The upper Ordovician succession at Norderhov and on Frognøya in Ringerike, Norway

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Owen, A. W.: The upper Ordovician succession at Norderhov and on Frognøya in Ringerike, Norway. *Norsk Geologisk Tidsskrift*, Vol. 58, pp. 245–258. Oslo 1978. ISSN 0029-196X.

Lithostratigraphical units in the Ordovician succession in Ringerike are named formally for the first time. The distribution of species of *Tretaspis* indicates that the highest beds of the oldest unit studied, the Solvang Formation, are younger on Frognøya (lowest Pusgillian) than at Norderhov (highest Onnian). The overlying shale unit, the Frognøya Shale, contains well preserved graptolites of the *Pleurograptus linearis* Zone (mid-Onnian to ?mid-Pusgillian). The succeeding units described are dominantly calcareous and are named the Sørbakken Limestone (late Pusgillian to ?low Rawtheyan) and the Bønsnes Formation (probably wholly Rawtheyan).

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Historically, the description of Cambro-Silurian successions within the Oslo Region has been undertaken largely with direct reference to the named units of the Oslo-Asker sequence (e.g. Strand 1933, Størmer 1953, Strand & Henningsmoen 1960). This has led to imprecision and misconceptions in correlation, examples of which are detailed below for the Ringerike district. The primary aim of this paper is to establish a named lithostratigraphical framework for the upper Ordovician succession in Ringerike prior to the description of the trilobite faunas.

It must be stressed from the outset that the writer advocates the discontinuation of the etasje nomenclature originally applied to the Oslo-Asker succession but subsequently imposed on other sequences in the Region. This terminology was devised by Kjerulf (1857) and subsequently developed by, amongst others, Brøgger (1882, 1887), Kiær (1897, 1902, 1908), Størmer (1953), and Henningsmoen (1957). Originally no more than a shorthand method of expressing litho- and biostratigraphical units, this nomenclature developed a chronostratigraphical connotation and Henningsmoen (1955) outlined a scheme for its use purely in chronostratigraphy. While this may be feasible for the Cambrian Alum Shale and Ceratopyge beds (Henningsmoen 1957:34–61), evidence is accumulating to show that the Silurian etasjer may lack even local chronostratigraphical significance (Worsley 1971, Bassett & Rickards 1971) and work on upper Ordovician successions in Ringerike and Hadeland shows that many of these units have a very limited application. Units of the Oslo-Asker succession referred to herein are interpreted purely lithostratigraphically.

Setting

The Ringerike district is situated to the north-west of Oslo (Størmer 1953, fig. 1). The local Lower Palaeozoic succession has a general north-east to south-west strike and youngs south-eastwards. The succession rests on Precambrian gneiss and is overlain in the east by Permian lavas. In the north-east, Ordovician rocks of Ringerike abut Silurian sediments of the Hadeland district against the Randsfjorden fault (Holtedahl 1960, pl. 13). A brief general account of the geology of the district and an extensive list of papers published since 1950 are given by Whitaker (1977).

The sections described here are the most complete upper Ordovician exposures in the district and are at Norderhov, 3 km south of Hønefoss and, 11 km along the regional strike, on the island of Frognøya (Fig. 1). At Norderhov 70 m of strata crop out by the roadside, dipping gently southwards, but only the lowest 15 m is readily accessable as much of the exposure is high and overhanging. The succession on Frognøya (Fig. 2) is well exposed on the north and west coasts of the island and there is intermittent outcrop on the east coast: exposure inland is very limited.

Few accounts of the Ordovician rocks of Ringerike have appeared in the literature although Kiær carried out extensive fieldwork.

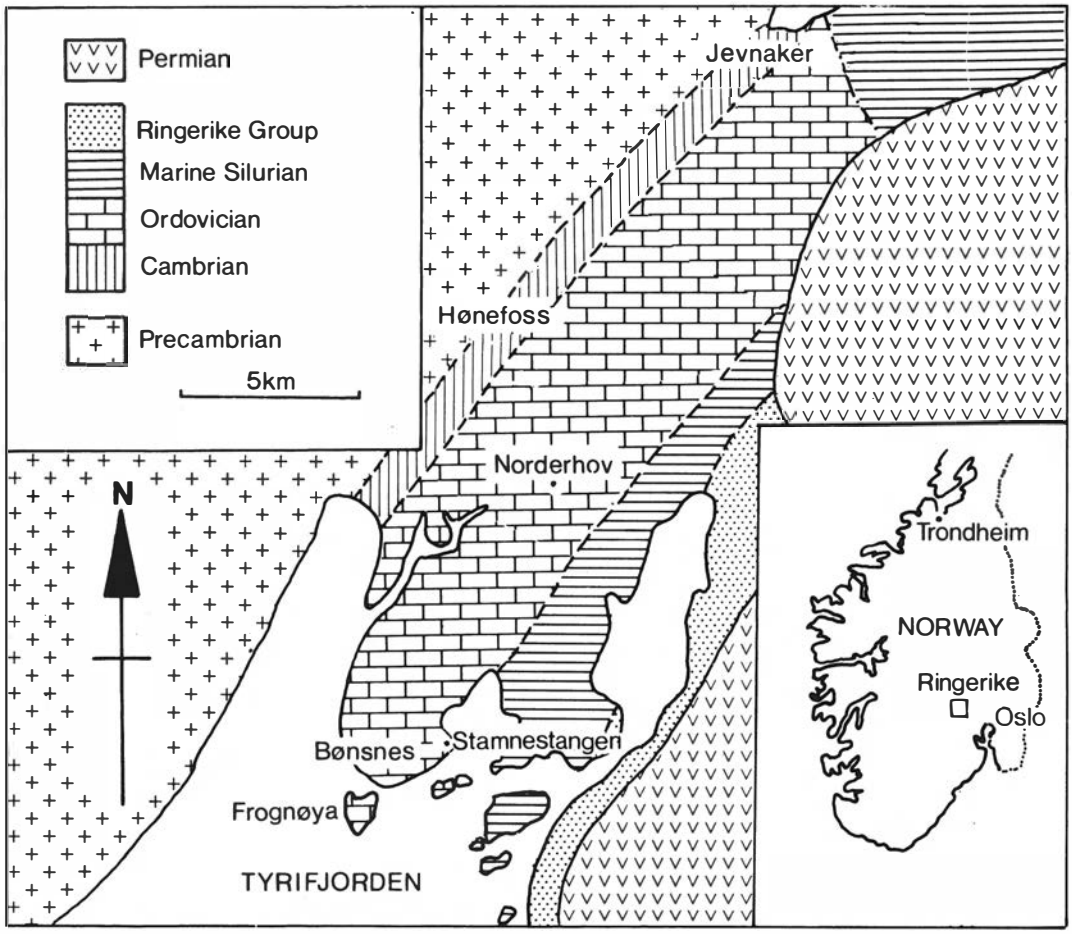

Fig. 1. Simplified geological map of the Ringerike district (based on Holtedahl 1960, pl. 3).

His collections and field note books pertaining to the Ordovician succession are housed in Paleontologisk museum, Oslo. More recently, David L. Bruton of Paleontologisk museum, Oslo has examined the Frognøya succession and has kindly given the writer free access to his collections. A summary of the lithostratigraphical units defined and newly named herein and their interpretation by previous workers is given in Fig. 3.

The Solvang Formation at Norderhov

Owen (1978:8–10) defined the Solvang Formation in Hadeland where it is developed as a nodular limestone over much of the area (the Nerby Member) and as interbedded limestones and shales (the Lieker Member) in the south-east of the district. The concept of the Solvang Formation is here broadened to include a coeval limestone unit in Ringerike, and the outcrop at Norderhov (NM71256585) is designated an hypostratotype. Although the base of the formation is not seen at Norderhov, the upper 12 m (Fig. 4) is exposed and small outcrops to the east suggest that this is close to the total thickness of the unit here. 80 m to the north of the Norderhov section, shales containing *Broeggerolithus discors* (Angelin, 1854) and *Lonchodomas* aff. *rostratus* (Sars, 1835) crop out by the roadside (= Upper Chasmops Shale of Størmer 1953:86) and are interpreted as belonging to the unit below the Solvang Formation.

The Solvang Formation at Norderhov is com-

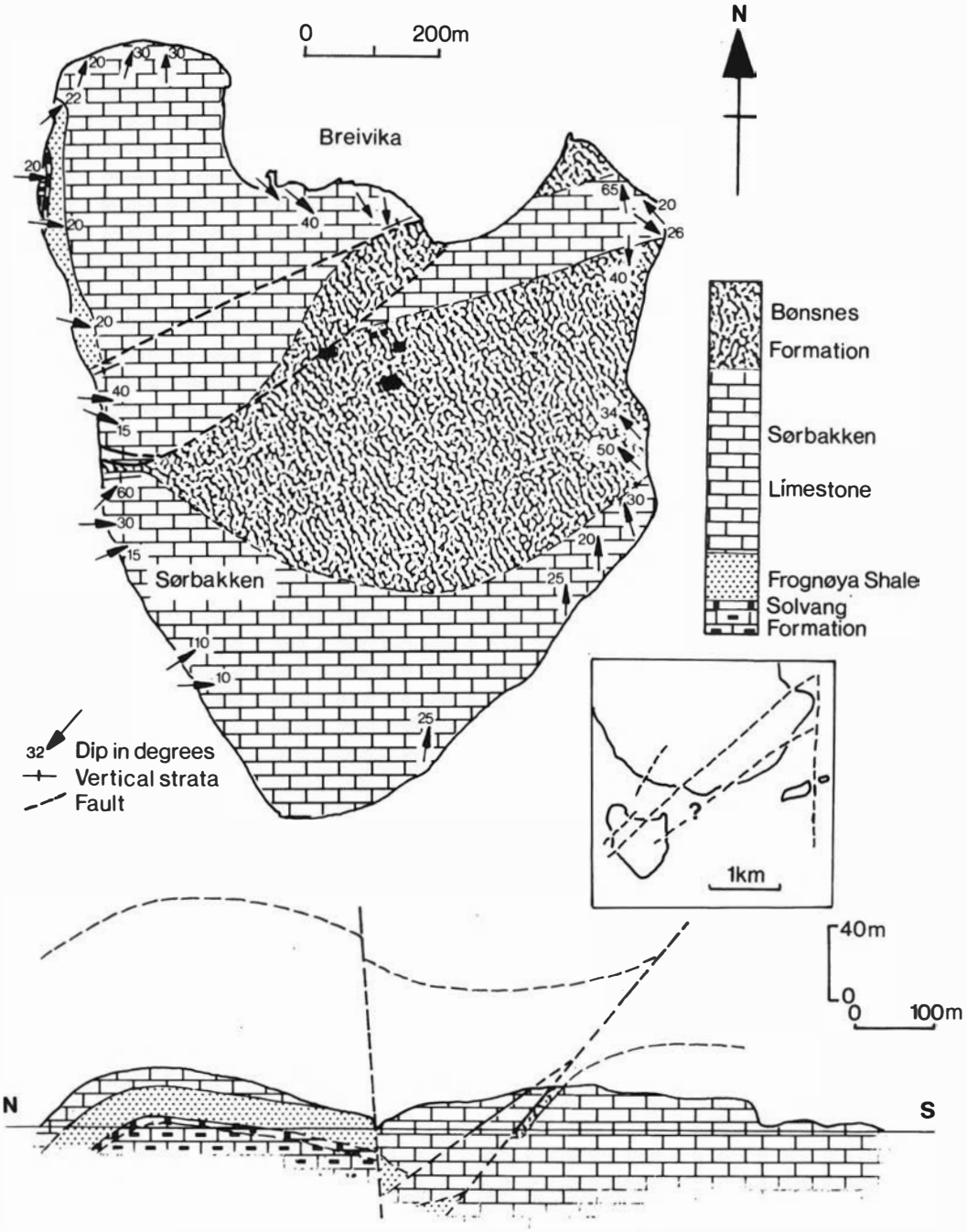

Fig. 2. Geological map (omitting Permian dykes) of Frognøya and section along the west coast. Horizontal line on section represents fjord level – approximately 60 m a.s.l. Inset map shows the position of the major dislocations on Frognøya and the mainland and is taken from an unpublished study of aerial photographs by J. F. Bockelie (1970).

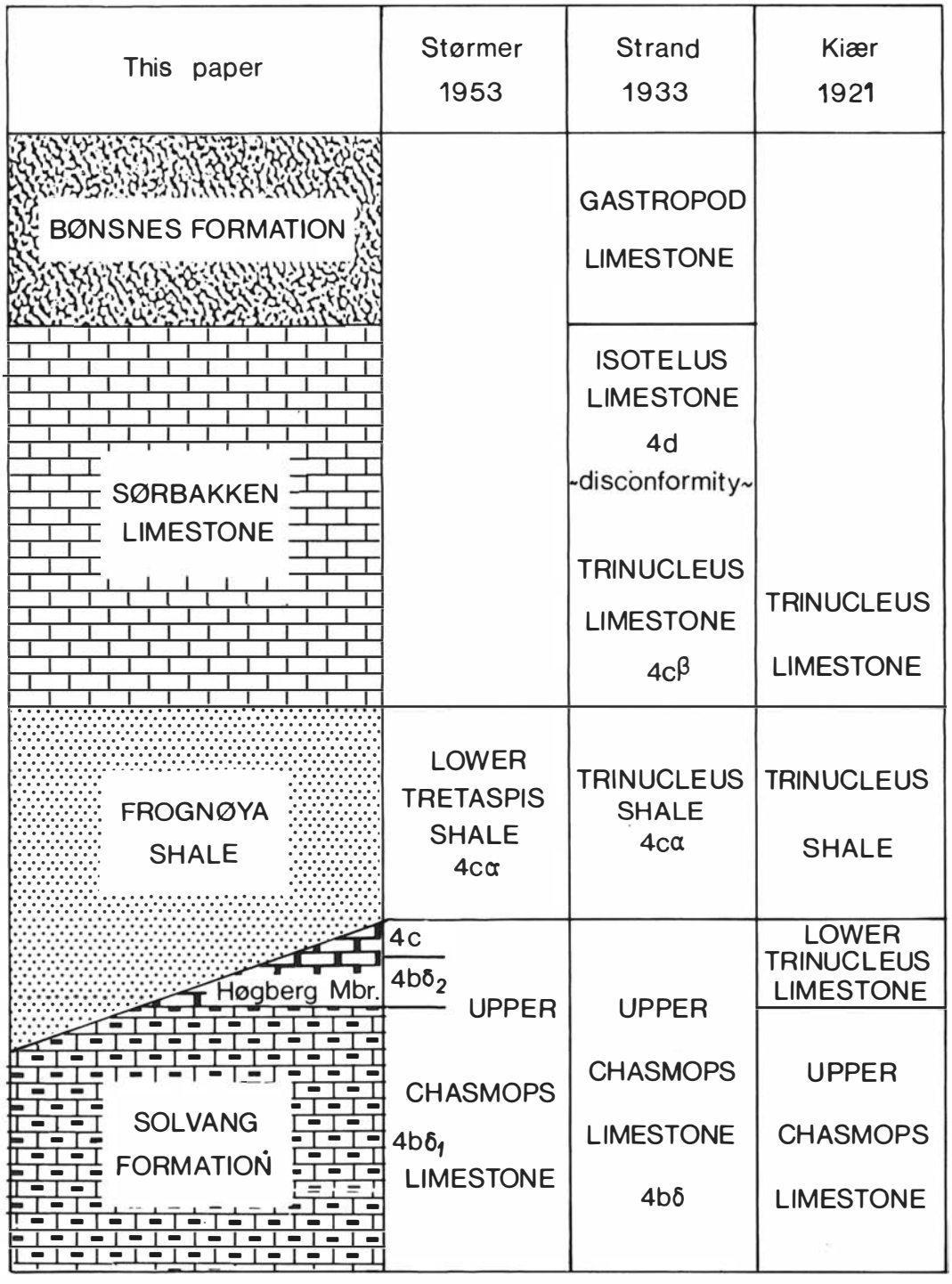

Fig. 3. The historical development of terms applied to the upper Ordovician successions at Norderhov and on Frognøya (not to scale). The Solvang Formation was originally recognised in Hadeland (Owen 1978), all other terms are new. The Høgberg Member of the Solvang Formation on Frognøya is the lateral equivalent of the lowest part of the Frognøya Shale at Norderhov

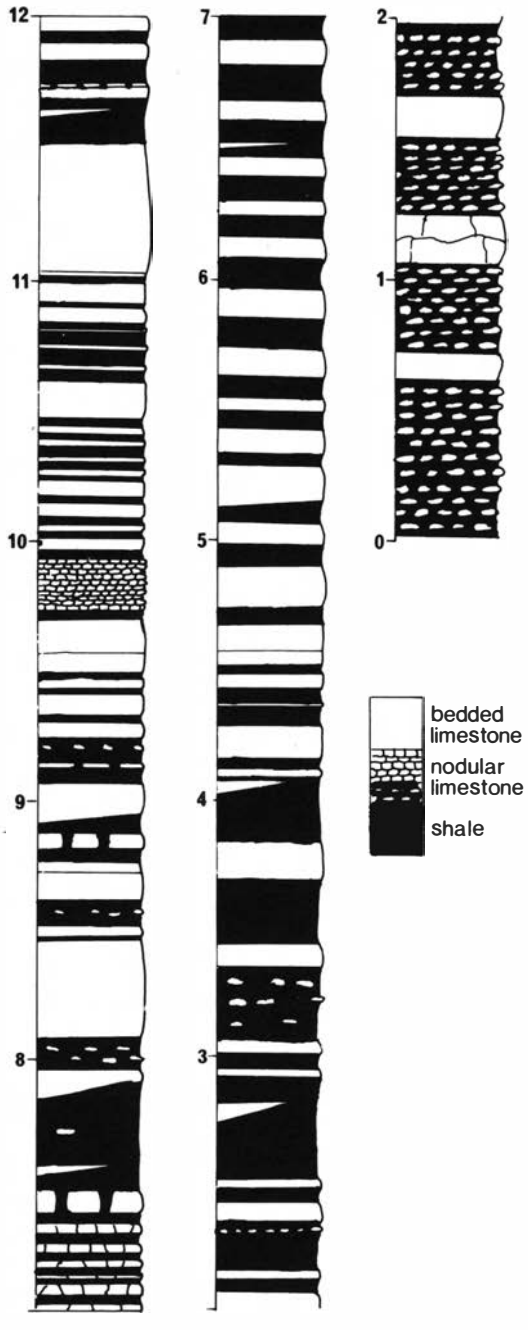

Fig. 4. Measured section through the Solvang Formation at Norderhov. Metre intervals are indicated.

posed of alternating limestone and shale horizons and thus most closely resembles the Lieker Member in Hadeland. Most of the limestones form continuous beds, although some are laterally impersistent and nodular horizons predominate in the lowest 2 m of the section. Between 2.07 and 2.27 m below the top of the unit are 10 closely-packed bands of limestone nodules with very little intervening shale. The junction of the Solvang Formation with the overlying shale unit is abrupt and lithologically distinctive.

Although most horizons in the section are extremely poorly fossiliferous, some contain a large, diverse fauna of trilobites, brachiopods, cystoids, crinoids, ostracods, and gastropods. A detailed log of the trilobite fauna is given by Bruton & Owen (1979, fig. 5) and it is sufficient to note here that the fauna is very similar to that of the Upper Chasmops Limestone in Asker.

The Solvang Formation on Frognøya

The upper 7.5 m of the Solvang Formation is exposed on the north-west promontory of Frognøya (NM65205820) where its development is very different from the exposure at Norderhov. The lower 4.42 m is composed almost entirely of thin horizons of nodular limestone with very thin shale partings. This nodular development may be represented as a thin tongue in the upper part of the section at Norderhov and strongly resembles the Nerby Member in Hadeland. 0.92 m below the top of the nodular beds on Frognøya there is a 14 cm thick zone of nodular limestone striking east-west and dipping northwards at 45°. This contrasts markedly with the gentle eastward dip of the succession above and below. It is not possible to assess the degree of dislocation at this level. The only fossiliferous horizon in these nodular beds is at the base of the section where the cystoid *Echinosphaerites* is abundant.

The upper 2.88 m of the Solvang Formation on Frognøya is composed of alternating limestone and shale beds and is here termed the Høgberg Member. Its base marks the abrupt change from nodular limestone and its top is the local base of the Frognøya Shale. It may prove desirable to regard the beds above the thin nodular development at Norderhov as belonging to the Høgberg Member also but this must await the documentation of the spatial development of the nodular horizons as must the use of member names currently used for the unit in Hadeland.

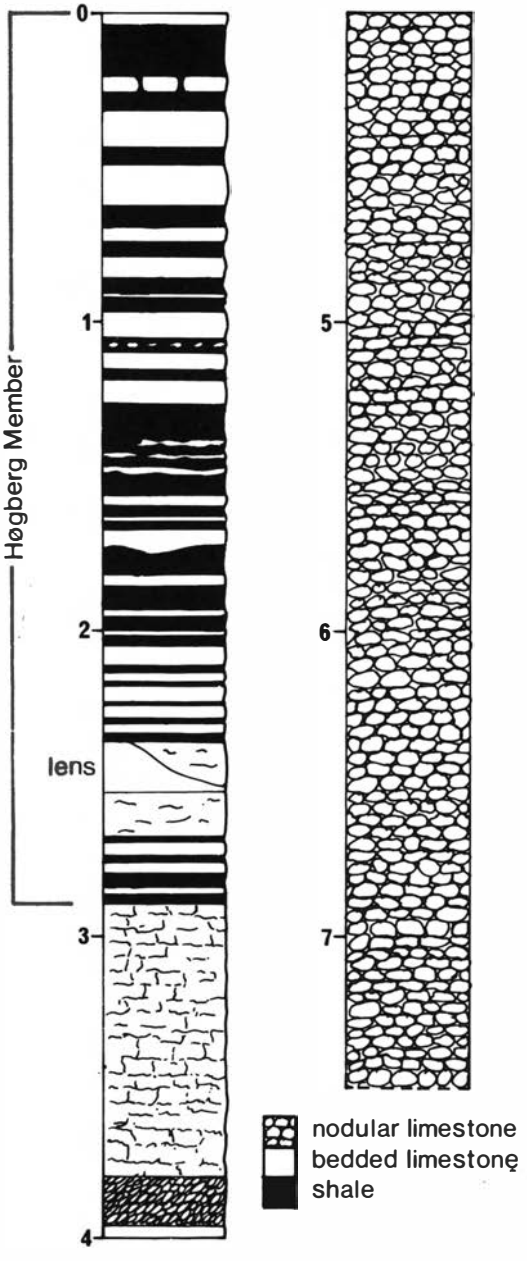

Fig. 5. Measured section through the Solvang Formation on Frognøya showing the development of the Høgberg Member. Metre intervals from the base of the overlying Frognøya Shale are indicated.

A diverse fauna, dominated by trilobites, is known from the Høgberg Member. Spjeldnæs (1957) described the brachiopods *Strophomena* sp. and *Gunnarella* cf. *rigida* (Barrande, 1879). Orthoids and inarticulate brachiopods, including *Lingula*?, also occur, as do cystoids and crinoids. Strand (1933) described a new nautiloid species, *Ephippiorthoceras frognoense,* and Sweet (1958) an indeterminate specimen of *Diestoceras*. Hamar (1966) detailed a very large conodont fauna from the unit.

The trilobite fauna of the Høgberg Member is listed in Fig. 6. No complete specimens are known and thoracic segments are rare. Many of the forms are known from a fossiliferous lens 2.35–2.52 m below the top of the unit and from beds 1.5–1.6 m below the top. In addition there are many specimens in Paleontologisk museum, Oslo, whose precise level is not known. Størmer (1930) described a specimen clearly belonging to *Tretaspis seticornis seticornis,* but its precise horizon is unclear, since it was recorded by him as being from 1.5 m (1930:57), 1 m (1930:76), 1.3 m (1945:76) and 1.3 m (1953:87) above the trilobite-rich lens. Størmer's comment (1953:87) that the boundary between the 'Chasmops Series' and the 'Tretaspis Series' (marked by the incoming of *T. seticornis*) lies in the middle of what is now regarded as the Høgberg Member indicates that the specimen of *T. seticornis seticornis* must have been from the upper half of the unit. A second specimen of this form is known from the unit but its precise level is also uncertain.

Stratigraphical relationships of the Høgberg Member

The trilobite-rich lens, probably a remnant of a shell bank, first attracted the attention of Kiær (1921), who correlated what he termed the Lower Trinucleus Limestone (= Høgberg Member) with a disconformity near the base of the Lower Tretaspis Shale in Oslo postulated by Raymond (1916:244). Størmer (1953:68, 87) concurred with this, pointing out that *T. kiaeri,* which occurs abundantly in the Høgberg Member, is unknown in Oslo-Asker where, he argued, its range is equivalent to a hiatus indicated by the phosphorite band near the base of the Lower Tretaspis Shale. The resultant changes in the stratigraphical nomenclature exemplify the confusion associated with the etasje terminology. Størmer (1953:68, 128) correctly implied that the lowest part of the Lower Tretaspis Shale on Nakholmen in Oslo contains *Tretaspis ceriodes,* a species which occurs also in the upper part of the Upper Chasmops Limestone in Asker to the

TRILOBITE SPECIES	Abundance	lens	1.5-1.6m below top
Bronteopsis sp.	VR	+	
Carrickia sp.	VR		
Deacybele gracilis (Nikolaisen, 1961)	VR	+	
Decoroproetus sp.	VR	+	
Flexicalymene sp.	VR	+	+
Frognaspis stoermeri Nikolaisen, 1965	C	+	
harpid gen. et sp. indet.	C	+	
Harpidella (s.l.) sp.	VR		+
Illaenus (Parillaenus) aff. *fallax* Holm, 1882	C	+	
Lonchodomas aff. *pennatus* (LaTouche, 1884)	A	+	+
Miraspis sp.	VR		+
Phillipsinella preclara Bruton, 1976	C		+
Prionocheilus aff. *obtusus* (McCoy, 1846)	VR	+	
Pseudosphaerexochus densigranulatus Nikolaisen, 1965	R		+
Raymondella sp.	VR		+
Remopleurella sp. nov.	VR		
Remopleurides sp. nov.	VR		+
Staurocephalus sp. nov.	VR		+
Stygina minor Skjeseth, 1955	C	+	+
Telephina sp.	VR		
Tretaspis kiaeri Størmer, 1930	A	+	+
Tretaspis seticornis seticornis (Hisinger, 1840)	VR		

Fig. 6. Trilobite species occurring in the Høgberg Member of the Solvang Formation on Frognøya. VR – very rare (less than 5 specimens known), R – rare (6–10 specimens), C – common (11–20 specimens), A – abundant (many hundreds of specimens).

west. He advocated therefore that the term '4bδ', which previously was no more than shorthand for the Upper Chasmops Limestone in a purely lithostratigraphical sense (Fig. 7A), should be redefined biostratigraphically and divided into two subzones – a lower *T. ceriodes* zone ('4bδ$_1$') extending into the lowest part of the Lower Tretaspis Shale in Oslo and a *T. kiaeri* zone ('4bδ$_2$') represented by the *T. kiaeri*-bearing beds on Frognøya but absent in Oslo-Asker (Fig. 7B).

T. ceriodes is succeeded stratigraphically by members of the *T. seticornis* group (of Ingham 1970, see also Hughes, Ingham & Addison 1975) without overlap, irrespective of lithology and commonly over a few tens of centimetres or less of strata in Oslo-Asker, Ringerike, Hadeland, Sweden, and northern England. This stratigraphical relationship is a close approximation to a time line and has great potential as a correlation tool. The highest beds of the Solvang Formation at Norderhov contain populations of *T. ceriodes*, including specimens of a morphological type (with a short extra arc of pits) which is known also from the youngest samples of *T. ceriodes* in the Upper Chasmops Limestone of Asker. Similarly, *Deacybele gracilis, Phillipsinella preclara,* and *Raymondella* sp. are all restricted to the upper parts of the Upper Chasmops Limestone in Asker and the Solvang Formation at Norderhov, but they occur also in the Høgberg Member on Frognøya. *Staurocephalus* sp. nov. occurs in the upper part of the Upper Chasmops Limestone in Asker and in the Høgberg Member. Despite this broad faunal similarity, the Høgberg Member also contains *T. seticornis* and therefore is probably younger than either the Upper Chasmops Limestone or the Solvang Formation at Norderhov. This indicates that limestone deposition and the incoming of new,

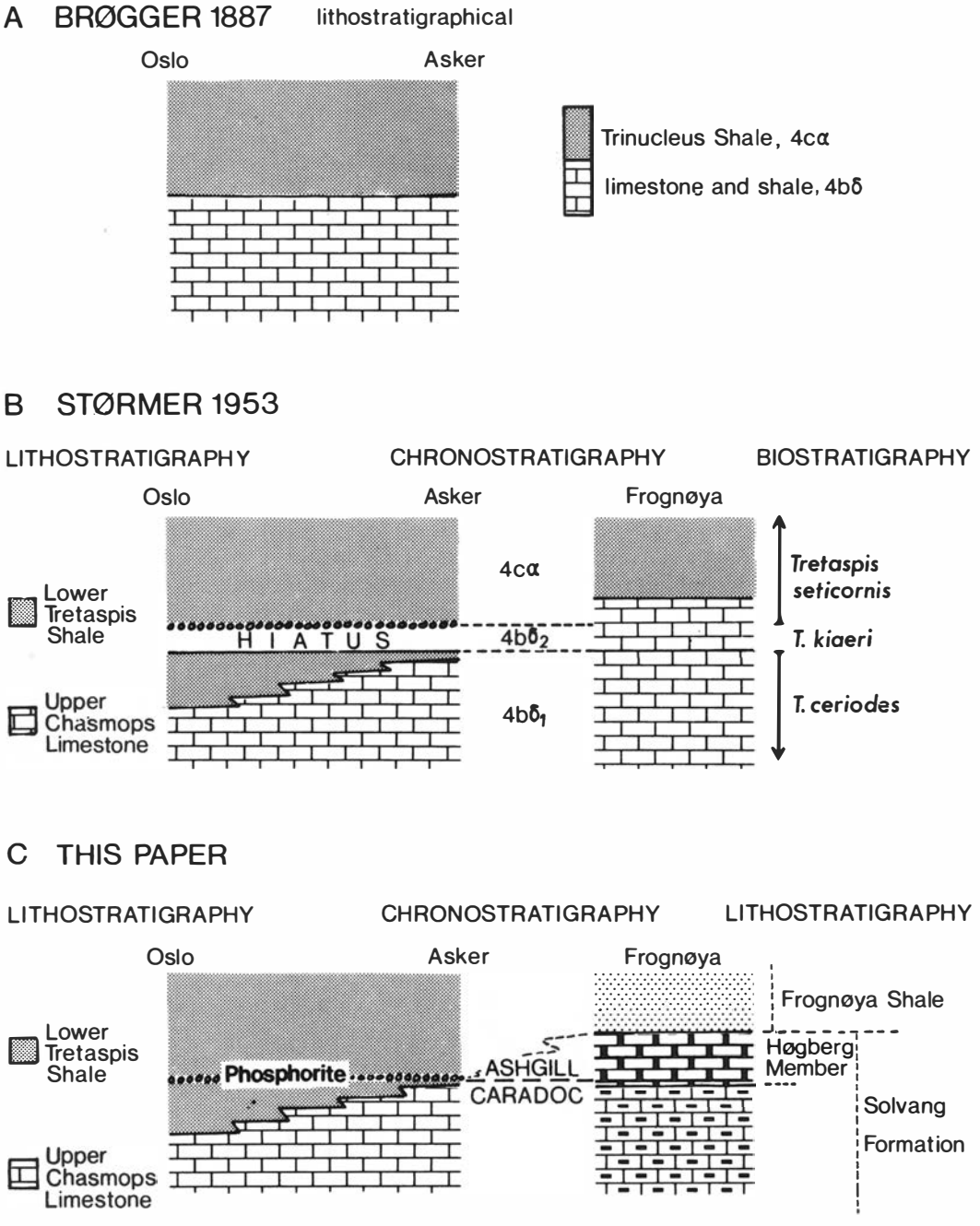

Fig. 7A–C. Schematic illustration of the historical development of stratigraphical terms applied to units at the Caradoc-Ashgill boundary in Oslo-Asker and Ringerike.

limestone-restricted species evident in the upper parts of these units persisted longer around Frognøya with, amongst others, the appearance of *T. kiaeri, Pseudosphaerexochus densigranulatus, Frognaspis stoermeri,* and *Miraspis sp. T. seticornis seticornis* also made its first appearance at this time but was much more facies-tolerant and thus occurs in the Høgberg Member limestones as well as the coeval shales of the Lower Tretaspis Shale of

Oslo-Asker (Fig. 7C). There is, therefore, no palaeontological evidence for a significant hiatus in the Oslo-Asker succession.

The Frognøya Shale

Much of this unit at Norderhov is talus covered, although the lowest 0.25 m is exposed. The stratotype is taken to be on the north-west promontory of Frognøya (NM65205820) where the formation is fully exposed and is 23.85 m thick (Owen 1977, fig. 23). Both the base and the top are sharp lithological boundaries with dominantly calcareous units above and below the formation. As is demonstrated in the preceding discussion, the base of the Frognøya Shale is diachronous. The lowest 4.25 m on Frognøya is composed entirely of shale and is succeeded by 4.85 m of shale with some limestone beds and isolated limestone nodules. The remaining 14.75 m of the unit contains some limestone nodules and a large number of limestone beds, many of which are argillaceous; some are strongly bioturbated.

Fossils in the shale are commonly fragmentary and crushed, but the better preserved material shows that *F. trinucleina*? occurs throughout the formation. On Frognøya, *Tretaspis* sp. nov. (=*T.* sp ?nov. of Ingham 1970) is found at many levels in the unit but the lowest few centrimetres contain very poorly preserved specimens resembling *T. hadelandica* Størmer, 1945. In addition, the upper half of the formation on Frognøya contains *T. seticornis anderssoni* Størmer, 1945.

Few complete trilobite specimens are known from the Frognøya Shale, and thoracic segments are rare. Some of the limestone beds contain a well preserved fauna and the collections of Paleontologisk museum, Oslo contain specimens of the trilobites *Cybeloides* (?*Paracybeloides*) aff. *girvanensis* Reed, 1906), *Calymene (sensu lato)* aff. *holtedahli* Størmer, 1945), *Stenopareia* sp. and *Calyptaulax norvegicus* Størmer, 1945. A limestone bed 7.5 m below the top of the unit on Frognøya has yielded a particularly rich fauna including the trilobites *Chasmops* cf. *extensa* (Boeck, 1838), *Flexicalymene trinucleina* (Tullberg, 1882)?, *Primaspis evoluta* (Törnquist, 1884) subsp. nov., *Tretaspis seticornis anderssoni* Størmer, 1945, and *T.* sp. nov. Lenses within this bed are made up almost entirely of small gastropods and the brachiopod *Chonetoidea;* also known are *Orbiculoidea* sp., a large strophomenid, and an ortocone. The horizon also contains the graptolites *Dicellograptus* cf. *johnstrupi* (Hadding, 1915) and *Orthograptus* sp. preserved in full relief.

Toni (1975) described the bivalves *Nuculites* sp. *Tancrediopsis plandorsata* (Ulrich, 1892), and an indeterminate pterinid from the Frognøya Shale. Specimens assigned by Toni to *Cyrtodontula ventricosa* (Hall, 1847) may be from this unit also.

The Sørbakken Limestone

There is no complete section through this unit. 37 m crop out at Norderhov but the base and the lowest few metres are talus covered here. The lowest 34 m crop out on the north-west promontory of Frognøya (NM65205820) and this constitutes the boundary stratotype for the base of the formation. The upper part of the unit crops out on the west, east, and north-east coasts of Frognøya, and the stratotype for the top of the formation is taken on the west coast of the island south of the major north-easterly striking dislocation where the upper 40 m is seen (NM65305775). The greatest measurable thickness of the formation is north of this dislocation where 50 m of strata crop out, but neither the base nor the top of the unit is exposed here. The trilobite faunas of the lower 34 m and upper 40 m of the Sørbakken Limestone suggest that there is no overlap between these two profiles and that the thickness of the formation based on outcrop pattern is of the order of 100 m.

There is no structural, palaeontological, or sedimentological indication of any hiatus in the Sørbakken Limestone. Strand's statement (1933:102) that there is a disconformity between the 'Trinucleus' and 'Isotelus' limestones was probably based on a reluctance to accept lateral facies variation and therefore the belief that a shale unit, the Upper Tretaspis Shale of Oslo-Asker, was missing on Frognøya and consequently must be represented by a break in sedimentation or by deposition followed by erosion. A more acceptable explanation is that part of the Sørbakken Limestone is the lateral equivalent of the Upper Tretaspis Shale.

The base of the Sørbakken Limestone marks a distinctive change from shale to limestone deposition. The top of the unit is marked by the first appearance of the calcareous alga

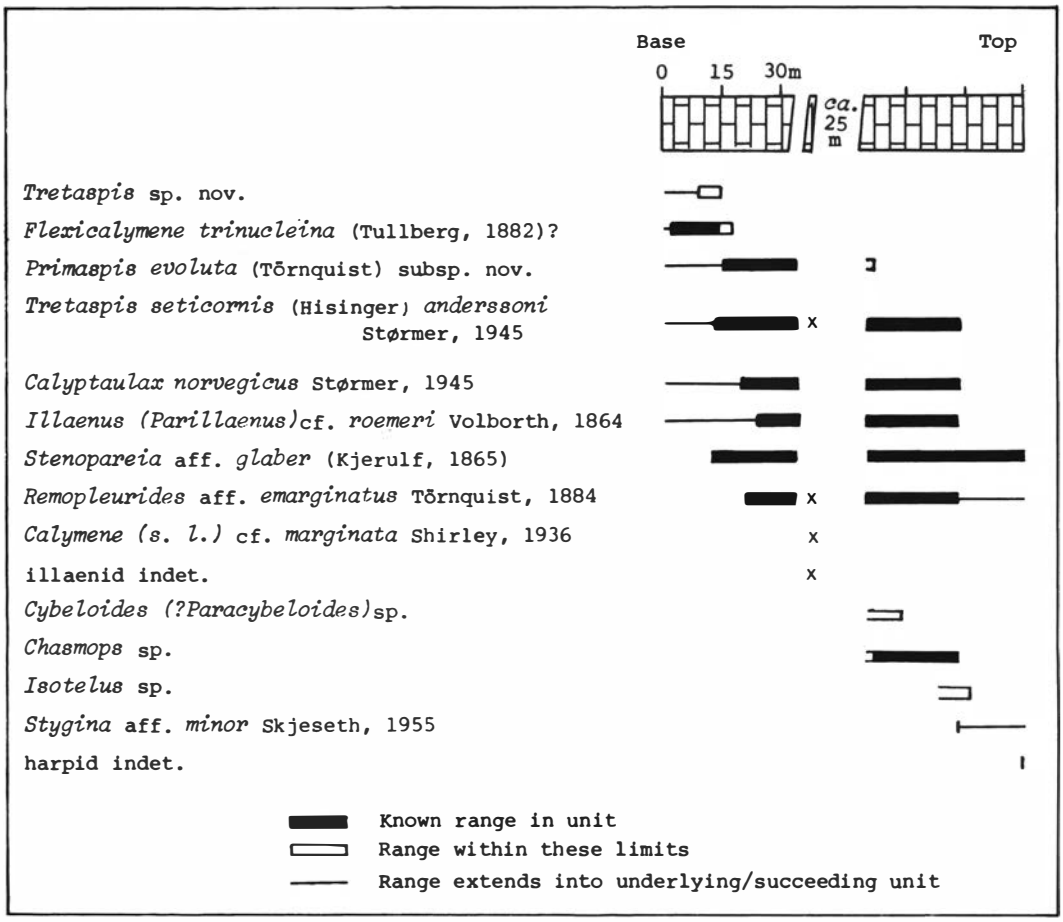

Fig. 8. The distribution of trilobite species in the Sørbakken Limestone on Frognøya. Specimens from 35–37 m above the lowest exposed part of the unit at Norderhov are indicated by crosses, but the precise relationship of this level to the Frognøya section is not known.

Palaeoporella in the basal beds of the overlying Bønsnes Formation. The lowest 9 m of the Sørbakken Limestone on Frognøya consists of grey, argillaceous, nodular limestone beds and silty shales up to 10 cm thick. In most of the remainder of the unit the limestones are less silty, and whilst most horizons are less than 10 cm thick, beds up to 30 cm thick are known. Most limestone horizons are to some extent nodular. The intervening shales are calcareous, and although most are only a few centimetres thick, some up to 20 cm thick occur, commonly containing isolated limestone nodules. Calcareous siltstones and fine sandstones are developed at some horizons. Towards the top of the unit the limestones are rather platy and dark grey, almost black, in colour.

With the exception of the lowest 9 m, the Sørbakken Limestone has a very diverse fauna dominated by brachiopods and, to a slightly lesser extent, trilobites. Most of the brachiopods have both valves preserved but few complete or almost complete trilobites are known and thoracic segments are otherwise rare.

The known distribution of trilobite species in the Sørbakken Limestone is illustrated in Fig. 8. Many forms have a long range in the unit and thus reflect a long period of sedimentary stability. Only one specimen of *Isotelus* sp. has been found by the writer, but there is a large amount of material of this form in Paleontologisk museum from unspecified horizons in the upper part of the unit. The following trilobites, also from the upper part of the unit, are known only from museum specimens: *Atractopyge* sp., *Chasmops* aff. *eichwaldi* Schmidt, 1881, en-

crinurid gen. et sp. indet., *Panderia insulana* Bruton, 1968, and *Sphaerexochus* sp. A cranidium ascribed to *Holotrachelus* cf. *punctillosus* (Törnquist, 1884) is known from an unspecified horizon probably in the upper part of the formation, and *Stygina* sp. occurs in the lower part of the unit.

The brachiopod fauna of the Sørbakken Limestone is dominated by orthoids and plectambonitaceans with most forms occurring at levels throughout the formation. These long-ranging forms include *Anisopleurella*? sp., *Cyclospira* cf. *pentagonalis* (Reed, 1897), *Dalmanella* sp., *Isorthis* sp., *Octoplecia* sp., and plectambonitacean sp. A few forms are more restricted in their distribution. A large strophomenid similar to the form found in the Frognøya Shale occurs between 9 and 17 m above the base of the Sørbakken Limestone on Frognøya and the upper few tens of metres of the unit contain *Platystrophia* sp., leptaenids, *Orbiculoidea* sp., and *Lingula*? sp.

The Sørbakken Limestone has a large molluscan fauna, and gastropods are common throughout the unit. Toni (1975) described the bivalve *Cleonychia* from an unspecified horizon in the formation and Strand (1933) described 15 nautiloid species, many new, from various horizons. Stick bryozoans and diplotrypid colonies occur throughout the formation and a fenestellate form encrusting a nautiloid was found in the lower part of the unit. Cystoids are known from the lower part of the formation, crinoid ossicles occur at many horizons, and a pyritized ostracod from the top 0.5 m of the unit on Frognøya strongly resembles specimens figured by Henningsmoen (1954) as *Macronotella* cf. *praelonga* (Steusloff 1894).

The Bønsnes Formation

Only the lower part of this unit is exposed on Frognøya, where its base is marked by the first appearance of the alga *Palaeoporella*. These algal limestones were described by Kiær (1922:122), who considered them to underlie the 'Gastropod Limestone' (of Kiær 1897). Strand (1933) however, considered them to be the basal beds of the Gastropod Limestone.

The lower part of the Bønsnes Formation is exposed on the west coast of Frognøya, just to the south of the north-east promontory and in the central part of the east coast. The first mentioned outcrop is taken as the stratotype for the base of the formation (NM65305775), but the greatest exposed thickness is on the east coast of the island where the lowest 34 m of the unit contains many *Palaeoporella*-rich limestones. These beds are platy, have irregular tops and bases, and many contain pyrite grains. On fresh surfaces the limestones are black, whilst on weathered faces the matrix is light grey and the rod-like algae are much darker in colour. Weathered surfaces also reveal pockets of ochreous fine sandy material. The *Palaeoporella* beds are overlain by lighter coloured bedded limestones, many of which contain silicified colonies of the corals *Catenipora* sp. and *Sarcinula* sp. up to 0.25 m in diameter. These beds are exposed only intermittently on the west coast of Frognøya and higher beds are not seen.

The *Palaeoporella* beds contain a varied fauna including the trilobite *Stenopareia* sp., leptaenid and plectambonitacean brachiopods, and also chain corals. No shelly fossils have been found in the overlying coral-rich beds.

The *Palaeoporella* beds form a convenient and mappable base to a unit here termed the Bønsnes Formation. It would be premature to suggest that the formation corresponds precisely to the 'Gastropod Limestone' until the more complete section at Stamnestangen and the top of Kiær's unit on Vestre Svartøya have been documented. This is being done by N. M. Hanken (pers. comm. 1978). Strand (1933) noted that the nodular limestones and shales which constitute much of Kiær's Gastropod Limestone pass gradually into the calcareous sandstones of the succeeding unit (Kiær's '5b' or 'Die obersten Chasmops Schichten' = the 'Calcareous Sandstone Formation' of Strand & Henningsmoen 1960). Although the incoming of sandstone horizons is gradual, this lithology actually becomes dominant quite abruptly and it should be possible to define the base of the overlying unit at this level.

Lithofacies distribution

When viewed in its regional context the succession described here lends support to the concept of concentric facies belts during the Ordovician within the Oslo Region, such belts being concave eastwards and suggesting a westward shallowing (e.g. Skjeseth 1952, Størmer 1967). Thus, the Solvang Formation in Ringerike and Hadeland and the Upper Chasmops Limestone in Oslo-

Asker represent deeper-water limestone deposits than the locally biohermal Encrinite and Mjøsa Limestones to the south and north respectively (see Størmer 1953 for stratigraphy). Moreover, the dominantly nodular limestone characterizing the Solvang Formation over much of Hadeland and on Frognøya may be a shallower-water facies than the interbedded limestone and shale development at Norderhov and the upper part of the formation in south-east Hadeland. The Upper Chasmops Limestone in Oslo-Asker is of the latter type also.

The Frognøya Shale is one of a number of shale units reflecting a transgression over much of the Oslo Region. There is no evidence for this transgression in the north of the Region, where the age of the upper part of the Mjøsa Limestone is still unclear although it is known to contain Ashgill conodonts (Hamar *in* Størmer 1967:204, Hamar *in* Bjørlykke 1974:18). The Mjøsa Limestone has a karst top locally (Størmer 1953, Skjeseth 1963) and is overlain by Llandovery quartzite. In Oslo-Asker and Ringerike this transgression is demonstrably from the east, but in Hadeland it is from the north, or even north west (Owen 1978:14–15), and here may be a result of fault control south of the Mjøsa districts.

The Sørbakken Limestone is very similar to the Gagnum Limestone Formation in Hadeland (see Owen 1978:17) but differs in having thicker shale horizons. The Herøy Limestone (Dahl *in* Kjerulf 1857, Brøgger 1884) in the Skien-Langesund district is in need of modern description but is of the same broad type as the Gagnum Limestone and Sørbakken Limestone. The three may eventually be best regarded as local representatives of one formation. This broad unit interdigitates with a more easterly shale succession. Such an interfingering is relatively simple in Hadeland, where the Gagnum Limestone divides the shales of the Lunner Formation into two tongue-like members in all but the south-east of the district (Owen 1978). In Oslo-Asker, it is probably represented by the alternation of limestone and shale units – the so-called Tretaspis and Isotelus series (Brøgger 1887, Strand & Henningsmoen 1960).

Facies patterns in the uppermost part of the Ordovician succession of the Oslo Region are much more complex, but the Bønsnes Formation is probably a lateral equivalent of the upper part of the Herøy Limestone in Skien-Langesund, the lower part of the Langåra Formation (Brenchley & Newall 1975) in Asker, and the Kalvsjø Formation in Hadeland. The overlying arenaceous unit has broad equivalents in Hadeland (the Skøyen Sandstone Formation), Oslo (the Langøyene Sandstone Formation), and in Skien-Langesund.

Correlation

All the trilobites known from the Solvang Formation at Norderhov occur also in the Upper Chasmops Limestone of Oslo-Asker, and the restriction of some forms to the youngest parts of both units is very similar. As Dean (1960, 1963) noted, the trilobite faunas of the Upper Chasmops Limestone and the Actonian and Onnian stages in England are very similar with species or closely related forms of *Ampyxella, Chasmops, Lonchodomas, Platylichas,* and *Tretaspis* common to both. In addition, *Triarthrus linnarssoni* Thorslund, 1940 occurs in the highest part of the Onnian Stage in Salop and the lowest part of the Lower Tretaspis Shale on Nakholmen, Oslo, where it is associated with *Tretaspis ceriodes* (*s. l.*). Similarly there is a strong faunal similarity between the Upper Chasmops Limestone and its correlatives in the Oslo Region and the Macrourus Limestone and its correlatives in Sweden.

The stratigraphical importance of members of the *Tretaspis seticornis* group succeeding *T. ceriodes* is discussed above. In northern England, the type region for the Ashgill Series, this change-over occurs at the Onnian-Pusgillian (i.e. Caradoc-Ashgill) boundary with *T. convergens* Dean, 1962 succeeding *T. ceriodes alyta* Ingham, 1970. The Høgberg Member of the Solvang Formation on Frognøya contains *T. seticornis seticornis* and thus is probably lowest Pusgillian in age. This species and *T.* sp. nov. are not known from Britain, but their relative distribution in Ringerike and the Lower Tretaspis Shale is the same as in the Fjäcka Shale and its correlatives in Sweden.

The upper part of the Lower Tretaspis Shale around Oslo contains specimens of *Dicellograptus* which, like those of the upper part of the Frognøya Shale, closely resemble *D. johnstrupi,* a species which occurs in the *Pleurograptus linearis* Zone (late Onnian to ?mid-Pusgillian) in Sweden. Thus the upper part of the Frognøya Shale is no younger than mid-Pusgillian in age.

The Sørbakken Limestone contains many long-ranging trilobite species which are of limited value in correlation. A cranidium from 35–37 m above the lowest exposed part of the unit at Norderhov is here compared with *Calymene* (*s. l.*) *marginata* Shirley, 1936 from the lower Drummuck Group (Cautleyan) of south-west Scotland. Ingham (1977) has also compared material with this species from the highest part of the Pusgillian Stage and the lower half of the Cautleyan Stage in northern England.

Isotelus sp. and *Chasmops* aff. *eichwaldi* occur in the upper part of the Sørbakken Limestone and are known also from Hadeland, where they occur with a demonstrably Rawtheyan fauna (Owen 1978:19). *Stygina* aff. *minor* occurs both in the upper part of the Sørbakken Limestone and in the Husbergøya Shale Formation (Brenchley & Newall 1975) in Oslo-Asker, where it is associated with *Mucronaspis kiaeri* (Troedsson, 1918). Troedsson's species is closely allied to *M. mucronata* (Brongniart, 1822), a form which first appears in northern England in the Cystoid Limestone (late Rawtheyan) and which is known from the upper part of the Ashgill Series in Britain, Sweden, Bohemia, Poland and Russia.

The lowest part of the Bønsnes Formation exposed on Frognøya contains no faunal elements of detailed correlative value but there is a very diverse trilobite fauna in collections in Paleontologisk museum, Oslo from the 'Gastropod Limestone' in Ringerike. This fauna contains many elements in common with the Husbergøya and lower part of the Langåra formations in Oslo-Asker (='5a' of Brenchley & Newall 1975). The upper few metres of the Husbergøya Formation contain *Tretaspis sortita* (Reed, 1935) *broeggeri* Størmer, 1945, which is no more than a local population of the nominate subspecies from the upper Drummuck Group (highest Rawtheyan) of south-west Scotland. The fauna of the 'Gastropod Limestone' of Ringerike contains forms known also from the Boda Limestone of the Siljan district of Dalarna, Sweden. The field relationships of the Boda Limestone indicate that it has a more extended stratigraphical range than the literature suggests (J. K. Ingham pers. comm. 1975), but until the distribution of species through the Boda Limestone has been documented, detailed correlations are not possible.

Acknowledgements. This study was undertaken during the tenures of a N.E.R.C. studentship at Glasgow University and a N.A.T.O. postdoctoral fellowship at Paleontologisk museum, Oslo. The writer is grateful to Professors T. N. George, B. E. Leake, and G. Henningsmoen for facilities at these institutions. I thank Dr. J. K. Ingham, who supervised the project, Dr. D. L. Bruton for much discussion and for his criticisms of an earlier draft of this paper, Professor A. D. Wright for identifying some of the brachiopods, the Engebretsen family of Ringerike for their hospitality, and my wife Gill for her help at various stages of this work.

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