: Tuv (>15m).

Definition. The original stratotype for the Tøyen Formation (Erdtmann 1965) was a temporary tunnel section at Tøyen, Oslo. This is no longer exposed and as there are no other sufficiently complete sections within Oslo, a neostratotype (see Hedberg 1976, p.26) is here designated immediately to the west, at Hagastrand in Asker (Fig. 4). The lowest member (the Hagastrand Member) is complete along the foreshore here as is the base of the overlying Galgeberg Member. This uppermost member is fully exposed in a shore section at Engervik only 500m to the north (Fig. 6). The base of the Tøyen Formation marks an abrupt change from the limestones of the Bjørkåsholmen Formation to shales with subordinate limestone horizons. The top of the formation is similarly distinctive, contrasting with the thick limestones of the Huk Formation. Only in the Mjøsa districts do the overlying basal beds of the Huk Formation include a significant amount of shale.

Discussion. The Tøyen Formation is known from all but the southerly parts of the Oslo Region and extends into Västergötland, Jämtland and Skåne in Sweden (Erdtmann 1965, Jaanusson 1982, Jaanusson, Larsson & Karis 1982, Bergström 1982) although its stratigraphical range in Sweden is locally more restricted than in Norway. Within the Oslo Region the formation is dominated by shales although limestones, (the Vestfossen Member of Fjelldal 1966) are developed at or near the base in northern Eiker-Sandsvær and locally in Oslo-Asker. Two distinct shale members are recognised over most of the region with the black shales of the Galgeberg Member succeeding the rusty weathering striped shales of the Hagastrand Member. In the thin developments of the formation in Eiker-Sandsvær and Modum, however, only the Galgeberg Member is present. It is not yet known whether this indicates an hiatus at the base of the formation in these areas as suggested by Erdtmann (1965).

In his original description of the Tøyen Formation, Erdtmann (1965) defined a member at the very top of the formation, the Slemmestad Member. As is noted below, this was done on faunal grounds rather than at a distinct lithological change and these strata are here reassigned to the Galgeberg Member.

Age. Although the Galgeberg Member is the only richly graptolitic member of the formation, the Hagastrand Member has yielded a few graptolites and the locally developed limestones at or near the base of the formation contain a shelly fauna dominated by trilobites. Erdtmann (1982) and Bruton & Erdtmann (1980) have discussed the problem of correlating the Hagastrand Member with the British series at around the Tremadoc-Arenig boundary and concluded that it equates with the Hunneberg Substage in Sweden. The fauna of the Galgeberg Member in Oslo-Asker undoubtedly indicates a range from the *Tetragraptus approximatus* to the lower part of the *Didymograptus hirundo* zones (Spjeldnæs 1953, Ertdmann 1965) and thus is equivalent to virtually the entire British Arenig (see Fortey & Owens 1987, Fig. 5).

Hagastrand Member (Hagastrandleddet)
(Erdtmann 1965)

(Previously termed: 3b?, 3b α (*pars*) 3b A (*pars*)).

Main Lithology. Black and grey striped shale.

Neostratotype. Oslo-Asker: Hagastrand (Fig. 4) (NM 842 297).

Thickness variation. Oslo-Asker: Hagastrand (10.6m) (Fig. 4), Tøyen (7.32m), Engervik (10.68m) (Fig. 6). Ringerike: Haug Skole (2.2m). Hadeland: Tuv (>3m).

Definition. The base of the Hagastrand Member marks the change from the limestones of the Bjørkåsholmen Formation to a sequence dominated by shales. At the neostratotype locality (Fig. 4) the lowest 2.3m comprises grey and rusty-weathering shales with limestone beds up to 15cm thick. There are thin strings of pyrite nodules in the lowest 50cm and pseudomorphs of calcite after ?barytes (Bjørlykke 1974, p.14) occur in the succeeding 1.55m. Barium feldspar is also present in the pseudomorphs (Bjørlykke & Griffin 1973). The overlying 4.6m of the member comprises grey and black striped shales followed by 1.5m

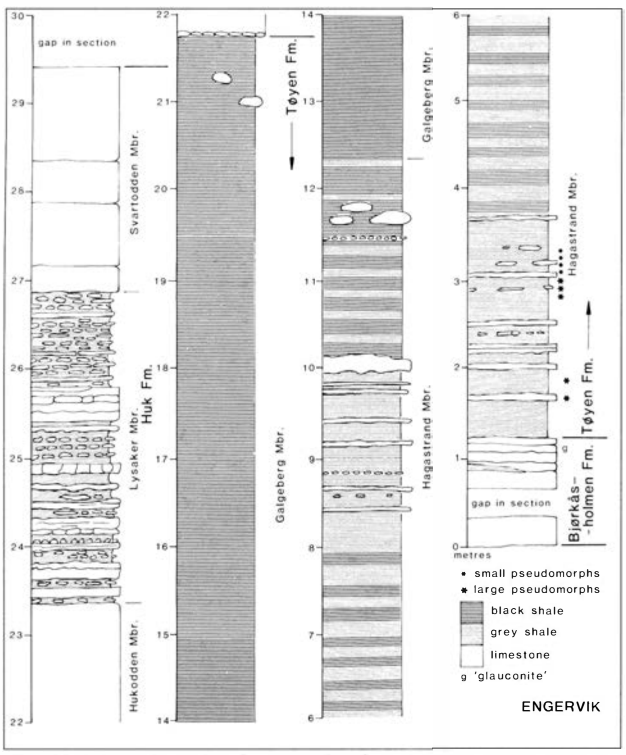

Fig. 6. Measured section through Bjørkåsholmen Formation, Tøyen Formation (including the neostratotype of the Galgeberg Member) and the hypostratotype of the Huk Formation at Engervik, Oslo (NM 843302 - 845306). The lower part of the sequence is repeated to the immediate north of this section.

of grey shales with thin, rusty weathering limestone beds and nodules. The uppermost part of the member comprises 2.2m of striped shale with a horizon of 20cm thick isolated limestone nodules at the top. An identical succession is well exposed at Engervik, 500m to the north (Fig. 6).

Discussion. The Hagastrand Member is present in Eiker-Sandsvær, Oslo-Asker, Ringerike, Hadeland and the Mjøsa districts but is considerably thinner outside the type district.
In parts of Oslo and in Eiker-Sandsvær up to 1.15m of limestone with subordinate shale (the Vestfossen Member of Fjelldal 1966) is developed within or above the Hagastrand Member. Thus at Vekkerø (Fig. 5) some 0.96-1.3m of grey and rusty weathering shales are developed between the Bjørkåsholmen Formation and these limestones which in turn are overlain by black shale of the Galgeberg Member. On nearby Killingen however, approximately a metre of grey shales with a few limestone nodules is developed between the limestones and shales and the Galgeberg Member.

Erdtmann (1965, p.525) noted the presence of the "Vestfossen Member" at Vekkerø which he interpreted provisionally as a 'facies island' not connected with the development in Eiker-Sandsvær. It seems reasonable, however, to postulate a zone of carbonate accumulation encompassing the two areas, perhaps situated on a topgraphic high above the periodically abiotic sites of mud accumulation.
A grey shale with limestone lenses is locally developed in the lower part of the Tøyen Formation in Ringsaker (Strand 1929; Skjeseth 1952, 1963; Erdtmann 1965) and was termed the Steinsodden Shale and Limestone by Skjeseth (1963, p.70). It may prove to be an equivalent of part of the Hagastrand Member or may, as Skjeseth (1963) suggested, best be included with the underlying formation. Detailed examination of the Ringsaker exposures is required before this problem can be resolved.

Fauna and Age. The shales of the Hagastrand Member have yielded a few graptolites, including *Kiaerograptus, Didymograptus protobalticus* and *Tetragraptus phyllograptoides* (Erdtmann 1965, 1982). Erdtmann (1965, Fig. 3) also recorded the trilobite *Megistaspis planilimbata* from a limestone horizon near the top of the unit suggesting a correlation with the upper Hunneberg Substage of Sweden. The difficulties of correlating the graptolite faunas with the British Tremadoc and Arenig series were discussed recently by Bruton & Erdtmann (1980) and Erdtmann (1982) who noted that the Hagastrand Member equates to levels within the overlap of the various definitions of the two series and is equivalent to the Hunneberg Substage in Sweden.

The trilobite fauna from the limestones and shales at the base of the formation in Eiker-Sandsvær includes *Megistaspis (Ekeraspis) armata, Niobella sp. Varvia sp.* and *Symphysurus sp.* (Klemm 1982, p.142). The first of these is the eponymous species of the *Megistaspis (Ekeraspis) armata* trilobite Zone in Sweden which is equated with the lower Hunneberg Substage of the Latorp Stage, the earliest dichograptid faunas and the lower *Paroistodus proetus deltifer* conodont Zone (see Tjernvik & Johansson 1980, Jaanusson 1982, Löfgren 1985, Bergström 1986). Erdtmann (1965, pp.524-5, Fig. 9) argued that there may be an hiatus at the base of the Tøyen Formation in Eiker-Sandsvær and that the graptolites in the overlying shales indicate a correlation with levels within the lower part of the Galgeberg Member at Tøyen, Oslo.

Galgeberg Member (Galgebergleddet)

(Erdtmann 1965)

(Previously termed: 3bα (pars) 3bβ−ε. 3bA (pars), 3bB-C).

Main Lithology. Black shale.

Neostratotype. Oslo-Asker: Engervik (Fig. 6) (NM 843 302)

Hypostratotypes. Eiker-Sandsvær: base - Skarakrysset, Vestfossen (NM 472 223), top - Råen (NM 459 176). Modum (Vikersund): Øvre Øren Farm (NM 556 444). Ringerike: Løkenåsen (NM 732 720). Hadeland: Helgåker (NM 847 945).

Thickness variation. Oslo Asker: Engervik (12m) (Fig. 6), Tøyen (12.43m) Eiker-Sandsvær: Hals (>3.72m). Modum: Øvre Øren Farm (7.5m). Ringerike: Løkenåsen (>20m). Hadeland: Helgåker (?>15m), Tuv (12m).

Definition. The base of the Galgeberg Member marks a sharp lithological change to black graptolitic shales from the striped shales and limestone nodules of the Hagastrand Member in parts of Oslo-Asker (including the neostratotype), Ringerike, Hadeland and Mjøsa, or from the limestone and shales of the "Vestfossen Member" in Eiker-Sandsvær and part of Oslo-Asker or from limestones of the Bjørkåsholmen Formation in Modum. The member is dominated by black shales with pyrite-bearing horizons. In Oslo-Asker isolated limestone nodules are developed in the uppermost metre and the shales become paler towards the base of the overlying formation. These upper beds were described by Spjeldnæs (1953 p.172) at Slemmestad, Asker and formed the basis for Erdtmann's (1965) Slemmestad Member. However, as Erdtmann (1965, p.488) noted, his base of this member was defined on faunal grounds not at an abrupt lithological change. These strata are here reassigned to the Galgeberg Member although they could eventually form the basis of a local biozone. Many of the exposures of the member in the Oslo Region show evidence of tectonism and thus the thickness estimates in Eiker-Sandsvær, Ringerike and Hadeland should be treated with caution.

Fauna and age. The rich graptolite fauna of the Galgeberg Member in Oslo-Asker has been documented by Monsen (1937), Spjeldnæs (1953) and Erdtmann (1965) and contains species indicative of the *Tetragraptus approximatus* to the lower part of the *Didymograptus hirundo* zones. It is thus equivalent to almost the entire Arenig Series. The faunas of the member in other districts of the Oslo Region have yet to be studied in detail but clearly contain the abundance of specimens of *Didymograptus, Tetragraptus* and *Phyllograptus* seen in the type district.

HUK FORMATION (Hukformasjonen)

(New name)

(Previously termed: 3c, 3cα−γ, Orthoceratitkalkstein, Orthocerkalk, Orthoceras Limestone, Vækerø Formation *(pars)*, Bestum Formation).

Main Lithology. Limestone (Huk Limestone, Hukkalken).

Basal Stratotype. Oslo-Asker: Huk (Fig. 7) (NM 938 410).

Hypostratotypes. Oslo-Asker: Engervik (NM 843 302), Vekkerø (NM 924 430), Skien-Langesund: Rognstrand (NL 409 411), Tangvalkleven (NL 397 429). Eiker-Sandsvær: Råen (NM 459 176), Hals (NM 486 230). Ringerike: Smeden (NM 756 721). Hadeland: Hovodden (NM 785 952), Granvollen (NM 845 934). Mjøsa: (Ringsaker) Herram (NN 989 485), (Nes-Hamar) Helskjer (PN 088 329), (Ringsaker) Stein (NN 919 539).

Thickness Variation. Oslo-Asker: Killingen (6.8m), Vekkerø (6.17m), Bjørkåsholmen (7.7m). Skien-Langesund: Rognstrand (2.42m), Tangvalkleven (2.56m). Eiker-Sandsvær: Råen (>11.55m), Hals (13.46m).

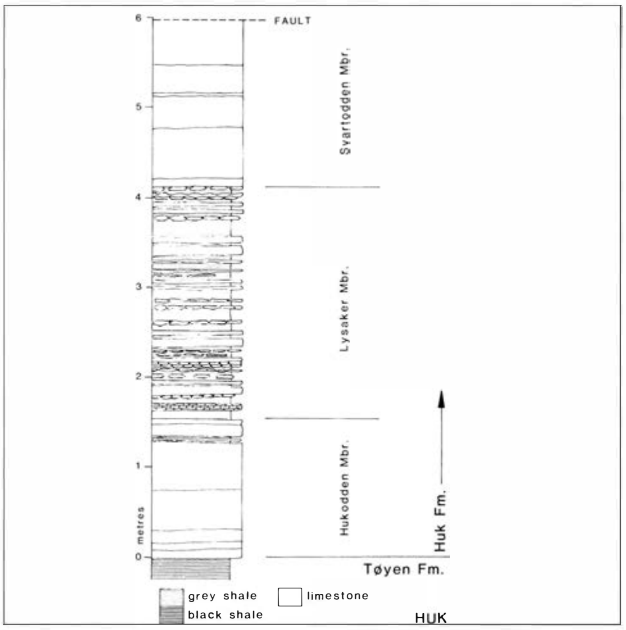

Fig. 7. Measured section through the basal stratotype of the Huk Formation and those of its component Hukodden, Lysaker and Svartodden members at Huk (Bygdøy, Oslo (NM 938410), (based on Skaar 1972). The top of the Svartodden Member has been faulted out (see Holtendahl & Dons 1957, p. 49).

Modum (Vikersund): composite value from Øvre Øren, Hovland and Vikersund ski jump (>8.4m). Ringerike: Smeden (>8.8m). Hadeland: Granvollen (7.31m), Mjøsa: Helskjer (10.75m), Stein (40m).

Definition. The Huk Formation succeeds graptolitic shales of the Tøyen Formation in all districts except southern Eiker-Sandsvær and Skien-Langesund. Here it overlies Cambrian Alum Shale; the contact being interpreted as a thrust plane in recent tectonic models of the Oslo Region by Ramberg & Bockelie (1981) and Bockelie & Nystuen (1985) but in a recent thesis, Ribland Nilssen (1985) has reinterpreted this 'Langesund hiatus' in terms of the southward transgression of the Ordovician rocks over the tilted Cambrian sequence. In most districts, the Huk Formation has a tripartite division with limestone members bounding a middle limestone-shale unit.

The top of the Huk Formation in most areas is a distinctive horizon rich in nautiloid cephalopods *(Cycloendoceras).* The overlying basal beds of the Elnes Formation are a transitional succession of limestones and shales (the Helskjer Member) passing up into the more typical dark shales of that formation. In its tripartite development, the Huk Formation maintains a fairly constant thickness although the middle member thickens somewhat in Eiker-Sandsvær thus giving an increased thickness to the formation there. The formation is thin in Skien-Langesund but in parts of the Mjøsa area (e.g. Nes-Hamar and E. Toten) the local bipartite division has a total thickness which is broadly comparable with that of the formation further south. However, in Ringsaker and W. Toten, the very thick Stein member is developed.

Discussion. The Huk Formation was the subject of an unpublished thesis by Skaar (1972) who termed the unit together with the overlying "Killingen Member", the 'Vækerø Formation'. This name, however, had been used earlier by Fjelldal (1966) for the Bjørkåsholmen Formation ('Ceratopyge Limestone') and overlying "Vestfossen Member". In view of the potential confusion, the name Vækerø Formation is not adopted here for either of these units. Harper (1986) and Owen (1987) used the term 'Bestum Formation' for the formation but this name was subsequently considered geographically inappropriate by the Norwegian Stratigraphical Committee.

Fauna and Age. In his study of the conodont faunas of the Huk Formation ('Orthoceras Limestone'), Kohut (1972) concluded that the entire formation with the possible exception of the uppermost part of the Stein Member lies within the upper part of the *Didymograptus hirundo* graptolite Zone. This conflicts with the correlation proposed earlier by Jaanusson (1960, pp.343-345) and Skevington (1965, p.70) who suggested that the base of the *D. 'bifidus'* Zone may lie at the top of or even within the middle member (Lysaker Member = 'Asaphus Shale') of the formation. Similarly whilst Kohut (1972) argued that the Huk Formation ranges in age from middle Volkhov to the Hunderum Substage of the Kunda Stage, Jaanusson (1960, Table 9) suggested a correlation with the upper Volkhov (Langevojan) to middle Kunda (Valaste) stages largely on the basis of the trilobite faunas. In the most recent correlation chart, Jaanusson (1982, Fig. 4) maintains this correlation between the conodont, graptolite and trilobite zones and the East Baltic stages. This is provisionally followed herein and is summarized on Fig. 8 along with Kohut's proposed correlation. A detailed re-study of the conodonts of the Huk Formation is being undertaken by Dr Svend Stouge and Mr Jan Rasmussen of Copenhagen University who have informed us (pers. comms. 1987 & 1989 and Rasmussen 1989) that their work largely confirms that of Kohut in the correlation of the typical tripartite development of the formation with the standard conodont zonation. This study complements one by Mr Arne Thorshøj Nielsen, also of Copenhagen, on the trilobites at the formation at Slemmestad and equivalent levels in Sweden and on Bornholm. The results of these studies should greatly clarify the correlation of the Huk Formation.

Hukodden Member (Hukoddleddet)

(New name)

(Previously termed: 3cα , Der Megalaspiskalk, Megistaspiskalk, Megalaspis Limestone, Megistaspis Limestone).

Main Lithology. Limestone.

Basal Stratotype. Oslo-Asker: Huk (Fig. 7) (NM 938 410).

Hypostratotypes. Oslo-Asker: Engervik (NM 843 302) (Fig. 6), Modum (Vikersund): Øvre Øren (NM 556 444). Eiker-Sandsvær, Ringerike, Hadeland: as for formation.

Thickness variation. Oslo-Asker: Huk, Killingen, Engervik, Vekkerø (1.6m). Eiker-Sandsvær: Råen, Stablum (1.0m), Hals (1.07m). Modum (Vikersund): Øvre Øren (0.9m). Ringerike: Smeden (1.0m). Hadeland: Hovodden (1.56m), Granvollen (1.6m).

Definition. The Hukodden Member marks an abrupt change from the shales of the Tøyen Formation and is a light weathering, fine grained, limestone with thin shale laminae. Much of the limestone is dolomitic and accumulations of shelly material are commonly visible along irregular bedding planes/pressure solution seams.

Fauna and Age. Macrofossils are difficult to extract from the member but it has yielded trilobites including the asaphid *Megistaspis (M) limbata limbata* (e.g. Brøgger 1882, Jaanusson 1960, p.345) indicating a correlation with the Langevoja Substage. In contrast, Kohut (1972, pp.442-443) argued that the conodonts from the member belong within Lindström's (1971) *Paroistodus originalis* Zone and thus indicate an older age for the member. Recent work by Stouge and Rasmussen (pers. comms. 1987 & 1989 and Rasmussen 1989) largely confirms Kohut's correlation and places the base of the *P. originalis* Zone above the base of the Hukodden Member and the base of the overlying *Microzarkodina parva* Zone also lies within the upper part of the member.

Lysaker Member (Lysakerleddet)

(New name)

(Previously termed: 3cß, Expansusskifer, Der Expansuschiefer, Expansus Shale and Limestone, Asaphus-skifer, Asaphus Shale).

Main Lithologies. Limestone and calcareous shales

Basal Stratotype. Oslo-Asker: Huk (Fig. 7) (NM 938 410).

Hypostratotypes. Modum (Vikersund): Hovland (NM 560 445). Eiker-Sandsvær, Ringerike and Hadeland: as for formation.

Thickness Variation. Oslo-Asker: Huk (2.56m) Vekkerø (1.5m), Killingen (2.5m), Engervik (3.5m), Tøyen (4.5m). Eiker-Sandsvær: Hals (9.75m). Modum (Vikersund): Hovland, Hovland Farm (2.6m). Ringerike: Løkenåsen, Klekken (2.15m), Smeden (ca 6.3m). Hadeland: Granvollen (1.6m).

Definition. The light grey calcareous shales or marls and nodular limestones of the Lysaker Member contrast markedly with the compact limestone members above and below. Some of the variation in thickness within and between districts may be a tectonic effect reflecting the difference in competence between the Lysaker Member and its confining units. Shales may have been squeezed out locally and strata may also be cut out or repeated by faults.

Discussion. Skaar (1972) introduced the name 'Bjerkås Shale and Limestone Member' for this unit but to avoid confusion with Fjelldal's (1966) term 'Bjørkåsholme Member' for the 'Ceratopyge Limestone' (= Bjerkåsholmen Formation herein) a completely new name is used here.

Fauna and Age. The Lysaker Member is richly fossiliferous. The asaphid trilobite *Asaphus expansus* occurs in abundance along with other asaphids (possibly including *Megistaspis (M) limbata* (see Jaanusson 1956), *Cybele bellatula* (see Owen & Tripp 1988), illaenids and pliomerids. The stratigraphical distribution of these trilobites has yet to be determined but will have great potential for correlation with uppermost Arenig - lowest Llanvirn in the Swedish successions. There is also an extremely diverse brachiopod fauna (Öpik 1939; Harper 1986) along with ostracods (Öpik 1939), echinoderms (Regnéll 1948, Bockelie 1981) and bryozoans.

Jaanusson (1960, pp.343-345) and Skevington (1965, p.70) equated most, if not all, of the member with the uppermost part of the *D. hirundo* graptolite zone whilst Kohut (1972) assigned conodonts from the member to the uppermost *originalis* to very lowest *variabilis* conodont zones. He argued therefore that the uppermost part of the *D. hirundo* Zone lies above the top of the Lysaker Member. As shown on Fig. 8, Jaanusson (1982, Fig. 4) equated the base of the *D. 'bifidus'* Zone with a level within the lowest part of the *variabilis* conodont zone (see also Bergström 1986, p.65). He also correlated the *Asaphus expansus* trilobite zone in Sweden with the uppermost *parva* and basal *variabilis* zones; a view also adopted by Löfgren (1985, Fig. 1) and Stouge & Rasmussen (pers. comms. 1987 & 1989 and Rasmussen 1989). These last workers also suggest that the base of the *parva* Zone lies within the underlying, Hukodden Member.

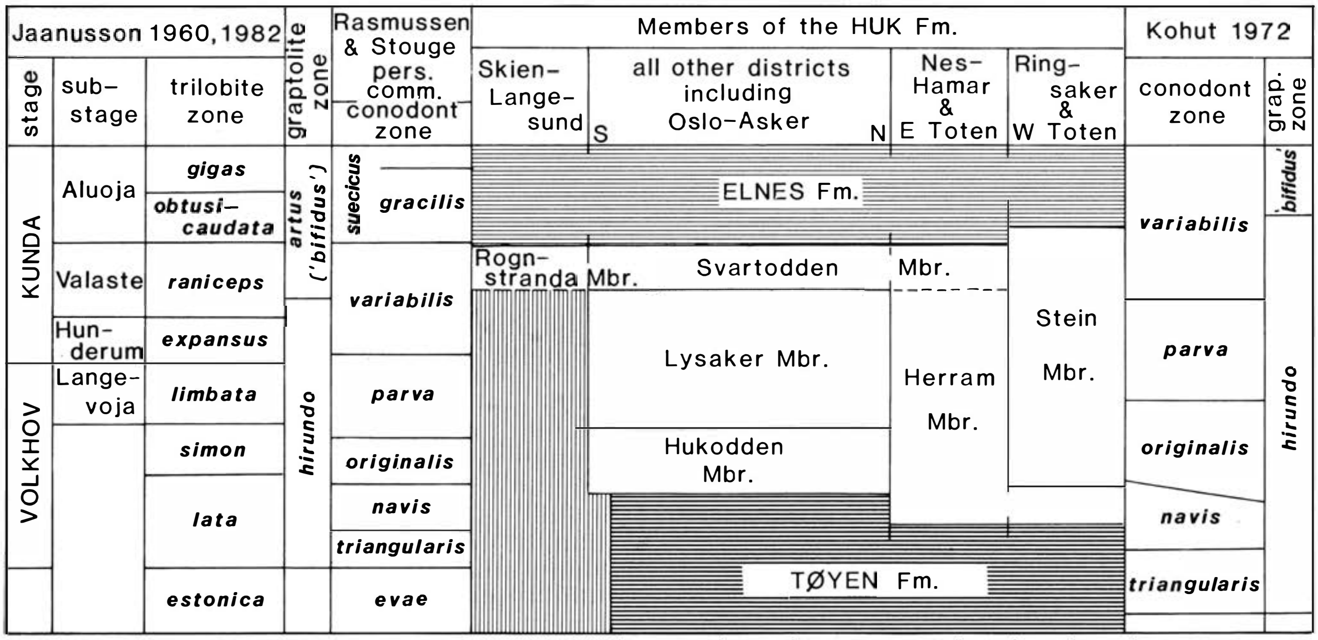

Fig. 8. The members of the Huk Formation and their correlation with the Baltic/Swedish chrono- and biostratigraphical units. That on the left relates recent conodont work on the formation by J.A. Rasmussen and S. Stouge of Copenhagen University (Rasmussen 1989 and pers. comms. 1987, 1988 and 1989) to the conodont-graptolite zonal ties discussed by Bergström (1986) and the trilobite zones and stage divisions of Jaanusson (1960, 1982). It contrasts with the earlier conodont work on the Huk Formation of Kohut (1972) shown on the right. Note that Fortey & Owens (1987) have proposed the *'D. artus* Zone' to replace the *'D. bifidus* Zone' in the European graptolite zonal scheme.

Svartodden Member (Svartoddleddet)

(New name)

(Previously termed: 3cγ , Orthocerkalk, Der Orthocerenkalk, Endoceratid Limestone)

Main Lithology. Limestone.

Basal Stratotype. Oslo-Asker: Huk (Fig. 7) (NM 938 410).

Hypostratotypes. Modum (Vikersund): Øvre Øren (NM 556 444). Mjøsa (Nes-Hamar): Helskjer (PN 088 329). Eiker-Sandsvær, Ringerike and Hadeland: as for formation.

Thickness Variation. Oslo-Asker: Bjørkåsholmen (2.4m), Killingen (2.6m), Vekkerø (2.7m). Eiker-Sandsvær: Råen (2.13m), Stablum (2.21m), Hals (2.64m). Modum (Vikersund): Vikersund ski jump (3.3m), Hovland (5.2m) n.b. both these sections contain faulted repeats. Ringerike: Løkenåsen, Klekken (1.7m). Hadeland: Hovodden (>4.5m), Granvollen (4.66m), Hvattum (4.0m). Mjøsa (Nes-Hamar): Helskjer (4.0m).

Definition. The base of the Svartodden Member is an abrupt change from shales and nodular limestones to compact light grey limestone with irregular, thin, shale laminae or pressure solution seams. In the southernmost Mjøsa district, Nes-Hamar, the Svartodden Member overlies the Herram Member but in the other districts of the Oslo Region where it is developed, it succeeds the Lysaker Member. The lower half of the Svartodden Member is bioturbated and contains phosphoritic and oolitic horizons (Skaar 1972). In the Eiker-Sandsvær district the lower part of the member constitutes the so called 'Porambonites Beds' (e.g. Klemm 1982, Fig. 5B). The upper part of the Svartodden Member is a massive limestone characterized, especially in the uppermost part, by abundant specimens of the nautiloid cephalopod *Cycloendoceras commune.*

Fauna and Age. As noted above, *Cycloendoceras commune* is the most characteristic fossil in the uppermost part of the member and both Skaar (1972) and Klemm (1982) have analysed the orientation of the conchs on individual bedding planes. Trilobites (notably asaphids), brachiopods (including *Porambonites)* and echinoderms also occur. Skaar (1972, p.443) ascribed the conodont fauna of the Svartodden Member to Lindström's (1971) *Eoplacognathus variabilis* Zone thus indicating a correlation with the Hunderum Substage of the Kunda Stage. As noted above, Jaanusson (1960, Table 9) argued that the trilobites of the Svartodden Member indicate a middle Kunda (Valaste) age. This is in agreement with the conodont studies of S.Stouge and J.Rasmussen of Copenhagen University who place the base of the *variabilis* Zone well below that of the Svartodden Member (pers. comms. 1987 & 1989 and Rasmussen 1989, see Fig. 8).

Rognstranda Member (Rognstrandleddet)

(New name)

(Previously termed: Endoceras Limestone, Endoceratid Limestone)

Main Lithology. Limestone.

Basal Stratotype. Skien-Langesund: Rognstranda (Fig. 9) (NL 409 411).

Definition. The Rognstranda Member is restricted to the most southerly district of the Oslo Region, Skien-Langesund, where it overlies Upper Cambrian (*Peltura* Zone) Alum Shales (Skaar 1972). This boundary has been interpreted as a tectonic junction, marking a plane of décollement above which the Ordovician and Silurian succession has been thrust southwards (e.g. Ramberg & Bockelie 1981, Fig. 2) but Ribland Nilssen (1985) has presented evidence for it being an unconformity. The Rognstranda Member is a 1.4m thick

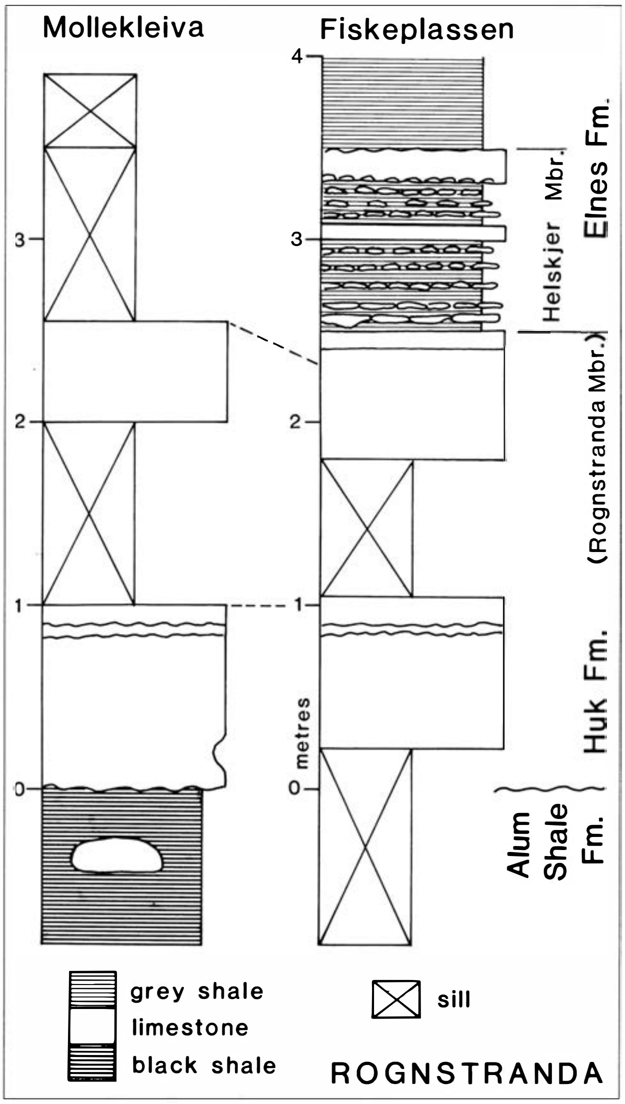

Fig. 9. Measured section through the basal stratotype of the Rognstranda Member of the Huk Formation at Rognstranda, Skien-Langesund (NL 408413-409411) based on Ribland Nilssen (1985). The exposure at Mollekleiva lies 250m NNW of that at Fiskeplassen.

black limestone with abundant pyrite in its lower part. The dark colour and absence of shale horizons contrast markedly with the overlying Helskjer Member of the Elnes Formation.

Discussion. This limestone was formerly ascribed to the 'Endoceratid Limestone' (i.e. Svartodden Member) (e.g. Størmer 1953; Strand & Henningsmoen 1960) but it was considered sufficiently distinctive to warrant separate named status by Skaar (1972) and this view is upheld here.

Fauna and Age. Kohut (1972) extracted a conodont fauna from the upper part of the Rognstranda Member which included *Eoplacognathus variabilis* indicating a correlation with the Svartodden Member elsewhere in the Oslo Region.

Herram Member (Herramleddet)

(Skjeseth 1963)

(Previously termed: 3b (pars), 3bε Heramb kalk og skifer)

Main Lithologies. Grey mudstones with limestone beds and nodules.

Basal Stratotype. Mjøsa (Ringsaker): Herram (formerly spelt Heramb) (NN 989 485).

Thickness variation. Mjøsa (Ringsaker): Herram (1.5m). (Nes-Hamar): Helskjer (>6.4m) (Fig. 10).

Definition. The grey mudstones and shales with limestone beds and lenses constituting the Herram Member contrast markedly with the underlying black shales of the Tøyen Formation. The member is overlain by nodular limestones and shales of the Stein Member in West Toten and Ringsaker and by the compact limestone of the Svartodden Member in East Toten and Nes-Hamar. The boundary with the Svartodden Member is, at least locally, a distinct erosion surface (Skjeseth 1963, Fig. 20). The thickest described development of the Herram Member is in Snertingdal, N.W. or Ringsaker, where A. Bjørlykke (1979, Fig. 18) recorded some 11.5m.

Discussion. Skjeseth (1952 pp.143-148; 1963 p.71) described the type development of the Herram Member in the context of the Tøyen Formation as a transition to the overlying Stein Limestone. He considered the Herram Member to be restricted to the northernmost part of the Mjøsa Area (Ringsaker) but it was subsequently identified by Skaar (1972) in the Toten and Nes-Hamar districts. Skaar (1972) also suggested that it is present in northern Hadeland but reexamination of this section at Hovodden shows that the lowest 50cm of these beds belong to the Hukodden Member of the Huk Formation and the remainder to the Lysaker Member. At Helskjer on Helgøya, Nes-Hamar, Skaar (1972 pp.30-32, Fig. A9) assigned approximately 4m of interbedded limestones and shales above the black shales of the Tøyen Formation to the

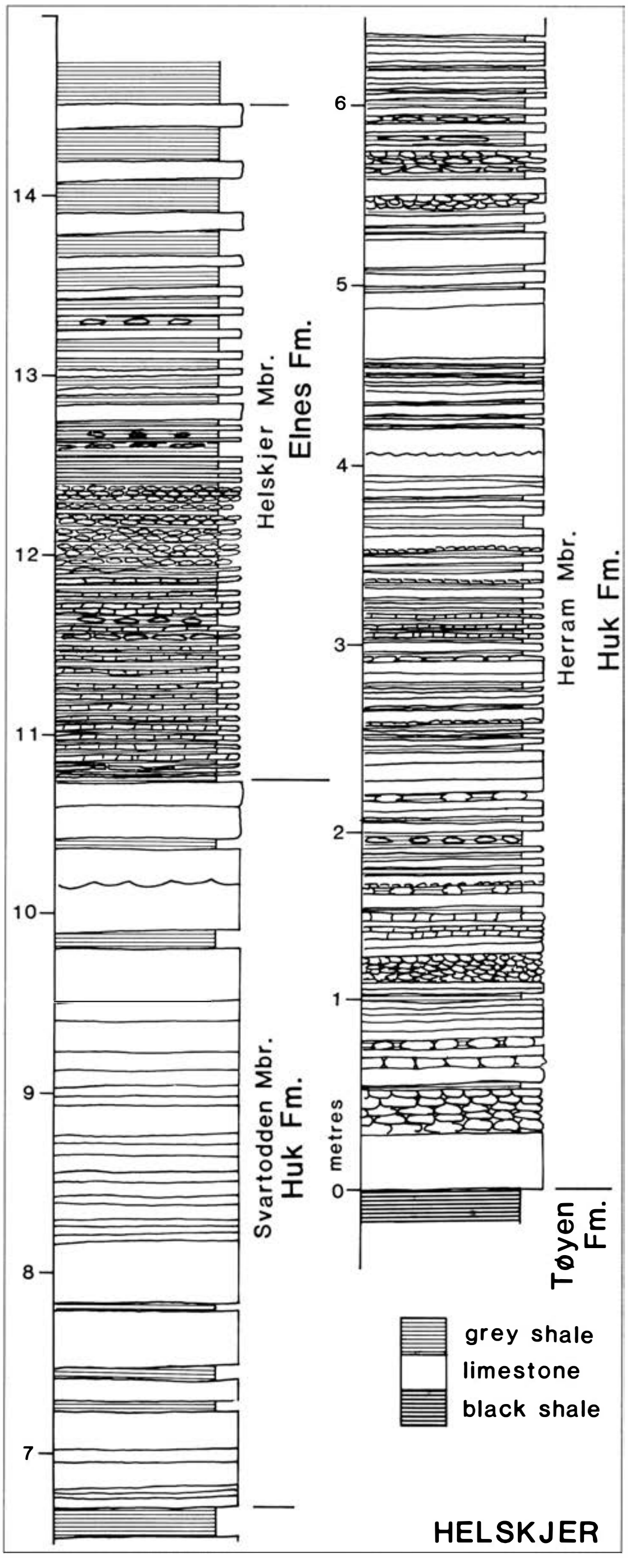

Fig. 10. Measured section through the basal hypostratotype of the Huk Formation and the basal stratotype of the Helskjer Member of the Elnes Formation at Helskjer, Nes-Hamar (PN 088329) (based on Skaar 1972).

Herram Member. These strata were not mentioned by either Størmer (1953 pp.101-102) or Skjeseth (1963 pp.62-63) who also discussed the section here. All three workers distinguished a tripartite division in the overlying 'Orthoceras Limestone'. Reinvestigation of the section, however, suggests that whilst the massive Svartodden Member can be recognised, there is insufficient differentiation of the underlying strata to recognise the Lysaker and Hukodden members. Consequently all the limestones and shales between the Tøyen Formation and the Svartodden Member of the Huk Formation are assigned to the Herram Member (Fig. 10).

Fauna and age. Skjeseth (1952, 1963) noted the mixed graptolitic/shelly fossil assemblage in the type development of the Herram Member. The trilobites are being studied by Mr A.T.Nielsen of Copenhagen University. Skjeseth identified the trilobites *Megistaspis planilimbata,* and *Raymondaspis limbata.* The former characterises the *planilimbata* Zone in Sweden but the latter occurs in the *simon* and *limbata* Zones (Tjernvik & Johansson 1980). The latter, younger, age is suggested by the work of Erdtmann (1965 p.523, Fig. 9) who recorded graptolites including *Tetragraptus bigsbyi, Dichograptus octobrachiatus, Phyllograptus densus* and *P. aff. angustifolius.* He thus suggested that the member here may be equivalent to the upper part of the Galgeberg Member of the Tøyen Formation in Oslo-Asker. Kohut (1972 pp.435, 437-8) recorded conodonts from the Herram Member at Herram which he interpreted as possibly indicative of an overlap between the *Baltoniodus navis* and *Paroistodus originalis* zones. He suggested that there may be an hiatus at an equivalent level in Sweden. Kohut also noted a conodont fauna extracted by G.Hamar from what he termed the 'lowermost bed of the Orthoceras Limestone at Helskjær'. This would certainly lie within the revised interpretation of the Herram Member presented here and may even be from the base of the member. He interpreted the fauna as belonging to the *Baltoniodus navis* Zone and Dr J.A.Rasmusson of Copenhagen University informs us (pers. comm. 1989) that the whole of the member in Ringsaker belongs in this zone as defined by Lindström (1971).

Stein Member (Steinsleddet)

(Skjeseth 1963)

(Previously termed: 3c, Orthoceras Limestone, Steinkalksten).

Main Lithology. Limestone.

Basal Stratotype. Mjøsa (Ringsaker): Stein Farm on Steinsodden (NN 919 539).

Thickness. Mjøsa (Ringsaker): north of Redalen (ca. 40m).

Definition. Skjeseth (1963 p.71, Fig. 26) noted the occurrence of the bedded limestones and thin sandy shales and mudstones in several localities around Stein. The base of the Stein Member is taken at the first of the continuous limestone horizons. These contrast with the nodular limestones of the underlying Herram Member. A. Bjørlykke (1979) noted that the Stein Member is about 40m thick at Stein but as little as 5m thick in some other locations.

Fauna and Age. Kohut (1972 p.435) recorded conodont samples from the Stein Member at Raufoss (Toten), Herram and Steinsodden (both Ringsaker). He concluded (1972 pp.439-443) that the unit encompasses the zones of *Paroistodus originalis* and *Microzarkodina parva* and at least part of the *Eoplacognathus variabilis* Zone. More recent work by Rasmusson & Stouge (1988) indicates that the upper part of the member extends into the lower *Eoplacognathus suecicus* Zone.

ELNES FORMATION (Elnesformasjonen)

(New name)

(Formerly termed: $4a\alpha_{1-4}$, Ogygiaskifer, Upper Didymograptus Shale, Ogygiocaris Shale, Cephalopod Shale).

Main Lithology. Shale (Elnes Shale, Elnesskiferen).

Basal Stratotype. Oslo-Asker: Bjørkåsholmen (Fig. 11) (NM 836 286).

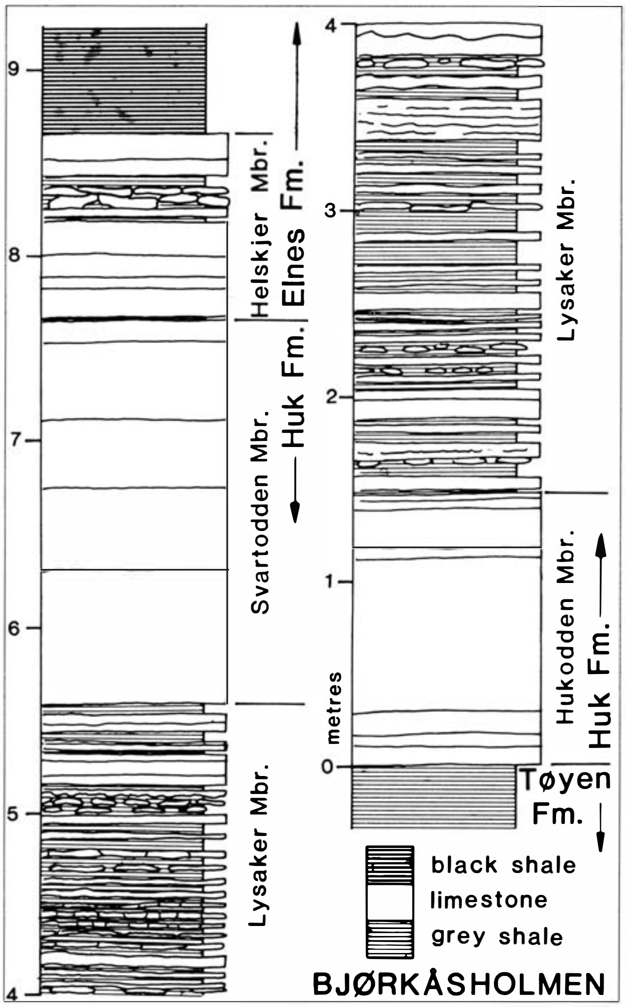

Fig. 11. Measured section through the Huk Formation and the basal stratotype of the Elnes Formation at Bjørkåsholmen, near Slemmestad, Asker (NM 836282-836286) (based on Skaar 1972). The Elnes Formation here comprises of hypostratotype of the Helskjer Member overlain by the basal stratotype of the Sjøstrand Member.

Thickness Variation. The tectonic incompetence of this formation compared to that of the underlying and succeeding units has resulted in its deformation in most districts by faulting and folding. Thus even in the best exposed area, (Oslo-Asker) its thickness can only be estimated (ca 60m). In the less well exposed districts no reliable estimate is possible other than to note that in Modum it may be in the region of 120m thick although this may include faulted repetitions of parts of the sequence.

Definition. The Elnes Formation was named without definition by Harper (1986) and Owen (1987). It is a dominantly shale unit the basal beds of which have previously been regarded as transitional from the limestones of the Huk Formation. In the environs of Oslo, this transition is represented by dolomitic limestones, while further west in Asker and also the other districts of the region a bedded limestone-shale unit (the Helskjer Member) is developed. In both cases the boundary with the underlying Huk Formation is sharp and in all but Skien-Langesund, Ringsaker and west Toten the top of that formation is characteristically rich in nautiloid cephalopods. In Oslo-Asker the Elnes Formation is divided into four members. A local member (the Heggen Member) is recognised in the southern districts but from Ringerike northwards the formation remains undifferentiated above the basal, Helskjer Member.

Høy & Bjørlykke (1980) introduced the term Bjørge Formation without formal definition on the Hamar map sheet in the Nes-Hamar district. The Norwegian Stratigraphical Committee have informed us that this formation name for the units previously termed the 'Ogygiocaris Series' has no formal status and hence the Elnes Formation is defined in Oslo-Asker and the name applied in the Mjøsa areas. Here, and in Hadeland, the succession above the Helskjer Member comprises black shales with limestone nodules, many of which weather to a rusty brown colour and although nodular limestone bands are common in the lower few metres of the member they became progressively rarer. In the middle part of the succession the shales are generally up to 40cm thick and the limestone nodules rarely more than 5cm in thickness although the upper part of the section at Hvattum in Hadeland also shows 20cm thick shale horizons separating 8cm limestone nodules. These may be equivalent to the nodular limestone described as marking the top of the 'Ogygiocaris Shale' in the Mjøsa area (Holtedahl 1909 p.8, Skjeseth 1963 p.64). The uppermost part of the Elnes Formation shows the shales becoming thicker and limestones rarer. In the Mjøsa districts the nodules of this part of the member are more rounded in outline than the flat nodules lower down and also contain barytes (Størmer 1953 p.103; Skjeseth 1963 p.64). They contain abundant cephalopods and hence this part of the succession was termed the 'Cephalopod Shale' (Holtedahl 1909, Størmer 1953). It is not possible even to estimate the total thickness of the Elnes Formation in the northern part of the Oslo Region.

Fauna and Age. As is discussed below, the various members of the Elnes Formation contain a diverse shelly and graptolitic fauna. Berry (1964) concluded that the graptolites indicated a range from the base of the *Didymograptus murchisoni* Zone to the top of the *Glyptograptus teretiusculus* Zone and thus a middle Llanvirn to early Llandeilo age. An historical account of work on the graptolites of the Elnes Formation was also given by Berry (1964 pp.64-68) and need not be repeated here. The basal Helskjer Member, however, contains a trilobite fauna which is very close to that of the *Megistaspis gigas* Zone in Sweden, which is latest Kunda in age and thus equivalent to the uppermost part of the *D. 'bifidus'* graptolite Zone (Wandås 1984). The naming of this lower Llanvirn graptolite zone has been problematical following the recognition that D. bifidus is an Arenig species from Canada and is not conspecific with the British Llanvirn material traditionally ascribed to it. Fortey & Owens (1987 p.90) have suggested that *D. artus* become the eponymous species for the lower Llanvirn biozone in Britain, although the base of such a zone has yet to be formally defined.

Helskjer Member (Helskjerleddet)

(Skjeseth 1955 *in* Strand & Størmer)

(Previously termed: basal transition beds, 3cδ (*pars*), Helskjær Shale and Limestone).

Main Lithologies. Limestones and shales.

Basal Stratotype. Mjøsa (Nes-Hamar): Helskjer (formerly Helskjær) (Fig. 10 and see Wandås 1984, Fig. 2) (PN 088 329).

Hypostratotypes. Mjøsa (Nes-Hamar): Nydal-Furnes Church (PN 099 472) (Wandås 1984 Fig. 2). Skien Langesund: Rognstranda (NL 409 411). Eiker-Sandsvær: Stablum (NM 443 160) (see Wandås 1984, p.212). Modum (Vikersund): Vikersund ski jump (NM 563 453) (Wandås 1984, Fig. 2). Oslo-Asker: Bjørkåsholmen (NM 844 294) (Fig. 11). Ringerike: Klekken (NM 741 713). Hadeland: Hovodden (NM 785 952) (Wandås 1984, Fig. 2).

Thickness Variation. Mjøsa (Nes-Hamar): Helskjer (3.75m), Road Section Nydal-Furnes Church (~3.4m). Skien-Langesund: Rognstranda (1.0m), Tangvalkleven (1.13m). Eiker-Sandsvær: Hals (1.58m). Modum (Vikersund): Vikersund ski jump (3.3m). Oslo-Asker: Bjørkåsholmen (0.8m). Ringerike: Klekken Post Office (0.35m). Hadeland: Hovodden, Hvattum (3.5m).

Definition. The Helskjer Member comprises bedded and nodular limestones interbedded with dark shales. The base is taken as the first shale above the compact limestones with *Cycloendoceras* of the Svartodden Member of the Huk Formation except in Skien-Langesund where the Helskjer Member marks a change to light limestones and thin shales from the dark limestone of the Rognstranda Member (Fig. 9). The top of the Helskjer Member is a change to shale as the predominant lithology.

Discussion. The Helskjer Member was formally defined by Skjeseth (1963 p.63) although the name was introduced by him earlier in the Lexique Stratigraphique (Strand & Størmer 1955). Although Nydal-Furnes was given as the type locality in the earlier publication, Skjeseth (1963) later designated Helskjer on the island of Helgøya as the stratotype and this is followed here in view of the superiority of exposure there. Lithological logs for the Nydal-Furnes church section (now largely overgrown) were given by Nikolaisen (1963 p.360 Fig. 3) and Wandås (1984 Fig. 2). The member has long been considered as a lithological transition from the 'Orthoceras Limestone' to a dominantly shale succession and tentatively included with the underlying unit (e.g. Holtedahl & Schetelig 1923, Størmer 1953, Skjeseth 1963, Skaar 1972, Kohut 1972). The Helskjer Member is here assigned to the Elnes Formation leaving the massive limestones packed with *Cycloendoceras* as an easily recognisable top to the underlying Huk Formation.

A 1m thick red-brown weathering dolomite contrasting strongly with the light coloured Huk Formation below is present in parts of Oslo at the base of the Elnes Formation. Skaar (1972 p.A142) recognised a local intraformational conglomerate near the base of the limestone consisting of 1-5cm blocks of the underlying grey limestone set in a dolomitic matrix. He termed the dolomite the Killingen Dolomite and included it with the underlying limestone unit, giving it the Etasje term '3cδ '. It is not formally defined herein but is considered an equivalent of the Helskjer Member and it is here assigned to the Elnes Formation.

Fauna and Age. The shelly fauna of the Helskjer Member was recognised by Størmer (1953) as being transitional between that of the underlying formation and that which is more typical of the shales of the Elnes Formation. Evidence for this was also presented by, amongst others, Skjeseth (1963) and Nikolaisen (1963). A detailed assessment of the rich trilobite fauna of the member has recently been made by Wandås (1984) who has demonstrated a very high degree of similarity at both genus and species level with faunas from the 'Gigas Limestone' in Sweden. The Norwegian faunas include *Megistaspis (M.) giganteus* Wandås, a species very *close to M. (M.) gigas* (Angelin) and indicates a latest Kunda age.

Kohut extracted conodonts from the Helskjer Member ('transition beds' outside Nes-Hamar) from most districts of the Oslo Region but with the exception of the sample from the Rognstranda section, diagnostic elements were absent (1972 p.441). He concluded that the Rognstranda conodonts indicated an horizon no older than the Valaste Stage and thus he placed the Arenig-Llanvirn boundary in the lower 50cm of the member there (see Fig. 8).

Sjøstrand Member (Sjøstrandleddet)

(New name)

(Previously termed: 4a$\alpha_{1\text{-}2}$ Upper Didymograptus Shale, øvre Didymograptusskifer)

Main Lithology. Black shale.

Basal Stratotype. Oslo-Asker: Bjørkåsholmen (Fig. 11) (NM 836 286).

Hypostratotype. Oslo-Asker: Svartodden (Vekkerø) (NM 924 430).

Definition. The Sjøstrand Member comprises black shales with scattered limestone lenses. Its base is taken above the last continuous limestone bed of the Helskjer Member.

Størmer (1953 pp.55-57) gave lithological and faunal details of various sections through the Sjøstrand Member in Oslo-Asker and estimated its thickness to be approximately 32m on Huk, Bygdøy and 49m at Slemmestad. It must be stressed, however, that such thicknesses may be misleading as we have yet to encounter a section which is not tectonically disturbed.

Fauna and Age. Although the Sjøstrand Member contains shelly fossils in the limestone lenses, notably species of the trilobites *Botrioides* (see Owen 1987) and *Ogygiocaris* (see Henningsmeon 1960), the fauna of the shales is dominated by graptolites (see Størmer 1953). Berry (1964) described the diverse graptolite fauna of the member on the basis of his own and existing museum collections. He ascribed the fauna of the whole unit to the *Didymograptus murchisoni* Zone (1964 p.77) and thus did not confirm Størmer's reference to the lower part of the member ('4aα_1') as the *'Didymograptus bifidus* Zone' (1953 p.119, Fig. 16). In a subsequent paper, however, Berry argued that the lower part of the *D. murchisoni* Zone in the Oslo Region may be equivalent to the upper *D. 'bifidus'* Zone in Britain (1968 p.226) (see Fortey & Owens 1987 for the renaming of this zone as the *D. artus* Zone).

Engervik Member (Engervikleddet)

(New name)

(Previously termed: 4aα_3 Ogygiocarisskifer, Ogygia Shale, Ogygiocaris Shale).

Main Lithologies. Grey shale with limestone horizons.

Basal Stratotype. Oslo-Asker: North of Engervik (Fig. 12) (NM 845 306).

Definition. The base of the Engervik Member is taken at the first continuous limestone bed which at the type locality succeeds 18.5m of black shale with scattered ellipsoidal limestone nodules of the underlying Sjøstrand Member. The Engervik Member consists of black shales with isolated nodules and continuous limestone beds commonly 5-10cm thick. Above 8.8m above the base in the type section, the trace fossil *Chondrites* is abundant. The Engervik section is the only one known to contain the base and top of the Engervik Member without obvious tectonic disturbance. However, the measured thickness of 15.5m should be viewed as no more than an approximation for the

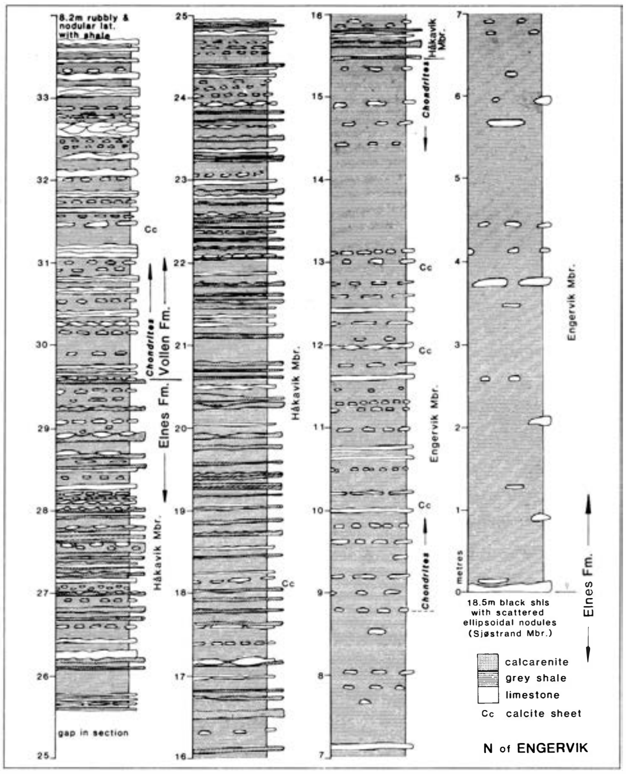

Fig. 12. Measured section through the basal stratotypes of the Engervik and Håkavik members of the Elnes Formation and the basal stratotype of the Vollen Formation on the shore north of Engervik, Asker (NM 843302-845306). The range of the trace fossil *Chondrites* is also shown.

thickness of the member as at least three slickensided calcite sheets are present parallel to the bedding (Fig. 12).

Fauna and Age. The shelly fauna of the Engervik Member is more diverse than that of the underlying unit. The fauna includes trinucleid (Størmer 1930, Owen 1987) asaphid (Henningsmoen 1960) telephinid (Nikolaisen 1963) and remopleuridid (Nikolaisen 1983) trilobites as well as brachiopods (Spjeldnæs 1957) and cephalopods (Sweet 1958). Amongst the trilobites, *Botrioides bronnii* (Boeck) appears in the member and ranges up into the lowest part of the Vollen Formation (Owen 1987, p.82). This species also occurs in the Lower Dicellograptus Shale (including the Killeröd Formation) in Skåne, S.E. Sweden which broadly equates with the *G. teretiusculus* graptolite Zone. Berry described the graptolites of the Engervik Member and concluded (1964 p.78) that the *Didymograptus murchisoni - Glyptograptus teretiusculus* Zone boundary lies within the unit.

Håkavik Member (Håkavikleddet)

(New name)

(Previously termed: 4aα_4, Ogygia (= Ogygiocaris) zone (pars), Trinucleus bronnii zone, Bronnii Beds).

Main Lithologies. Grey shales, limestones and calcarenites.

Basal Stratotype. Oslo-Asker: North of Engervik (Fig. 12) (NM 845 306).

Hypostratotype. Oslo-Asker: Huk (Bygdøy) (NM 938 410).

Thickness Variation. Oslo-Asker: North of Engervik (14m), Killingen (*ca.* 12m).

Definition. As described by Størmer (1953 pp.58-61) the unit consists of alternating calcarenites up to 10cm thick, bedded and nodular limestones also up to 10cm thick and grey calcareous shales up to 30cm thick. Many of the calcarenites show cross and convolute lamination. The base is defined at the first calcarenite bed and this level also marks the disappearance of *Chondrites* which reappears at the base of the succeeding unit.

Discussion. The strata of this unit formed the basis for Størmer's *Trinucleus bronnii* Zone (1953 pp.58-61) although as Owen has pointed out (1987 p.84) the characteristic trinucleid is *Botriodes impostor* Owen, not *B. bronnii* (Boeck). Størmer's zone was essentially a biostratigraphical concept but he chose Huk on Bygdøy as the type section for the sedimentary development. This section is less complete than that near Engervik and the latter is here designated as the stratotype for the Håkavik Member. The unit is 14m thick here, including a 65cm gap in exposure 4m from the top. The calcarenites of the Håkavik Member were first noted by Brøgger (1887 p.17) and their sedimentary structures discussed by Størmer (1953), Seilacher & Meischner (1964) and Bjørlykke (1965, 1974). In contrast to Seilacher & Meischner's interpretation, Bjørlykke concluded that the laminated calcarenites are not turbidites but represent fairly shallow water deposits laid down by storm-induced currents. He argued that the size of the quartz grains (less than 30-40mm) indicates reworking within the basin rather than an influx of extrabasinal material.

Fauna and Age. In addition to the trinucleid *Botrioides bronnii and the very abundant B. impostor* (see Owen 1987), other trilobites from the Håkavik Member include asaphids, raphiophorids and cybelines. The rest of the shelly fauna is sparse but includes brachiopods (Spjeldnæs 1957). Berry (1964 pp.78-79) included the graptolites of the member entirely within the *Glyptograptus teretiusculus* Zone.

Heggen Member (Heggenleddet)

(New name)

(Previously termed: 4aα_{1-4}, Upper Didymograptus Shale, Ogygiocaris Shale).

Main Lithologies. Shales with limestone nodules.

Basal Stratotype. Modum (Vikersund): Road to Vikersund ski jump (Wandås 1984, Fig. 2) (NM 562 449).

Hypostratoptypes. Eiker-Sandsvær: Rønningsfossen (NM 358 035). Skien-Langesund: Blekkebakken (Frierfjord) (Fig. 17) (NL 385 466) (NL 388 466).

Thickness variation. Modum (Vikersund): area around Vikersund ski jump (ca 120m). Eiker-Sandsvær: Rønningsfossen (>62m).

Definition. The base of the Heggen Member is defined at the first thick shale bed above the Helskjer Member. The unit is dominated by dark shales which weather brown. The shale beds are commonly of the order of 50 cm thick and are separated by horizons of dark nodular limestone. In Skien-Langesund, phosphatic horizons are developed at several levels (Størmer 1953, pp.71-73). Calcarenites are not developed in the uppermost part of the formation in contrast to the succession in Oslo-Asker.

Fauna and Age. The Heggen Member contains a rich shelly and graptolitic fauna. Its distribution in Skien-Langesund and Eiker-Sandsvær was outlined by Størmer (1953 pp.71-73, 78-80) and Wandås (1982 p.6) has listed the trilobites of the lowest part of the member. Some of these extend up from the Helskjer Member but *Megistaspis (Megistaspidella) maximus, Botrioides simplex* (see Owen 1987) and *Ogygiocaris* all make their first appearance in the lowest 10m of the Heggen Member.

Berry (1964) described graptolites of the *Didymograptus murchisoni* Zone (but see comments above on its possible partial equivalence with the *D. 'bifidus'* Zone) from the base of the Heggen Member in Skien-Langesund and a level within the member in Eiker-Sandsvær.

VOLLEN FORMATION (Vollformasjonen)

(New name)

(Previously termed: 4aß Ampyxkalk, Ampyx Limestone).

Main Lithology. Limestone (Vollen Limestone, Vollkalken).

Basal Boundary Stratotype. Oslo-Asker: North of Engervik (Fig. 12) (NM 845 306).

Hypostratotypes. Oslo-Asker: Vollen (Fig. 13) (NM 839 310). Huk (Bygdøy) (NM 932 412), Ildjernet (NM 350 355). Ringerike: Kullerud (NM 724 694).

Definition. This formation name was introduced without definition by Owen (1981). The disappearance of calcarenite horizons and the reappearance of the trace fossil *Chondrites* mark the base of the Vollen Formation (Fig. 12) and whilst a complete section across this boundary is exposed north of Engervik, only the lowest 13m of the formation can be studied here. This comprises rhythmically alternating limestone horizons (beds and nodules) with interbedded calcareous shale. Bjørlykke (1974 p.17) noted that there are two cycles with approximate average thicknesses of 10cm and 40cm. He suggested that they may represent cycles of 15,000 and 60,000 years respectively and alluded to unpublished work by O.A.Christophersen relating them to astronomically controlled climatic-changes. There is no known complete section through the whole formation. Approximately 40m is exposed on Bygdøy where the base is faulted and about 44m crop out at Vollen but the base is not seen here.

Discussion. The Vollen Formation is also developed in Ringerike (Størmer 1953 pp.83-84) although the distinct rhythmicity seen in Oslo-Asker is not as evident. The base of the formation locally comprises a 10-20cm thick conglomeratic horizon (Størmer 1953 pp.83-84, Hamar 1964 pp.251-252). This is now only seen at Kullerud in a tightly folded sequence and a polished section of the conglomerate from here was illustrated by Hamar (1964 Fig. 3) who also published photomicrographs of thin sections from Gomnes (1964 Fig. 2). Hamar noted that the conglomerate comprises two horizons of coarse material and two of cross-bedded sand grade material. Clasts in the coarse horizons include shales and quartzite as well as fossil fragments.

Fauna and Age. The Vollen Formation contains a sparse but diverse shelly fauna dominated by trilobites, notably: asaphids (Henningsmoen 1960), cheirurids (Nikolaisen 1961), the trinucleids *Reedolithus carinatus* (Angelin) throughout the formation and species of *Botrioides* (in the lower part of the unit - Owen 1987) and three species of chasmopines (McNamara 1980), *Chasmops tumidus* (Angelin), *Scopelochasmops conicophthalmus* (Sars & Boeck) and *Bolbochasmops bucculentus* (Schmidt). Amongst the brachiopods are several strophomenids described by Spjeldnæs (1957) including species of *Alwynella, Grorudia and Christiania.* Other elements of the shelly fauna include cephalopods (Sweet 1958), gastropods (Yochelson 1963), bivalves (H. and T.Soot-Ryen 1960, H.Soot-Ryen 1966) ostracods (Henningsmoen 1953) and cystoids (Bockelie 1981, 1984). The correlative value of the shelly fossils has yet to be adequately tested.

Hamar (1964, 1966) described conodont faunas from the Vollen Formation in Oslo-Asker and Ringerike and distinguished three 'sub-zones' within the formation. He suggested a late Llandeilo or early Caradoc age for the formation which he equated with the *Nemagraptus gracilis* Zone and which is now considered largely of Llandeilo age (e.g. Williams et al. 1972). In a re-evaluation of Hamar's faunas, Bergström (1971 p.104) ascribed the fauna from the basal Vollen Formation in Ringerike to the lower *Pygodus anserinus* Zone (= upper *G. teretiusculus* Zone) and that of the middle Vollen Formation in Oslo-Asker to the upper *P. anserinus* Zone (= lower *N. gracilis* Zone).

ARNESTAD FORMATION (Arnestadformasjonen)

(New name)

(Previously termed 4bα, Skifer med *Chasmops conicophthalma,* Undre Chasmops-Skifer, Lower Chasmops Shale).

Main Lithology. Shale (Arnestad Shale, Arnestadskiferen).

Basal Stratotype. Oslo-Asker: Vollen (Fig. 13) NM 839 310).

Hypostratotypes. Oslo-Asker: Rabben (NM 840 308), Rodeløkken (Bygdøy) (Fig. 14) (NM 947 432). Ringerike: Bratterud (NM 650 610).

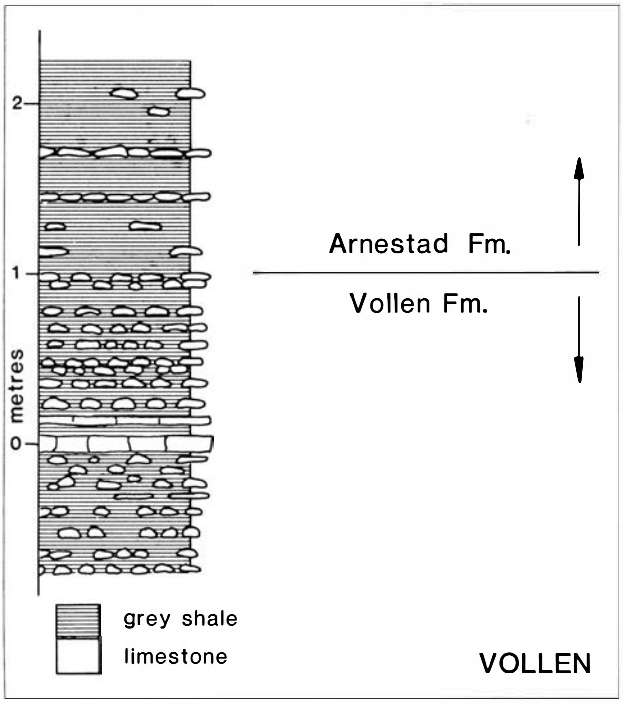

Fig. 13. Measured section through the basal stratotype of the Arnestad Formation at Vollen boat club, Asker (NM 839310). The shales weather rusty brown and the limestones contain the trace fossil *Chondrites.*

Definition. The formation name was published as a replacement for 'Lower Chasmops Shale' by Harper (1986) and Owen (1987) but without formal definition. Kvingan (1986) also used the name in an unpublished thesis on the formation. The base of the Arnestad Shale Formation is defined at the development of thick dark shales with subordinate limestone horizons. This coincides with the occurrence of abundant specimens of *Echinosphaerites aurantium* Hecker (see Bockelie 1981) in many localities but at others, e.g. Huk and Killingen, this cystoid is present in the upper beds of the underlying unit. Shale horizons within the formation are commonly 30-40cm thick with a maximum of about 70cm. Nodular and bedded limestone horizons are almost invariably less than 10cm thick. In Oslo, the shales are dark grey weathering to light grey whereas in the west in Asker and Ringerike they are green-grey in colour and this becomes more pronounced on weathering. Bentonites are developed in the formation at various localities in Oslo-Asker (Hagemann & Spjeldnæs 1955). Measured sections through the upper part of the Arnestad Formation and succeeding units (= the 'Chasmops Beds') on Persteilene and Fornebu were given by Størmer (1953 Fig. 5) and Toni (1975a Fig. 1) respectively. The thickness of the

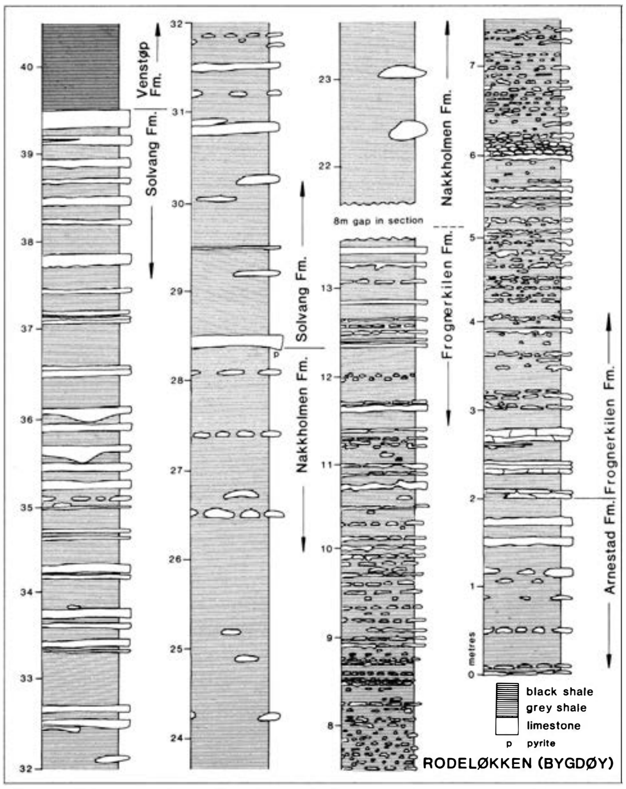

Fig. 14. Measured section through the hypostratotype of the Arnestad Formation, the basal stratotype of the Frognerkilen Formation, the Nakkholmen Formation and the hypostratotype of the Solvang Formation at Rodeløkken (Bygdøy) Oslo (NM 947432-947430).

formation is difficult to estimate owing to tectonism and poor exposure and was estimated to be up to about 45m by Brøgger although most recently Kvingan (1986) gave a figure of about 22m.

Fauna and Age. The Arnestad Formation contains a rich shelly fauna with both diversity and abundance generally increasing westwards from Oslo into Asker.

The ostracods were described by Qvale (1980) who noted the presence of a large number of endemic taxa and suggested a correlation of the upper part of the formation with the lowest part of the Skagen Limestone (mid Caradoc) of Sweden. Jaanusson (1964 p.53) also argued that ostracods from the lower part of the Arnestad Formation indicate a correlation with the Upper Dalby Formation (lower Caradoc) in Sweden (see Bruton 1976 p.716). Over 30 trilobite species are known from the Arnestad Formation and include remopleuridids (Nikolaisen 1983), asaphids (Henningsmoen 1960), illaenids, proetids (Owens 1970), trinucleids (Owen 1987), cheirurids (Nikolaisen 1961), encrinurids (Nikolaisen 1961), calymenids (Siveter 1977), pterygometopids (McNamara 1980) and lichids. In describing a new species of *Phillipsinella, P. fornebuensis,* from the uppermost 5m of the formation, Bruton (1976 p.716) noted that the associated trilobites are known also from the Skagen Limestone in Sweden. This supports the correlation indicated by Qvale (1980). The supposed proetid *Analocaspis ursina* described by Owens (1970) from the Arnestad Formation was subsequently reassigned by him to the aulacopleurid genus *Rorringtonia* Whittard (Owens 1981). *Rorringtonia* is restricted to Llandeilo and lower Caradoc horizons in Britain and an early Caradoc age for the Norwegian species would conform to this.

Over 56 brachiopod species occur in the Arnestad Formation (pers. comm. D.A.T.Harper 1983 and Harper 1986) of which only strophomenids have so far been described (Spjeldnæs 1957). One of the most characteristic elements of the fauna is *Kullervo cf. lacunata* Öpik which, again, indicates an early Caradoc age for the formation (pers. comm. D.A.T.Harper 1983). Many of the immigrant brachiopod taxa are of Scoto-Appalachian affinity (Harper 1986). Cystoids from the formation were described by Bockelie (1984).

Hamar (1966) extracted a conodont fauna from near the top of the formation at Rodeløkken, Bygdøy. He noted (1966 p.42) that it marked the disappearance of species of *Eoplacognathus* and *Polyplacognathus* characteristic of older units and the appearance of *Ambalodus* and Amorphognathus. He included the fauna with that of the succeeding three formations within his 'middle zone' and suggested (1966 p.43) that the Arnestad Formation may be broadly equivalent to the Dalby Formation (= *D. multidens* graptolite Zone, Lower Caradoc - Jaanusson and Karis 1982) in Jämtland, Sweden.

The tremendous increase in diversity of shelly fossils seen in the Arnestad Formation compared to earlier units may reflect the 'Skagenian' immigration documented by Jaanusson (1976) elsewhere in Baltoscandia but the precise level of this change has yet to be determined.

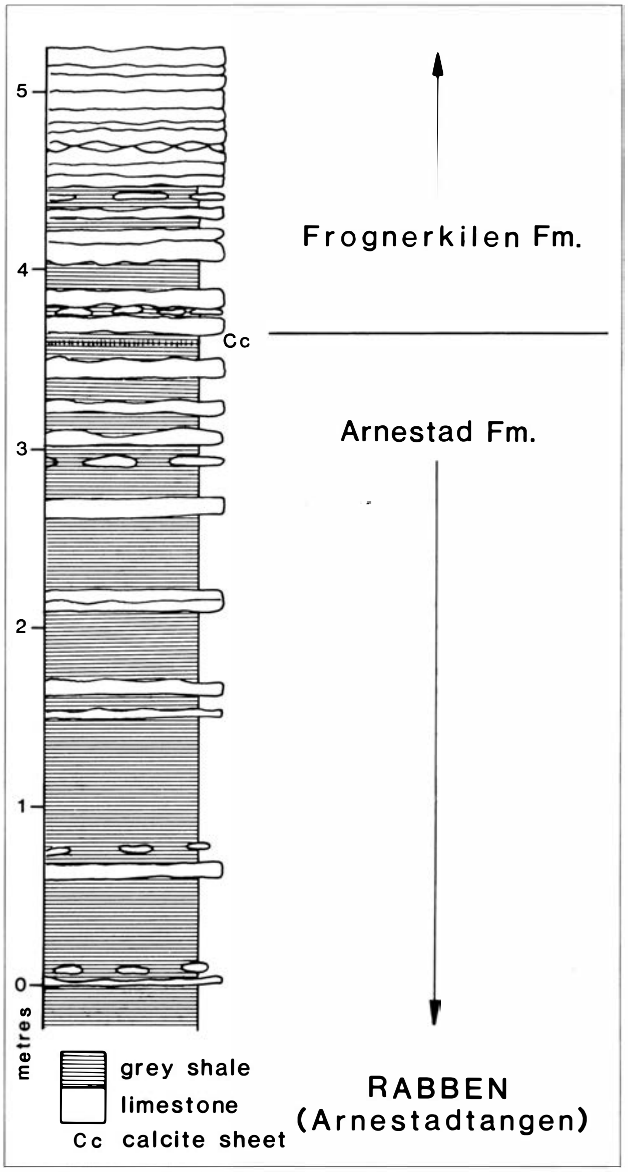

Fig. 15. Measured section through the boundary between the Arnestad Formation and the hypostratotype of the Frognerkilen Formation, Rabben, Asker (NM 840308).

FROGNERKILEN FORMATION
(Frognerkilformasjonen)
(New name)

(Previously termed: 4bß, Undre Chasmopskalk, Lower Chasmops Limestone, Rodeløkken Formation).

Main Lithologies. Bedded limestones and shales (Frognerkilen Limestone, Frognerkilkalken).

Basal Stratotype. Oslo-Asker: Rodeløkken, Frognerkilen (Bygdøy) (Fig. 14) (NM 947 430).

Hypostratotypes. Oslo-Asker: Rabben (Fig. 15) (NM 840 308), Fornebu (Toni 1975a Fig. 1, 3.95-19.25m in section) (NM 915 416). Ringerike: Bratterud (NM 650 610), Norderhov (NM 710 666).

Thickness Variation. Oslo-Asker: Semsvann (>18m), Fornebu, Persteilene (15.8m), Rodeløkken, Bygdøy (11.5m), Nakkholmen (*ca.* 10m), Alnabru (7m).

Definition. This unit was termed the Rodeløkken Formation by Harper (1986) and Owen (1987). The Norwegian Stratigraphical Commission consider the name inappropriate and hence it is changed herein. In the type area, the base of this formation marks an abrupt change from a shale dominated succession to rubbly limestones up to 10cm thick passing upwards into nodular limestones (up to 10cm) and shales (up to 35cm). The rubbly limestone is not developed in Ringerike. The uppermost 2-3m of the formation comprises bedded limestones (5-10cm) and shales (5-30cm). A measured section through the formation on Persteilene was given by Størmer (1953 Fig. 5) including these beds within the Frognerkilen Formation but Toni (1975a Fig. 1) assigned similar horizons on Fornebu to the overlying Nakkholmen Formation. Re-examination of the latter profile indicates that the base of the Nakkholmen Formation should best be placed at the 19.25m level (see Toni 1975a Fig. 1) and thus Størmer's approach is adopted.

The Frognerkilen Formation thins eastwards in the Oslo-Asker district from over 18m at Semsvann to about 7m at Alnabru (Qvale 1980 Fig. 22). Its thickness in Ringerike is difficult to assess but Størmer (1953 p.86) suggested that it may be of the order of 25m.

Fauna and Age. The Frognerkilen Formation contains a fairly sparse fauna, most elements of which occur also in the underlying unit (e.g. Spjeldnæs 1957, Henningsmoen 1960, Hamar 1966, Qvale 1980, McNamara 1980, Harper 1986) and thus indicate a mid-Caradoc age. Paul and Bockelie (1983) described a new species of cystoid, *Sphaeronites (Peritaphros) paucicsleritatus* from the middle part of the formation in the western (shallower) part of Oslo-Asker.

NAKKHOLMEN FORMATION (Nakkholmformasjonen)

(Owen 1983, Harper et al. 1985)

(Previously termed: 4b γ , Øvre Chasmopsskifer, Upper Chasmops Shale, Norderhov Formation).

Main Lithology. Shale (Nakkholmen Shale, Nakkholmskiferen).

Basal Stratotype. Oslo-Asker: Nakkholmen (Harper et al. 1985, Fig. 2) (NM 949 403).

Hypostratotypes. Oslo-Asker: Persteilene (Spjeldnæs *in* Størmer 1953, Fig. 5, 45.6 to 23.4m in section) (NM 903 321; Ringerike: Norderhov (NM 710 666).

Thickness Variation. Oslo-Asker: Nakkholmen (13-14m), Persteilene (22.3m).

Definition. The base of the Nakkholmen Formation is defined by the development of thick dark shales which typify the unit in the eastern part of Oslo-Asker where they are more than 1m thick at some horizons. Black limestone nodules, some septarian, occur at various levels: those in the lower part of the formation being large (up to 30cm thick), isolated and ellipsoidal in outline, those in the upper part being thinner (up to 10cm) and forming distinct horizons. Pyrite nodules are present throughout the unit. In the western part of Oslo-Asker the formation becomes calcareous with nodular limestone horizons more common and the shale thinner and paler in colour. A similar change occurs in Ringerike (Harper et al. 1985 pp.298-299). The formation thins eastwards from an estimated 30-40m in Asker (Størmer 1953 p.65) to 12-13m in Oslo.

The unit in Ringerike was originally termed the Norderhov Formation (Owen & Harper 1982) but it is very poorly exposed here. Having taken advice from the Norwegian Stratigraphical Committee we here suppress the formation name in favour of the Nakkholmen Formation which is more firmly based, especially in terms of its upper and lower boundaries.

Fauna and Age. The Nakkholmen Formation contains a shelly fauna of brachiopods and trilobites which increases in diversity westwards and indicates a Woolstonian-Actonian age (Harper et al. 1985, Figs 3 & 4 and references therein). The brachiopod faunas share few elements in common with contemporaneous units elsewhere in the Oslo Region and even differ markedly from west to east within the formation. In contrast many of the trilobites are known also from the upper Furuberg Formation in Hadeland. The shelly fauna of the type Nakkholmen Formation is of very low diversity and is dominated by the brachiopods *Hisingerella nana* (Hadding), *Onniella cf. bancrofti* Lindström and *Sericoidea gamma* Spjeldnæs and the trilobite *Broeggerolithus discors* (Angelin). Graptolites are also known from the formation here and comprise *Amolexograptus rugosus* (Hadding), *Climacograptus antiquus lineatus* Elles & Wood and *Corynoides incurvus* Hadding indicative of the lower part of the *Dicranograptus clingani* Zone (Harper et al. 1985). Conodonts (Hamar 1966), ostracods (Henningsmoen 1953, Qvale 1980), gastropods (Yochelson 1963), bivalves (H. and T.Soot-Ryen 1960) and scolecodonts (Harper et al. 1985) are also known from the formation.

SOLVANG FORMATION (Solvangformasjonen)

(Owen 1978)

(Previously termed 4b δ_{1-2}. Øvre Chasmopskalk, Upper Chasmops Limestone, Sphaeronidkalken (*pars*), Dasyporella - kalken, Sphaeronid Limestone (*sensu* Størmer 1945), Lower Trinucleus Limestone, Høgberg Member).

Main Lithologies. Nodular limestone and bedded limestones with shale (Solvang Limestone, Solvangkalken).

Basal Stratotype. Hadeland: 0.45km southeast of Nerby (Owen 1978, p.8, pl.1) (NM 859 887).

Hypostratotypes. Hadeland (top): Lunner Railway Section (Owen 1978, Fig. 7) (NM 878 862), (whole unit): Tønnerud shore section (NM 780 922). Ringerike: Norderhov (Owen 1979, Fig. 4) (NM 709 667), Frognøya (NM 652 581). Oslo-Asker: Ø.Raudskjer (Fig. 16) (NM 865 347). Fornebu (Toni 1975a, Fig. 1 above 44.95 in section) (NM 915 416). Rodeløkken (Bygdøy) (Fig. 14) (NM 947 430). Nakkholmen (Harper et al. 1985, Fig. 2 for base (NM 949 404), Williams & Bruton 1983, Fig. 4 for top (NM 948 404)).

Thickness Variation. Hadeland: Tønnerud (17m), Lunner (ca. 70m). Ringerike: Norderhov (ca. 12m). Oslo-Asker: Rodeløkken (12m), Nakkholmen (14.5m), Fornebu (15.5m), Raudskjer (*ca.* 20m), Persteilene (23.3m).

Definition. The Solvang Formation is a limestone unit containing varying amounts of interbedded calcareous shales but contrasting markedly with the dominantly shale units both above and below. The formation was defined originally in Hadeland (Owen 1978 pp.8-10) where it comprises a nodular development with little shale (the Nerby Member) and interbedded limestones and shales (the Lieker Member). Owen subsequently applied the formation name to the equivalent limestone unit in Ringerike (1979 pp.248-253) although only the bedded limestones and shales

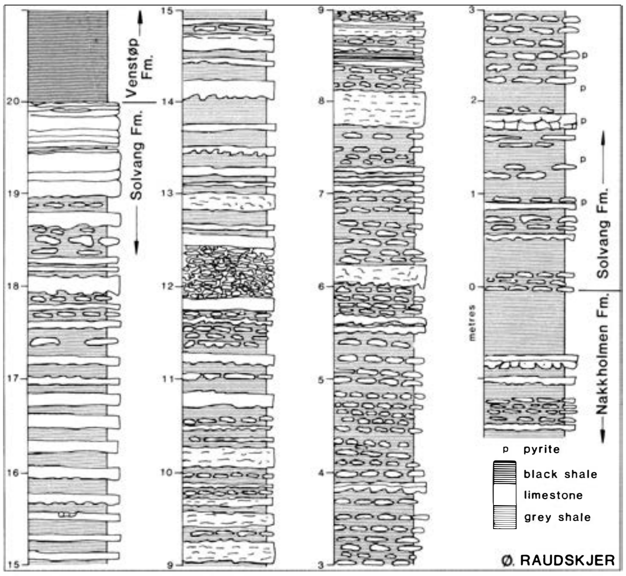

Fig. 16. Measured section through the hypostratotype of the Solvang Formation on Ø. Raudskjer, Asker (NM 864347).

of the uppermost part on Frognøya were given named member status as the Høgberg Member (see below). The name Solvang Formation is formally used herein for the unit in Oslo-Asker which has historically been termed (*inter alia*) the 'Upper Chasmops Limestone' although Owen (1981 p.5) has already informally introduced the new formation name to the succession in this district; a practice continued by Williams & Bruton 1983; Harper et al. 1985. Preliminary analysis indicates that the Solvang Formation in Oslo-Asker should eventually be divided into several members.

The base of the Solvang Formation in Oslo is taken at the conspicuous pyrite band which is overlain by nodular and bedded limestones with subordinate shale horizons (Størmer 1953 p.65, Fig. 5; Toni 1975a Fig. 1; Bruton & Owen 1979 p.216). This basal boundary is unequivocal on Nakkholmen, Persteilene and Bygdøy but further west, e.g. at Fornebu and on Raudskjer, several pyrite horizons are present and the base of the Solvang Formation is drawn at the top of the last thick shale of the underlying Nakkholmen Formation. There is a pyrite horizon within 1m above this at most localities.

On Nakkholmen, and at Bygdøy and Fornebu, the formation is composed of bedded and irregularly nodular limestone up to 20cm thick with intervening calcareous shales up to 60cm thick. On Raudskjer (Fig. 16), such a development is only seen between 1-7m below the top of the formation; the underlying portion containing some rubbly limestone beds but mostly composed of small, closely spaced, limestone nodules. A similar development is seen on Persteilene (Størmer 1953 Fig. 5). The uppermost 1m on Raudskjer comprises planar limestone beds up to 15cm thick with very thin, light weathering, shale partings. This is reminiscent of the uppermost beds (formerly termed the Høgberg Member) on Frognøya, Ringerike (Owen 1979) and the underlying 6m on Raudskjer broadly similar to the Lieker Member in Hadelend (Owen 1978).

Distinctive bioclastic limestones, rich in trilobites, notably illaenids (Owen & Bruton 1980 Fig. 3), can be traced over the whole Oslo-Asker district. In the east, on Nakkholmen, only one such bed is present, 1m below the top of the formation. This corresponds to a similar bed 5m below the top on Ostøya, 5.5m on Fornebu, 6m on Persteilene and 8m on Raudskjer. Thus this bed occurs at successively greater distances below the top of the formation as it is traced eastwards. Similarly, a second bed is present at the top of the formation at Fornebu and on Persteilene, 1m below the top on Ostøya and 2m on Raudskjer.

The upper 1m of the Solvang Formation on Nakkholmen above the 'illaenid bed' has been included in the overlying Venstøp Formation by some authors (e.g. Owen 1979, 1981, see also Størmer 1953 pp.65, 68). However, Williams & Bruton (1983 Fig. 4) have reassigned these dark bioturbated shales and limestones to the Solvang Formation. This was done largely on palaeontological grounds but it does mean that the overlying phosphorite conglomerate, which represents a demonstrable hiatus, is taken as the base of the Venstøp Formation. This phosphorite is equated with other such horizons which rest directly on the unequivocal top of the Solvang Formation elsewhere in Oslo-Asker.

The uppermost 2.88m of the Solvang Formation on Frognøya, Ringerike comprises planar limestones and interbedded shales. These overlie tightly nodular (stylonodular) limestone and were termed the Høgberg Member by Owen (1979). The geographical component of this name was a local term, not on any published map, and could be confused with other names applied in the nappes to the north east of the Oslo Region (e.g. Nystuen 1980, Rasmussen & Stouge 1989). The term is therefore abandoned herein.

Fauna and Age. The Solvang Formation is one of the most fossiliferous units in the Oslo Region. The trilobites have been described by Nikolaisen (1983), Owen & Bruton (1980) and Owen (1980a, 1981), strophomenid brachiopods by Spjeldnæs (1957), ostracods by Qvale (1980), echinoderms by Bockelie (1981, 1984) and conodonts by Hamar (1966); see also Bergström (1971). Other elements of the shelly fauna yet to be fully explored include the remainder of the brachiopod groups (Harper 1986 and in prep.), cephalopods (Sweet 1958), gastropods (Yochelson 1963), bivalves (H. & T. Soot-Ryen 1960), and bryozoans. Bruton & Owen (1979) interpreted the trilobite distribution in the Solvang Formation in terms of the progressive immigration of species with an abrupt faunal shift being marked by the base of the overlying Venstøp Formation. They argued that the Solvang Formation trilobites in Oslo-Asker indicate a westward younging of the top of the unit and an overall correlation with the Actonian and Onnian stages in Britain. There are several species in common between the two countries, the most important being *Tretaspis ceriodes* (Angelin) (see also Owen 1980a, 1987a). This occurs in the uppermost part of the formation in Bærum and Asker and also in the dark limestone in the shales between the illaenid bed and phosphorite on Nakkholmen (see above). The shale below this dark limestone (i.e. below the *T. ceriodes* occurrence) has recently yielded a graptolite fauna which belongs to the middle? *Dicranograptus clingani* Zone (Williams & Bruton 1983). The uppermost part of the Solvang Formation on Frognøya, Ringerike (formerly the Høgberg Member) contains trilobites (Owen & Bruton 1980, Owen 1980a) indicating an earliest Ashgill (Pusgillian) age for this part of the unit (see also Owen 1979 ppl 250-252, Bruton and Owen 1979 pp. 219-221). This and lower parts of the formation also contain conodonts including *Amorphognathus complicatus* Rhodes (see Hamar 1966) which Bergstrøm (1971 p.105) interpreted as indicating the upper part of the *A. superbus* Zone.

Nerby Member (Nerbyleddet)

(Owen 1978)

(Previously termed: 4b?, Dasyporella-Kalken, Lower Sphaeronid Limestone (*sensu* Størmer 1945)).

Main Lithology. Nodular limestone.

Basal Stratotype. Hadeland: as for formation.

Høypostratotypes. Hadeland (top): Lunner Railway Section (Lauritzen 1973, Fig. 2), (unit) (NM 877 862): Tønnerud shore section (NM 780 922).

Definition. The Nerby Member constitutes the whole of the formation (16-7m) at Tønnerud and over all but the southeast of Hadeland. It comprises thin (up to 5cm), nodular and stylonodular limestone horizons with little or no intervening shale. The base marks a distinct change from the interbedded shales and limestones of the Furuberget Formation and except in the southeast, the top is marked by the base of the calcareous shales of the Gagnum Member of the Lunner Formation.

Lieker Member (Liekerleddet)

(Owen 1978)

Previously termed: 4bδ , Upper Chasmops Limestone).

Main Lithologies. Nodular and bedded limestones with shales.

Basal Stratotype. Hadeland: Lunner Railway Section (Lauritzen 1973 Fig. 2 also Owen 1978 Fig. 7 for top) (NM 877 862).

Definition. The nodules and irregular beds of limestone and interbedded shales of this member constitute the upper 20.6m of the formation in the unit stratotype and extend for only 1.5km west of Lunner (Owen 1978 plate 1). A measured section, faunal log and microfacies analysis of the Lunner railway section was presented by Lauritzen (1973 Figs 2-3, 1975). The Lieker Member succeeds and passes laterally into the Nerby Member and is overlain by shales and limestones of the Lunner Formation.

FOSSUM FORMATION (Fossumformasjonen)

(Dahll 1857)

(Previously termed: 4a, 4b-d, 4a-4bγ , Fossum Kalkstein, Ampyxzone, Chasmopskalk und Schiefer, Ampyx Limestone and Shale, Echinosphaerites zone, Echinosphaerites beds, Bryozoan zone, Bryozoan beds, Mastopora-Coelosphaeridium zone, Coelosphaeridium-Mastopora beds.

Main Lithologies. Rubbly, thinly bedded limestones and shales (Fossum Limestone, Fossumkalken).

Basal Stratotype. Skien-Langesund: Blekkebakken (Frierfjord) (Fig. 17) (NL 385 466 - NL 388 466).

Hypostratotypes. Eiker-Sandsvær: Rønningsfossen (NM 358 035), Lindset (NM 355 021). Modum (Vikersund): Vikersund ski jump (NM 564 454).

Definition. The history of the terminology applied to this unit was summarized by Harland (1980 Table 1). The formation was originally included with the Steinvika Formation (see below) as the Fossum Kalkstein by Dahll (1857). The Fossum Kalkstein and overlying 'Venstob Schiefer' together comprised Dahll's 'Fossum Gruppe'. The beds between the Elnes Formation and the Steinvika Formation ('Encrinite Limestone') were subdivided by Brøgger (1884), Størmer (1953) and Strand & Henningsmoen (1960) largely on palaeontological grounds but are here assigned to a revised version of Dahll's 'Fossum Kalstein', the Fossum Formation.

As Størmer (1953 p. 73) noted, the base of the Fossum Formation along the shore of the Frierfjord in Skien-Langesund lies within a transition from the shales with limestone nodules of the Elnes Formation to rather rubbly thinly bedded limestones with thin shales of the Fossum Formation. This lithology typifies

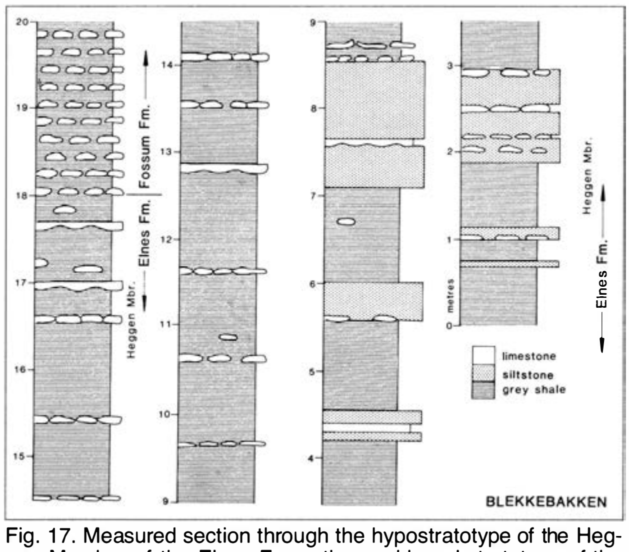

Fig. 17. Measured section through the hypostratotype of the Heggen Member of the Elnes Formation and basal stratotype of the Fossum Formation at Blekkebakken (Frierfjord), Skien-Langesund (NL 385466-388466) (from Ribland Nilssen 1985).

the whole formation although the shale horizons are thicker at some levels. A description of the lithofacies directly below the Steinvika Limestone was given by Harland (1981 pp.6-8). The formation is estimated to be of the order of 150m thick in Skien-Langesund and a similar thickness is probably present in Eiker-Sandsvær and Modum.

Fauna and Age. As noted above, although there is little lithological variation there is an upward change in the dominant fauna and flora of the Fossum Formation and this gave rise to the biostratigraphical subdivision of the unit best summarized by Størmer (1953 pp.73-75, 80-81). The lowest part of the unit is characterized by trilobites including asaphids and raphiophorids, together with trinucleids (see Owen 1987) namely *Botrioides* and (a little higher up) *Reedolithus carinatus* (Angelin). It is succeeded by a diverse shelly fauna including trilobites, brachiopods and several echinoderms (Bockelie 1981, 1981a) including the cystoid *Echinosphaerites aurantium* (Gyllenhaal) and the eocrinoid *Bockia grava* Bockelie. Bockelie (1981a pp.133-134) gave a full list of the echinoderms present and argued that the preservation of ambulacral appendages in *E. aurantium* indicates rapid burial by periodic influxes of fine terrigenous mud. The fauna also includes bryozoans which become more abundant in the succeeding more shaly beds. The uppermost part of the formation is characterized by the calcareous algae *Mastopora* and *Coelosphaeridium,* the latter occurring in great abundance at some levels. The boundaries between these various 'biozones' are gradational and it is not possible at the moment to define a formal biostratigraphical subdivision of the Fossum Formation.

The trilobites of the lower part of the Fossum Formation indicate a Llandeilo age and the formation probably extends well into the Caradoc.

STEINVIKA FORMATION (Steinvikformasjonen)

(Harland 1980)

(Previously termed: 4e, 4bδ , Encrinitenkalk, Encrinite Limestone)

Main Lithology. Limestone (Steinvika Limestone, Steinvikkalken)

Basal Stratotype. Skien-Langesund: Steinvika (Harland 1980 Fig. 4) (NL 429 397).

Hypostratotype. Eiker-Sandsvær: Lindset (NM 355 021).

Definition. The Steinvika Formation is a limestone unit comprising a variety of lithofacies (Harland 1980, 1981). Its base is slightly transitional but marks a change from the pale limestones, sandstones and shales of the Fossum Formation to dark, thickly bedded bioclastic limestones. The top is an abrupt change from pale limestones and mudstones to the dark shales of the Venstøp Formation.

Harland (1981) recognised 13 different lithofacies within the Steinvika Formation representing environments from intertidal to well circulated shelf. He subdivided the formation into four members (see below and Fig. 18 herein), the formation as a whole being 41.4m thick in its type development. The formation in Eiker-Sandsvær is too poorly known at present for any formal subdivision or estimate of thickness to be made.

Fauna and Age. The Steinvika Formation is richly fossiliferous at some horizons and contains local bioherms of calcareous algae, stromatoporoids and corals (Harland 1980, 1981, 1981a). As noted by Harland (1980 p.277) the occurrence of the trilobite *Toxochasmpos extensus* (Boeck) suggests a correlation with the upper Caradoc units elsewhere in the Oslo Region.

Bunes Member (Bunesleddet)

(Harland 1980)

Main Lithologies. Thickly bedded limestone with organic buildups.

Basal stratotype. Skien-Langesund: Bunes (Harland 1980 Fig. 5) (NL 406 449).

Definition. The Bunes (formerly Bunæs) Member marks the base of the formation throughout Skien-Langesund and is dominantly a thickly bedded, dark bioclastic limestone with 'patch reefs' (Harland 1980, 1981a) 4-6m thick developed in its lower half. The

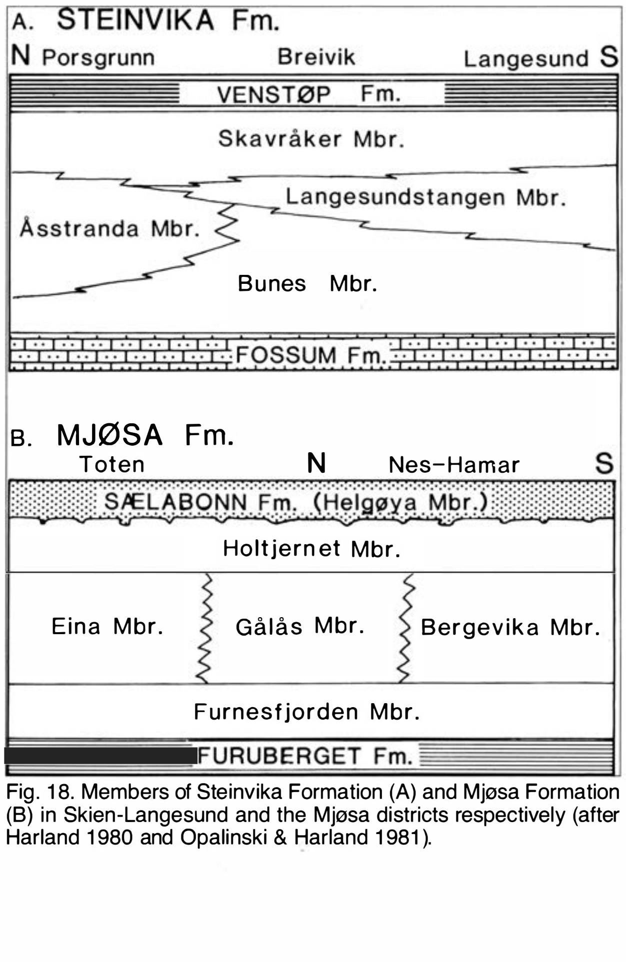

Fig. 18. Members of Steinvika Formation (A) and Mjøsa Formation (B) in Skien-Langesund and the Mjøsa districts respectively (after Harland 1980 and Opalinski & Harland 1981).

member is 21.6m thick at Bunes where it is overlain by the Langesundstangen Member. It has a maximum thickness of 23m at Brevik and thins southwards to 17.2m at Steinvika in which direction its upper parts pass laterally into the Langesundstangen Member. The Bunes Member also thins northwards where its upper part passes into the Åsstranda Member (see Fig. 18).

Fauna. Harland (1980 pp.272-3) noted the rich shelly fauna in the algal-stromatoporoid-coral bioherms (see also Bockelie 1979, p.395) and recognised two brachiopod dominated assemblages at other levels in the member. The trilobites *Stenopareia glaber* (Kjerulf) and *Toxochasmpos extensus* (Boeck) occur in the more diverse of these associations.

Åsstranda Member (Åsstrandleddet)

(Harland 1980)

Skien-Langesund: Åsstranda (Harland 1980, Fig. 6) (NL 372 510)

Main Lithologies. Limestone and quartz siltstone.

Definition. The Åsstranda Member is restricted to the northern part of Skien-Langesund. Its lower part passes laterally into the Bunes Member, its upper part into the Langesundstangen Member except in the very north where it passes into the Skavråker Member (see Fig. 18). Its base lies in a transition from coarse bioclastic limestones into pale calcilutites and the member is characterised by massive and laminated calcilutites and laminated quartz siltstones (Harland 1980, Fig. 6). It is 24m thick in its type development but wedges out southwards.

Fauna. With the exception of echinoderm, mollusc, brachiopod and bryozoan bioclasts the member is reported to be unfossiliferous.

Langesundstangen Member (Langesundstangleddet)

(Harland 1980)

Main Lithologies. Limestone and mudstone.

Unit Stratotype. Skien Langesund: Steinvika (Harland 1980, Fig. 7) (NL 429 397).

Definition. This limestone-mudstone member is developed in the southern and central parts of Skien-Langesund. Its diachronous base overlies the Bunes Member over most of its outcrop and the Åsstranda Member in its most northerly exposures. The top of the member interfingers irregularly with the Skavråker Member (see Fig. 18). The Langesundstangen Member is 14.1m thick at Steinvika and tapers out northwards.

Fauna. Harland (1980 p.275) recorded fossils and bioclasts to be abundant at several horizons. Recognisable fossil material includes brachiopods, trilobites and bryozoans.

Skavråker Member (Skavråkleddet)

(Harland 1980)

Main Lithologies. Limestone and mudstone.

Basal Stratotype. Skien-Langesund: Skavråker (Harland 1980 Fig. 8) (NL 388 489).

Definition. This uniform sequence of thin beds of bioturbated calcilutites and mudstones constitutes the uppermost part of the Steinvika Formation over the whole of Skien-Langesund. It rests on, and interfingers slightly with, the Åsstranda Member in the north of the district and the Langesundstangen Member over the rest of the area (see Fig. 18). The member maintains a fairly constant thickness over the district being 12.45m thick at the type locality and between 8.3m - 10.9m elsewhere (Harland 1980 p.275). The top of the member is the abrupt change to dark shales of the Venstøp Formation.

Fauna. The Skavråker Member contains a sparse fauna of brachiopods, trilobites and echinoderms and many horizons are heavily bioturbated (Harland 1980 p.276).

HOVINSHOLM FORMATION (Hovinsholmformasjonen)

(Skjeseth 1963).

(Previously termed: 4aß-4bα, Robergia Beds, Hovinsholm Shale).

Main Lithology. Shale (Hovinsholm Shale, Hovinsholmskiferen).

Basal Stratotype. Mjøsa (Nes-Hamar): Hovinsholm Farm, Helgøya (PN 098 327).

Definition. The Hovinsholm Formation is restricted to the Mjøsa districts and comprises grey shales alternating with calcarenites and scattered limestone nodules. The top of the formation is transitional to the overlying Furuberget Formation (Skjeseth 1963 pp.64,74). The thickness of the formation cannot be determined in the type area (Skjeseth 1963 p.65) but some 78m of the unit including the transition to the overlying unit at Holmen in Brummundal, Ringsaker was reported by Størmer (1953 pp.109-110) and Skjeseth (1963 p.74).

Fauna and Age. As Skjeseth (1963 p.64) noted, these strata were termed the 'fossil-barren beds' by Holtedahl (1909) but following the discovery in Ringsaker of specimens of the remopleuridid *Robergia microphthalma* (Linnarsson) (see also Nikolaisen 1983 pp.294-5), Størmer (1953 p.109) renamed them the Robergia Beds. The only fossils known from the Hovinsholm Formation in Nes-Hamar are in the upper transition beds (Skjeseth 1963 p.65) but the formation as a whole has yielded a diverse shelly and graptolitic fauna at Herram and Holmen in Ringsaker (Størmer 1953 pp.109-110; Skjeseth 1963 p.72; Nikolaisen

1983 p.295). Shelly fossils from these localities include trilobites, ostracods and graptolites and indicate a correlation with the Andersö Shale in Jämtland (upper Llanvirn - lower Caradoc). The graptolite fauna was identified by Bulman (*in* Størmer 1953 pp.109-110) with that from the upper part of the Holmen section considered to be indicative of an horizon 'somewhat higher than the zone of *Nemagraptus gracilis'.* An early Caradoc age for the top of the formation is thus suggested.

FURUBERGET FORMATION
(Furubergformasjonen)
(Skjeseth 1963)

(Previously termed: 4a, 4bγ ?, Coelosphaeridium Zone, Cyclocrinus Zone, Coelosphaeridium Beds, Cyclocrinus Beds, Coelosphaeridium Shale, Cyclocrinus Shale and Limestone).

Main Lithologies. Shale with limestones and calcareous siltstones.

Basal Stratotype. Mjøsa (Nes-Hamar): Furuberget Railway Section (PN 092 443).

Hypostratotypes. Mjøsa (Ringsaker): Fangberget (PN 021 527). Hadeland: 600m east of Raknerudtjern (NM 860 905), Lunner road section (see Lauritzen 1973, Fig. 4) (NM 865 863).

Definition. In the Mjøsa districts the base of the Furuberget Formation is in a gradational sequence from the grey shales of the Hovinsholm Formation to green/grey shales with limestones and calcareous siltstones. The formation was defined originally in the Mjøsa area (Skjeseth 1963 pp.65, 74) but is now also recognised in Hadeland (Harper & Owen 1984, p.21) where its base is also marked by the development of calcareous sandstones although these are restricted to 2.2m of the succession.

Spjeldnæs (1982 pp.150-152) noted that cross bedding in the siltstones and limestones of the lower Furuberget Formation in Nes-Hamar indicates a palaeo-slope from west to east. He also argued that the limestones of the formation were channel-fill sediments derived from a carbonate platform in the west.

The upper part of the formation contains thicker limestone horizons (>10cm) in the Mjøsa areas. In addition in Hadeland, 1.2m thick bed of tightly nodular limestone very near the top of the formation is considered anticipatory of the overlying Nerby Member of the Solvang Formation. Limestones and shales which Kiær (1897) and Holtedahl (1909) ascribed to the Mjøsa Limestone were assigned to the uppermost Furuberget Formation by Størmer (1953 p.104) and Skjeseth (1963 p.65) and this view is followed here. Moreover, Spjeldnæs (1982) has argued that the base of the overlying Mjøsa Formation is diachronous.

Fauna, Flora and Age. Størmer (1953) and Skjeseth (1963) recognised two "zones" in the Furuberget Formation on the basis of fossil calcareous algae. The 'Coelosphaeridium zone' overlain by the 'Cyclocrinus zone'. These have yet to be defined in any formal way although Skjeseth (1963 p.65) referred to them as informal members of the Furuberget Formation. The limestones and to a lesser extent the shales of the formation contain a diverse shelly fauna which Spjeldnæs (1982 p.150) argued had been washed in from the west. Trilobites (Henningsmoen 1960; Nikolaisen 1961, 1963, 1983; Bruton 1965; Owens 1970), brachiopods (Holtedahl 1916; Spjeldnæs 1957) and a possible alga (Nitecki & Spjeldnæs 1989) have been described from the Furuberget Formation in the Mjøsa districts. Here Spjeldnæs (1982 p.152) suggested that the presence of the brachiopods *Christiania holtedahli* Spjeldnæs and *Kullervo* sp. in the lower part of the unit may indicate a correlation with the Arnestad Formation of Oslo-Asker and thus an early Caradoc age. The brachiopods and trilobites from the uppermost part of the formation in Hadeland were described by Harper & Owen (1984) who suggested a Marshbrookian - early Actonian age for this part of the formation and a similar age is indicated by Spjeldnæs (1982 p.152) for the uppermost part of the unit at Furuberget (Nes-Hamar) which is similar to that of the Oandu Stage in Estonia on the basis of the bryozoan fauna. Spjeldnæs also suggested that these beds at Furuberget may be equivalent to the lower part of the Mjøsa Formation at Bergevika south.

MJØSA FORMATION (Mjøsformasjonen)
(Kiær 1908)

(Previously termed: 5a (*pars*) 5b, 4bδ , ?4bδ +, der Mjøsen Kalk, Mjøskalk).

Main Lithology. Limestone (Mjøsa Limestone, Mjøskalken).

Basal Stratotype. Mjøsa (Toten): Eina (Opalinski & Harland 1981, Fig. 5) (NN 876 238).

Definition. The Mjøsa Formation is a varied limestone-dominated unit which maintains a thickness of about 100m over the Mjøsa districts. Its base in the Toten district is an abrupt change to bioclastic limestone from the shales and calcareous siltstones of the underlying Furuberget Formation (Opalinski & Harland 1981 p.61). The same is probably true in Ringsaker (Størmer 1953, Skjeseth 1963) but the boundary lies within a transitional succession. The top of the Mjøsa Formation is a distinct karst surface overlain by Llandovery sandstones of the Helgøya Member of the Sælabonn Formation (Skjeseth 1963; Opalinski & Harland 1981; Worsley et al. 1983).

Opalinski & Harland (1981) subdivided the Mjøsa Formation in Toten and Nes-Hamar into five named members and these are summarized here (Fig. 18). Spjeldnæs (1982) however, preferred not to use a formal lithostratigraphy in his excursion guide to these areas. The development in the Ringsaker district has yet to be described in detail but it is broadly divisible into two parts (Størmer 1953 p.111; Skjeseth 1963 p.75). The lower 30m of compact limestone rich in the alga *Solenopora* may be broadly equivalent to the Furnesfjorden Member further south whereas the overlying 60-70m of red calcareous shales appears to have no lithological equivalent in Toten or Nes-Hamar.

Fauna, Flora and Age. The Mjøsa Formation contains a diverse fauna and algal flora and locally includes the development of 'reefs' (Harland 1981a). Algae from the unit were described by Kiær (1922) and Høeg (1927) and stromatoporoids by Webby (1979). Faunal elements include: brachiopods (Holtedahl 1916; Spjeldnæs 1957; Harper in prep.), trilobites (Nikolaisen 1961; Henningsmoen 1960; Siveter 1977), corals (Hill 1953), ostracods (Henningsmoen 1953), cephalopods (Sweet 1958) and bivalves (H. & T. Soot-Ryen 1960).

The Mjøsa Formation was originally thought to be late Ordovician in age (Kiær 1897, 1908; Holtedahl 1909) but Raymond (1916) and Kiær (1922, 1922a) recognised the hiatus at the top of the formation and equated the Mjøsa Limestone with late Caradoc units elsewhere in the Oslo Region. The described faunas generally confirm this correlation although some elements are endemic to the unit and reflect environments otherwise unknown in the Oslo Region. Spjeldnæs (1982 p.152) argued that the lower part of the Mjøsa Limestone at Bergevika south is equivalent to the upper part of the Furuberget Formation at Furuberget and that both have a bryozoan fauna indicating a correlation with the Oandu Stage (mid-Caradoc) of Estonia. Hamar (*in* Størmer 1967 p. 204; *in* Bjørlykke 1974 p. 15), noted the existence of conodont evidence indicating that the formation extends into the lower Ashgill but details have not been published. The very thin development of the overlying Sælabonn Formation compared to elsewhere in the Oslo Region has led Worsley et al. to suggest that the hiatus above the Mjøsa Limestone may also include the lowest Llandovery (1983 Fig. 5).

Furnesfjorden Member (Furnesfjordleddet)

(Opalinski & Harland 1981)

Main Lithologies. Bioclastic limestone, calcareous sandstone and mudstone.

Basal Stratotype. Mjøsa (Nes-Hamar): Snippsand (Opalinski & Harland 1981, Fig. 6) (PN 074 430).

Definition. The Furnesfjorden Member is characterized by bioclastic limestones, calcareous sandstones and mudstones. The calcareous alga *Solenopora* is common and locally forms bioherms. Peloidal limestones are developed in the upper part of the member at many localities in Toten. The Furnesfjorden Member is the basal member of the formation throughout the Toten and Nes-Hamar district and is 23.3m (Bergevika) to 30.7m (Snippsand) thick.

Fauna and Flora. In addition to *Solenopora* the Furnesfjorden Member contains a diverse fauna of brachiopods, trilobites, ostracods, gastropods, bivalves and, in the *Solenopora* bioherms, corals (Opalinski & Harland 1981 pp.63-65).

Eina Member (Einaleddet)

(Opalinski & Harland 1981).

Main Lithologies. Calcisiltite, peloidal, dolomitic and micritic limestone.

Basal Stratotype. Mjøsa (Toten): disused quarry at Eina (Opalinski & Harland 1981, Fig. 7) (NN 876 238).

Definition. The Eina Member is restricted to the Toten district and comprises grey calcisiltites overlain by a sequence of peloidal, dolomitic and micritic limestones. The base is a fairly abrupt change from the dark bioclastic limestones of the underlying Furnesfjorden Member and the thickness of 38.4m of the Eina Member in its type locality is broadly maintained over the district.

Fauna and Flora. The Eina Member contains diverse but at many levels fragmentary shelly fossils along with algae and stromataporoids. Local 'reefs' were described by Opalinski & Harland (1981 pp.67-69).

Gålås Member (Gålåsleddet)

(Opalinski & Harland 1981).

Main Lithologies. Micritic and peloidal limestones.

Basal Stratotype. Mjøsa (Nes-Hamar): Snippsand (Opalinski & Harland 1981, Fig. 8) (PN 074 430).

Definition. This member is only developed in northern Nes-Hamar where it is approximately 36.5m thick at Snippsand and Furuberget. It overlies the Furnesfjorden Member and is dominated by pale grey micrites and peloidal limestones. Selective dolomitization of burrow systems give weathered surfaces a reticulate appearance.

Fauna and Flora. The Gålås Member is poorly fossiliferous although widely spaced stromatoporoids occur at levels throughout the member and *Solenopora* and shelly fossils are known from some horizons.

Bergevika Member (Bergevikleddet)

(Opalinski & Harland 1981).

Main Lithologies. Mudstones, calcareous sandstones, limestone.

Basal Stratotype. Mjøsa (Nes-Hamar): Bergevika south (Opalinski & Harland, Fig. 9) (PN 101 364).

Definition. The Bergevika Member is restricted to Helgøya (Nes-Hamar) where the only complete section is at Bergevika south and where the member is 35.45m thick. Its base marks the development of 8.6m of alternating mudstones and calcareous sandstones overlying the Furnesfjorden Member. The succeeding 21.25m is composed entirely of limestones with stromatoporoid 'reefs' up to 15m thick developed in the upper part (Opalinski & Harland 1981 pp.70-73; Harland 1981a pp.181-186; Webby 1979). The uppermost 5.6m of the member comprises thickly bedded dark micrites similar to those of the Gålås Member but lacking reticulate weathering.

Fauna and Flora. The lower part of the member contains bioclastic limestones rich in brachiopods and sparse, large, strophomenid brachiopods occur in the uppermost dark micrites. The 'reefs' of the central part of the Bergevika Member comprise a variety of facies with algae, stromatoporoids, corals and echinoderm fragments the most abundant fossils.

Holtjernet Member (Holtjernleddet)

(Opalinski & Harland 1981)

Main Lithologies. Limestones with local siltstone.

Basal Stratotype. Mjøsa (Toten): Holtjern (Opalinski & Harland 1981, Fig. 10) (NN 907 262).

Definition. The Holtjernet Member is developed above the Eina Member in Toten, the Gålås Member in northern Nes-Hamar and the Bergevika Member on Helgøya, southern Nes-Hamar (Fig. 18). Its base comprises coarse, conglomeratic, bioclastic limestones in Toten and fissile siltstones in Nes-Hamar. The remainder of the member is composed of reticulate weathering bioturbated limestone. The Holtjernet Member is 25.9m thick at Holtjernet and maintains this thickness except at Kyset (Toten) where it is much thinner. The top of the member is the karst top of the formation.

Fauna and Flora. Opalinski & Harland (1981 pp.74-76) recognised four lithofacies within the Holtjernet Member and listed diverse shelly faunas and algal floras from two of them: the limestone conglomerates and the fissile siltstones which constitute the basal parts of the member.

VENSTØP FORMATION (Venstøpformasjonen)

(Dahll 1857)

(Previously termed: 4b, 4f, 4cα, Venstöb-Schiefer, Trinucleusschiefer, Trinucleus Shale, Lower Tretaspis Shale, Frognøya Shale).

Main Lithology. Shale (Venstøp Shale, Venstøpskiferen)

Neostratotype. Skien-Langesund; Langesundstangen (Harland 1980, Fig. 4) (NL 432 392).

Hypostratotypes. Oslo Asker: Nakkholmen (Williams & Bruton 1983, Fig. 4) (NM 949 404). Ringerike, N.W. Frognøya (Williams & Bruton 1983, Fig. 7) (NM 652 582).

Thickness Variation. Skien-Langesund: Langesundstangen (11.1m). Oslo-Asker: Nakkholmen (7.4m)-Nesbru (10.9m)(see Williams & Bruton 1983). Ringerike: N.W. Frognøya (26.0m). Modum (Sylling): Nysæterbrenna (>14m).

Definition. The Venstøp Formation is a dark, locally graptolitic, shale which occurs in Skien-Langesund, Eiker-Sandsvær, Modum (Sylling), Oslo-Asker and Ringerike. The original type area for the formation was a series of exposures around Venstøp (Dahll 1857). Harland (1980 pp.276-277), however, designated a neostratotype on the southern tip of Langesundstangen as the Venstøp localities have deteriorated and are unsatisfactory as type exposures. Harland noted (1980 pp.272, 276) that both the base and the top of the formation in Skien-Langesund are abrupt lithological changes, with pale coloured limestones occurring both above and below the Venstøp Formation. In its type deveopment, the formation is composed of dark, iron-stained shales with scattered limestone concretions (Harland 1980 p.276, Fig. 4; 1981 pp.25-26). The top of the formation is here taken to include planar limestones which are also developed at various horizons, especially near the top, elsewhere in the Oslo Region. In all districts the Venstøp Formation is bounded by limestone formations. In Oslo-Asker there is a thin phosphorite conglomerate at its base. The formation here was described in detail by Williams & Bruton (1983) who informally subdivided it into a lower dark shale member with rare limestone nodules and an upper member of alternating pale shales and limestone. Limestone horizons are much more common in the thick development of the formation in Ringerike (Owen 1979, Williams & Bruton 1983) and the unit here was considered to represent a local member, the Frognøya Shale Member by Owen (1979, 1981). Now that the Venstøp Formation has been more fully documented from other districts of the Oslo Region, this local unit term is abandoned herein.

Fauna and Age. Graptolites of the *Pleurograptus linearis* Zone are abundant at some levels in the Venstøp Formation in Skien-Langesund (Harland 1980 p.277), Oslo-Asker (Williams & Bruton 1983) and Ringerike (Owen 1979 p.253; Williams & Bruton 1983), and together with the trilobites, notably species of *Tretaspis,* indicate an early Ashgill (Pusgillian) age. Williams & Bruton (1983) argued that the phosphorite conglomerate in Oslo-Asker represents an hiatus equivalent to the upper *D. clingani* and lowest *P. linearis* graptolite zones.

The shelly fauna is commonly one of high abundance but low diversity. Thus Harland (1980 p.277) reported bedding planes packed with brachiopods, notably species of *Onniella* and *Hisingerella* along with rarer specimens of *Sericoidea, Dalmanella* and inarticulates. A broadly similar association is being described by Harper (in prep.) from the formation in Eiker-Sandsvær. Harland also noted (1980 p.276) the scattered occurrence of species of the trilobites *Tretaspis, Flexicalymene* and *Primaspis.* This is also the case in Eiker-Sandsvær and Oslo-Asker and the lower part in Ringerike. In the upper part of the formation in Ringerike specimens of *Tretaspis* and *Flexicalymene* occur in great abundance at some horizons. Brachiopods (Owen 1979, Hanken & Owen 1982), bivalves (Toni 1975) and gastropods also occur here. With the exception of *Flexicalymene,* the trilobites of the Venstøp Formation were described by Owen (1980a, 1981). The formation contains a relatively higher proportion of articulated individuals than in other upper Ordovician units, suggesting quiet conditions of deposition. Orthocone nautiloids, gastropods, bivalves and conulariids are also known from the formation and some horizons, especially bedded limestones, are bioturbated with *Chondrites* being particularly common.

GRIMSØYA FORMATION (Grimsøyformasjonen)

(New name)

(Previously termed: 4cß, Trinucleuskalk, Trinucleus Limestone, Tretaspis Limestone).

Main Lithology. Limestone (Grimsøya Limestone, Grimsøykalken).

Basal Stratotype. Oslo-Asker: Grimsøya (Asker)(Fig. 19) (NM 889 384).

Hypostratotypes. Oslo-Asker: Raudskjer (NM 864 347), Kalvøya (NM 864 401), Nakkholmen (NM 949 405).

Definition. The term Grimsøya Formation was introduced without detailed description for this unit by Owen (1981 Fig. 1). The lower part of the formation (10.85m in the basal stratotype) comprises thin (rarely more than 6cm) nodular limestone horizons with rusty weathering shale partings. This contrasts with the shale-limestone alternations of the top of the underlying Venstøp Formation (Williams & Bruton 1983, Figs. 2-6). The upper part of the Grimsøya Formation is 29.0m thick on Grimsøya and is made up of alternating bedded limestones and shales. Siltstone beds are also present in this upper development, the first lying at 18.8m above the base of the formation in the basal stratotype. As Brøgger (1887 pp.25-6) indicated, the formation thins eastwards from above 46m at Odden on the Asker coast to as little as 10m on Rambergøya, Oslo. Spjeldnæs (1964 p.9) also noted that the unit thins to about 0.5m in Nittedal northeast of Oslo.

Fauna and Age. Much of the Grimsøya Formation is unfossiliferous but trilobites (Owen 1980a, 1981), corals (Spjeldnæs 1964), echinoderms (Bockelie 1984) and cephalopods (Strand 1933) have been described from various horizons. None of the fauna is particularly diagnostic in terms of the position of the unit in the Ashgill Series.

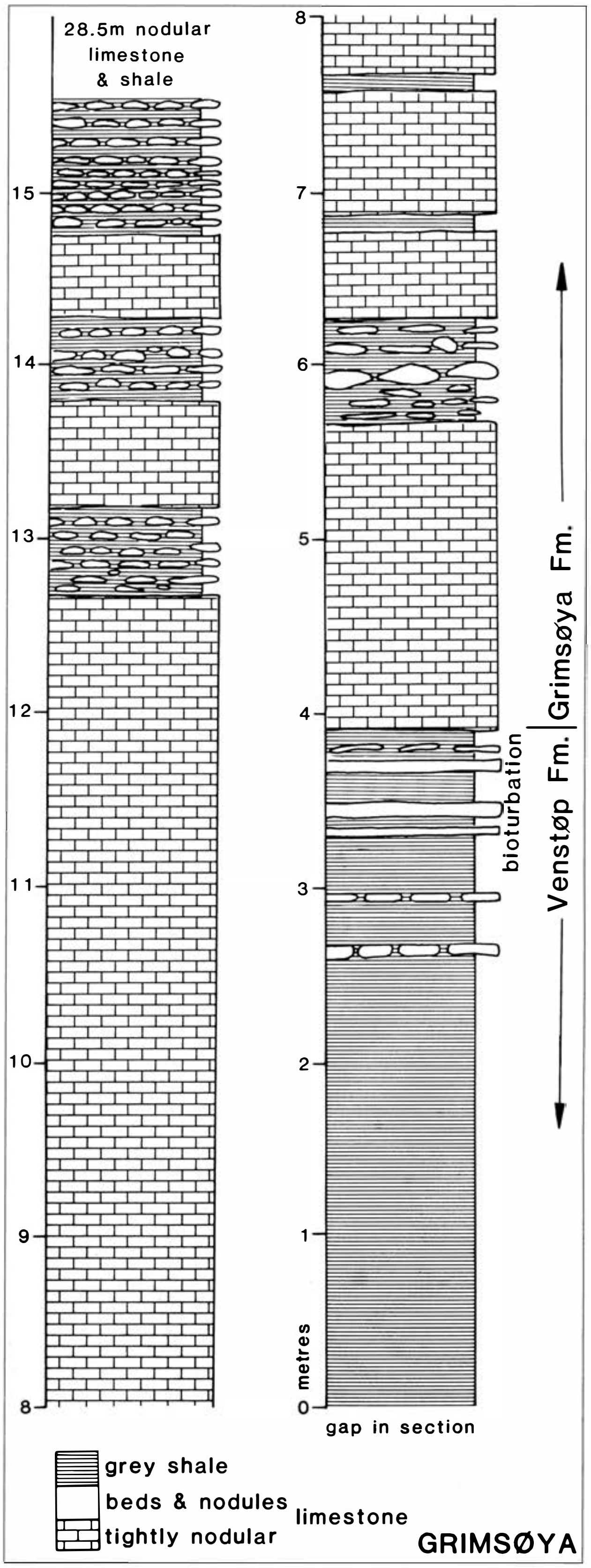

Fig. 19. Measured section through the basal stratotype of the Grimsøya Formation on Grimsøya, Bærum (NM 889384) (based partly on Williams & Bruton 1983).

SKJERHOLMEN FORMATION (Skjerholmformasjonen)

(New name)

(Previously termed: 4cγ , Øvre Trinucleusskifer, Upper Trinucleus Shale, Upper Tretaspis Shale).

Main Lithologies. Calcareous shales with limestones, siltstones and fine sandstones.

Basal Stratotype. Oslo-Asker: Søndre Skjerholmen (Fig. 20) (NM 968 365)

Hypostratotypes. Oslo-Asker: Grimsøya (base) (NM 889 384). Skogerholmen (top)(Fig. 21) (NM 862 353).

Definition. As with the underlying and overlying units, the Skjerholmen Formation was named but not defined by Owen (1981 Fig. 1). The formation comprises light grey, rusty weathering calcareous shale beds up to 50cm thick but commonly less than 20cm alternating with nodular silty limestones, calcareous siltstones and fine calcareous sandstone the majority of which are less than 10cm thick. In the basal stratotype on S. Skjerholmen (Fig. 20) the base of the formation is taken at the first thick shale (20cm) above nodular limestones of the Grimsøya Formation. The siltstones and sandstones are more common towards the top of the formation and some are cross-bedded. Many horizons are strongly bioturbated and small scale channelling is evident at some levels.

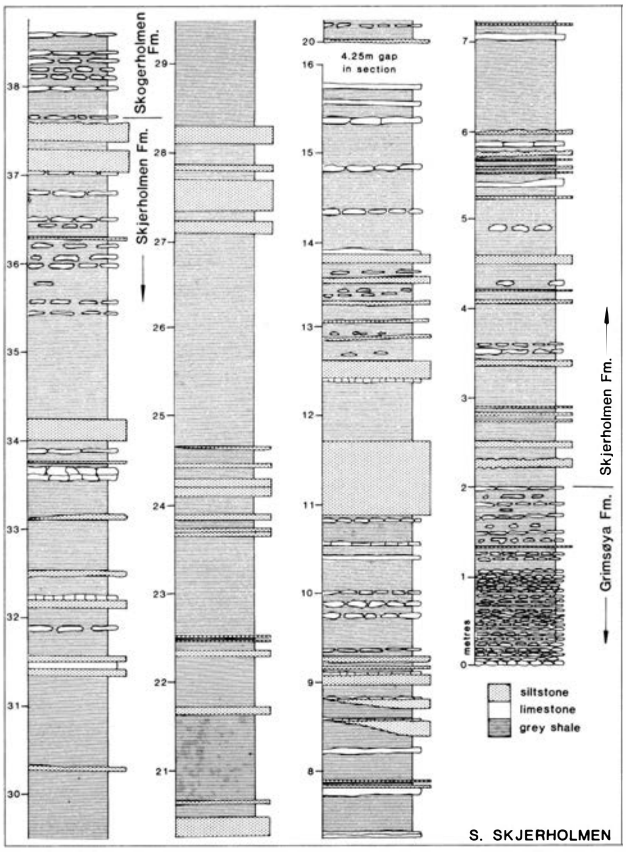

Fig. 20. Measured section through the basal stratotype of the Skjerholmen Formation and basal part of the hypostratotype of the Skogerholmen Formation on Søndre Skjerholmen, Oslo (NM 968365). Note that the shales are commonly brown weathering and contain very thin siltstone seams, too thin to show at this scale. Many of the thicker siltstones show sedimentary structures including bedding-parallel lamination, cross bedding, channels ripples and bioturbation.

The distinction between the Skjerholmen Formation and the underlying limestone unit is clear in the east but westwards towards Asker the boundary lies within a transitional sequence (e.g. Spjeldnæs 1964 p.9). Thus it is defined on Grimsøya at a 5cm siltstone bed above which shale beds become thicker and siltstones more common than in the underlying unit. The lower 16.5m of the Skjerholmen Formation are exposed above this boundary on Grimsøya.

The thickness of the Skjerholmen Formation varies considerably but this may in part reflect tectonic dis-

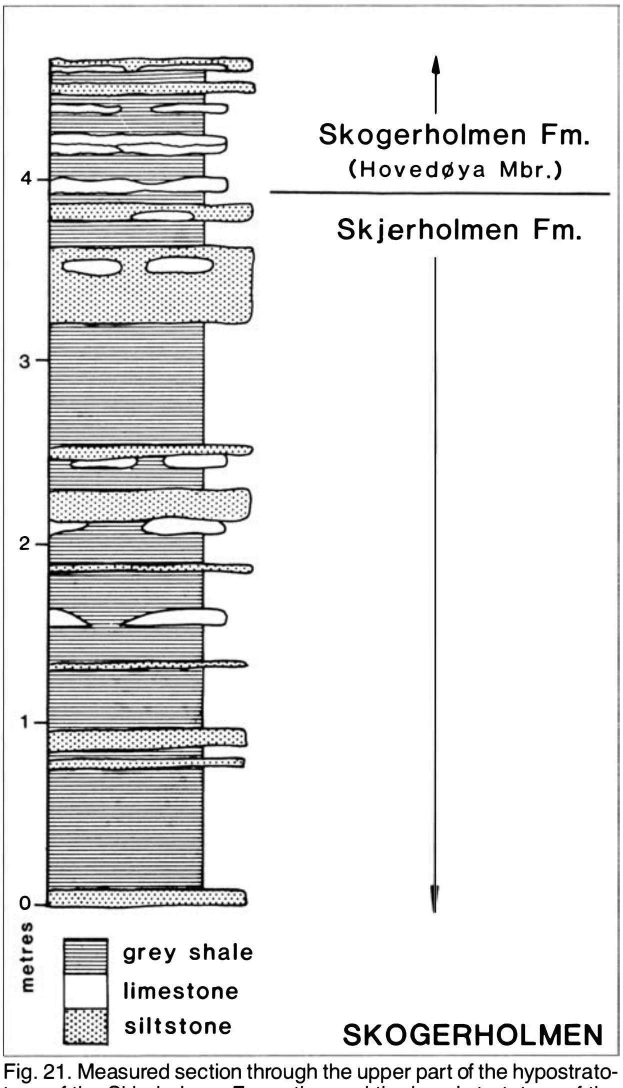

Fig. 21. Measured section through the upper part of the hypostratotype of the Skjerholmen Formation and the basal stratotype of the Skogerholmen Formation on Skogerholmen, Asker (NM 862353)

turbance. It is 35.6m thick on Søndre Skjerholmen and Brøgger (1887 pp.28-29) gave thicknesses between 35 and 43m for sections around Oslo and 22-48m in Asker although it is not clear how he defined the base of the unit in the west.

Fauna and Age. The Skjerholmen Formation is very poorly fossiliferous and although Brøgger (1887 p.29) listed trilobites, cephalopods and indeterminate gastropods and brachiopods, only trilobites (Owen 1980a, 1981) a tabulate coral (Spjeldnæs 1964) and a monoplacophoran (Yochelson 1977) have been described from the formation and indicate no more than an Ashgill age.

SKOGERHOLMEN FORMATION (Skogerholmformasjonen)

(New name)

(Previously termed: 4d; Isotelus beds)

Main Lithologies. Limestone, shale and siltstone.

Basal Stratotype. Oslo-Asker: Skogerholmen (Fig. 21) (NM 862 353).

Hypostratotypes. Oslo-Asker: Søndre Skjerholmen (NM 968 365), S.W. Hovedøya (Figs. 22, 23) (NM 968 409), Spannslokket (NM 855 358).

Definition. The Skogerholmen Formation and its two members were named by Owen (1981 Fig. 1) but not defined. The base of the formation marks a change to a limestone dominated succession from the largely shaly Skjerholmen Formation and is defined at the first continuous limestone horizon in the type (Skogerholmen) section (Fig. 21). The formation is 33.06m thick on Skogerholmen, about 43m on Hovedøya and about 39m on Skjerholmen.

Fauna and Age. The Skogerholmen Formation is generally poorly fossiliferous but shelly fossils, notably trilobites, brachiopods and cephalopods are known from various horizons, especially in the upper part, and indicate an Ashgill age.

Hovedøya Member (Hovedøyleddet)

(New name)

(Previously termed: 4dα, Undre Isoteluskalk, Lower Isotelus Limestone).

Main Lithologies. Limestone, siltstone and shale.

Basal and Hypostratotypes. As for formation.

Definition. The Hovedøya Member comprises alternating limestone, siltstone and shale beds. In contrast to the underlying unit, the combined thickness of limestone and siltstone beds exceeds that of the shales although some individual shale horizons are thicker (up to 30cm) than the thickest (*ca.* 15cm) limestone or siltstone beds. All the lithologies are dark grey when fresh but whereas the shales weather dark blue-grey, the limestones and siltstones become a light grey or even creamy colour. The basal boundary is well exposed in the stratotype on Skogerholmen (Fig. 21) and is defined at the first continuous limestone horizon. The Hovedøya Member here is 12.48m thick and this slight westward thinning of the member is consistent with the thickness estimates given by Brøgger (1887 pp.29-30).

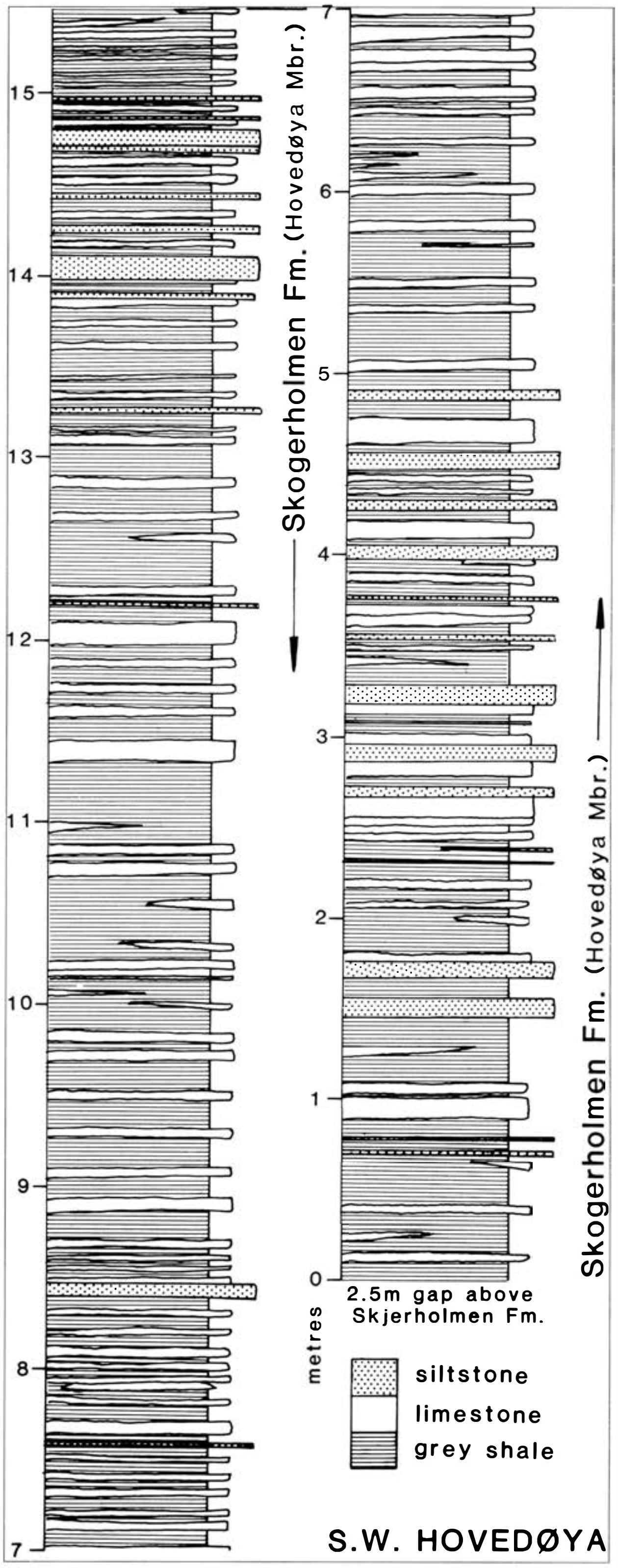

Fig. 22. Measured section through the hypostratotype of the Hovedøya Member of the Skogerholmen Formation on S.W. Hovedøya, Oslo (NM 968409).

Fauna and Age. Very few fossils are known from the Hovedøya Member of the Skogerholmen Formation and although Brøgger recorded eight trilobite genera from the unit, only five are preserved in existing museum collections (Owen 1981, table 1).

Spannslokket Member (Spannslokkleddet)

(New name)

(Previously termed: 4dß-γ, Isotelusskifer, Øvre Isoteluskalk, Isotelus Shale, Upper Isotelus Limestone).

Main Lithologies. Shale (lower part), limestone, siltstone and shale.

Basal and Hypostratotypes. As for formation.

Definition. As defined here the Spannslokket Member comprises two units recognised by earlier workers. The lower one ('Isotelus Shale' '4dß') is a distinct shale unit in the east six to nine metres thick but further west it thins to three to five metres thick and becomes more calcareous. The lower part of the shale is dark in colour; the upper part greenish grey and silty. Pending a detailed study of the whole Skogerholmen Formation, this is simply regarded as the shaly lower part of the Spannslokket Member and as such it differs from the underlying Hovedøya Member.

The remainder of the Spannslokket Member strongly resembles the Hovedøya Member and is an alternating succession of limestones, siltstones and shales although the development of siltstones up to 30cm thick contrasts with the thinner beds in the lower member. The limestones are bedded in the lower part of this portion of the Spannslokket Member but become nodular in the uppermost part of the member where siltstones become much rarer (Fig. 23). Limestone nodules in the upper part may be only 2-3cm thick and thus resemble the lower part of the Grimsøya Formation but they are not as tightly packed as in the densely nodular part of that formation.

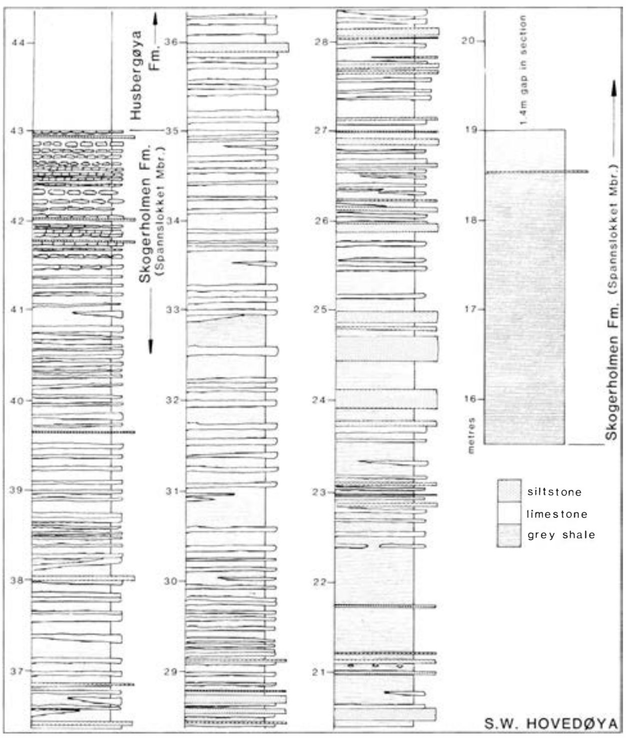

Fig. 23. Measured section through the hypostratotype of the Spannslokket Member of the Skogerholmen Formation and the base of the Husbergøya Formation on S.W. Hovedøya, Oslo (NM 968409). This section is a continuation of that shown on Fig. 22.

The Spannslokket Member is 20.58m thick in its type development on Skogerholmen and approximately 27.4m thick on Hovedøya. As with the underlying Hovedøya Member, this westward thinning conforms to the thickness estimates made by Brøgger (1887 pp.30-31).

Fauna and Age. Although much of the Spannslokket Member is unfossiliferous, some limestone horizons are locally richly fossiliferous, yielding a shelly fauna of Ashgill age which includes trilobites (Owen 1980a, 1981), cephalopods (Strand 1933) and brachiopods. Brøgger (1887 p.30) recorded indeterminate graptolites from the lower shale beds of the member. *Chondrites* and *Planolites* burrows are a common feature of some horizons in the member.

HUSBERGØYA FORMATION (Husbergøyformasjonen)

(Brenchley & Newall 1975)

(Previously termed: 4bδ, 5a, Øverste Chasmopsnivå, Gasktropodkalk (*pars*)).

Main Lithology. Shale (Husbergøya Shale, Husbergøyskiferen).

Basal Stratotype. Oslo-Asker: N.W. Husbergøya (Oslo)(Brenchley & Newall 1975, Fig. 4) (NM 962 377).

Definition. The Husbergøya Formation was defined and described in detail by Brenchley & Newall (1975) who also discussed the historical development of the terminology applied to this part of the Norwegian succession. The base of the formation marks an abrupt change from nodular limestones of the Spannslokket Member to a shale dominated succession. Thin calcareous sandy horizons become progressively more common up through the formation and the top of the unit in the east is developed as a brown weathering bedded sandstone up to 5m thick. Bioturbation is common with *Chondrites* occurring throughout the unit and a horizon containing a large trace fossil referred to *'Tricophycus'* by Seilacher & Meischner (1964) (but see Brenchley and Newall 1975 p.257) can be recognised a short distance above the base of the formation in many sections. The formation was interpreted as representing a deep shelf environment by Brenchley et al. (1979) and Brenchley & Cocks (1982).

The Husbergøya Formation is 18.5m thick in the type section and shows an overall thinning to as little as 10m in Asker although in its northernmost development in the west, at Sandvika (Bærum) it thickens to 35m (Brenchley & Newall 1975). The upper part of the formation in Oslo passes westwards into the Langåra Formation. The brown bioturbated sandstone at the top of the Husbergøya Formation in the east can be traced into the Langåra Formation thus enabling fairly precise correlation across the Oslo-Asker district (Brenchley & Newall 1975 p.259).

Fauna and Age. The Husbergøya Formation contains a sparse but fairly diverse fauna which was listed by Brenchley & Cocks (1982 pp.792-3) who termed it the *'Tretaspis* Association'. These authors also illustrated some of the trace fossils from the formation (1982 Pl.85, Figs 3-5) (assigned to the *Thalassinoides* association by Stanistreet 1989). Brenchley & Cocks (1982 p.793) ascribed some samples from the upper part of the formation to a *'Tretaspis-Onniella* Association, in which brachiopods characteristic of the *Onniella* Association occur along with typical *Tretaspis* Association elements. These authors also assigned the fauna of the bioturbated sandstone at the top of the formation in Oslo to this 'mixed' association. Bockelie (1984 p.10) termed this latter fauna the *'Tetreucystis tetrabrachiolata* association' which also includes the trilobites *Mucronaspis mucronata* (Brongniart) *kiaeri* (Troedsson) (Owen 1982) and *Platycoryphe* sp. Owen (1986 p.233) has noted that the occurrence of these trilobites along with an *Hirnantia* brachiopod fauna at one locality represent an early stage in the spread of Gondwanan elements onto lower latitude shelves. Elements of the Husbergøya Formation fauna which have received taxonomic attention include the trilobites (Owen 1980, 1980a, 1981, 1982), ostracods (Henningsmoen 1954), cephalopods (Strand 1933), brachiopods (Holtedahl 1916, Cocks 1982), cystoids (Bockelie 1984) and monoplacophorans (Yochelson 1977).

The trilobites include several species which indicate a Rawtheyan age for the unit (Owen *in* Cocks 1982 p.756) and the presence of *Tretaspis sortita* (Reed) *broeggeri* Størmer in the uppermost part of the Husbergøya Formation suggests a correlation with the Lady Burn Starfish Beds of Girvan, Scotland and thus a late Rawtheyan age (Owen 1980a, Harper 1982).

LANGØYENE FORMATION
(Langøyformasjonen)

(Brenchley & Newall 1975).

(Previously termed: 5b, Kalksandstein, Calcareous Sandstone, Calcareous Sandstone Formation).

Main lithology. Sandstone (Langøyene Sandstone, Langøysandsteinen).

Basal Stratotype. Oslo-Asker: South East Langøyene (Brenchley & Newall 1975, Fig. 4) (NM 968 385).

Definition. The base of the formation in the east is defined at the base of the shales, laminated sandstones and thin limestones which overlie the brown weathering sandstone at the top of the Husbergøya Formation. Brenchley & Newall (1975) produced a large number of measured sections in their original description of the formation showing the diverse, but dominantly arenaceous, facies present. They subsequently published detailed sedimentological evidence indicating that deposition took place within a major regressive phase on the Baltic craton (1980) and argued that this was of glacio-eustatic origin. Many of the sandstone beds are interpreted as having had a storm surge origin (Brenchley et al. 1979) and there is evidence of channelling (Brenchley & Newall 1975, 1980). Contorted bedding in both sandstones and shales indicates periodically high sedimentation rates and possibly seismic shocks related to basement faulting (Brenchley & Newall 1977).

The Langøyene Formation is 51m thick in its type development and has a maximum thickness in the east of some 60m. Westwards all but the uppermost part passes laterally into the Langåra Formation. Thus the formation thins to 8m on Langåra; at Sandvika it is developed as only a metre of oolite breccia and at Haga there may be as little as 50cm of breccia. The formation is overlain with a distinct lithological change by shales, siltstones and limestones of the Silurian Solvik Formation (Worsley et al. 1983 pp.12-13; Baarli 1985). These become more calcareous westwards.

Discussion. The uppermost Ordovician units to the west and south of Oslo-Asker, and that in Ringerike are here tentatively assigned to the Langøyene Formation. However, lithological heterogeneity is one of the characteristics of this part of the sequence and local formation (or at least member) names may eventually be established.

The largely arenaceous unit at the top of the Ordovician in Skien-Langesund was the subject of an unpublished thesis by Rønning (1979) who did not formally name it as he considered it may best be grouped with the lowest part of the overlying Silurian succession. Worsley et al. (1983 p.17), however, assigned the lowest Silurian to their Sælabonn Formation and noted that the base of this formation is an erosive one. The base of the underlying unit (tentatively assigned to the Langøyene Formation herein) can be defined at the level where sandstone becomes markedly more common than in the upper part of the underlying Herøya Limestone Formation (Rønning 1979 p.13, Fig. 3). As Rønning noted (1979 p. 10) there is no complete section through the formation but the best group of exposures are along a series of steep westward facing scarps between Versvika farm and Rød. The formation is approximately 40m thick and was divided into five informal members by Rønning. From base to top these were termed: the lower siliciclastic member, the lower limestone member, the middle siliciclastic member, the upper limestone member and the upper siliciclastic member. Rønning interpreted the whole sequence as having been deposited in a wave and storm dominated shallow sea and he recognised two different depth regimes within the district. He considered the more calcareous successions in the north as having been deposited in shallower water than the largely siliciclastic sequence of the south with a fairly abrupt break between the two lying somewhere between Gimsøy and Herøya.

The uppermost 40m of the Ordovician in Ringerike has been the subject of detailed study by N.-M. Hanken of Tromsø University who has described aspects of the sedimentology and faunas of this part of the succession (1974, 1979, 1979a) and proposes to establish a formal lithostratigraphy in due course. Hanken & Owen (1982 pp.126-131, Figs 4-7) summarized the complex lithofacies distribution, diagenetic history and fauna of these beds and noted that the only complete section is on Store Svartøya where there is a gradational change from the limestones and shales of the Bønsnes Formation to sandstones. The 15m of sandstone at the base of the formation is overlain by limestones with a basal conglomerate composed of locally derived material. The limestones include a variety of types including small unbedded patches and, on the mainland at Ullerntangen, an extensive area of carbonate blocks. The various limestone facies pass northeastwards into sandstones (Hanken & Owen 1982 Fig. 4). The base of the overlying Silurian Sælabonn Formation is an irregular karst surface at the top of the limestones on Store Svartøya (Worsley et al. 1983, Fig. 8) whilst further north there is a planar erosion surface (Thomsen 1982 p.2).

Fauna and Age. The diverse sedimentary environments from inner shelf to tidal channels represented in the Langøyene Formation are also reflected in the faunas with Brenchley & Cocks (1982) recognising several different associations within the formation in Oslo-Asker. These range from the moderately diverse brachiopod dominated *Hirnantia* Association in the basal part of the formation in the east (see also Brenchley & Cullen 1984) to faunas rare in body fossils but containing a variety of trace fossils including *Monocraterion, Planolites, Chondrites* and *Teichichnus.* Stanistreet (1989) ascribed the trace fossils from most of the formation to the *Diplichnites-Phycodes* association.

Systematic studies have been carried out on the trilobites (Owen 1981, 1982) and brachiopods (Cocks 1982) which together indicate a Hirnantian age. Monoplacophorans (Yochelson 1977) and ostracods (Henningsmoen 1954) have also been described.

LANGÅRA FORMATION (Langårformasjonen)

(Brenchley & Newall 1975)

(Previously termed: 5a (pars), 5b (pars), Gastropodkalk, Gastropod Limestone).

Main Lithologies. Limestone and shale (Langåra Limestone-Shale).

Basal Stratotype. Oslo-Asker: Langåra (Brenchley & Newall 1975, Fig. 7) (NM 856 356).

Definition. The Langåra Formation is restricted to the western part of Oslo-Asker and is a lateral equivalent of the upper part of the Husbergøya Formation and all but the uppermost part of the Langøyene Formation. The sandstone bed at the top of the Husbergøya Formation in the east can be recognised within the Langåra Formation at many localities. It was interpreted as an isochronous level by Brenchley & Newall (1975) who used its top as the boundary between their informal 'stages' 5a and 5b (Brenchley & Cocks 1982 pp.784-5).

The base of the Langåra Formation was chosen at a fairly arbitrary level within a transitional sequence at the type locality by Brenchley & Newall (1975) who noted that the top of the formation here and at most other localities is an abrupt change to massive sandstones of the Langøyene Formation. At Sandvika, however, the Langåra Formation is overlain by a limestone breccia ascribed to the Langøyene Formation.

The Langåra Formation is 13m thick on Langåra and attains a maximum thickness of 35m at Sandvika. In the southern part of its outcrop, the formation comprises shales and thin limestones but further north thick nodular limestones commonly containing the calcareous alga *Palaeoporella* are developed as are horizons rich in the pentameroid brachiopod *Holorhynchus.* Limestone conglomerates within the Langåra Formation at some localities represent channel fill deposits (Brenchley & Newall 1975, 1980).

Fauna and Age. Much of the Langåra Formation contains a low density but high diversity fauna which Brenchley and Cocks (1982) referred to as the *Onniella* Association. The fauna is dominated by brachiopods but trilobites are present and more diverse than at equivalent levels further east. Molluscs, bryozoans, echinoderms and corals occur amongst the rest of the fauna and as noted above, the alga *Palaeoporella* is present in the upper part of the formation in its more northerly outcrops. The *Onniella* Association is interpreted as a mid-shelf equivalent of the deeper partly coeval *Tretaspis* Association found in the Husbergøya Formation. A similar relationship within an inner shelf environment was proposed for the *Hindella-Cliftonia* Association recognised by Brenchley & Cocks in the Langåra Formation at a broadly equivalent level to the Hirnantia Association further east. The uppermost part of the Langåra Formation in the north west contains brachiopod-dominated faunas termed the *Holorhynchus* Association by Brenchley & Cocks (1982) and interpreted as representing an inner shelf environment. The complex distribution of trace fossil assemblages in the Langåra Formation was described by Stanistreet (1989).

Trilobites (Owen 1980a, 1981; Owens 1973), brachiopods (Kiær 1902; Holtedahl 1916; Wright 1965; Boucot et al. 1971; Cocks 1982), ostracods (Henningsmoen 1954), cephalopods (Strand 1933), bivalves (Toni 1975), corals (Neuman 1975) and echinoderms (Bockelie 1984) have been described from the Langåra Formation which is late Rawtheyan to Hirnantian in age.

HERØYA FORMATION (Herøyformasjonen)

(Dahll 1857)

(Previously termed: 5a, 4g, 4h, 4cß-5a, Venstöb oder Herö-kalkstein, Isotelustalk, Gastropodenkalk, Isotelus Limestone, Gastropod Limestone, Upper Tretaspis Beds).

Main Lithology. Limestone (Herøya Limestone, Herøykalken).

Basal Stratotype. Skien-Langesund: Steinvika (NL 429 397).

Definition. Little is known in detail of the Herøya Formation but its base is here defined as being at the sharp change from dark shales with planar limestones of the Venstøp Formation to pale coloured, tightly nodular, limestones with little intervening shale. This is a similar change to that seen in Oslo-Asker where the Venstøp Formation is succeeded by the Grimsøya Formation. However, the latter formation is only one of several Ashgill limestones in Oslo-Asker which alternate with calcareous shale units whereas the Herøya Formation extends almost to the top of the Ordovician in Skien-Langesund and Eiker-Sandsvær. The thickness of the Herøya Formation is unknown but is in excess of 50m and above the tightly nodular lower part it comprises interbedded limestones and shales with subsidiary sandstones. As noted by Owen (1979 p.256) and Harland (1981 p.33) the Herøya, Sørbakken and Gamme (formerly Gagnum) limestones may belong to a single, carbonate facies belt. Once the Herøya Formation is better known, there may be a case for reducing the Sørbakken and Gamme limestones to member status and using Dahll's unit as the formation name in all the relevant districts. However, there are differences between the three units and separate formations are provisionally retained herein. The Ashgill limestones of Oslo-Asker probably represent 'tongues' of this carbonate belt.

Fauna. Gastropods, cephalopods (Strand 1933) and bivalves (Toni 1975) are known from the upper part of the Herøya Formation but otherwise the fauna of the unit has yet to be studied.

SØRBAKKEN FORMATION (Sørbakkformasjonen)

(Owen 1979)

(Previously termed: 4cß, 4d, Trinucleuskalk, Trinucleus Limestone, Isotelus Limestone).

Main Lithology. Limestone (Sørbakken Limestone, Sørbakkalken).

Basal Stratotype. Ringerike: N.W. Frognøya (Williams & Bruton 1983, Fig. 7) (NM 652 582).

Hypostratotype. Ringerike: W. Frognøya (top) (NM 653 577).

Definition. Although there is no complete section through the formation, Owen (1979 p.235) estimated that it is of the order of 100m thick. The lowest 34m crop out on northwest Frognøya and 37m at Norderhov. The base marks a sharp change to limestone with subordinate shale although the uppermost part of the underlying Venstøp Formation can be regarded as transitional to this. The Sørbakken Formation comprises grey, nodular and bedded limestones up to 30cm thick alternating with thinner, calcareous shales. The lithology was outlined by Owen (1979 pp.253-254) who noted that there is no palaeontological or lithological evidence for the disconformity within the unit suggested by Strand (1933 p.102).

Fauna and Age. The Sørbakken Formation contains a diverse shelly fauna including trilobites (Owen 1979, 1980a, 1981; Bruton & Owen 1988), brachiopods (Owen 1979 p.255, Harper in prep.), cephalopods (Strand 1933), bivalves, gastropods, echinoderms, ostracods and bryozoans. Many of the trilobites range throughout the formation and six species occur in the underlying unit. However, *Calymene (s.l.) cf. marginata* Shirley occurs at 35-37m above the base of the formation suggesting a correlation with the Lower Drummuck Group (Cautleyan) of Girvan, S.W. Scotland and occurrence of *Isotelus frognoensis* Owen, *Toxochasmops aff. eichwaldi* (Schmidt) and *Stygina latifrons* (Portlock), *extensa* (Reed) in the upper part of the unit indicates a correlation with Rawtheyan units in Oslo-Asker and Hadeland.

BØNSNES FORMATION (Bønsnesformasjonen).

(Owen 1979)

(Previously termed: 5a Gastropodenkalk, Gastropod Limestone).

Main Lithologies. Limestone and calcareous shale (Bønsnes Limestone, Bønsneskalken).

Basal Stratotype. Ringerike: West Frognøya (NM 653 577).

Definition. The base of this ca. 100m thick formation was taken by Owen (1979 p.255) at the first development of dark, platy limestones containing the alga *Palaeoporella.* These strata are overlain by lighter coloured limestones containing silicified corals. At Stamnestangen and on Store (=Vestre) Svartøya, higher levels in the Bønsnes Formation include rubbly limestones with interbedded calcareous shales which have yielded the very diverse shelly faunas listed by Kiær (1897). The highest part of the formation comprises calcareous (>45cm thick) shales with scattered limestone nodules.

Fauna, Flora and Age. In addition to algae (Kiær 1922) and stromatoporoids (Kaljo et al. 1963), the Bønsnes Formation contains trilobites (Owen 1981; Bruton & Owen 1988), brachiopods (Kiær 1897; Holtehahl 1916; Hanken & Harper 1985; Harper in prep.), cephalopods (Strand 1933), gastropods and monoplacophorans (Koken 1925; Yochelson 1977), bryozoans (Brood 1980), corals (Bassler 1950; Hanken 1979a; Kaljo et al. 1963; Kiær 1899, 1903, 1929; Neuman 1969, 1975; Scheffen 1933) and ostracods (Henningsmoen 1954). The trilobite fauna indicates a Rawtheyan age and includes species of *Stenopareia Remopleurides, Eobronteus, Stygina, Holotrachelus,* proetids, *Erratencrinurus (Celtencrinurus), Atractopyge* and *Amphilichas.*

LUNNER FORMATION (Lunnerformasjonen)
(Owen 1978)

(Previously termed: 4c, 4cα, Trinucleusskifer, Tretaspis Shale, Sphaeronidskifer, Gagnum Shale).

Main Lithology. Shale (Lunner Shale, Lunnerskiferen).

Basal Stratotype. Hadeland: Lunner Railway Section (Owen 1978 Fig. 7) (NM 877 862).

Hypostratotype. Hadeland: Road south of Lunner (NM 869 859 - 874 859). (See also stratotypes for individual members.)

Definition. The Lunner Formation is dominantly a shale unit which is thick (?of the order of 185m - Owen 1978 p.11) in the southeast of Hadeland around Lunner but which thins north westwards in which direction it is divided into two tongue-like members by the Gamme (formerly Gagnum) Formation. The lowest of these, the Gagnum Member, is present in the most northerly outcrop at Tønnerud where it is 7m thick. The upper member, the Grinda Member, wedges out completely.

Around Lunner the formation is composed largely of dark calcareous shales which become grey and friable. About 9m of nodular and bedded limestones are developed in the lowest part (the Lunner Kirke Member of Owen 1978; a term here considered unnecessary) and near the top but are fairly rare in most of the formation in the southeast. Thin siltstone horizons occur at various levels. Limestones are much more abundant in the Grinda and, especially, Gagnum members.

Fauna and Age. The Lunner Formation around Lunner contains a low diversity shelly fauna dominated by the trilobites *Tretaspis hadelandica* Størmer and *Flexicalymene trinucleina* (Tullberg)? (Owen 1981 p.7) and species of the brachiopods *Onniella* and *Chonetoidea.* Graptolites in the lower part of the formation here probably belong to the upper *Pleurograptus linearis* Zone and thus indicate a Pusgillian age. The Gagnum and Grinda shale members contain much more diverse shelly fauns (Owen 1981 Fig. 2). The Gagnum Shale contains *T. ceriodes* in its lowest part and *T. hadelandica* at higher levels indicating that the base of the Lunner Formation is slightly older (latest Caradoc) in the north than in the south (Owen 1978). The Grinda Member contains a fauna of Rawtheyan age which compares closely with that of its lateral equivalent in the south, the Kjørrven Formation.

Gagnum Member (Gagnumleddet)
(Størmer 1945)

(Previously termed: Sphaeronidskifer, Sphaeronid Shale)

Main Lithology. Calcareous shale with limestone nodules.

Basal Stratotype. Hadeland: Field outcrops east of Nerby (see Owen 1978, Fig. 8) (NM 859 887).

Hypostratotypes. Hadeland: Tønnerud shore section (see Bockelie 1984, Fig. 9B for schematic section) (NM 780 922). Gammehaugen (NM 841 912), Roko (NM 840 916).

Definition. The type locality for the Gagnum Member was given by Strand & Størmer (1955) as being near Nerby. As Owen (1978 p.13) noted, the exposures here are poor but the boundary with the underlying Solvang Formation can be defined to within 0.5m. The member is fully exposed only in the road and coast sections at Tønnerud and the latter is here designated as a hypostratotype.

At Tønnerud the Gagnum Member is some 7m thick but mapping of the unit has shown that this increases to 17m at Gammehaugen (where all but the lowest part crops out) and 40m west of Lunner. It becomes more calcareous northwards where, although the base is a sharp boundary, the upper part marks a transition to the Gamme Formation and the member is essentially a marl with limestone nodules.

Fauna and Age. West of Lunner, where the Gamme Formation is at its thinnest, the thick development of the Gagnum Member is indistinguishable lithologically and faunally from the Lunner Formation around Lunner. North of the Kjevlingen Fault (Owen 1978 p.13), however, the shelly fauna becomes much more diverse in the more calcareous development. Some 22 trilobite species are known from the member (Owen 1981 pp.6-7, Fig. 2, Table 1) and whilst the trinucleid *Tretaspis hadelandica hadelandica* occurs throughout most of the unit, the lowest part in the north contains *T. ceriodes* (Angelin) *angelini* Størmer (Owen 1978, 1981). Thus the base of the member may be diachronous with the oldest, *T. ceriodes angelini* bearing beds in the north being latest Caradoc in age whilst the rest of the unit, including the base further south is early Ashgill. Other elements of the diverse fauna include brachiopods (Bassett in prep.; Harper in prep.), echinoderms (Bockelie 1984), corals, cephalopods and bryozoans.

Grinda Member (Grindleddet).
(Owen 1978)

Main Lithologies. Shale with limestone nodules and beds.

Basal Stratotype. Hadeland: Grinda (Owen 1978, Fig. 9A) (NM 845 874 - 848 872).

Hypostratotype. Hadeland: North of Korsrudtjern (Owen 1978, Fig. 9B (NM 836 884).

Definition. The Grinda (formerly spelled Grina) Member is composed of shales with some limestone beds and nodules. It overlies and passes northwards into the Gamme Formation and over most of its outcrop it is overlain by, and passes southwards into the limestones, siltstones and shales of Kjørrven Formation. In its most northerly development, seen in the hypostratotype, it is overlain by the Kalvsjøen Formation.

Fauna and Age. The diverse shelly fauna is very similar to that of the Kjørrven Formation (Owen 1981 p.8, Table 1) and indicates a Røawtheyan age (see below).

GAMME FORMATION (Gammeformasjonen).

(New name).

(Previously termed: Gagnum Limestone, Sphaeronidkalken (*pars*)).

Main Lithology. Nodular Limestone (Gamme Limestone, Gammekalken).

Basal Stratotype. Hadeland: Gammehaugen (NM 840 916).

Hypostratotype. Hadeland: Gagnum (NM 858 893 - 856 894).

Definition. The top of the Gamme Formation is not known at outcrop but the change from shales to nodular limestone at the base is exposed on Gammehaugen and the typical development seen in the road section at Gamme. The lowest 25m is exposed at Tønnerud (e.g. see Bockelie 1984, Fig. 9B). The formation is composed of nodular limestones up to 20cm thick with little or no intervening shale. It has a maximum thickness of 85m near Grinda, thinning northwards to about 50m at Gammehaugen and tapering out southwards where it extends to within 800m of Lunner (Owen 1978, plate 1).

Discussion. This unit was formerly termed the Gagnum Limestone (Størmer 1945) and this name was retained by Owen (1978) who recognised the undesirability of having the same geographical name as in another unit (the Gagnum Shale of Størmer 1945) but felt it important to retain an historically important term. However, following a recommendation by the Norwegian Stratigraphical Committee we replace the name Gagnum by Gamme herein.

Fauna and Age. Much of the Gamme Formation is unfossiliferous and where a fauna is present, it is dominated by the trilobites *Tretaspis hadelandica hadelandica* and *Flexicalymene jemtlandica?* Some 14 other trilobite species are known (Owen 1981 p.7, Table 1) but these are rare. Brachiopods, echinoderms (Bockelie 1984) and bryozoans are a little more common. The fauna indicates no more than an Ashgill age but the age constraints on the confining units indicate a maximum range from mid? Pusgillian to early/mid Rawtheyan.

KJØRRVEN FORMATION (Kjørrvenformasjonen)

(Owen 1978)

(Previously termed: 4d, 4cα (*pars*), 4cß-4d, Isotelus Shale).

Main Lithologies. Limestone, calcareous siltstone and shale.

Basal Stratotype. Hadeland: Track to Finnlaus, Grinda (Owen 1978 Fig. 9A) (NM 845 874).

Hypostratotype. Hadeland: Railway cuttings east of Kalvsjø (NM 876 853).

Definition. The Kjørrven Formation comprises beds of limestone and calcareous siltstone up to 20cm thick alternating with silty shales commonly less than 16cm thick but in some instances up to 60cm in thickness (Owen 1978 p.18, Figs 9,10). The dark grey limestones decalcify to brown rottenstones and the grey shales become pale and friable on weathering. The base of the formation is transitional around Lunner but further north in the basal stratotype it marks an abrupt change from the shales of the Grinda Member of the Lunner Formation. Limestone horizons become more common towards the top of the Kjørrven Formation and the unit has a maximum thickness of about 100m.

Fauna and Age. The Kjørrven Formation contains a very diverse fauna of trilobites, brachiopods, corals, bryozoans, cephalopods, ostracods, echinoderms and conulariids. The trilobite fauna comprises at least 25 species (Owen 1981 pp.7-8, Tables 1, 2, Fig. 2) and although the association of genera is most similar to that of the type Cautleyan Stage, the species present most notably *Sphaerocoryphe aff. kingi* Ingham and *Calymene* (s.l.) *holtedahli* (Størmer) indicate a Rawthyan age. The same is also true for the brachiopods (pers. comm. D.A.T. Harper 1983).

KALVSJØEN FORMATION (Kalvsjøformasjonen)

(Owen 1978)

(Previously termed: 5a, Gastropodkalken, Gastropod Limestone).

Main Lithologies. Limestones (Kalvsjøen Limestone, Kalvsjøkalken)

Basal Stratotype. Hadeland: Track to Finnlaus, Grinda (Owen 1978, Fig. 9A) (NM 845 872).

Definition. The Kalvsjøen Formation largely consists of nodular and bedded bioclastic limestones alternating with thin shales (Owen 1978 p.18, Fig. 9; Heath 1989). The formation contains local accumulations of carbonate blocks, the best exposed being at Kalvsjø quarry where it is at least 20m thick. These are interpreted by Dr R.A.Heath of Aberdeen University as channel fill deposits (1989). The base of the Kalvsjøen Formation marks a fairly abrupt change to bedded limestones with thin shales. It overlies the Kjørrven Formation in the south, the Grinda Member of the Lunner Formation in the central part of its outcrop and the Gamme Formation in the north. The formation thickens southwards from approximately 60m at Grinda and Gammehaugen to about 80m around Lunner. It probably represents part of the same carbonate facies belt as the Langåra Formation in Oslo-Asker and Bønsnes Formation in Ringerike. It differs however in lacking thick shales (except very locally), in *Palaeoporella* limestones being very rare and in the development of local channel fill deposits.

Fauna and Age. Unlike the underlying units and equivalents in Oslo-Asker and Ringerike, trilobites are rare in the Kalvsjøen Formation (Owen 1981 p.8, Table 1). The occurrence of *Amphilichas dalecarlicus* in the lower part of the formation suggests a correlation with the Rawtheyan Bønsnes Formation in Ringerike. The only diverse trilobite fauna from the Kalvsjøen Formation is outlined by Owen & Heath (1990) and has a similar generic composition to faunas from the underlying Kjørrven Formation. Some of the echinoderms from the Kalvsjøen Formation have been described and include cystoids (Bockelie 1979, 1984), crinoids (Briskeby 1980) and a bothriocidarid echinoid (Bockelie & Briskeby 1980). Other elements of the biota include brachiopods, gastropods, corals, bryozoans, and (rarely) the calcareous alga *Palaeoporella*.

SKØYEN SANDSTONE (*pars*)

(Skøyensandsteinen)
(Owen 1978)

(Previously termed: 5b)

Discussion. Owen (1978 p.20) originally defined the Skøyen Sandstone as a dominantly arenaceous formation which extends up into the lowest Silurian. In their revision of the Silurian successions of the Oslo Region, Worsley et al. (1983, p.18) argued that the upper part of the Skøyen Sandstone may be ascribed to their lower Llandovery Sælabonn Formation. A detailed study of the whole Skøyen Sandstone is currently being undertaken by Dr R.A.Heath of Aberdeen University and, following Worsley et al., the unit is here given informal status pending the results of this work. In her PhD thesis, Heath (1989) ascribed the lithologically variable lower part of the Skøyen Sandstone to a new formation, the Klinkenberg Formation. The upper part was assigned to the Sælabonn Formation.

Distribution of Ordovician Sequences

SKIEN-LANGESUND

Setting. The Cambro-Silurian succession of Skien-Langesund forms a NNW-SSE belt bounded on the west by Precambrian rocks and on the east by Permian igneous rocks. The lower part of the sequence has been intruded by basaltic-doleritic sills causing low grade contact metamorphism but unlike most other districts of the region there are few tectonic complications affecting the Lower Palaeozoic succession which is gently tilted to the east. The Tremadoc and much of the Arenig is missing in Skien-Langesund with the Rognstranda Member of the Huk Formation resting on Upper Cambrian Alum Shale. Ramberg & Bockelie (1981 Fig. 2) and Bockelie & Nystuen (1985) interpreted this as a thrust contact but Ribland Nilssen (1985) has reinterpreted it as an erosional unconformity. On the basis of Ribland Nilssen's work, a sole thrust may be present actually within the Cambrian Alum Shale Formation.

Stratigraphy. As Størmer (1953 p.46-48) has discussed, some of the earliest stratigraphical studies in the Oslo Region were undertaken in Skien-Langesund by Forbes (1856) and Dahll (1857). The latter author introduced a shorthand notation for the succession which differed from that introduced at the same time by Kjerulf (1857). Similarly, the scheme used by Brøgger in his detailed study of 1884 was unique to Skien-Langesund. Subsequent stratigraphical and palaeontological studies by Kiær (1897, 1908) and Strand (1933) on the Upper Ordovician and Størmer (1953) on the Middle Ordovician have attempted to impose the Oslo-Asker etasjer on the Skien-Langesund succession (see Strand & Henningsmoen 1960 pl.7 for synthesis), but as much of the sequence is very dissimilar this was not a very workable scheme. In the most recent work on the district Harland (1980, 1981), has abandoned the shorthand schemes but retained several of Dahll's formation names. This conservative approach is maintained here.

The Huk Formation is represented by a single local member, the Rognstranda Member, which along with the overlying Elnes Formation is well exposed in the south of the district west of Langesund (Skaar 1972, Størmer 1953, Ribland Nilssen 1985). The nodular limestones of the Fossum Formation also crop out here as well as on the shore of the Frierfjord to the north (Størmer 1953, Ribland Nilssen 1985). The late Caradoc Steinvika Formation was described by Harland (1980, 1981) from many localities between Porsgrunn and Langesund, and the overlying Venstøp Formation is seen at localities from north of Skien to Langesund in the south. The Herøya Formation has yet to be studied in detail but its basal stratotype is here chosen in the south at Steinvika where the underlying succession down to the upper part of the Fossum Formation is exposed along the coast. The uppermost Ordovician in Skien-Langesund is well exposed in both inland and coastal sections and has been studied by Rønning (1979). It is tentatively ascribed to the Langøyene Formation.

EIKER-SANDSVÆR

Setting. The Cambro-Silurian outcrop of Eiker-Sandsvær extends west from Drammen to Hokksund, here striking south south west to form the western margin of the Oslo Region towards Kongsberg and the mountains of Skrim. The outcrop is bordered to the west by Precambrian Telemark and Kongsberg series granitic rocks and gneisses (Starmer 1977), whilst Permian intrusives (larvikite and ekerite) make up the southern and eastern contact. Published geological maps at a scale of 1:1 million by Brøgger & Schetelig (1919, 1926) cover the area, whilst Rohr-Torp (1973) has provided a detailed map of the extreme southwestern part of the outcrop south of Kongsberg. Recent detailed mapping on a scale of 1:5000 is to be found in unpublished theses by Cadow (1985), Ludvig (1985), and Svendsby (1987) covering the area from Eikeren to Skollenborg. Two of the present authors (DLB and AWO) are currently completing mapping of the remaining areas along with Dr D.A.T. Harper of Galway. This work, together with unpublished stratigraphical and sedimentological observations by Fjelldal (1966), Skaar (1973), Gjessing (1976) and a short note by Klemm (1982) has thrown considerable light on details of the Ordovician succession discussed by Størmer (1953).

Stratigraphy. All the Ordovician formations recognised in the Skien-Langesund area by Rønning (1979) and Ribland Nilssen (1985), can be traced into the present area where the maximum thickness of the system is approximately 500m. In the south west the succession dips at only 10-20° towards the south east (reflecting a similar dip of the underlying Precambrian peneplain), but dips increase southwards towards the Permian intrusions. In the neighbourhood of Hokksund, a complex fold and fault pattern is an exception. Metamorphism of the higher units is intense but fossiliferous Venstøp and Herøya formations, the latter with *Palaeoporella* and *Holorhynchus,* have been recognised at Skogsleet west of Vestfossen and at Kvisthogst north east of Skollenborg.

At the base of the succession, units thin, overstep and die out towards the southwest. Thus alum shales with *Dictyonema* and the overlying Bjørkåsholmen Formation have not been found south of Skollenborg and near Flata, the Huk Formation overlies Upper Cambrian beds containing *Peltura scarabaeoides.* Ramberg & Bockelie (1981) and Bockelie & Nystuen (1985), have invoked thrust ramping to explain this break but this is not supported by field evidence, here or in the Skien-Langesund area (for discussion see Ribland Nilssen 1985).

At Skara the lower part of the Tøyen Formation is a 0.5-0.8m, thick limestone (the Vestfossen Member of Fjelldal 1966 - *Megistaspis (Ekeraspis) armata* Zone). The formation can be traced south to Skollenborg. At Flata a more or less complete Ordovician section from the base of the Huk Formation can be followed up the Ravalsjø river to Lindset. The section includes the approximately 70m thick section of the Heggen Member of the Elnes Formation at Rønningsfossen, containing *Ogygiocaris dilatata,* and equivalent beds in Muggerudkleiva containing *Didymograptus murchisoni geminus,* and *Glyptograptus teretiusculus* (Berry 1964). These beds and the underlying Huk Formation can be seen in numerous sections along the road from Råen to Hassel and along the scarp front to the east. The Svartodden Member of the Huk Formation is recognised by the abundant accumulation of conchs of *Cycloendoceras* some exceeding 10cm in diameter and over 2m in length. Bedding plane measurements of orientated specimens have been made at Såsen south of Vestfossen (Svendsby 1987), Haugnes, near Krekling (Skaar 1972, Klemm 1982) and at Hillestad south of Kongsberg, a distance along strike of 18km.

The dark silty shales with widely spaced limestone concretions forming the Elnes Formation are succeeded by tightly nodular, rubbly, platy limestones with shale partings forming the Fossum Formation with a thickness of 140-160m. The beds are extremely fossiliferous in a continuous section south of Rønningsfossen to Sagvollen and in the waterfall below Lindset, and in a section along the toll road east of Klunderud. Størmer (1953) attempted to recognise units of the Oslo-Asker district in this succession based on the occurrence of the trilobites *Reedolithus carinatus, Ampyx* sp., certain brachiopods, the bryozoan *Diplotrypa* and the dasycladacean alga *Coelosphaeridium.* Lithologically, however, the sections are identical to the Fossum Formation in its type area (Ribland Nilssen 1985).

Dark crinoidal limestones of the Steinvika Formation occur at Lindset and in numerous outcrops around Kvisthogst. Outcrops between Råensætravei and Skallerudtjern have yielded numerous brachiopods including *Dinorthis aff. flabellum, Strophomena* cf. keilhaui and *Sowerbyella aff. sericea* (Harper pers. comm. in Cadow 1985 p.55). The estimated thickness of the Steinvika Formation is 40-75m. The overlying Venstøp Formation (30-35m) is difficult to recognise in the field because of the metamorphic grade. However, near Trengen, an abundant but restricted fauna is dominated by the enteletacean *Onniella* and the plectambonitacean *Chonetoidea.*

The succeeding Herøya Limestone is a well bedded limestone - shale/siltstone succession at least 100m thick, containing colonial corals and the alga *Palaeoporella* with *Holorhynchus giganteus* in its upper part. A good section with the overlying sandstone formation forming the top of the Ordovician has been described from Mølleseter by Svendsby (1987).

MODUM

Setting. The Modum district lies to the west of Oslo-Asker. In the north it is bounded by arms of the Tyrifjord, in the west and south by the Drammen River. The Lower Palaeozoic rocks of the district partly circumscribe two large Permian igneous intrusions (Ramberg & Larsen 1978 pl. 1) and there is a narrow west-east trending connection with that of Oslo-Asker. The Cambro-Silurian succession is variably baked by the intrusions. Precambrian rocks crop out to the west but the contact with the Cambrian is not seen. The Lower and Middle Cambrian sequence is relatively undisturbed tectonically but has been intruded by maenite sills. The overlying succession, however, is tightly folded and there is also a series of strike faults which Wandås (1982 p.133) suggested may have involved both Caledonian and Permian movement. In the eastern part of the district a gentle syncline in the Permian lavas also indicates Permian tectonic activity.

Stratigraphy. The Lower Palaeozoic rocks of Modum have received very little attention. Størmer (1953 p.82) made some general comments on the Middle Ordovician succession but the only detailed work has been that of Wandås (1981, 1982) on the Lower and Middle Ordovician rocks in the northwest of the area around Vikersund. Here he described the succession from the Tremadoc units through the Tøyen and Huk formations into the Llanvirn-Llandeilo Elnes Formation. He has also noted the Fossum Formation ('Ampyx Limestone') at the Vikersund ski jump. Most recently he has described the trilobite fauna from the Helskjer Member at the base of the Elnes Formation (1984).

A reconnaissance study of the Sylling area in the eastern part of Modum was undertaken by the present authors and shows the Caradoc and Ashgill succession to be transitional between those of the Eiker-Sandsvær and Ringerike districts. At Veslesæter nodular limestones and shales containing *Bockia* and *Echinosphaerites* resemble part of the Fossum Formation further south. At Nysæterbrenna 13m of limestone crop out and are thought to overlie the beds seen at Veslesæter. The lowest 10.5m consists of tightly nodular limestones, a few limestone beds and relatively little shale. This is reminiscent of the Nerby Member of the Solvang Formation in Hadeland and the nodular beds below the uppermost limestone beds of that fromation in Ringerike. The cystoids *Echinosphaerites grandis* and *Haplosphaeronis* sp. occur at 3.5m below the top of the nodular limestone. The upper 2.5m is made up of beds of coarse bioclastic limestone and shale. This again resembles parts of the Solvang Formation in Ringerike. These limestones, tentatively assigned to the Solvang Formation are succeeded by approximately 14m of black shales with planar limestones in the upper part. This is interpreted as the Venstøp Formation. Nodular limestones cropping out nearby may overlie the shale but this is by no means certain.

At Toverud, tens of metres of steeply dipping limestones and shales crop out. Some of the limestones contain abundant corals and the overall lithology resembles that of the Bønsnes Formation in Ringerike.

OSLO-ASKER

Setting. The Oslo-Asker district lies in the central part of the Oslo Region with the city of Oslo itself situated in the eastern part of the area at the head of the Bunnefjord. To the immediate west is Bærum and Asker which lie along the northern end of the Oslofjord. The Lower Palaeozoic rocks of the district are faulted against Precambrian gneiss in the east but a stratigraphical contact between Middle Cambrian sediments and metamorhic basement is seen in the south at Slemmestad (Spjeldnæs 1955, Størmer *in* Holtedahl and Dons 1966). Permian igneous rocks crop out in the north and west but there is a narrow connection with the Lower Palaeozoic rocks of the Modum district to the west. A 1:50,000 geological map of the Oslo-Asker district was produced by Holtedahl & Dons in 1952 and a guide book in Norwegian (1955, Dons 1977) and English (1957, 1966) published to accompany it. The whole of the Ordovician outcrop in Asker and parts of Bærum have been mapped on a 1:5,000 scale by J.F. and T. Bockelie and a 1:50,000 sheet (Asker) is to be published (Naterstad et al. in press).

The Lower Palaeozoic rocks of the district are tightly folded, locally overturned and have an overall SW-NE strike. There is also considerable faulting associated with a major décollement within the Cambrian Alum Shale; many of the faults being listric splays from the sole thrust (Ramberg & Bockelie 1981, Bockelie 1982, Bockelie & Nystuen 1985 and Morley 1986).

The Ordovician succession is up to 475m thick and is well exposed on the coasts and islands of the Oslo- and Bunnefjord as well as in road cuttings and temporary sections within the built-up inland area.

Stratigraphy. The Oslo-Asker district was the type area for the Etasje system established by Kjerulf (1857) and the well exposed, easily accessible, Ordovician succession has been subject to a considerable amount of stratigraphical, sedimentological and palaeontological investigation. The stratigraphical scheme established by Kjerulf was modified by Brøgger for the Lower (1882), Middle and Upper (1887) Ordovician. Brøgger's terminology has remained largely unaltered until recent years and his map of the Ordovician rocks on the islands of the Bunnefjord (1887) is still the most detailed one available. A generalized summary of the sedimentology of the Ordovician succession was published by Seilacher & Meischner (1964) and an essentially geochemical analysis was produced by Bjørlykke (1974). Möller & Kvingan (1988) have discussed the origin of the nodular limestones but otherwise the only detailed major sedimentological work to be published has been on the uppermost Ordovician (see below).

Tremadoc rocks are well exposed in the south west of Oslo-Asker and Bruton et al. (1982, 1988) described the section at Nærsnes as a possible stratotype for the Cambrian-Ordovician boundary. Tremadoc faunas have been described by, *inter alia,* Brøgger (1882, 1896) Henningsmoen (1957, 1959), Spjeldnæs (1963), Erdtmann (1982) and Gjessing (1976). An unpublished thesis by Fjelldal (1966) included sedimentological information on the Bjørkåsholmen Formation in Asker and more limited sedimentological studies have been carried out on the underlying shales (Størmer 1938, Bjørlykke 1974, Bjørlykke & Griffin 1973).

The Arenig Tøyen Formation is known from several coastal and inland exposures in the west of the area (Spjeldnæs 1953) but is restricted to inland outcrops in Oslo. Some of the best of these have been temporary exposures, one of which, at Tøyen, formed the basis for Erdtmann's work on the lithology and graptolite faunas of this shale unit (1965).

As with the Bjørkåsholmen Formation, the Huk Formation has been the subject of an unpublished sedimentological study (Skaar 1972) and crops out over the whole district although coastal exposures are largely restricted to the west. The tripartite development of the formation is similar to that in several other districts of the Oslo Region. Palaeontological studies include works by Öpik (1939), Regnéll (1948), Bockelie (1981), Tjernvik (1956) and Kohut (1972).

The succession between the Huk and Venstøp formations constitutes the Middle Ordovician of Størmer (1953) and is well exposed over the entire district. It comprises a sequence of alternating shale and limestone units. Bentonites are present in the lower Caradoc Arnestad Formation (Hageman & Spjeldnæs 1955). The research on successions investigated by Størmer has largely been published in the 'Middle Ordovician of the Oslo Region' series in Norsk Geologisk Tidsskrift (see Bruton & Williams 1982 pp. 215-216 for a list of the first 30 contributions) and much of it relates primarily to Oslo-Asker. Størmer's description of the lithological succession (1953 pp.54-69) provided an excellent stratigraphical base for these works.

Partly as a result of the emphasis on the 'Middle Ordovician', the Ashgill succession has received little attention until recent years; the most comprehensive overall description of the stratigraphy being that of Brøgger (1887). As with the underlying succession, most of the Ashgill sequence comprises alternating limestone and shale units but the faunas are generally sparser and siliciclastic horizons become increasingly more common. Both the Middle and Upper Ordovician of the district show a westward shallowing with most units also thickening and limestone becoming more common in that direction. The uppermost part of the sequence shows a much more complex facies distribution than in the rest of the Ordovician and has been the subject of several sedimentological studies (e.g. Kiær, 1902; Spjeldnæs 1957a; Lervik 1969; Brenchley & Newall 1975, 1977, 1980; Brenchley et al. 1979). The latest Ordovician marks a major shallowing interpreted by Brenchley and his co-workers as glacio-eustatic in origin and Stanistreet (1983) has presented evidence for synsedimentary faulting associated with basement blocks during the deposition of these rocks. Systematic studies of the Ashgill faunas include works by Bruton & Owen (1988) Owen (1980, 1980a, 1981, 1982). Owens (1983), Spjeldnæs (1964), Henningsmoen (1954), Holtedahl (1916), Kiær (1902), Cocks (1982), Bockelie (1984), Toni (1975), Neuman (1975) and Williams & Bruton (1983). Trace fossil associations in the uppermost Ordovician have been discussed by Stanistreet (1989).

RINGERIKE

Setting. The Cambro-Silurian succession of Ringerike overlies Precambrian crystalline basement in the west and abuts Permian igneous rocks in the east. Glacial and post-glacial sediments cover large tracts of the district (Østmo et al. 1978) and thus outcrops of Lower Palaeozoic rocks are restricted to islands, shore sections of the inland fjords and a few large inliers (e.g. Harper & Owen 1983, Fig. 1.)

A geological map of the island of Frognøya was published by Owen (1979, Fig. 2) and the Ordovician rocks of the whole district have recently been mapped by A.W. Owen & D.A.T. Harper on a 1:5,000 scale. Preliminary results (Harper & Owen 1983) show that whilst the Middle and Upper Ordovician rocks in the south of the area are only gently folded, the Lower Ordovician of the north dip steeply and are repeated many times by high-angle strike faults. This is interpreted as reflecting a major thrust system which ramps upwards along a SW-NE trending fault (the Klekken Fault) and thus the deformed Lower Ordovician rocks of the north were emplaced over younger lesser deformed rocks to the south.

Stratigraphy. The Ordovician succession of Ringerike is being revised in the light of the stratigraphical scheme presented here (Owen & Harper in prep.). This follows recent work on the Upper Ordovician by Owen (1979) and Hanken (1974, 1979) and earlier studies by Kiær (1897, 1908, 1921, 1922) Størmer (1953) and Hamar (1964, 1966). Thus whilst the Caradoc and Ashgill succession has been documented in some detail the rest of the Ordovician has been rather neglected. The structural complexity of the northern part of the district makes the assessment of the thickness of individual units there very difficult. Nonetheless, it is clear that the pre-Ashgill succession is very similar to that of Oslo-Asker.

The Tremadoc shales are poorly exposed but the albeit thin Bjørkåsholmen Formation is a good stratigraphical marker in northern Ringerike enabling the fault bounded repetitions of the sequence to be recognised. The overlying Tøyen Formation is well exposed around Klekken and contains an abundant graptolite fauna in its Galgeberg Member.

The Huk Formation is also a good marker for recognising the imbricate structure and has tripartite development typical of the central Oslo Region. Størmer (1953, p.83) described the upper part of this unit along the Nordfjord at Gomnes where Hamar (1964 pp. 250-251) also noted that the upper 20m is transitional to the nodular limestones and shales of the Vollen Formation. The base of the latter unit is marked by a 10-20cm thick conglomerate at Kullerud and Gomnes (Størmer 1953, Hamar 1964 pp.251-252, Fig. 3) but this bed is absent elsewhere (e.g. Gullerud, see Størmer 1953 pp.83-84). Hamar also (1966 p.31) described a section from the upper Elnes Formation to near the top of the Vollen Formation at Tandberg Farm. The rhythmical alternation of limestone and shale in the

Vollen Formation in Ringerike is broadly similar to the development in Oslo-Asker as are the shales of the overlying Arnestad Formation which was described at Bratterud by Størmer (1953 pp.84-85).

The Frognerkilen and younger formations are only known from south of the Klekken Fault and road cuttings south-east of Norderhov Church show good exposures of all the units from the Frognerkilen Formation to the middle part of the Sørbakken Formation. The base of the Frognerkilen Formation is faulted out here but is exposed at Bratterud. The formation is about 25m thick (Størmer 1953 p.86) and is overlain by the Nakkholmen Formation, the shelly fauna of which was described by Owen & Harper (1982). The overlying Solvang Formation crops out in the road cutting at Norderhov (Owen 1979). A log of the trilobites in this section was also presented by Bruton & Owen (1979 Fig. 4) who later described the trilobites from here and the island of Frognøya (Owen & Bruton 1980). The upper part of the formation on Frognøya was described by Owen (1979) following earlier work by Kiær (1921) and Størmer (1953). Owen termed the uppermost 2.88m the Høgberg Member (a name abandoned herein) and argued that the fauna of these limestones indicates an early Ashgill age whereas the rest of the formation elsewhere in the central Oslo Region is late Caradoc in age (see also Bruton & Owen 1979). The Solvang Formation also crops out at several inland localities of the Bønsnes Peninsula.

The Venstøp Formation was describe on Frognøya and at Norderhov by Owen (1979) who termed it the Frognøya Shale although this name is now considered unnecessary. The formation crops out as far north as the Klekken Fault at Børgerhagen and its trilobite and graptolite faunas were described by Owen (1980a, 1981) and Williams and Bruton (1983) respectively. The overlying thick limestone unit, the Sørbakken Formation, has a similar outcrop distribution pattern and was also defined originally on Frognøya (Owen 1979).

The uppermost part of the Ordovician succession in Ringerike, the Bønsnes Formation and overlying unit (tentatively ascribed to the Langøyene Formation) were summarized by Hanken & Owen (1982 pp.126-131). As a result of Kiær's studies (1887, 1903, 1922) there has been considerable interest in the fauna and flora of these units and recent work by Hanken (1974), Hanken & Owen (1982) and Owen (1979) has clarified some of their sedimentological and stratigraphical complexities. The uppermost Ordovician units crop out in a northeastward trending belt from the islands of the Tyrifjord, Frognøya and Svartøyene across the Bønsnes peninsula to Sponbråtan just south of the Klekken Fault. The overlying lower Silurian succession has been described by Thomsen (1982).

HADELAND

Setting. The Lower Palaeozoic succession of Hadeland is bounded to the south and east by Permian igneous rocks and to the west by the Randsfjord fault which marks the local western edge of the Oslo Graben. In the north, Cambrian rocks overlie Precambrian crystalline basement. A 1:100,000 geological map of most of the district was published by Holtedahl & Schetelig (1923) and a 1:15,000 map of the Middle Ordovician to Silurian succession in the central part of Hadeland was produced by Owen (1978). A 1:50,000 map by Owen showing almost the entire outcrop of this part of the sequence was included in an unpublished thesis by Høstmark (1979 Appendix 1) on the hydrogeology of the area and Morley (1987 Fig. 9) included a simplified version of this in a summary map of the district. A slightly revised version is being incorporated in the 1:50,000 sheet Gran to be published by Norges Geologiske Undersøkelse (Olerud & Owen in prep.).

The Cambrian to lower? Caradoc succession of Hadeland is highly imbricated with numerous, hinterland dipping faults rising from a low angle plane of décollement low in the Cambrian Alum Shales (Morley 1987). In contrast, the Upper Caradoc to Wenlock sequence shows westward plunging, open folds and a set of widely spaced strike faults (some of which are high angle reverse faults) and a series of wrench faults (Owen 1978 and *in* Høstmark 1979). Morley (1987 p.48) postulated a detachment within the Middle Ordovician shale sequence to account for these differences in structural style.

Stratigraphy. Aspects of the Ordovician stratigraphy of Hadeland have been considered by Kiær (1908, 1926), Holtedahl & Schetelig (1923), Størmer (1943, 1945, 1953), Major (1946), Skaar (1972), Lauritzen (1973), Owen (1978, 1982a), Harper & Owen (1984) and Heath (1989).

The Lower Ordovician rocks of the district have yet to be investigated in detail although Holtedahl & Schetelig (1923) outlined the succession. Størmer (1921) and Henningsmoen (1957) described trilobites and graptolites from the Tremadoc formations and Erdtmann (1965 Fig. 8) described a section through the upper 15m of the Tøyen Formation near Tuv. He indicated that the lower 3m of this is grey/green in colour and thus belongs to the Hagastrand Member. Recent mapping by Owen has demonstrated the occurrence of the Galgeberg Member at Helgåker, Granvollen and Hvattum. At Helgåker, some 15m of black shales of this member crop out but the section shows evidence of crumpling suggesting that the measured thickness is at best only approximate.

The tripartite Huk Formation is the most well exposed unit in northern Hadeland but is commonly disturbed and repeated by thrusts (Morley 1987 Fig. 1). It is well exposed around Granvollen and Hvattum and a measured section at Hovodden was given by Skaar (1972: Fig. All) who interpreted part of the profile as a basal transition equivalent to the Herram Member in the Mjøsa area. Reinvestigation of this locality, however, indicates that the lowest 50cm of these beds belongs to the Hukodden Member and the remainder to the Lysaker Member. The Helskjer Member of the Elnes

Formation is also well exposed above the Huk Formation at Hovodden (Wandås 1984, Fig. 2). Whilst Størmer (1953 pp.88-89) assigned some 14m to this member (as the 'basal transition beds') only the lowest 4m is here placed in the Helskjer member; the top being taken at the base of the first thick (25cm) shale bed.

The Llanvirn to Caradoc succession between the Helskjer Member and the late Caradoc Solvang Formation is poorly exposed and tectonically disturbed. As a result, Owen (1978 pp.6-8) assigned it to an informal unit, the Kirkerud Group. Following more recent mapping, this group was formalised by Harper & Owen (1984) with its base being defined at the base of the Helskjer Member. These authors assigned the upper part of the group to the Furuberget Formation, a unit with its type development further north in the Mjøsa area. Harper & Owen defined the base of the Furuberget Formation in Hadeland at the development of thick sandstone beds near Raknerudtjern and they described the brachiopods and trilobites from the uppermost part of the formation. The strata between the Helskjer Member and the Furuberget Formation are here ascribed to undifferentiated Elnes Formation. It is not possible even to estimate the thickness of the Elnes and Furuberget formations as even small exposures show evidence of folding and faulting.

The late Caradoc and Ashgill succession is well exposed in central and southern Hadeland and a modern lithostratigraphical terminology for these units was introduced by Owen (1978). In addition to the map of the central part of Hadeland, Owen (1978 Figs. 5-9) also produced measured sections and maps of key areas, namely around Lunner, Grinda (= Grina) and Gagnum. The important section around Tønnerud was outlined by Owen in 1982 (pp.146-147).

The Solvang Formation is developed as a nodular limestone (the Nerby Member) over most of central Hadeland but a more bedded limestone-shale member (the Lieker Member) constitutes the upper part of the formation in the south east around Lunner. The overlying Lunner Formation is a dominantly shale unit with a slightly diachronous base which becomes younger southwards. With the exception of its lower part, the Lunner Formation passes northwards into the Gamme Formation (formerly termed the Gagnum Limestone) which locally divides it into two tongue-like members. The uppermost part of the Lunner Formation also passes southwards into the limestones, siltstones and shales of the Kjørrven Formation. The limestones of the Kalvsjøen Formation mark a return to a more uniform depositional environment over the whole district although locally the formation contains large unbedded carbonate block deposits currently being studied by Dr R.A. Heath and interpreted as channel fill sediments (Heath 1989).

The very top of the Ordovician in Hadeland is marked by a dominantly arenaceous unit which extends up into the Llandovery. This unit was termed the Skøyen Sandstone Formation by Owen (1978 pp.20-21) but following Worsley et al. (1983 p.18), it is here regarded as an informal supraformational unit pending the results of a detailed study by Dr R.A. Heath (see Heath 1989).

Whilst the naming of these Ashgill units refers only to Hadeland, the base of the Lunner Formation broadly represents the same onset of mud-dominated deposition as the Venstøp Formation, the Gamme Formation is similar to the Sørbakken and Herøya limestones and the Kalvsjøen Formation could be regarded as a lateral continuation of the Bønsnes Formation. As in most districts, the uppermost Ordovician in Hadeland marks a major episode of regression.

FEIRING

Setting. The Feiring district lies at the southern end of Lake Mjøsa with the Lower Palaeozoic rocks situated on the western side of the lake at the local eastern margin of the Oslo Graben (Ramberg & Larsen 1978 Pl.1). Precambrian gneiss crops out to the north, south and east but in the west the Lower Palaeozoic succession abuts, and is thermally metamorphosed by Permian intrusions.

Stratigraphy. Little is known of the heavily baked, poorly exposed, Ordovician succession in Feiring. Vogt (1884) recorded the Bjørkåsholmen Formation, Tøyen Formation, Huk Formation and overlying Middle Ordovician shales (Størmer 1953, Fjelldal 1966) but nothing is known of their detailed stratigraphy. Major (1946) described a late Ordovician/early Silurian sandstone unit from Feiring but its precise stratigraphical position is unclear.

MJØSA

Setting. The Mjøsa area comprises the northernmost districts of the Oslo Region: Toten, Nes-Hamar and Ringsaker. These are situated along Lake Mjøsa and can be conveniently grouped together in terms of their Ordovician successions.

In Toten the outcrop extends south-westwards from Lake Mjøsa to Eina. The sequence overlies Precambrian basement in the south and is faulted against these gneisses in the west. The Lower Palaeozoic outcrop extends north-eastwards into Nes-Hamar where it is seen on the Nes peninsula, the island of Helgøya and the eastern mainland of Lake Mjøsa. Here too Precambrian gneisses crop out in the south east and are faulted against the Lower Palaeozoic rocks on Nes but on the mainland the latter abut late Precambrian sediments of the Hedmark Group along the Caledonian front. The Lower Palaeozoic rocks of the Ringsaker district lie to the north of this thrust front and thus are allochthonous, forming part of the Osen-Røa Nappe Complex (Nystuen 1981, 1982, 1987; Bockelie & Nystuen 1985). Despite the fact that the Ordovician succession of Ringsaker may have been thrust southwards in excess of 150km (Nystuen 1981) it is very similar to that of Toten and Nes-Hamar.

The Ordovician succession in all the Mjøsa districts is tightly folded and affected by strike faulting with the competence and thickness of individual rock units strongly influencing their degree and style of deformation (Skjeseth 1963, pp.93-111). There is also a series of block faults extending down below the Lower Palaeozoic sequence (Skjeseth 1963 pp.111-118).

Stratigraphy. Various aspects of the Ordovician sequence in the Mjøsa districts have been studied and a review of works up to the early 1960's was given by Skjeseth (1963) in his description of the late Precambrian and Palaeozoic succession. Skjeseth's paper also included a geological map of the area. More recent published works include regional mapping by the Geological Survey and sedimentological studies of the late Caradoc - early Ashgill Mjøsa [Limestone] Formation (Harland 1981, Opalinski & Harland 1981). An excursion guide to this unit and the underlying Furuberget Formation was produced by Spjeldnæs (1982) and elements of the Middle Ordovician faunas are included in papers in the 'Middle Ordovician of the Oslo Region' series.

The Lower Ordovician of the Mjøsa district shows many similarities to the sequences elsewhere in the Oslo Region. The Tremadoc units were recorded from Nes-Hamar and Ringsaker by Skjeseth (1963 p.60,70) and the Bjørkåsholmen Formation at Steinsodden and Tomten Farm in Ringsaker was described by Fjelldal (1966) in an unpublished thesis. The Tøyen Formation is present but poorly exposed in Toten and Nes-Hamar and the section at Herram, Ringsaker, was described by Skjeseth (1952, see also Erdtmann 1965 pp.523-4). The possible lower part of the formation at Herram is a grey shale with limestone lenses termed the Steinsodden Shale and Limestone by Skjeseth (1963 p.70). Further investigation is required to determine whether these beds should be ascribed to the Tøyen Formation or the underlying Bjørkåsholmen Formation.

The Huk Formation of the Mjøsa districts shows several differences from the tripartite development elsewhere in the Oslo Region. As Skjeseth (1963 pp.71-2) noted, most of the formation in Ringsaker comprises the alternating bedded limestones and thin sandy shales or mudstones constituting the Stein Member. Skjeseth's basal transition beds, the 'Heramb Shale and Limestone' are here given formal member status as the Herram Member. These latter beds are exposed at Herram along with the lower part of the Stein Member. The best exposures of the Stein Member are around Stein. A similar development of the Huk Formation to that of Ringsaker was also described from west Toten by Skaar (1972). The massive limestones of the Hukodden Member at the base of the Huk Formation appear to be absent in Nes-Hamar (cf. Skjeseth 1963, Skaar 1972) and the limestones and shales between the black shales of the Tøyen Formation and the thick limestones of the Svartodden Member are here assigned to the Herram Member of the Huk Formation. Skjeseth (1963, p.63, Fig. 20) noted a distinct 'corrosion' surface at the boundary between the Herram and Svartodden members.

The Middle Ordovician of the Mjøsa districts has been summarized by Størmer (1953 pp.95-111) and Skjeseth (1963 pp.63-70, 72-74). The type development of the Helskjer Member of the Elnes Formation, now recognised over almost the entire Oslo Region, is at Helskjer on Helgøya (Nes-Hamar) and the member is also well documented from near Furnes Church (e.g. Nikolaisen 1963, Fig. 3, Wandås 1984, Fig. 2). It is not known from the Ringsaker district (Skjeseth 1963) where shales with limestone lenses of the Elnes Formation overlie the Stein member of the Huk Formation. The Elnes Formation is succeeded over the entire Mjøsa area by the Hovinsholm Shale Formation; the type development of which is on Helgøya (Nes-Hamar) but the unit has also been desribed from Herram and Holmen in Ringsaker (Skjeseth 1963). The overlying Furuberget Formation also crops out both in the northern and southern parts of the Mjøsa area and is well exposed at Furuberget and Hole in Nes-Hamar and at Fangberget, Ringsaker (Skjeseth 1963, Spjeldnæs 1982).

The Mjøsa Formation has been the most studied and most contrtoversial formation in the Mjøsa area. This thick limestone comprises a variety of facies and is probably the best exposed unit in the area. Descriptions of its development in Toten and Nes-Hamar have been given recently by Opalinski & Harland (1981) and Spjeldnæs (1982). Harland (1981) also described the structure of 'reefs' within the formation in these districts. The Mjøsa Formation in Ringsaker has a more shaly development than further south (Størmer 1953 p.111; Skjeseth 1963 p.75) and has yet to be described in detail. The karst top of the formation is filled by sandstones of the overlying Llandovery Helgøya Member of the Sælabonn Formation (Skjeseth 1963; Worsley et al. 1983). Most, if not all, of the Ashgill is thought to be absent in the Mjøsa area.

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Appendix

Grid references of localities mentioned in the text

References from Topografisk Kart 1:50 000 M711 series. Sheets listed by district (see Fig. 1), localities in each district listed in order of appearance in text. Note that most entries refer to the location of particular outcrops at, in, or near the place names mentioned.

SKIEN-LANGESUND

PORSGRUNN Sheet 1713 II (1970)

Rognstranda (= Fiskeplassen)	NL 409 411
Blekkebakken	NL 385 466-388 466
Tangvalkleiva	NL 397 429
Bunes (=Bunæs)	NL 406 449
Brevik	NL 399 461
Åsstranda	NL 372 510
Skavråker	NL 388 489
Venstøp	NL 332 665
Versvik-Rød (= Rønning's Herøya section)	NL 378 518-378 514
Gimsøy	NL 350 625
Herøya (= Herøyvegen, Gunnekleiv)	NL 375 532
Porsgrunn	NL 372 556

LANGESUND Sheet 1712 I (1971)

Steinvika	NL 429 397
Langesundstangen	NL 432 392

EIKER-SANDSVÆR

KONGSBERG Sheet 1714 II (1974)

Krekling	NM 434 149
Hals	NM 486 230
Skara	NM 472 223
Klunderud	NM 452 169
Råen	NM 459 176
Stavlum (= Stablum)	NM 443 160
Rønningsfossen	NM 358 035
Lindset	NM 355 021
Skogsleet	NM 528 213
Kvisthogst	NM 429 106
Flata	NM 354 041
Råen-Hassel	NM 454 170-430 132
Såsen	NM 492 205
Haugnes	NM 458 175
Hillestad	NM 373 060
Klunderud	NM 455 171-465 155
Trengen	NM 380 045
Mølleseter	NM 524 200

MODUM

LIER Sheet 1814 IV (1974)

Nysæterbrenna	NM 636 371
Veslesætra	NM 640 365
Toverud	NM 751 432
Øvre Øren	NM 556 444
Hovland	NM 560 445
Vikersund ski jump	NM 563 453

OSLO-ASKER

ASKER Sheet 1814 I (1976)

Rortunet N	NM 835 280
Breidablikk	NM 844 261
Vekkerø	NM 925 432
Sjøstrand (= Hagastrand)	NM 842 297
Bjørkåsholmen	NM 844 294
Engervik	NM 843 302-845 306
Killingen (Huk Formation)	NM 928 431
Killingen (Elnes-Vollen formations)	NM 929 426
Nærsnes	NM 844 258
Slemmestad	NM 836 282-836 286
Huk (Huk Formation)	NM 938 410
Huk (Elnes-Vollen formations)	NM 938 410-932 412
Vekkerø (Sjøstrand Member)	NM 924 430
Vollen (Vollen-Arnestad Formation)	NM 839 310
Rabben (= Arnestad)	NM 840 308
Rodeløkken	NM 947 432-947 430
Persteilene	NM 903 321
Fornebu	NM 915 415-915 416
Semsvatnet	NM 803 370
Nakkholmen (Frognerkilen Formation)	NM 949 403
Nakkholmen (Nakkholmen-Solvang formations, top & base)	NM 949 404
Grimsøya Formation	NM 949 405
Raudskjer (Ø)	NM 864 347
Grimsøya	NM 889 384
Kalvøya	NM 864 401
Skogerholmen	NM 862 353
Spannslokket	NM 855 358
NW Husbergøya	NM 962 377
Langåra	NM 856 356
Sandvika	NM 852 402

OSLO Sheet 1914 IV (1976)

SE Langøyene	NM 968 385
SW Hovedøya	NM 968 409
Søndre Skjerholmen	NM 968 365
Tøyen (T-banen)	NM 994 434
Tøyen (Finnmarksgt.)	NM 994 436
Alnabru PM 027 548	

RINGERIKE

HØNEFOSS Sheet 1815 III (1969)

Haug skole	NM 734 717
Løkenåsen	NM 732 720
Smeden	NM 756 721
Klekken	NM 741 713
Kullerud	NM 724 694
Gomnes	NM 652 617

Bratterud	NM 650 610
Norderhov	NM 710 666-709 667
Vestbråten	NM 656 596
N W Frognøya	M 652 581-652 582
W Frognøya	NM 653 577
Stamnestangen	NM 681 597
Store Svartøya	NM 680 584 & 678 586
Ullerntangen	NM 685 610
Gullerud	NM 723 686
Tandberg	NM 707 678
Norderhov Church	NM 706 669
Bøgerhagen	NM 741 703
Sponbråten	NM 735 691

HADELAND

GRAN Sheet 1915 I (1972)

Tuv	NM 841 947
Helgåker	NM 847 945
Hovodden	NM 785 952
Granvollen	NM 845 934
Hvattum	NM 851 940
Tønnerud	NM 780 922
Nerby	NM 859 887
Lunner railway section	NM 877 862
Raknerudtjern (600m east of)	NM 860 905
Lunner road section	NM 875 863
Lunner road to south	NM 869 859-874 859
Gammehaugen	NM 840 916
(Skøyen Sandstone)	NM 841 912
Grinda	NM 845 874-845 872
Korsrudtjern (north of)	NM 836 884
Gagnum	NM 858 893-856 894
Kalvsjø railway section	NM 876 853-881 852
Kalvsjø quarry	NM 874 852
Bjertnestangen	NM 761 872-762 874

THE MJØSA DISTRICTS

EINA Sheet 1816 II (1968)

Eina	NN 876 238
Holtjern	NN 907 262

HAMAR Sheet 1916 IV (1975)

Nydal (= Furness kirke)	PN 099 472
Furuberget	PN 092 443
Snippsand	PN 074 430
Herram (= Heramb)	PN 989 485
Brumunddal - Holmen (section of Skjeseth 1963 p.74)	PN 068 610
Fangberget	PN 021 527

GJØVIK Sheet 1816 I (1972)

Stein	NN 919 539
North of Redalen	NN 904 532

ØSTRE TOTEN Sheet 1916 III (1968)

Helskjer (= Helskjær)	NN 088 329
Hovinsholm	NN 098 327
Bergevika S	PN 101 364

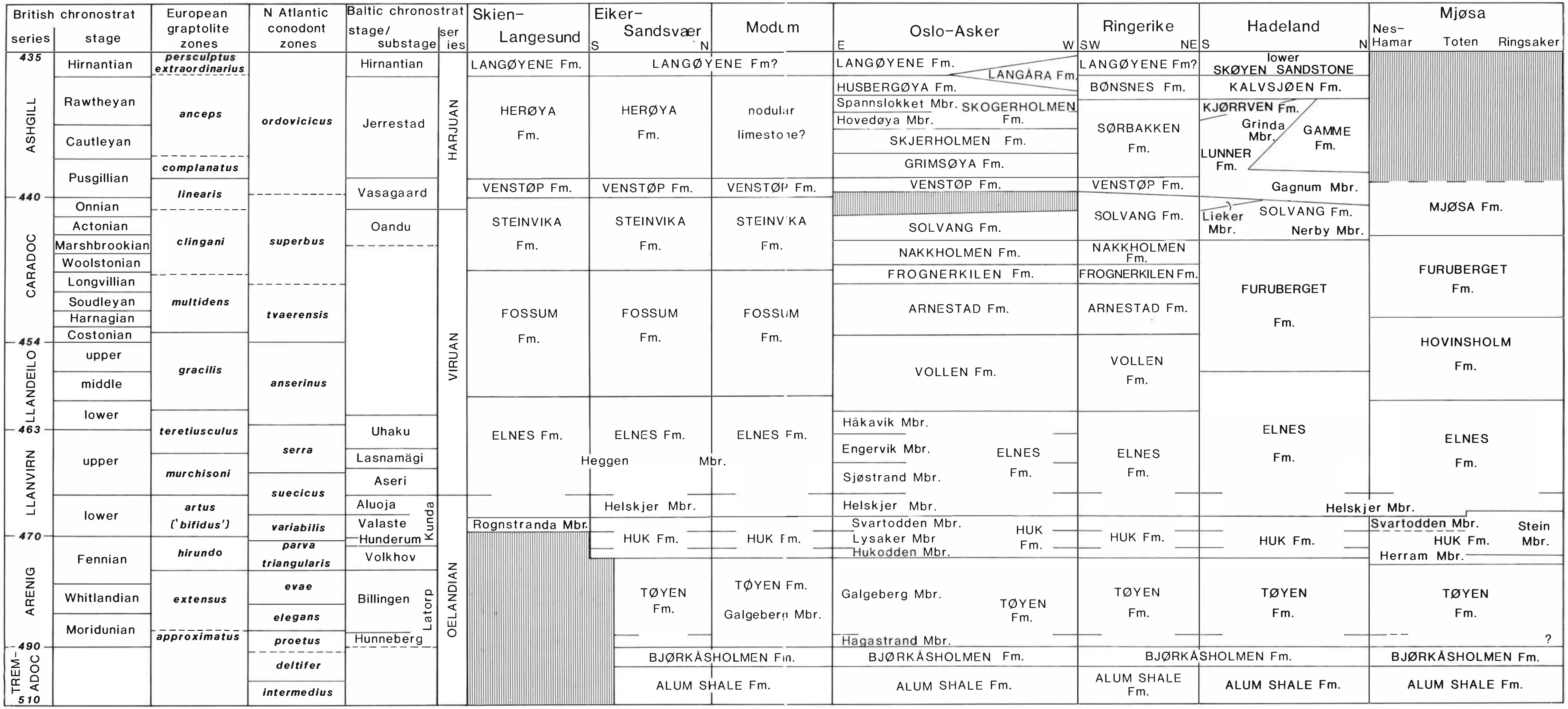

Plate 1. The correlation of the Ordovician succession of the districts of the Oslo Region with the standard northern European chrono- and biostratigraphical schemes. Note that the relative sizes of the chronostratigraphical units are not equivalent to their absolute durations but are scaled to enable the complexity or otherwise of the Oslo Region sequences to be shown. Details of the upper Arenig sequences and their correlation and the Steinvika and Mjøsa limestone formations are shown in Figures 8 and 18 respectively. Equivalence of the chrono- and biostratigraphical units based on Bergström (1986), Bassett (1984), Fortey et al. (in press), Fortey & Owens (1987), Harper et al. (1985) and Jaanusson (1982).

The Oslo Region is one of the classical areas of Lower Palaeozoic rocks which crop out for 100 km to both the north and south of the Norwegian capital. Ordovician limestones and shales (some highly fossiliferous) cover over 2000 km^2 and occur in each of the eleven districts of the region. The lower part of the Ordovician shows considerable spatial uniformity but above this, the sequence in each district becomes progressively more distinctive – a reflection of the increasing proximity of the developing Scandinavian Caledonides to the Oslo Region basin during the Ordovician.

The Oslo Region is the type area for a multitude of Lower Palaeozoic fossils first described in the classical monographs of Angelin, Brøgger, Størmer, Monsen, Henningsmoen and numerous others. It is regarded internationally as a standard reference area for Lower Palaeozoic geology and thus a modern stratigraphical framework for the region is essential.

The authors of this Geological Survey of Norway Special Publication synthesise two decades of their own work on the Ordovician of the Oslo Region in the context of over two centuries of stratigraphical, palaeontological, sedimentological and tectonic interest in the area. They replace the 'Etasje' system of numbered and lettered unit terms with a modern lithostratigraphical terminology. Twenty-nine formations are defined (some with constituent members). Type localities are designated and many illustrated by measured sections. New biostratigraphical data are incorporated in a correlation of the sequences in each district with the standard British and Baltic chronostratigraphical schemes.

The paper is laid out in two parts: a description of each formation and an account of the succession in each district. There is a large correlation chart and a list of over 220 references. The paper is therefore a much needed summary of present knowledge of the Ordovician of this classical area and a vital framework for future studies.

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