THE ORDOVICIAN OF OSLO – ASKER

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The Lower Palaeozoic succession of the Oslo—Asker District is folded and contained in a complex dêcollement and splay thrust system with listric faults (Bockelie & Nystuen in prep.). This deformation is primarily the result of Caledonian deformation which is responsible for some shortening of the sequence (Ramberg & Bockelie 1981). A sole thrust is regionally present in the Cambrian sequence, generally 1-2 m above the Precambrian basement. The black Alum shale of the Cambrian is an ideal lithology for a thrust plane. Sediments below this thrust plane are influenced by Permian block faulting only by being tilted, whereas the sediments above this sole thrust are folded.

The Ordovician rocks of Oslo—Asker (Fig. 1) comprise approximately 400 m of alternating limestone and shale units, richly fossiliferous, with frequent occurrences of clastics in the Upper Ordovician. Details of the depositional history are to be found in Bjørlykke (1974). The Tremadoc immediately succeeding the Cambrian consists of black Alum shales with Stink-stone lenses, grading into shallow water limestones and grey-black shales in the Upper Tremadoc—Arenig.

The tri-partite Orthoceras Limestone containing the Arenig—Llanvirn boundary (Kohut 1972) is very fossiliferous, particularly in its middle part. The unit represents the second phase of shallowing in the Balto-scandian Basin. The Llanvirn—Caradoc succession consists of alternations between shales and nodular limestone, terminating with a shallow water bioclastic Upper Chasmops Limestone. Detailed analyses of the fossil content of this unit in the Oslo—Asker and adjoining Districts have recently been made. (Bruton & Owen 1979; Qvale 1980; Owen & Bruton 1980). Present investigations indicate shallow water conditions in Asker/Bærum with local synsedimentary breccias (Bockelie in prep.).

		OSLO REGION		Correlation with Great Britain	Thickness in m	OSLO-ASKER		
		Series	Stages & substages					
Ordovician	U.O.	Tretaspis series (4c—5b)	5b	Ashgill	max. 30	5b	Calcareous sandstone formation	
			5a		45-80	5a	Gastropod limestone, etc.	
			4d			$4d\alpha-\gamma$	Isotelus shales ($4d\alpha$, γ) & limestone ($4d\beta$)	
			$4c\beta-\gamma$		55-90	$4c\beta-\gamma$	Upper Tretaspis sh. ($4c\gamma$) & Tretaspis lst. ($4c\beta$)	
			$4c\alpha$			$4c\alpha$	Lower Tretaspis shale	
	M.O.	Chasmops series ($4a\beta$—4b)	$4b\delta_2$	Caradoc	120-165	$4b\delta_2$		
			$4b\delta_1$			$4b\delta_1$	Upper Chasmops limestone (10—25 m)	
			$4b\gamma$			$4b\gamma$	Upper Chasmops shale	
			$4b\beta$			$4b\beta$	Lower Chasmops limestone	
			$4b\alpha$			$4b\alpha$	Lower Chasmops shale	
			$4a\beta$			$4a\beta$	Ampyx limestone	
		Ogygiocaris series ($4a\alpha$)	$4a\alpha_{3-4}$	Llandeilo	70	$4a\alpha_{3-4}$	Ogygiocaris shale	
			$4a\alpha_{1-2}$	Llanvirn		$4a\alpha_{1-2}$	Upper Didymograptus shale	
	L.O.	Asaphus series (3b—c)	$3c\gamma$	Arenig	10	$3c\gamma$	Endocerarid limestone	Orthoceras limestone
			$3c\beta$			$3c\beta$	Asaphus shale	
			$3c\alpha$			$3c\alpha$	Megiataspis limestone	
			3b		10	$3b\alpha-\varepsilon$	L. Didymograptus sh. (= Phyllograptus sh.)	
		Ceratopyge series (2e—3a)	$3a\gamma$	Tremadoc	20	$3a\gamma$	Ceratopyge limestone	
			$3a\alpha-\beta$			$3a\alpha-\beta$	Ceratopyge shales	
			2e			$2e\alpha-\delta$	Dictyonema shale	
Cambrian	U.C.	Olenid series (2a—d)	$2d\varepsilon$	Olenus series	45	$2d\varepsilon$	Acerocare	Alum shale with stinkstone concretions
			$2d\alpha-\delta$			$2d\alpha-\delta$	Peltura	
			2c			2c	Leptoplastus & Eurycare	
			2b			2b	Parabolina spinulosa	
			$2a\beta$			$2a\beta$	Olenus & Agnostus obesus	
			$2a\alpha$			$2a\alpha$	Agnostus pisiformis	
	M.C.	Paradoxides series (1c—d)	1d	Paradoxides series	20	1d	Paradoxides forchhammeri	
			$1c\beta-\delta$			$1c\beta-\delta$	Paradoxides paradoxissimus	Basal cgl.
			$1c\alpha$			$1c\alpha$		
	L.C.	Holmia series (1a—b)	$1b\beta$	Olenellus series		$1b\beta$		
			$1b\alpha$			$1b\alpha$		
			$1a\beta$			$1a\beta$		
			$1a\alpha$			$1a\alpha$		
Underlying:						Precambrian (Pre-Sparagmitian)		

Figure 1. Stratigraphical succession of the Ordovician in the Oslo—Asker district (after Henningsmoen in Strand & Henningsmoen 1960). For modifications of Upper Ordovician succession see Fig. 10.

The black Tretaspis Shale, succeeding the Upper Chasmops Limestone, indicates an extensive transgression close to the Caradoc/Ashgill boundary. A progressive shallowing of the Oslo—Asker District took part in the Upper Ordovician, ending with local supratidal conditions in Asker and Bærum.

The increase in sedimentation rates throughout the Upper Ordovician is probably related to Caledonian movements and proximity to source areas supplying coarse clastic sediments. Microtectonic triggering mechanisms have been suggested for several of the sandstone beds in the Upper Ordovician (Brenchley & Newall 1977). Irregularities in the basement with differential movements of blocks of Pre-Cambrian rocks may account for some of the recurrencies of topographic highs and lows during the Cambro-Silurian.

A sharp boundary between the Upper Ordovician Langøyene Sandstone and the Lower Silurian shale (etage 6 of Kiær 1906) is locally interpreted as an erosional contact. The presence of a *Climacograptus* apparently of the *normalis* group in the Husbergøya shale (Brenchley & Newall 1975) suggests that the Ordovician—Silurian boundary may be within the 'Calcareous Sandstone' unit generally referred to as Ordovician (etage 5: see Brenchley & Newall 1975).

ITINERARY

The route goes from Sundvollen to Nærsnes by bus, passing through the Permian lavas of Krokskogen, further in areas of folded Ordovician and Silurian rocks. On the west side in Røyken and parts of Asker we will see Permian intrusives (granite). The bus will join the E18 (Drammensveien) at Sandvika and follow the western part of the fjord to Holmen, leaving the E18 here and taking route 167 to Slemmestad and Nærsnes. In Asker good sections of Middle and Upper Ordovician and Lower Silurian will be seen from the bus. Also good views of the Precambrian faultline down the eastern side of the Oslo fjord. At Nærsnes we shall study a potential Cambrian/Ordovician boundary section (Bruton *et al*. 1982).

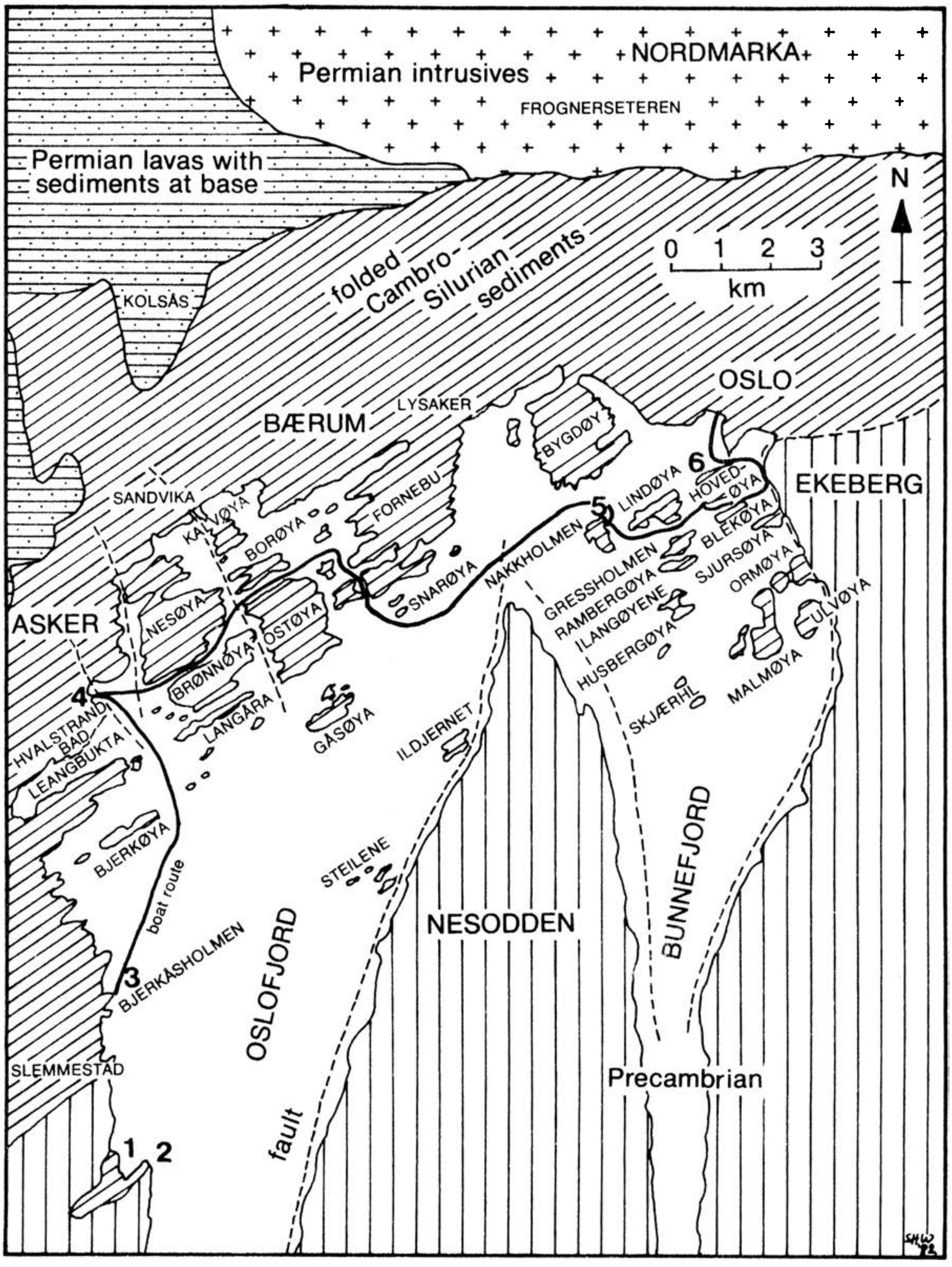

Figure 2. Map of Oslofjord showing boat route after locality 3.

After STOP 3, the excursion will travel by boat on the Oslofjord (Fig. 2).

STOP 1 NÆRSNES TYPE PROFILE (Fig. 3) (David L. Bruton, Bernd-D. Erdtmann & Leif Koch). Henningsmoen (1957, 41, Fig. 6) briefly described this locality and provided a composite section. The locality has since been cleared, and carefully logged for fossils (Bruton _et al_. 1982).

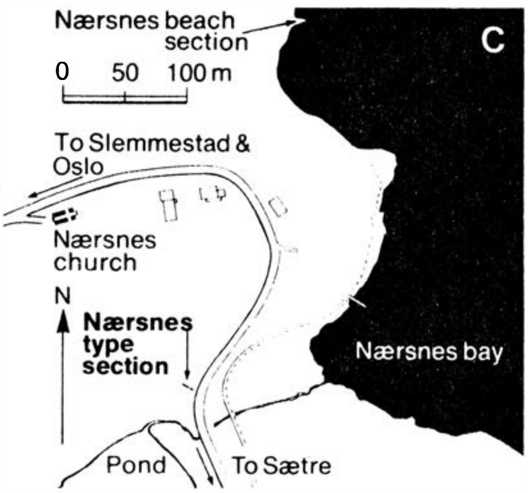

Figure 3. Location of the Nærsnes type section

Folded Upper Cambrian alum shales and limestone of the Olenid Series (_pars_) crop out at the roadside 400 m south-south-east of Nærsnes Church (Fig. 3). Approximately 47 m north of a small bridge and 2.3 m in the section above the footpath, limestone concretions contain well preserved _Peltura scarabaeoides scarabaeoides_ (Wahlenberg, 1821), _Ctenopyge bisulcata_ (Phillips, 1848) and _Sphaerophthalmus humilis_ (Phillips, 1848), characteristic of the Upper Cambrian _P. scarabaeoides_ Zone 2dγ. If traced south along strike and under scree approximately 8 m above the footpath, this zone would crop out 2 m below a limestone concretion in the northernmost of two profiles. This concretion contains abundant _Acerocare ecorne_ Angelin, 1854 and _Parabolina acanthura_ (Angelin, 1854) of the Upper Cambrian _A. ecorne_ Zone 2dε. This zone can be identified in two more concretions 8 m along strike to the base of the southern profile (concretion 1, Fig. 4). This profile is the one proposed as a candidate for the Cambrian—Ordovician boundary stratotype at the base of the Tremadoc Series.

Above concretion 1 occur two successive concretions (2 and 3, Fig. 4) each containing _Boeckaspis hirsuta_ (Brøgger, 1882). Graptolites first occur 52 cm above the base of concretion 2 and are a new form of _Dictyonema_. _D. flabelliforme sociale_ occurs sparsely 35 cm

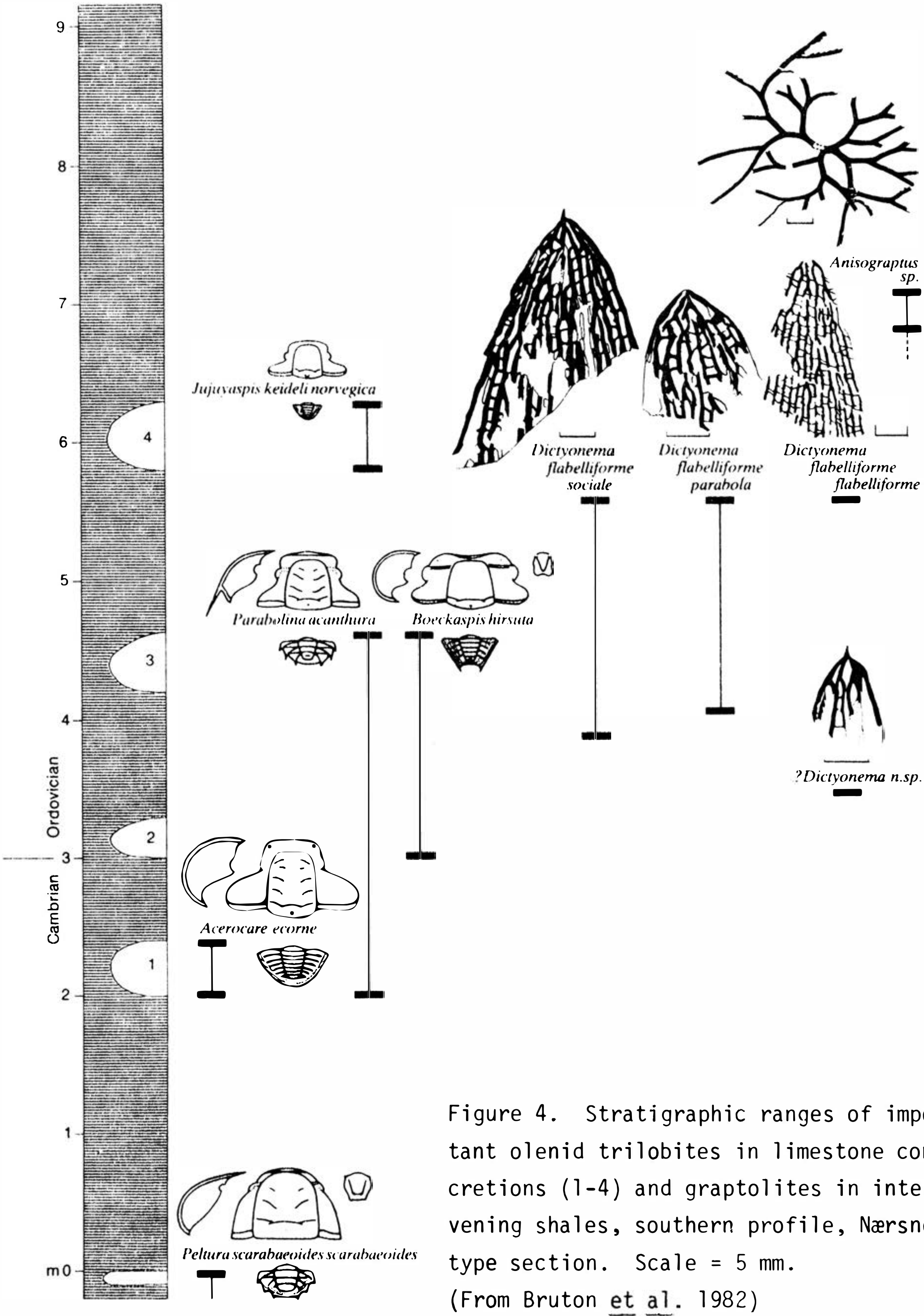

Figure 4. Stratigraphic ranges of important olenid trilobites in limestone concretions (1-4) and graptolites in intervening shales, southern profile, Nærsnes type section. Scale = 5 mm.
(From Bruton et al. 1982)

higher. Abundant *D.f. parabola* and a few *D.f. sociale* occur 75 cm above concretion 2 and below concretion 3. The succeeding shales are undisturbed and have yielded abundant *D.f. parabola* and a few *D.f. sociale* in a 6 cm thick band 30 cm below concretion 4 which contains the trilobite *Jujuyaspis keideli norvegica* Henningsmoen, 1957. A higher horizon 20 cm below concretion 4 has yielded *D.f. parabola*, *D.f. sociale* and *D.f. flabelliforme*. Stipes of a large *Anisograptus* sp. occur at two levels repectively 50 and 65 cm above concretion 4. Shales in the remaining 2.15 m of the section contain abundant, though incomplete specimens of a phyllocarid crustacean and inarticulate brachiopods. The profile is terminated further north by a diabase sill.

The boundary between the Cambrian and the Ordovician is defined at the base of concretion 2 (Fig. 4), the first of two concretions containing *Boeckaspis hirsuta* within a graptolite succession of the Tremadoc acmezone of *D.f. parabola*. The lowest concretion 1 (Fig. 4) contains *A. ecorne* and *P. acanthura*, representing what in Scandinavia is accepted as the topmost zone of the Upper Cambrian (Martinsson 1974; Henningsmoen 1957, 1973). The Nærsnes section therefore fulfils the following criteria which Henningsmoen (1973) considered important in choosing a suitable boundary stratotype between the Cambrian and the Ordovician systems:

1 The boundary is placed in a uniform sedimentary sequence.
2 The sequence contains cosmopolitan fossils in the form of non-benthonic graptolites and abundant, well defined and documented species of probably non-benthonic olenid trilobites.
3 Fossiliferous horizons occur above and below the boundary in a continuous sedimentary sequence.

To these may be added:

4 The boundary is defined within the same general development of the biostratigraphic succession as the British (Welsh) succession, which for so long has been used as the standard

reference.

5 The boundary stratotype section is easily accessible.

STOP 2 NÆRSNES BEACH SECTION (Fig. 3) Here a succession of alum shales and concretions occurs to the north and south of a metre thick Permian sill. A section south of the sill (Fig. 5)

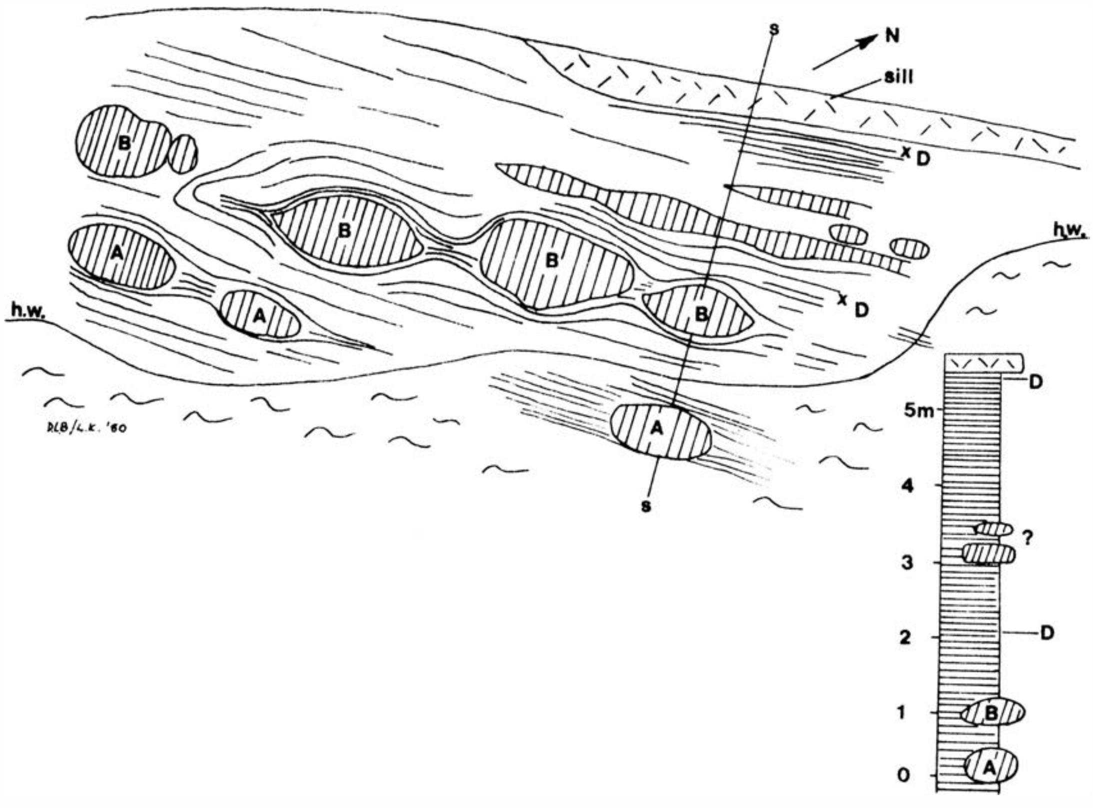

Figure 5. Sketch of Nærsnes beach section south of sill (from Bruton & Erdtmann 1980). Limestone concretions with cross-hatching contain A - Acerocare, B - Boeckaspis. D - Dictyonema vertical section along line s—s.

shows concretions containing Acerocare ecorne and Parabolina acanthura on the beach just below high water mark, succeeded by an horizon of large concretions containing Boeckaspis hirsuta. Dictyonema flabelliforme parabola occurs in the shales at three levels, 2 metres and 2 m 10 cm above the Acerocare layer, and at

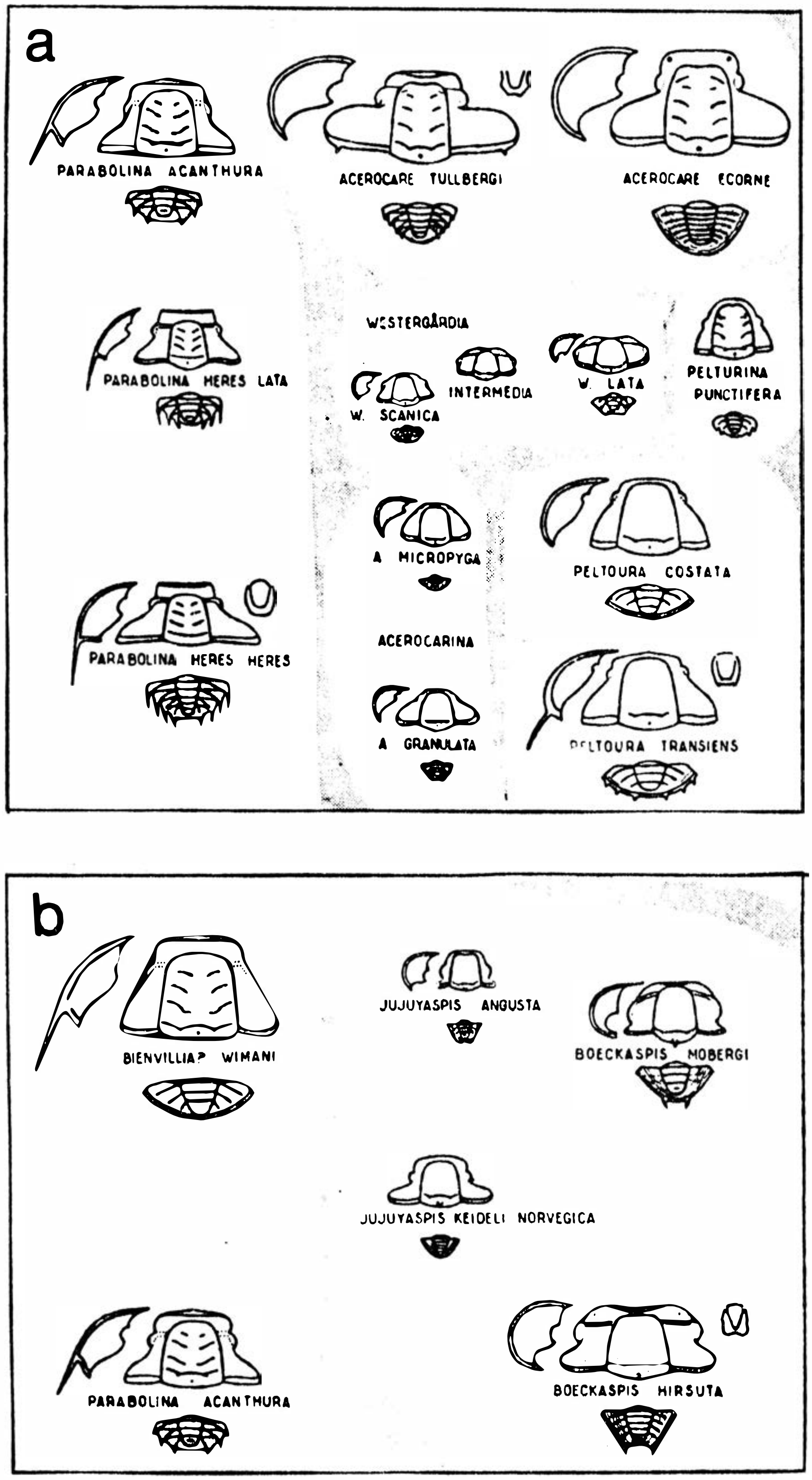

Figure 6. Olenid trilobites common in a, Upper Cambrian and b, Lower Tremadoc, at Nærsnes (from Henningsmoen 1957).

10 cm below the sill. Two irregular limestone beds and associated concretions occur between the lower and upper Dictyonema horizons but so far they have not yielded trilobites. These compact beds might correspond to the second Boeckaspis horizon in the northern section at the Nærsnes Type Profile.

North of the sill, at about high water mark, is a succession of tightly folded alum shale containing Dictyonema at 6 different horizons. Dictyonema flabelliforme parabola has been identified at 2.2 metres above the sill and approximately 1 metre above a concretion containing Boeckaspis hirsuta. The highest beds contain Dictyonema flabelliforme sociale. At the top of the section is an horizon of concretions similar in appearance to those containing Jujuyaspis at the Nærsnes Type Profile. Thus, despite the folding, the succession is thought to be a normal one though thicknesses of shales are difficult to estimate. In terms of the boundary, the sill and the succession north of it is of less significance, though it provides an ideal parastratotype section.

STOP 3 BJERKÅSHOLMEN, ASKER (Fig. 7) (J. Fredrik Bockelie)

The peninsula consists of a sequence of Lower Ordovician fossiliferous limestone and shales (Ceratopyge Limestone, Lower Didymograptus Shale (Arenig) and Orthoceras Limestone (Arenig—Llanvirn). The section dips about 45^{o} north-west. On the southern side of the peninsula is a strongly folded sequence of Lower Didymograptus Shale, eroded to sea-level. Fold axes with north-eastern plunges can be measured directly, and individual limestone beds (2-5 cm thick) can be traced in the intricate fold pattern. A thrust plane can be observed close to the cliff.

The Ceratopyge Limestone contains a varied shelly fauna of trilobites including Ceratopyge forficula, Euloma ornatum, Symphysurus angustatus and Niobe insignis. One of the earliest articulate brachiopods, Archaeorthis christianae, is found here. Note the dark concretions at the base containing the 'last' olenid, Triarthrus. The limestone is glauconitic and contains arrow-like

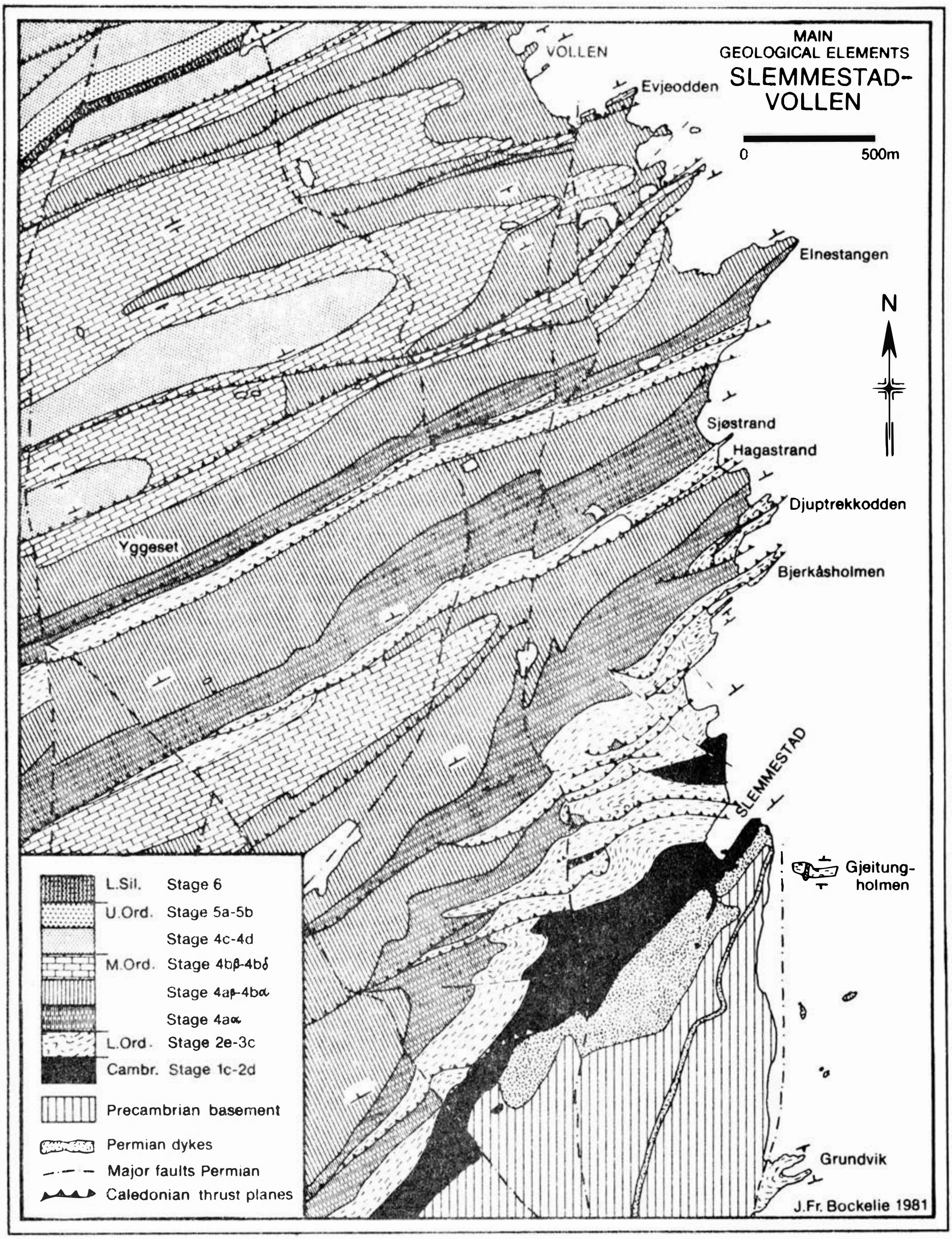

Figure 7. Geological map of the Slemmestad—Vollen area (after J.F. Bockelie MS).

pseudomorphs of gypsum(?). The overlying Didymograptus Shale is not particularly fossiliferous here and the base shows a green-grey-black colour transition. The tri-partite division of the Orthoceras Limestone is best seen along the northern flank of the peninsula. All units are very fossiliferous and contain trilobites (Brøgger 1882), brachiopods (Øpik 1939), cephalopods (Sweet 1958), echinoderms (Bockelie 1981), conodonts (Kohut 1972), bryozoa and ostracodes. The Megistaspis Limestone is partly dolomitic and the Endoceratid Limestone contains several hard grounds with phosphate (Skaar 1972). The unit is interpreted as having been deposited in shallow water.

From here the excursion will join the boat for lunch.

STOP 4 HOLMENSKJÆRET (J. Fredrik Bockelie) A sequence of low energy Palaeoporella Limestone (Ashgill) with a rich fauna of trilobites, brachiopods, gastropods and corals, but dominated by the codacean algae Palaeoporella. The frequency of Palaeoporella increases throughout the unit and reaches a maximum density at the top. A sharp boundary to the overlying Holorhynchus shale can be studied on a small peninsula. This locality has the highest faunal diversity in the Upper Ordovician with more than 80 taxa recorded.

From Holmenskjæret the boat will pass several islands in the western part of the fjord and various features, particularly the folding, will be pointed out.

STOP 5 ISLAND OF NAKHOLMEN (A. Owen, F. Bockelie, D. Harper) This island is one studied and mapped by Brøgger (1887). Fig. 8 has been adapted from Brøgger's map to show the outcrops of the Caradoc—Ashgill units to be examined. The boat will land at 'Loffen' (Stop A) and examine the richly fossiliferous uppermost bed of the Upper Chasmops Limestone containing abundant Stenopareia glaber, Platylichas laxatus, Lonchodomas aff. pennatus and Ampyxella aculeata (for references see Owen & Bruton 1980). The dark, bioturbated limestone 0.85-1.02 m above this bed locally contains trilobites (including Tretaspis ceriodes angelini) which only occur in the upper parts of the Upper Chasmops Limestone in Bærum and Asker. The occurrence of rare Triarthrus linnarssoni may suggest a deeper water environment than further west. About 10 cm above this bed is the 'phosphorite conglomerate' once thought to indicate a substantial break in deposition (but see Bruton & Owen 1979).

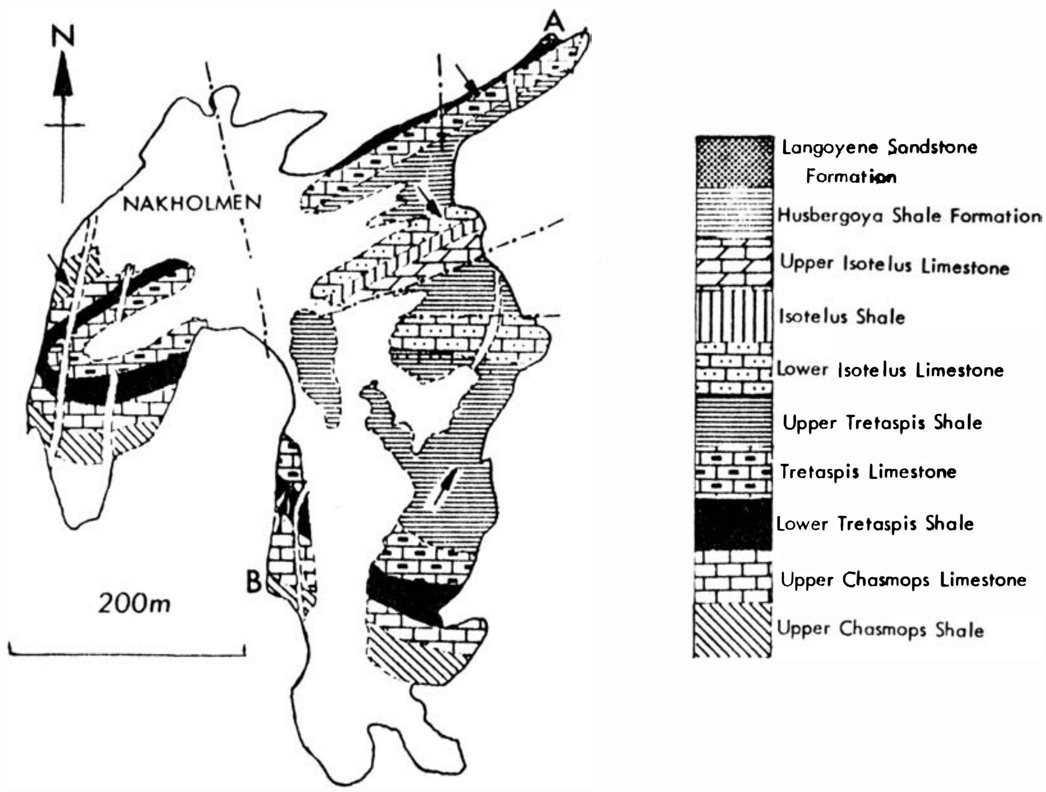

Figure 8. Geological map of the island of Nakholmen, Oslo, locality 5 with stops A and B (after Brøgger, 1887 and Owen, 1977).

The overlying Lower Tretaspis Shale is about 7 m thick and shows the characteristic planar limestones in the upper part. Fossils are difficult to collect here but localities in Oslo have yielded a linearis Zone graptolite fauna. The base of the overlying Tretaspis Limestone is distinctive, showing the characteristic small, tightly packed limestone nodules. These pass up into larger nodules and more planar limestone beds. A more or less complete profile from the Upper Chasmops Limestone through the underlying Upper Chasmops Shale (9-10 m thick), Lower Chasmops Limestone (10 m) and Lower Chasmops Shale, is best exposed on the south west coast. If time allows, we shall walk there (stop B).

The Upper Chasmops Shale is composed almost entirely of thinly bedded, dark grey to black shales although there are a few calcareous nodules, some septarian. The formation is locally fossiliferous and contains a low diversity fauna including *Broeggerolithus discors*, *Lonchodomas* aff. *rostratus*, lingulids and species of *Onniella*, *Chonetoidea* and *Sericoidea*. These and the underlying beds will be ideal for a discussion on the formation of the limestone nodules (Bjørlykke 1973, 1974) or concretions (Henningsmoen 1974).

STOP 9 ISLAND OF HOVEDØYA (J.F. Bockelie & A.W. Owen) The boat will moor on the west side of the island and we shall walk to the south-west corner. Fig. 9 has been adapted from Brøgger 1887 to show the Middle and Upper Ordovician units. We shall concentrate on the Upper Ordovician (Ashgill) Husbergøya Shale and Langøyene Sandstone (Brenchley & Newall 1975; see Fig. 10).

The Lower Isotelus Limestone (15.4 m) is exposed by the track and contains well developed siltstones-sandstones and shales. The Isotelus Shale (7 m) is also exposed in the track while the overlying Upper Isotelus Limestone crops out both by the track and along the foreshore. It comprises some 18.7 m of limestones, siltstones-sandstones and shales. Some (but not many) of the limestones contain pockets of shelly fossils including *Tretaspis latilimbus norvegicus*, *Brachyaspis* sp. and cepahlopods. The overlying succession exposed along the foreshore was described by Brenchley & Newall (1975, Fig. 5) while Spjeldnæs (1957) discussed the upper parts.

Husbergøya Shale Formation contains a silty shale thought to have been deposited in an offshore environment with periodic storms causing deposition of 1-3 cm thick siltstone beds. At the base of this formation is a zone with numerous 'Trichophycus'. Individual silt beds can be traced for several hundred metres, occasionally some kilometres. The formation is relatively poor in fossils, but the faunal frequency and diversity increases from

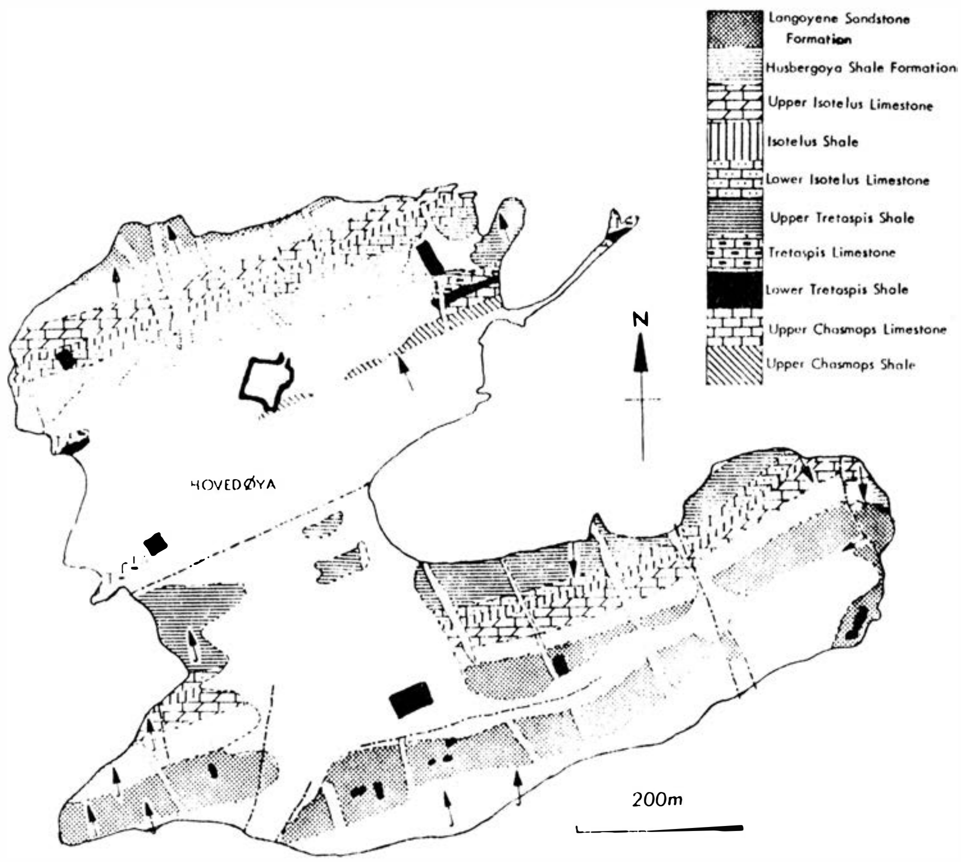

Figure 9. Geological map of the island of Hovedøya, Oslo (after Brøgger 1877 and Owen 1977).

east to west. The top of the formation is marked by a bioturbated fine sandstone which is a good marker. It can be traced on all the islands both in Oslo and Asker. This bed contains a fairly rich fauna of trilobites (Owen 1981), brachiopods, bryozoa and echinoderms (Bockelie, in press). A Climacograptus sp. of the normalis group has been found at this level on one of the nearby islands (Bockelie, in press). Even in this bed the diversities and frequencies of the fauna increases from east to west.

The Langøyene Sandstone represents a sequence of coarse sandstones with quartz grains up to 5 mm in diameter. Rapid changes in facies related to inshore, foreshore, intertidal and subtidal conditions make detailed correlations difficult. The most conspicuous units in this formation are the oolite shoal deposits in Asker (up to 11 m thick) and the thick sequences of beds showing cross-stratification and large scale ball-and-pillow structures (Brenchley & Newall 1977, 1979). The former are regarded as inshore, intertidal to subtidal deposits, the latter as seismically triggered. They are more common in Oslo than in Asker probably because of different sedimentation rates and the lower carbonate content of rocks in Oslo. At the top of the formation is an intraformational channel, infilled with large blocks of calcareous sandstones from near-by areas and overlain by Silurian shales.

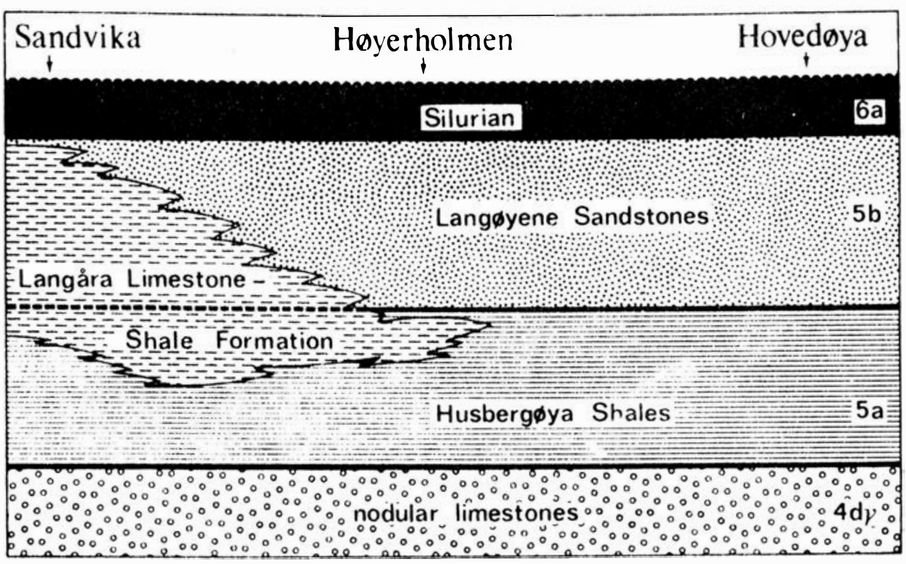

Figure 10. Stratigraphy of Upper Ordovician in Oslo—Asker (from Brenchley & Newall 1975).

From here the boat will return to the Oslo city hall quay where the buses will be waiting. Estimated time of arrival at Sundvolden is 18 00.