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Proterozoic Basement and Scandian Geology of the Outer Trondheimsfjord Region

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REPORT

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Summary:

The report is a guidebook for a one day excursion in connection to the COPENA meeting held at NGU 18-22. Aug. 1997. The excursion route is Trondheim - Orkanger - Lensvik - Agdenes - Ørlandet - Hasselvika - Rissa - Rørvik - Trondheim. The purpose of the excursion is to demonstrate lithologies in the Proterozoic basement in the Western Gneiss Region and the Caledonian nappe sequences that are down folded into the basement in thight synclines. The effect of the Scandian deformation and metamorphic overprinting on the Proterozoic gneisses will also be emphasised. The following tectonic units will be studied: Proterozoic gneisses of the Western Gneiss Region; The Risberget Nappe consisting of augen gneisses; The Sætra Nappe consisting of flagstones; The Blåhø Nappe with mica schist, hornblende schist, amphibolite and marble; The lowgrade Støren Nappe with greenstones, schists, marbles and gabbroic to felsic intrusions; Devonian sediments.

Keywords: Berggrunn	Prekambrium	Strukturgeologi
Stratigrafi	Dateringer	Fagrapport

COPENA CONFERENCE AT NGU, TRONDHEIM, NORWAY

Guidebook for Conference Field Trip B-1
August 20, 1997

Proterozoic Basement and Scandian Geology of the Outer Trondheimsfjord Region

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INTRODUCTION

The purpose of this conference field trip is to give participants an opportunity in one day to appreciate aspects of the geology of ancient Baltica in a location where the Proterozoic basement is strongly involved in Scandian (Late Silurian and Lower Devonian) deformational events and generally intense metamorphism, though not generally at such high pressures as found further south in the Western Gneiss Region (see Trip A-3, this Conference). Thirty years ago a rather wide area of the Western Gneiss Region was considered to be entirely Precambrian basement, but as detailed mapping and geochronologic studies have continued, a progressively larger part of the rocks have been identified as belonging to Caledonide nappes previously thrust into position and then deeply infolded into the basement (Krill, 1980; Tucker, 1986; Solli, 1995). At the same time a greater sophistication in geochronology has permitted accurate determination of the ages of the Proterozoic basement itself (Tucker et al., 1991). This process of nappe differentiation continues to the present time (Tucker et al., 1997a; Robinson et al., 1997) with the recognition that certain highly deformed gneisses have nothing to do with the Proterozoic but are part of a large complex of Ordovician intrusions belonging to one of the highest thrust nappes (Fig. 1). Another recent part of the story (Seranne, 1992; Andersen and Jamtveit, 1990) is the recognition that the "post-orogenic" Devonian sandstones and conglomerates are nowhere in contact with Proterozoic basement, but lie unconformably on weakly deformed rocks that were transported on major extensional detachments from somewhere closer to the foreland of the orogen, where they experienced far less ductile deformation and metamorphism. A still more recent development is to find a difference in the extent of metamorphic recrystallization between Baltica basement, which shows 100% recystallization of metamorphic sphene over wide areas at 395±2 Ma, and the infolded ductilely deformed Ordovician intrusions in thrust nappes that still retain essentially igneous sphene at about 450 Ma. These findings support the idea that many of the present thrust nappe contacts are actually early extensional detachments along which the nappes have been juxtaposed during an early phase of extensional collapse, before imposition of a pervasive late ductile strain field, probably under sinistral transpression.

The route of the field trip (Fig. 1) is determined by geography of the shores and highways in the region, as well as the system and schedule of ferries. The trip begins in the Støren Nappe of the Trondheim Synclinorium which is well exposed on the grounds of NGU and will not be included in the stops. It is hoped that informal walking excursions can be conducted during the meeting. In the morning we will travel west and northwest from Trondheim along the south side of the fjord (Fig. 1), visiting a generally downward progression through the thrust nappes, with Seve (Stop 1), Seve (Stop 2), and Risberget Nappes (Stop 3), the last itself containing in an interesting part of Middle Proterozoic history, to the Proterozoic basement. As we travel northwest we will visit various increasingly complex and more highly metamorphosed infolds of Caledonide nappes in basement (Stops 4, 5, 8) including belts of Ordovician intrusions (Stops 6, 7, 9) some of which were previously confused with basement. At Valset Ferry we will see one of these Ordovician gneiss belts (Stop 9), which also lies adjacent to the brittle detachment fault below the Devonian basins. We will cross this fault en route across the fjord to Ørlandet where we will enter a different world, lacking the effects of strong Scandian strain. Here we will visit an earliest Silurian granite at that appears completely undeformed (Stop 10) and the Devonian sandstones and conglomerates (Stop 11). On our return journey along the north side of the fjord we will examine mylonitic rocks close to the detachment (Stops 12, 13), and further exposures of nappes and basement (Stops 14, 15), concluding with the 1653±2 Ma Ingdal Granite before catching a seond ferry (Stop 16) back to Trondheim.

PROTEROZOIC BASEMENT IN THE WESTERN GNEISS REGION

Proterozoic Supracrustal Rocks

At the present time there are essentially no identifications of major areas of Early to Middle Proterozoic supracrustal rocks in the Trondheim Region, except for minor fragments at individual outcrops. For a broader discussion about identification of such rocks farther south, see the Introduction for Trip A-3, this meeting. In a number of areas of detailed study, supracrustal rocks previously assigned to basement can be proved or implied to be within complex infolds of thrust nappes (Tucker, 1986; Krill, 1987; Robinson, 1995, 1997; Tveten and Lutro, 1996). These comments about supracrustal rocks do not apply, of course, to Late Proterozoic sequences, that are a key part of the sedimentary history of the Baltic margin that was later enveloped in the Caledonides.

Late Paleoproterozoic Igneous Belt (1686-1650 Ma)

To the extent of coverage of reliable radiometric ages, the most widespread gneisses near and within 100 km south of Trondheimsfjord in the Western Gneiss Region are derived from tonalitic to granitic intrusions in the age range 1686-1650 (Tucker et al., 1991), which falls within the time span of the Transcandinavian igneous belt ("TIB"), but is strictly speaking not part of it, because of very different igneous geochemistry (Roland Gorbatschev, Personal communication, August 17, 1997). Named and mapped units in this range include the Ingdal Granite (1653±2 Ma) and the Våvatnet Granitic Gneiss (1646 Ma). Though dominantly highly deformed amphibolite-facies gneisses, there are locations where the amount of strain is low and simple igneous textures are preserved. Despite efforts to find younger granitic rocks, no examples of Sveco-norwegian granites have been found north of line approximately from Ålesund to Dombås (see Guidebook for Trip A-3, this meeting) and the region appears to lie entirely east of the Protogine Zone of the foreland which disappears beneath the Caledonides close to the Norwegian-Swedish border. A problem in these rocks is to understand the age of later apparent partially melting features: Are they the product of Proterozic high grade

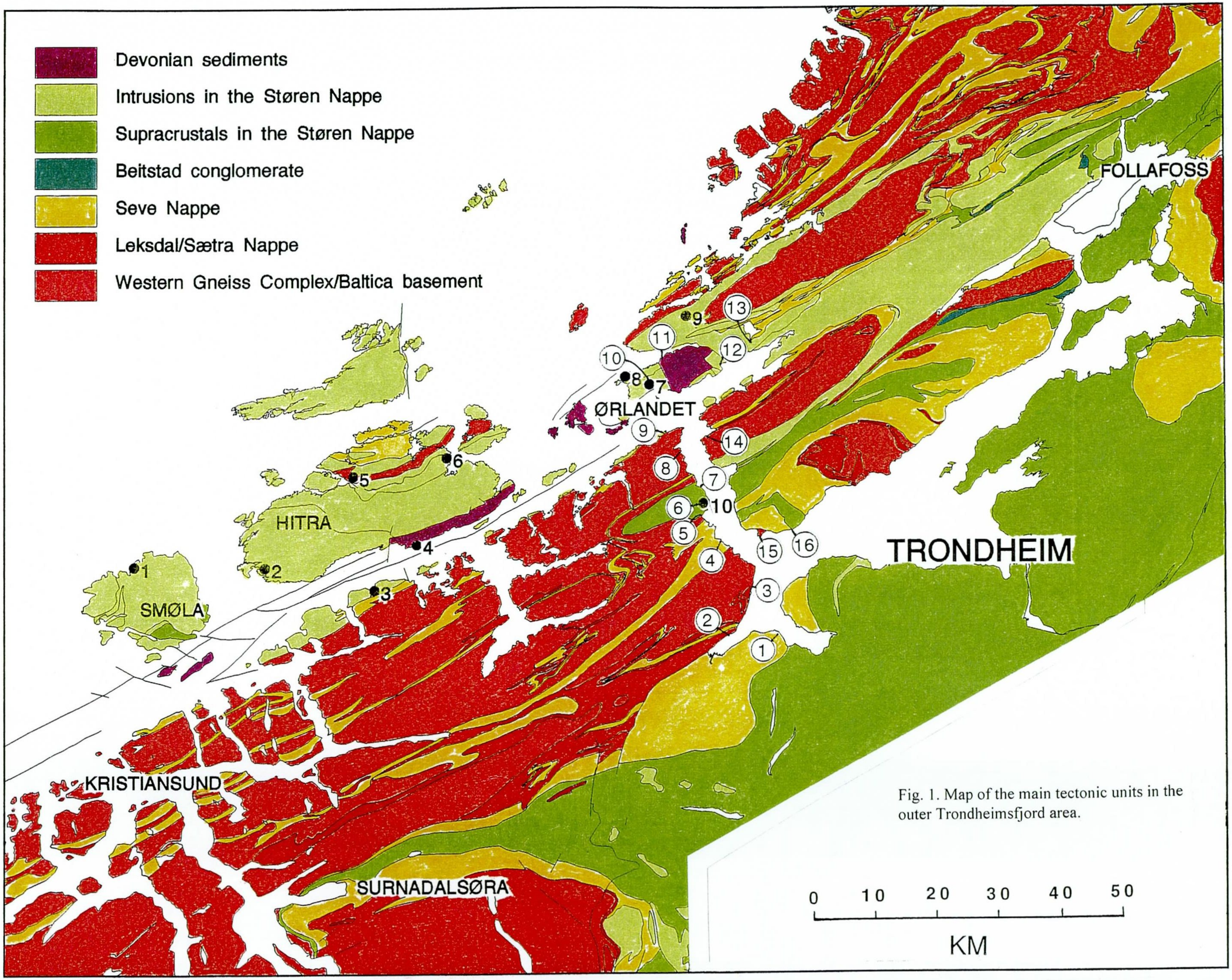

Fig. 1. Map of the main tectonic units in the outer Trondheimsfjord area.

metamorphism or of Scandian partial melting? In at least one example hornblende-bearing felsic leucosomes in the Våvatnet Gneiss have yielded approximately 400 Ma igneous zircons.

Augen Orthogneiss (±1500 Ma)

This rock, in its least deformed state, is a generally granulated rapakivi granite, and is widespread in parts of the Western Gneiss Region, where it has been most extensively studied near Molde and the islands of Midsund by Carswell and Harvey (1985). They obtained a Rb-Sr whole rock isochron for these rocks of 1506±22 Ma, and more recently the same rock has yielded a U-Pb zircon age of 1508 Ma (Tucker et al., 1991). A similar porphyritic mangerite at Flatraket near Måløy has yielded a U-Pb zircon age believed to indicate the time of igneous crystallization at 1520±10 Ma (Lappin et al., 1979). Augen gneisses broadly similar appearance to this are present in the Trondheim Region, but no date in this age range has been determined.

Gabbros (±1650, ±1460 Ma)

Gabbros are widespread in the Western Gneiss Region. Limited radiometric dating indicates they span a large age range and no clear groupings have been established. The best dated gabbroic rocks near the field trip area are southwest of the Trondheimfjord at Damvatnet, where a leucogabbro gneiss has yielded a zircon age of 1657 +5-3 Ma, and at Selsnes on Snillfjord where baddeleyite has yielded an age of 1462±2 Ma (Tucker et al., 1991).

PROTEROZOIC BASEMENT ROCKS IN THRUST SHEETS

Risberget Nappe of the Lower Allochthon (1650-1642 Ma, 1190-1180 Ma)

Until recently the rapakivi granites of the Risberget Nappe were believed to be about 1500 Ma, based on the Rb-Sr isochron of Krill (1983a) from Oppdal and the similarity of the rocks to the augen orthogneiss of the Western Gneiss Region discussed above. New concordant zircon ages (Handke et al., 1995) indicate that these distinctive rapakivi granites fall into two age groups, 1650-1642 Ma at 5 localities, just slightly younger than the dominant nearby basement granitoids, and 1190-1180 Ma at four localities, just older than a cross-cutting pegmatite at Oppdal dated by Krill (1983a) by the Rb-Sr method at 1163± 80 Ma. Two of the older augen gneisses are in the area southwest of Trondheimsfjord studied by Tucker (1986) at Omnsfjellet and at Karøydalen, and one of the younger ones is at Rønningen on the fjord shore which will be visited on Stop 3. Although of two different ages, neither age group corresponds to known igneous ages in the immediately underlying Baltica basement, not even to the 1500 Ma age of recognized augen gneisses derived from rapakivi granites. Thus the thrusting of this nappe seems to have sampled a section of Baltica not quite like the part now exposed in the Western Gneiss basement itself.

EVIDENCE FOR EARLY TO MIDDLE PROTEROZOIC METAMORPHISM

Clear evidence for the age or ages of Proterozoic metamorphism is difficult to find despite widespread evidence for an early granulite-facies event in the southwestern part of the Western Gneiss Region. Tucker et al. (1991) make the point that there is no evidence for disturbance of the Early Paleoproterozoic rocks between their age of crystallization and the age of Scandian recrystallization. For more extensive discussion in connection with rocks farther to the south see Guidebook for Trip A-3, this Conference.

TECTONO-STRATIGRAPHY OF CALEDONIDE NAPPES

Understanding of the Scandinavian Caledonides is based on 1) the identification and mapping of a complex sequence of tectono-stratigraphic units and 2) the recognition that these represent rocks generated in a wide variety of settings that were later assembled in a major continental collision during which shortening and thrust translation over distances of 100's of kilometers was characteristic. For the non-specialist the array of units and unit names is challenging (Gee and Sturt, 1985), and the details of correlation, even for the area of interest in west-central Trøndelag, is beyond the scope of this guidebook. Here we have adopted a general and very simplified sequence of units most easily understood both in local terms and in terms of orogen-wide correlations. The correlation of the units used here and those used in other papers on west-central Trondelag and adjacent areas is shown in Figure 2, and is the basis for the map shown in Figure 1.

The lowest tectono-stratigraphic unit exposed in the map area is the Baltica basement, a segment of the former Baltic craton dominated by Late Paleoproterozoic granitoid intrusive rocks in the age range 1686-1650 Ma (Tucker et al., 1991) that were locally intruded by rapakivi granites dated in one location at Molde at 1508 (Tucker at al., 1991) and by gabbros dated at 1657 +5-3 Ma and 1462± 2 Ma (Tucker at al., 1991). The Paleoproterozoic granitoids are similar in age to part of the Transcandinavian Igneous Belt, but are geochemically unlike it. Generally there is evidence of an early Scandian overprint ranging in intensity from low-amphibolite facies to eclogite facies followed by a general late Scandian amphibolite facies overprint. The best recent understanding is that the Baltica basement in the map area, although providing the basement for emplacement of the sequence of far-traveled thrust nappes, is not truly autochthonous with respect to the Baltic shield exposed in front of the Scandian orogen in Sweden and southern Norway. Evidence for this comes in two main forms. In the part of the western Gneiss Region exposed in Trollheimen, just southeast of the area of Figure 1, maps clearly delineate two levels of basement, each capped by a quasi-continuous layer of variable deformed late Proterozoic quartzite and pebble conglomerate. It is inescapable that the

Tectonic Units	Northwestern Areas		Southwestern Areas			Central Areas		Eastern Areas
		Hemne	Molde	Trollheimen	Oppdal	West-central	East Jamtland	Central and southern
	This Paper	*Tucker (1986)*	*Robinson (1995)*	*Gee (1980)*	*Krill (1980)*	*Roberts and Wolff (1980)*		*Gee (1975)*
Late orogenic sediments	Devonian					Late Silurian/ Mid-Devonian	Early Devonian	
Upper Allochthon	Støren Nappe		Støren Nappe		Tronget Unit	Støren Nappe	Meråker Nappe	Kölli Nappes
	Seve Nappe	Gagnåsvatn Nappe Unit	Blåhø-Surna Nappe	Blåhø Unit	Surna Unit Blåhø Unit	Gula Nappe Levanger/ Skjøtingen Nappes	Øyfjell/ Essandsjø Nappes	Seve Nappes
Middle Allochthon	Särv Nappe	Songa Nappe Unit	Sætra Nappe	Sætra Nappe	Sætra Unit	Leksdal Nappe Upper part Leksdal Nappe Lower part	Remsklapp Nappe	Särv Nappe
	Risberget Nappe	Rønningen Augen Gneiss	Risberget Nappe	Augen Gneiss	Risberget Unit	Hærvola Nappe		Tännäs Augen Gneiss Nappe
Lower Allochthon and Parauthochthon	Absent or too thin to show	Øyangen Formation	Åmotsdal Quartzite	Gjevilvatnet Group	Åmotsdal Unit	Quartzite, rhyolite, granitic gneiss Bjørndalen Formation *Gee (1977)*	Quartzites, black phyllites	Jämtland Nappes
Autochthon	Precambrian Basement	Våvatn Migmatite Gneiss	Baltica Basement		Lønset Unit	Precambrian crystalline basement		Precambrian granite and gneisses

Fig. 2. Correlation of main tectonic units in the central southern part of the Scandinavian Caledonides

upper level of basement forms a vast and highly folded thrust sheet emplaced above the lower level of basement and its autochthonous cover (Nilsen and Wolff, 1989). Robinson (1997) has deduced a similar situation within the anticlinal culmination centered on Rekdalshesten southwest of Molde and there are various other indications of probable segmentation of Baltica basement within the northern part of the Western Gneiss Region. The second form of evidence is in the deep seismic seismic profile from Trondelag across the orogen to the Baltic shield in Sweden (Huric, 1988) clearly showing that the Baltica basement exposed in various tectonic windows near the Norwegian-Swedish border lies above a major shallowly dipping reflector that appears to correspond to the authochthon exposed at the front of the orogen.

Above the Early to Middle Proterozoic Baltica basement in various parts of the map area are vestiges of a very thin authochthonous sedimentary cover sequence, usually consisting of probable late Proterozoic quartzites and conglomerates, and overlying pelites representing metamorphosed Cambrian alum shale. Within the map area of Figure 1, at the scale used, these units of the autochthon and Lower Allochthon are too thin to show. In many parts of the map area they are entirely absent or recognized with difficulty, and usually not distinguishable from each other. They are, however, reported locally, for example in the previously mentioned quartzites of Trollheimen, and in the Øyangen Formation (Tucker, 1986) of quartzite and overlying mica schist in an area west of Orkanger. In the unmetamorphosed lowest thrust allochthon in Sweden, these are overlain by a thicker sequence, which, includes Baltica basement, late Proterozoic sandstones, a limestone-shale sequence of Cambrian-Ordovician age, and a thin Silurian sequence of sandstone and limestone grading upward into turbidites that may range into lowest Devonian.

Above the autochthonous cover and Lower Allochthon, and commonly in direct contact with Baltica basement, are the rocks of the Middle Allochthon. In the area of Figure 1 the lowest recognized unit, again too thin to show, is the Risberget Augen Gneiss Nappe correlated with the Tännäs Augen Gneiss Nappe in Sweden (see Stop 3). The unit is dominated by variously deformed Middle Proterozoic rapakivi granites with various associated gabbros, anorthosites, and other granitoid rocks. Earlier assigned an age of 1500 Ma (Krill, 1983a), new concordant zircon ages (Handke et al., 1996) indicate that these distinctive rapakivi granites fall into two age groups, 1659-1642 Ma and 1190-1180 Ma. The other key part of the Middle Allochthon, finally extensive enough to show on Figure 1, consists of feldspathic quartzites derived from late Proterozoic feldspathic sandstones, interlayered with amphibolites derived from later Proterozoic diabase dikes. This unit variously known in Norway as the Sætra, Songa, and Leksdal Nappes is here assigned the Swedish term Särv Nappe, to emphasize the importance of orogen-wide correlation (see Stops 2, 4, 8, and 14). Furthermore, a few areas of very feldspathic rocks, intricately interlayered with amphibolites, might not be the Särv itself, but Baltica basement to the Särv Nappe heavily intruded by the same late Proterozoic dike swarm. In the front of the Caledonides in Sweden, the late Proterozoic sandstones of the Särv Nappe are as much as 2 km thick. By contrast, in parts of the Western Gneiss Region the equivalent quartzite-amphibolite sequence has been mapped where it is from 10 m (Robinson, 1995) to as thin as 1m (Terry and Robinson, 1996).

In Sweden the Upper Allochthon has traditionally been mapped as two major units, the lower Seve Nappe, characteristically containing medium- to high-grade metamorphic rocks, and the upper Köli Nappes containing medium- to low-grade metamorphic rocks, locally with Ordovician fossils. The traditional equivalent names in Norway have been the Skjøtingen and Støren = Meråker Nappes respectively. In the central part of the Caledonian sequence the high grade Gula Nappe has been regard as a separate nappe between the Støren=Köli and Skjøtingen=Seve, but we regard the Gula Nappe as an equivalent of Seve. Geotectonically, the rocks of the Seve and Gula Nappes have been considered as the extreme outboard assemblage of the Baltica continental margin, and to have been subjected to high-grade, even locally high P metamorphism in pre-Scandian and/or early Scandian time. The Köli and Støren = Meråker Nappes are considered to have a largely exotic origin as Late Cambrian - Earliest Ordovician ophiolite sequences and Ordovician volcanic-arc sequences and their unconformable Late Ordovician to possibly early Silurian cover from Iapetus Ocean. Ordovician fossil affinities in the Støren Nappe suggest deposition proximal to Laurentia, and possibly even that the strata were thrust or obducted onto Laurentia in the Ordovician Taconian orogeny, and then later transferred onto the Baltic margin in the Scandian collision.

In detailed subdivision of the Seve equivalents in the Trollheimen region of Norway, Krill, (1987) identified a lower Surna Nappe characterized by higher grade metamorphism and abundant intrusions of Trondhjemite and pegmatite, and an upper Blåhø Nappe, usually slightly less metamorphosed and lacking such intrusions. Robinson (1995) did not attempt to carry this distinction in his correlation within the Moldefjord region and adapted the composite term Blåhø-Surna Nappe, but for the Ålesund and Ulsteinvik 1/250,000 sheets Tveten and Lutro (1996) simplified this to Blåhø Nappe.

Within the area of Figure 1, it has been most practical to map two nappes. The lower nappe is characterized by medium- to high-grade mica schists, commonly with garnet±kyanite±sillimanite, and with variably distributed granitoid intrusions and pegmatites, by abundant coarse amphibolites, commonly with garnet and pyroxenes, and by fairly common layers of coarse-grained marble. The upper nappe is dominated by low- to medium-grade metamorphosed volcanic and related intrusive rocks including ophiolite fragments, by metamorphosed volcano-sedimentary sequences, and by metamorphosed black shale. An additional component of this nappe, recognized earlier (Tucker, 1988; Gautneb and Roberts, 1989) but receiving special emphasis in this guidebook, is a variety of middle to late Ordovician medium- to coarse-grained calc-alkaline intrusive igneous rocks that were contemporary with the extrusion of the arc volcanics. A common distinction between the lower and upper nappes is that the lower one contains medium- to high-grade rocks with coarse garnet, whereas the upper one contains low- to medium-grade rocks with no more than 2-3mm garnets if any at all. For this guidebook we have adopted the name Seve for the lower nappe to emphasize its broad geotectonic affinities and high grade metamorphism, and the name Støren for the upper nappe to emphasize its Ordovician igneous characteristics, its fossil affinities, and its general lower grade metamorphism.

LATE OROGENIC CLASTIC SEDIMENTS

At the top of the tectono-stratigraphic section, and indeed not really a part of it, are the moderately deformed and slightly metamorphosed conglomerates, sandstones, shales and rare limestones of the Devonian Old Red Sandstone basins (Steel at al., 1985). They are exposed on Smøla, Hitra, and Ørlandet (see Stop 11) and a large number of small islands near Trondheim, and in four major basins in west Norway, from north to south Hornelen, Håsteinen, Kvamshesten, and Solund. The best palynological data from Asenøya, north of Ørlandet (Fig. 1) suggests a late Emsian age of deposition (Allen, 1976), about 395-392 Ma based on the new Devonian time scale (Tucker et al., 1997). According to a structural study by Seranne (1992) (see Fig. 3) and in agreement with studies of other Devonian basins in west Norway (Andersen and Jamtveit, 1990; Andersen, 1993), all of these strata lie on the upper plates of major top-to-west extensional detachment faults that carried both the Devonian strata and their immediately underlying igneous-metamorphic substrate for many kilometers southwestward or westward from their original sites of deposition. The rocks unconformably beneath the basins have escaped much of the deformation characteristic of the Western Gneiss Region and appear to belong to parts of the Caledonides normally exposed far to the east and also commonly rather low in the regional nappe stratigraphy. In the case of the basins near Trondheimsfjord, detailed studies suggest that movement on the detachment fault was west-southwestward, in essentially the same direction as the slightly earlier and more ductile folds and dominant lineation that pervade the region.

EFFECTS OF SCANDIAN DEFORMATION AND METAMORPHISM ON PROTEROZOIC ROCKS

In the immediate surroundings of the Trondheimfjord, Scandian metamorphic overprinting is intense, but apparently at slightly lower pressures than near Kristiansund to the southwest. However small bodies of gabbro with eclogitic rims are to be found about 30 km to the southwest. It is obvious that many of the Proterozoic rocks became hot enough to provide small amounts of partial melt, that formed pegmatites. Commonly these pegmatites appear "cross-cutting" even in large outcrops, particularly of relatively massive host rocks, but elsewhere show signs of strong deformation. U-Pb ages on zircons from several of these (Fig. 4) give ages around 400 Ma, similar to the age of 401±2 Ma for zircon overgrowth on baddeleyite in the Selsnes Gabbro and about 5 m.y. earlier than the typical cooling age of 395±2 Ma on sphene in metamorphosed basement rocks. (See below).

Basement sphene in late Paleoproterozoic basement studied in detail by Tucker et al., (1987, 1991 and in preparation) shows variable degrees of recrystallization from the igneous protolith age of around 1657 Ma toward the time when Scandian lead loss was terminated. The remarkable feature is not that there are variable degrees of lead loss, but that all samples, regardless of degree of lead loss, fall on the same chord at 395±2 Ma, implying cooling over a very broad region in a very short period of time. Furthermore, Ordovician intrusive rocks of the Støren Nappe, locally only 1 km from completely recrystallized basement, for example at Kjørsvika along strike from Valset Ferry (Stop 9), show little or no resetting of their Ordovician igneous sphene, implying a major early extensional detachment between the nappe and basement (Robinson et al., 1996; Tucker et al., 1997a; Robinson et al., 1997). These data, combined with the limited U-Pb dating of new metamorphic zircon in the Selsnes gabbro at 401±2 Ma imply that many of these rocks may have been subducted and cooled below 600°C in a little as 10 m.y.! Furthermore, new time-scale data based on dating of tuffs in fossiliferous sections (Tucker et al., 1997b) indicates that the Devonian began about 418 Ma, and thus that most of these Scandian events took place in Early Devonian rather than Silurian time.

SEQUENCE OF SCANDIAN STRUCTURAL DEVELOPMENT

The discussions of deformations given above cannot bring the reader to a full appreciation of the complexity of this part of the Western Gneiss Region, nor how strongly the Proterozoic basement was involved. Fig. 5 from Tucker (1986), showing a small area that can be recognized on Fig. 1 not far southwest of Stop 5, gives a greater appreciation. The oldest recorded deformation was the establishment of a series of thrust nappes involving transport of various terranes for hundreds of kilometers onto the Baltica margin. Locally some folds may have also formed during this deformation. This thrusting essentially established the sequence of rock units upon which maps are based. It was during this phase that Baltica basement reached its deepest location in the northwest- dipping subduction zone beneath overriding Laurentia. It has been argued above that this was followed by early extensional collapse, which brought some cooler high level nappes into close or direct contact with cooling high-T high-P Baltica basement, while at the same time probably producing great thinning of some of the nappe units. It is believed that this early extensional collapse terminated Pb loss in sphene of the Baltica basement at about 395±2 Ma. This thrust and extensionally juxtaposed column then was subjected to several phases of ductile folding. In the area of Fig. 5, Tucker recognises a phase of recumbent folding which he divides into three parts, Early (axial surfaces 1 and 2), Main (axial surface 3) and Late (axial surfaces 4, 5, and 6). All of these are then deformed in a phase of tight upright folding (axial surfaces 7, 8, 9 and others) associated with strong generally northeast-trending subhorizontal stretching lineation in most outcrops. The latter is commonly believed to be the early ductile phase of sinistral transtension than led up to the brittle detachments

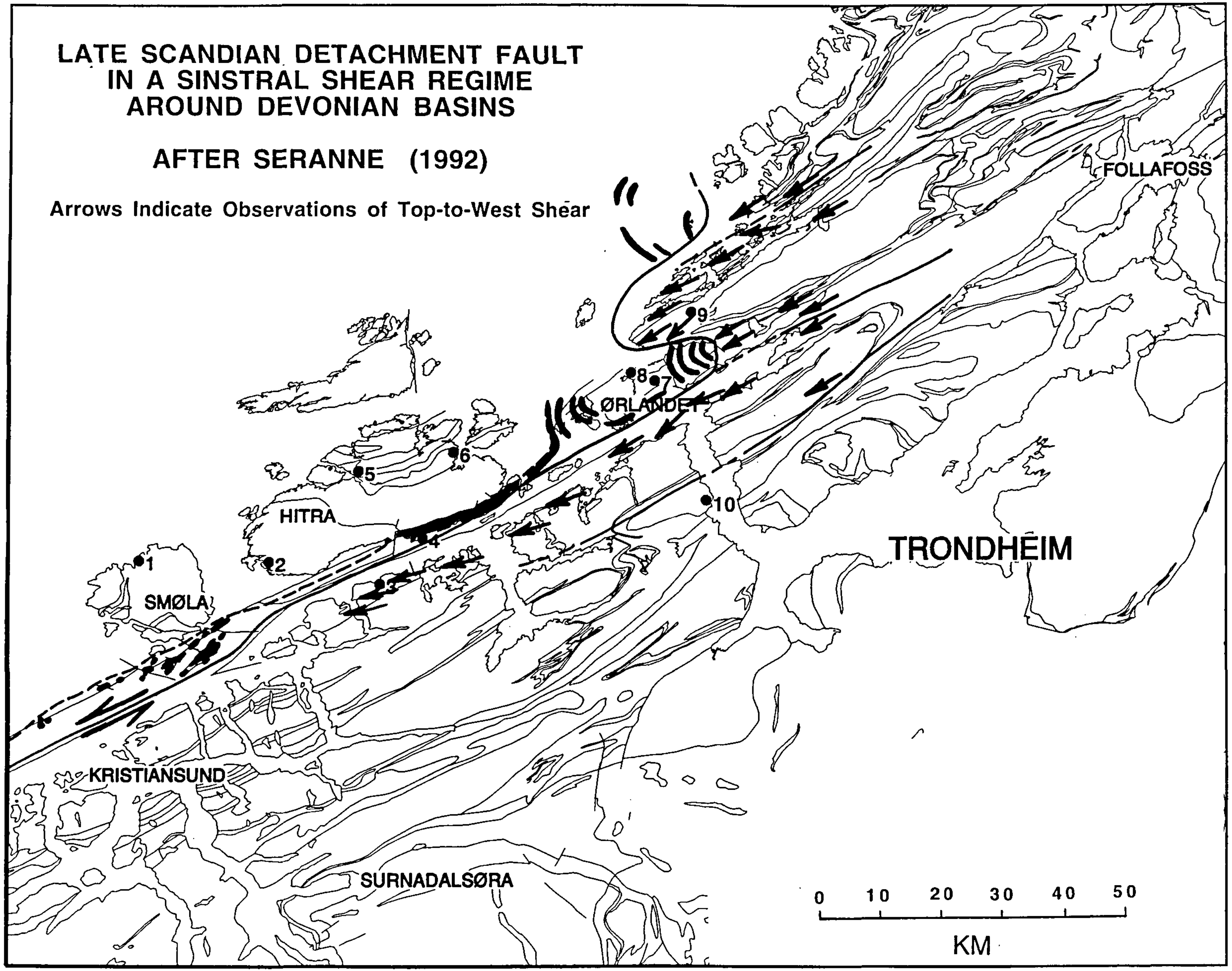

Fig. 3. The late Scandian detachment in the outer Trondheimsfjord area.

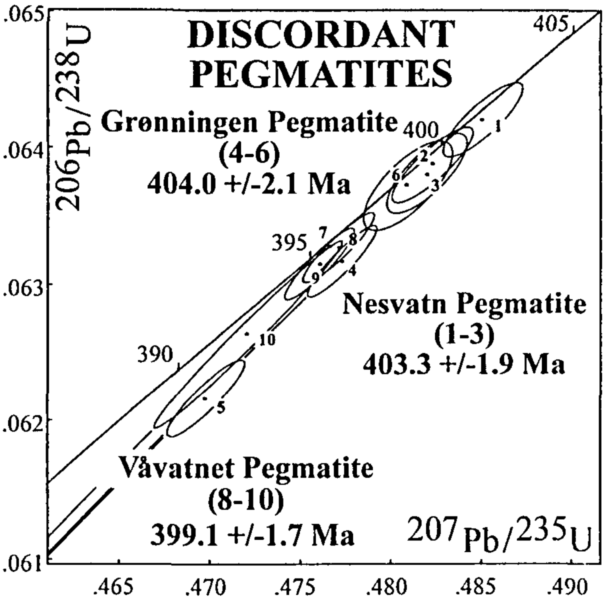

Fig. 4. U-Pb concordia diagram for discordant pegmatites in the gneisses of Western Gneiss Region at Rønningen, Nesvatn and Våvatnet.

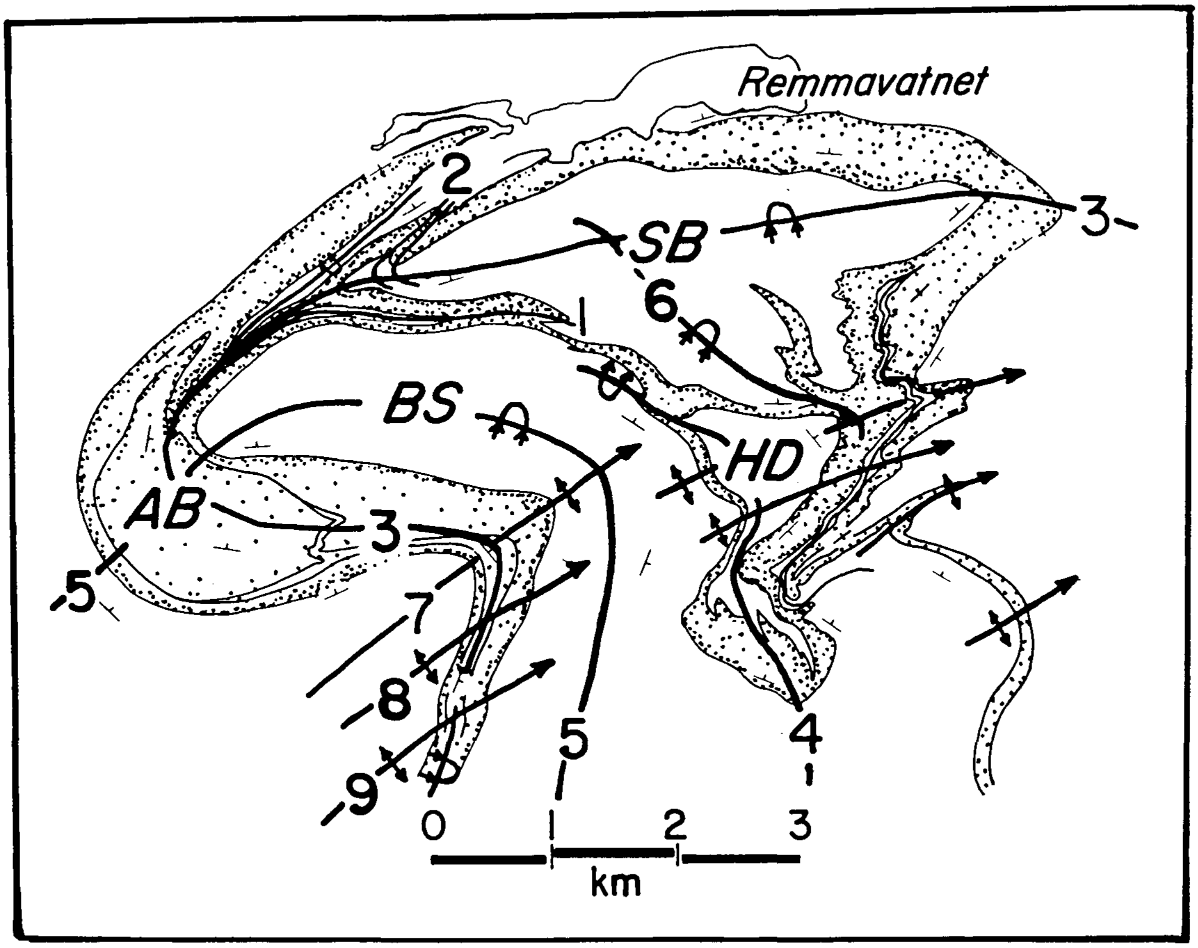

Fig. 5. Fold axial surface map of the Remmafjell structure (SW stop 5) showing major structural features and the trace of various Caledonian surfaces (from Tucker 1986). Arrows denote the trend and plunge of map-scale folds. Stippeld area is cover rocks. AB - Almfjell basin; BS - Bergsvard synform, HD - Heklefjell dome; SB - Skropligdal basin. Numbers refers to structures described in the text.

associated with the Devonian basins. A slight variant of this interpretation would have most or all of the folds formed during a single prolonged phase of sinistral transtension with continued folding about northeast-plunging tubular axes (see Stop 3-7, Guidebook for Field Trip A-3, this Conference). This alternative in no way changes the sequence of major events, nor the obvious conclusion that in these circumstances basement and cover deformed together in an extremely ductile fashion.

A PRACTICAL NOTE TO PARTICIPANTS

Depending on information available it is expected to pick up participants either at NGU, at Hotels in Trondheim, or at a central location in Trondheim about 8:15 A. M. Wednesday August 20, and proceed direct to Stop 1 on Route E39 west of Borsa. Participants will be returned to the same locations shortly after 18:00 in the evening. Cost of $60 U. S. includes guidebook, all transportation including ferries, and lunch. Most stops are near the road, and walks will be short though locally steep. Expected weather can be anything from hot sunshine to strong wind with horizontal rain. Waterproof boots, rain suit, and pack to carry them are highly recommended. In addition to the rocks, this trip will cover some pleasant ocean, forest, and hill country scenery. This field trip was designed to give participants the maximum amount of insight into the geology, within a single day. Emphasis is on "seeing the rocks", admittedly the most easily accessible rocks, and not on extended descriptions and discussions, which may nevertheless take place in unscheduled moments. The distance to be travelled is about 200 km, mostly on paved roads and some of the stops are quite short, so participants will have to acquire a certain degree of self-discipline to gain full benefit from the experience. A further degree of discipline is imposed by the schedule of two ferries, which must be conformed to. Therefore, when leaders indicate that it is time to leave a stop, the intention is serious and your welfare is involved. In return the ferries do supply an opportunity for informal refreshments and abundant public toilets which **should not be missed**. The ferry fares of all participants will be paid by the leaders. During ferry trips it is always possible to climb to a sun deck for further enjoyment of scenery and geology.

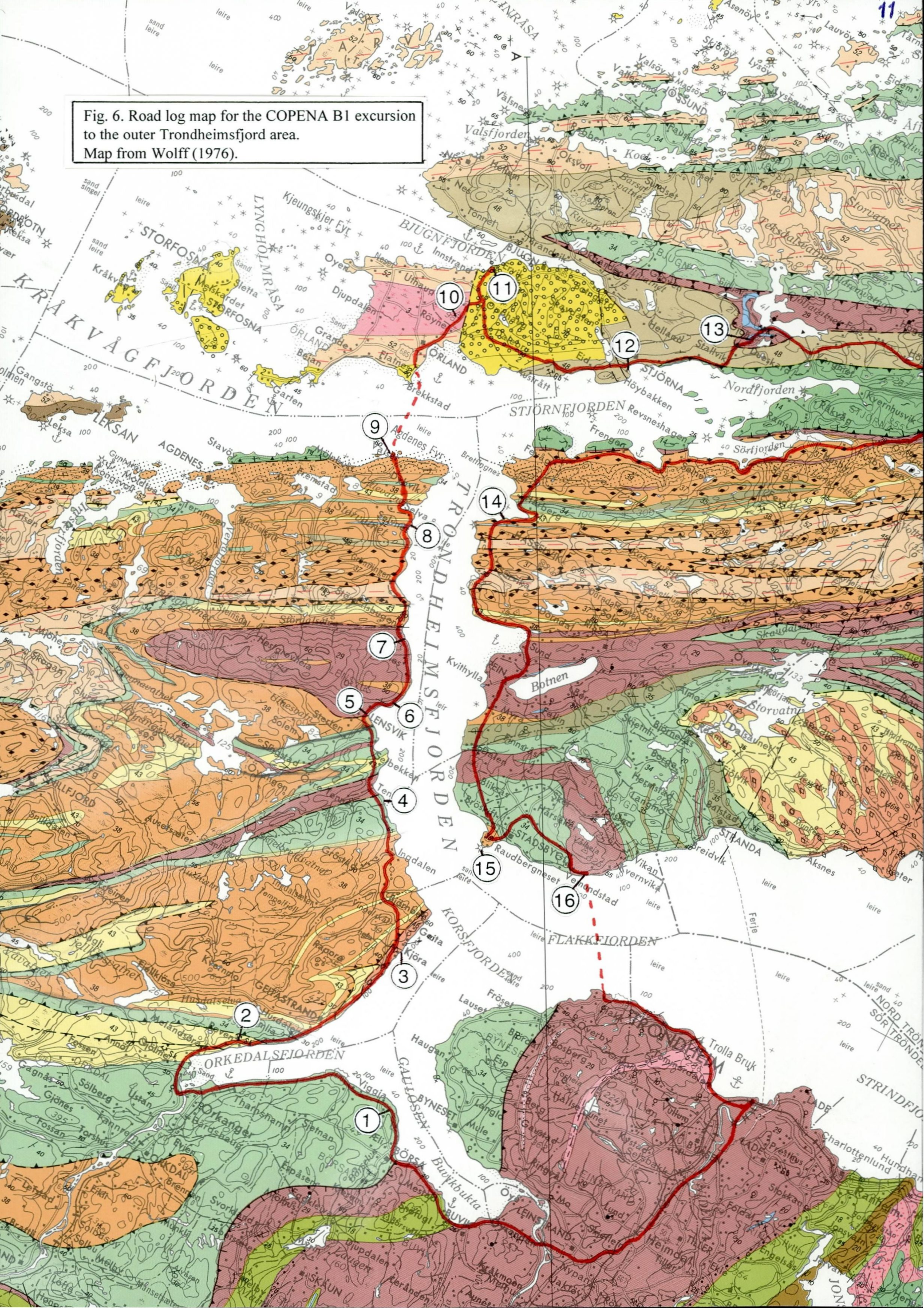

Fig. 6. Road log map for the COPENA B1 excursion to the outer Trondheimsfjord area.
Map from Wolff (1976).

ROAD LOG

Total Time	Time since prev.	Total Km	Km since prev.	
8:30				Pick up participants Trondheim Railroad Station. Proceed on E6 toward Oslo.
8:51	-	0.0	0	Klett traffic circle. Go straight toward Orkanger on E39.
8:54	3	2.3	2.3	Bridge over Gaula River.
8:58	4	5.1	2.8	Øyesand beach on right. Begin winding road. Cliffs of Støren greenschists on left dipping south. The section on this mountain has recently been interpreted as an inverted section of ophiolite (Tom Heldal, NGU, personal communication, 1997). Talc-carbonate rocks in the original basal section were mined for construction of the oldest parts of Nidaros Cathedral in Trondheim.
9:03	5	8.2	3.1	Stormøllen grain storage.
-	-	8.6	0.4	Road cut in Gula Nappe on left.
9:04	1	10.0	1.4	More narrow coast road. Rocks of Gula Nappe.
9:09	5	12.6	2.6	Small tunnel in Gula Nappe.
9:10	1	14.2	1.6	Borsa Junction. Note turn off for Skaun, the adult home of "Kristin Lavransdottir" in Sigrid Undset's Nobel Prize winning novel. Stay on E39.
9:13	3	16.4	2.2	Two-sided road cut. Possible to park on right.

STOP 1: (10 minutes) Gula = Seve biotite-diopside schist and garnet-biotite schist dipping gently north beneath Støren Nappe. Tectonic foliation is cut by pegmatites which are themselves deformed. These probably belong to the same group of deformed pegmatites which Tucker has dated at 430.6±2.4 Ma. at Tråsåvika and 422.7±2 Ma. at Orkanger (see Fig. 7). These results indicate that the peak high-grade metamorphism in the Seve Nappe took place more than 25-30 m.y. before the peak Scandian metamorphism of the underlying basement at 400-395 Ma. Here there is some evidence for late sinistral shear (top to east) which appears to be typical along what is interpreted as the back-folded upper limb of an original southeast-facing recumbent syncline as delineated near Surnadal (Krill, 1987)..

Total Time	Time since prev.	Total Km	Km since prev.	
9:23	**10**	-	-	Leave Stop 1.
9:27	4	20.5	4.1	Viggja. Viking Monument.
9:29	2	22.2	1.7	Tråsåvika Camping. Pegmatite on left beyond entrance in Gula Nappe is dated by U-Pb zircon at 430.6±2.4 Ma (Tucker et al., in preparation). Pegmatite cuts earlier foliation but is itself highly deformed.
-	-	25.1	2.9	Amphibolite in Gula Nappe in big road cuts on left.
9:36	7	30.4	5.3	Exit from E39 toward Agdenes on Route 710.
9:37	1	30.8	0.4	Traffic circle. Straight on 710.
9:39	2	31.9	1.1	Road cut. Gula = Blåhø = Seve mica schist on left.
9:40	1	32.8	0.9	Large quarry on left. Layered amphibolite with some garnet in Gula Nappe. Bear northeast along side of Orkdalsfjorden.
9:43	3	35.2	2.4	Road cuts in slabby quartzite/amphibolite of Särv Nappe for a long distance along the coast.
9:46	3	37.9	2.7	Lumber yard and quarry on left at Almlia.

STOP 2: (15 minutes) Särv Nappe. Arkosic psammite and metadolerite. Description based on Krill (1981).

"The rocks are strongly folded and foliated but cross-bedding and chilled contacts to the dolerites are locally preserved. In less deformed parts of these rocks, 15-20km to the southwest, the metadolerites clearly cut the sedimentary layering. In that area cross-bedding and graded beds face southeast, away from the underlying unit of Risberget augen gneiss (Peacey 1963). The rocks in the qyarry are folded by near vertical down-plunging open folds and has a marked steep lineation. It is not known wether this structure is of early or late origin. The metadolerites are 1-1.5m thick showing a relict plagioclase porphyritic texture. Geochemically (Roberts pers. comm. 1980) and texturally they resemble the Ottfjellet dolerites of the Särv Nappe (Solyom et al. 1979), the dikes in the upper part of Leksdal Nappe (Andreasson et al. 1979) and the metadolerites in the Sætra Nappe at Oppdal (Krill, 1980). Near Oppdal the dikes in the Sætra Nappe are dated to 745±37 Ma (Rb-Sr) (Krill 1983b), which is similar to date obtained on the Ottfjellet dikes of the type area (Claesson 1976). The dikes are interpreted to represent magmatism conected to early rifting and opening of the Iapetus Ocean."

In examining the dikes note that some are dark green porphyry dikes and some cross-cut bedding of feldspathic quartzite. The steep lineation and fold axes could be early.

Total Time	Time since prev.	Total Km	Km since prev.	
10:01	**15**	-	-	Leave Stop 2. Many road cuts in Seve schist along coast.
10:08	7	42.3	4.4	Geitastrand. Baltica basement begins just beyond.
-	-	46.9	4.6	Begin road cuts in augen gneiss of Risberget Nappe.

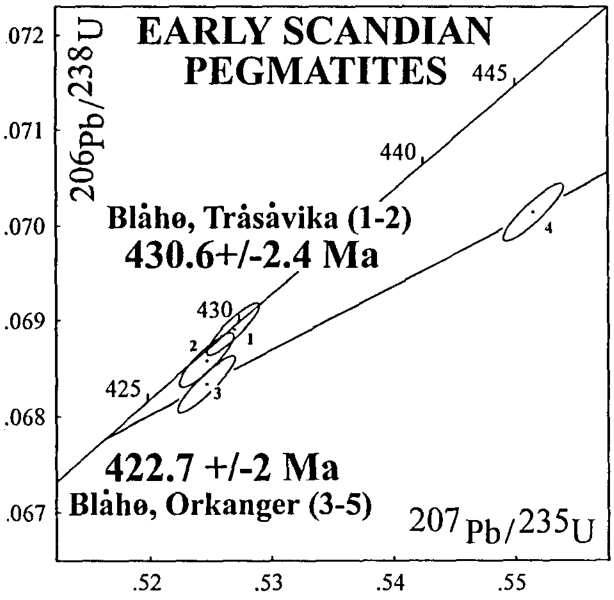

Fig 7. U-Pb concordia diagram for the deformed pegmatites in Blåhø Nappe at Tråsåvika and at Orkanger.

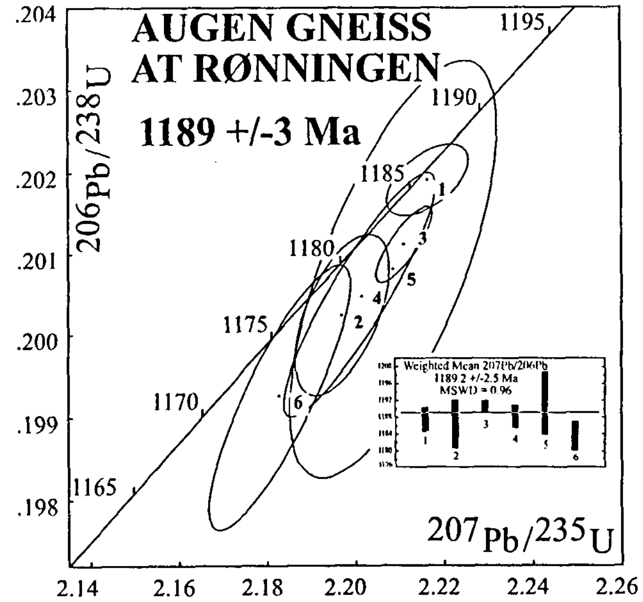

Fig 8. U-Pb concordia diagram for the augen gneiss in the Risberget Nappe at Rønningen, Kjøra.

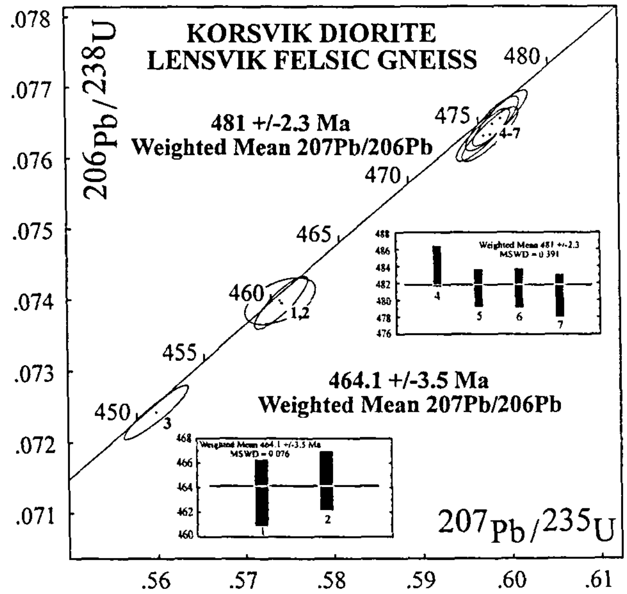

Fig. 9. U-Pb concordia diagram for the Kjørsvika diorite and the Lensvik felsic gneiss.

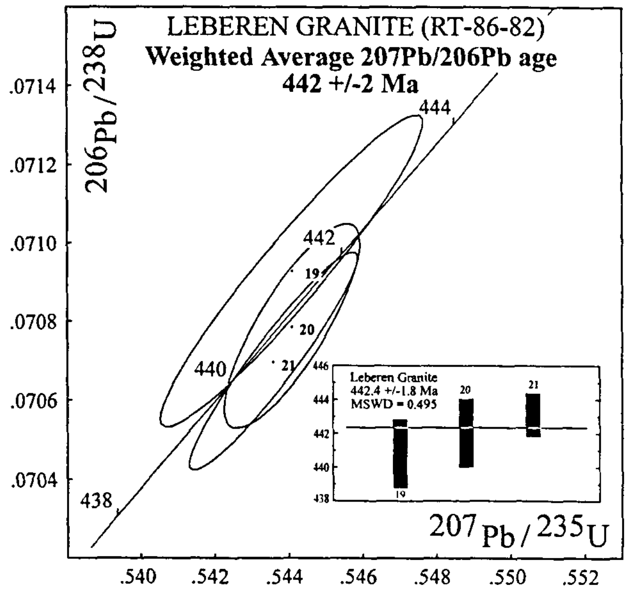

Fig 10. U-Pb concordia diagram for the Lerberen Granite on Ørlandet.

10:14	6	48.0	1.1	Turn right on side road to Kjøra (yellow sign) and descend to village of Rønningen. Use cut off of old road.
10:16	2	48.7	0.7	Back to old road. Turn left (north) along coast.
10:17	1	49.0	0.3	Park near yellow house.

STOP 3: (40 minutes) Risberget Augen Gneiss. Rapakivi granite with U-Pb zircon age by R. D. Tucker of 1189.1±2.5 Ma (see Fig. 8) cut by mafic dikes.

Both Krill (1981) and Tucker (1986) report that distinctive foliation and mylonite zones are truncated by the dikes. Tucker (1986) reports that the geochemistry of the dikes is nearly identical to the dikes cutting Late Proterozoic sandstones in the Särv Nappe in Sweden. If the dikes are late Proterozoic, as suspected, then the deformation may be mid-Proterozoic, possibly Sveco-Norwegian. In our examination of the outcrop we could not find clear cross-cutting relations and considered the possibility that a mylonite zone actually might cut through a dike, but in a place where there is no outcrop. The photograph published by Tucker is more convincing than anything we saw in place. It would be ironic as well as informative if evidence of a Sveco-Norwegian deformation were preserved in the allochthon in this location, and not in the autochthon. That may be what is the case with the Jotun Nappe and the Western Gneiss Region basement beneath it (see Guidebook for Trip A-3, this meeting).

10:57	**40**	-	-	Turn around at yellow house.
11:01	4	50.0	1.0	Back on Route 710. Continue toward Agdenes. Inland until Ingdal.
11:09	8	57.0	7.0	Ingdal
-	-	57.3	0.3	Road cut in Ingdal granite, impossible to park.
11:12	3	60.2	2.9	Turn out. Road cut and coastal exposure of mica schist. Walk north end of dirt, then down short trail to shore.

STOP 4: Sålåtneset. (15 minutes) Seve mica schist and marble. Big beautiful outcrop of rusty biotite-hornblende schist and rare marble. Vertical folds with dextral asymmetry.

11:27	**15**	-	-	Leave Stop 4. Continue northwest on 710.
11:33	6	65.5	5.3	Lensvik Kirke.
11:34	1	66.1	0.6	Big turnout on right. Storage for telephone poles.

STOP 5: (15 minutes) Section showing basement gneiss, Särv Nappe, and Seve Nappe on south limb of Lensvik syncline. Most of the road section is garnet -biotite schist with some amphibolite all belonging to the Seve Nappe. Near the base of the nappe is quartz-muscovite-calcite schist and very impure marble. This can best be seen in shore sections. South of this is a section of feldspathic quartzite with some amphibolite belonging to the underlying Särv Nappe. Total thickness of the Särv Nappe here is only about 10m. South of this is granitic gneiss, most probably belonging to the basement, but close to the Särv Nappe a very sheared variety of the Risberget Augen gneiss might occur.

11:49	**15**	-	-	Leave Stop 5. Continue on 710.
11:53	4	68.1	2.0	Turn-out on right surrounded by steel railing. No picnic table. Trail over steep bank leads to shore exposure.

STOP 6: (10 minutes) Mixed strongly foliated and lineated Ordovician intrusive rocks in Lensvik syncline. These rocks are easily mistaken for Proterozoic basement of the Western Gneiss Region. These are now assigned to the Støren Nappe of the Upper Allochthon. R. D. Tucker dated a sample collected near here that has yielded a zircon U-Pb age of 481±2.3 Ma. (see Fig. 9).

The rocks we see here are not typical for the rocks in the Støren Nappe as they appear in the central part of the Trondheim region. There the rocks are made up of a thick unit of basic volcanics (the Støren greenstone) and phyllites and greywacke with greenschist facies metamorphism and primary structures commonly visible. Large intrusions are very rare although they might occur particularly in the volcanic units. The eastern equivalent of the Støren greenstone, the Fundsjø Group, has however a lot of of intrusions ranging in composition from mafic to felsic, and the same kind of mixing of rocks as we see here is common (eg. Grenne et al. 1994, Wolff 1973). The felsic intrusions in the Fundsjø Group has been dated to 488±2 Ma (Bjerkgård & Bjørlykke 1994) which is aproximately the same age as for the intrusions in the Lensvik syncline.

12:03	**10**	-	-	Leave Stop 6. Continue on 710.
-	-	68.7	0.6	Picnic table as advertised before. Green rock begins just after this.
12:07	4	71.3	2.6	Big road cut and shore exposures of mafic Ordovician intrusive rocks and volcanics.
12:08	1	71.9	0.6	Turn out on right. Outcrops at Litleneset and shore to south.

STOP 7: (10 minutes) Spectacular coarse Støren hornblende gabbro in Lensvik syncline. Strong shear fabrics with subhorizontal lineation. These rocks are nearly identical to Støren gabbros described by Robinson (1995) near Molde and Brattvåg.

12:18	**10**	-		Leave Stop 7.

12:23	5	76.6	4.7	Kjerringneset basement at turn out. No stop.
12:24	1	77.7	2.0	Tunnel. Long cuts in basement.
12:27	3	79.7	2.0	Park to left by old tunnel mouth at Hambortåa.

STOP 8: (20 minutes) Basement gneisses and Seve Nappe. Section showing migmatitic basement gneisses and Seve Nappe consisting of garnet-hornblende schist, amphibolite and marble. Description based on Krill (1981).

"A typical section of the Seve Nappe consisting of garnet-hornblende schist, amphibolite and white marble are exposed southeast of the Hombortåa tunnel. Small amounts of kyanite can be found in the schists and diopside in the marble. The contact to the basement is at the entrance of the tunnel, but the contact is strongly sheared and not easy to locate. The basement consists of reddish gray migmatitic gneiss of granodioritic composition. Characteristic for the gneisses are granitic neosomes with hornblende selvages of Scandian (??) age.

12:46	**20**	-	-	Leave Stop 8.
12:49	2	80.3	0.6	Folded interlayered amphibolite and quartz-rich granulite - possible Särv Nappe.
12:51	2	81.6	1.3	Selva
12:54	3	84.9	3.3	Pass. Huge outcrops of Agdenes type Proterozoic basement. Stop if time permits.
12:56	2	86.2	1.3	Valset Ferry

STOP 9: (19 minutes) Ordovician (?) amphibolite intruded by dioritic gneiss, assigned to the Støren Nappe. The southern part of the outcrop is dominated by simple hornblende amphibolites, probably metamorphosed mafic intrusives. The northern part is dominated by strongly foliated and lineated diorite to tonalite that probably intrudes the amphibolite. The dioritic gneiss is typical of a very long stretch of coast to northeast and southwest, including a locality at Kjørsvika from which R. D. Tucker has obtained a U-Pb zircon age of 464.1±3.5 Ma (Fig. 9). An important feature at Kjørsvika is that although the rock is highly deformed and contains the same late structural fabric as the adjacent basement gneiss, the sphene still retains an Ordovician age of about 450 Ma, whereas the sphene of the adjacent basement gneiss has been 100% recrystallized during the Scandian at 395 Ma. The implication of this is that the Ordovician intrusions and other rocks of the Støren Nappe have been emplaced against hotter Proterozoic basement during a Scandian phase of extensional detachment that took place before the phase of sinistral transtension that produced the dominant fabric (Tucker et al., 1997, Robinson et al., 1997, and in preparation).

13:15	**19**	-	-	Drive onto ferry. (Ferries 12:25, 13:15, 14:35) LUNCH
13:35	**20**	86.2		Arrive Brekkstad. Drive off ferry. Stay to right on Route 710.
13:36	1	87.1	0.9	Sharp right, northeast on Route 710.
13:38	2	88.9	1.8	Right angle junction. Turn left toward Aune.
-	-	89.2	0.3	Sharp right toward Lerberen Quarry. Bypass quarry to left and up narrow gravel road.
13:42	4	90.2	1.0	Road to summit blocked here. Bear left and park by water tank.

STOP 10: (15 minutes) Lerberen Granite. Very fresh exposures in cuts of road leading to summit. The granite is non-foliated, typical of many of the Ordovician to early Silurian intrusive rocks above the detachment fault associated with the Devonian basins. It has.yielded a U-Pb zircon age of 442±2 Ma (Fig. 10) which places it in the earliest Silurian according to the Tucker and McKerrow (1995) time scale. Walk to top of hill for view.

13:57	**15**	-	-	Head back toward main road.
14:01	4	91.2	1.0	Left on main road.
14:02	1	91.5	0.3	Junction. Left on 710 toward Opphaug.
14:04	2	93.7	2.2	Center of Opphaug. Junction. Turn left toward Innstrand, Grøtan, Døsvika.
14:05	1	94.5	0.8	Right turn at Grøtan toward Ervik. Follow road straight to coast and continue to north end of harbor.
14:07	2	95.8	1.3	Park at north end of harbor at Døsvika.

STOP 11: (15 minutes) Devonian sandstone and cobble conglomerate.

The Devonian on Ørlandet belongs to a very long and narrow basin of Devonian rocks. The total length of the basin is ca. 200km and the width is only 5 to 20km. The shape of the basin is thought to be tectonically controlled. The Devonian on the mainland on Ørlandet is subdivided into two formations (Siedlecka, 1975): The lowermost Austrått Formation is about 500m thick consisting of sandstones, pebbly sandstones and conglomerates. It is interpreted to have been deposited in a braided river system. The Bjugn Conglomerate is more than 2000m thick and consists of coarse grained conglomerates. It is interpreted to have been deposited as alluvial fans. On the islands southwest of Ørlandet there are other types of Devonnian sediments not easily correlated to those on the mainland. An interpretation of the sedimentary environments and palaeogeographic reconstructions has been made by Steel et al. (1985) (Fig 11).

At Døsvika we can see outcrops of the Bjugn Conglomerate (Wolff et al. 1980). Polymict conglomerates, and fining-upward cycles in sandstones and minor mudstones are well exposed. The conglomerate is reddish-gray, poorly sorted, and has local cobbles up to 20cm across.. Common pebble types in the conglomerate are granite, granitic gneisses, red jasper, sandstone, quartzite and quartz. The sandstone portions may contain pebbles and exhibit cross bedding. Ripple-cross stratification is present at the transition into the mudstone which is gray and micaceous.

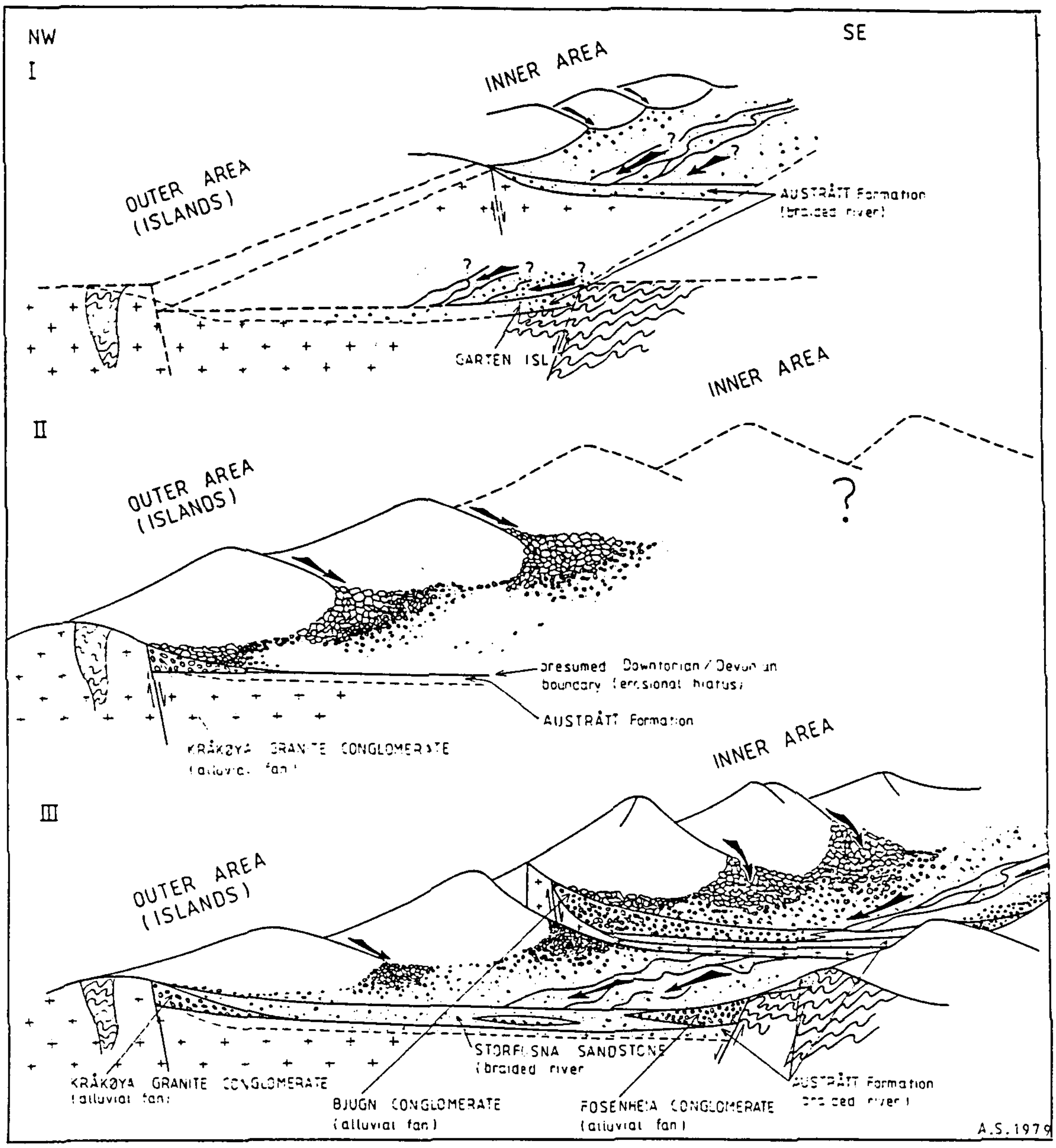

Fig 11. Diagrammatic representation of the sedimentation in the Fosen area in Late Silurian to Middle Devonian time. From Wolff et al. 1980.

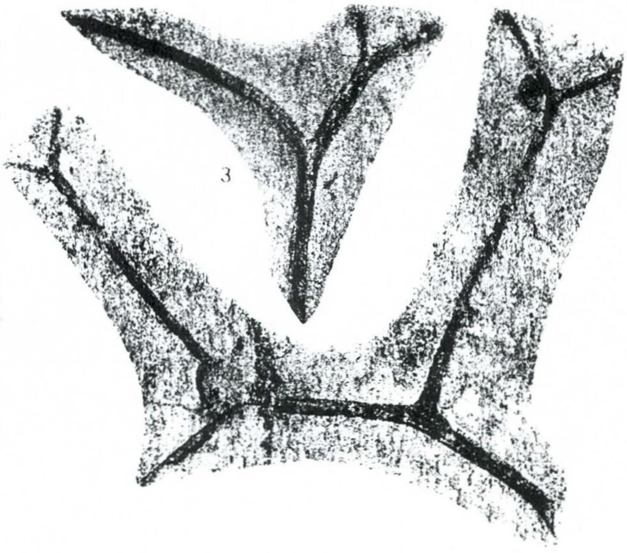

Fig. 12. Naked-branched systems of *Hostimella* from Døsvika, Ørlandet. From Høeg (1945). Natural size.

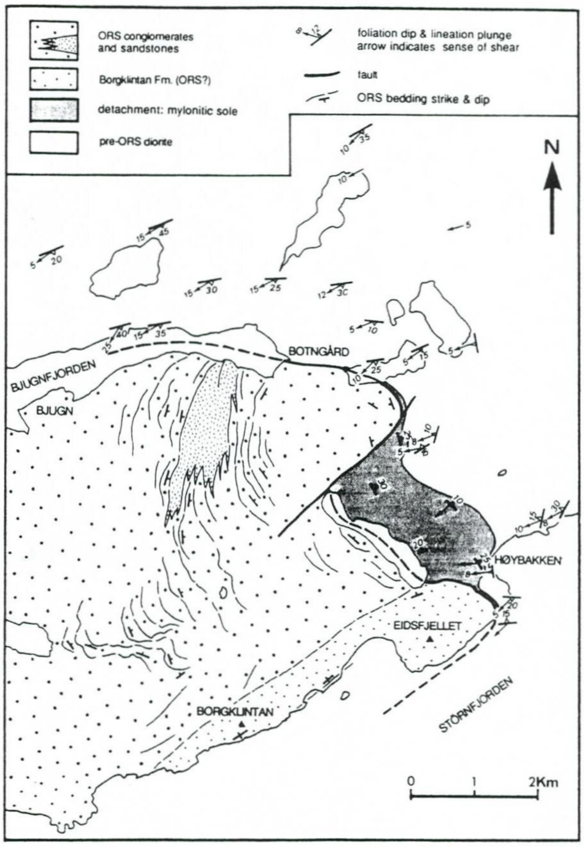

Fig. 13. Structual map of the eastern part of the Devonian Bjugn Basin and the Høybakken detachment. From Seranne (1972)

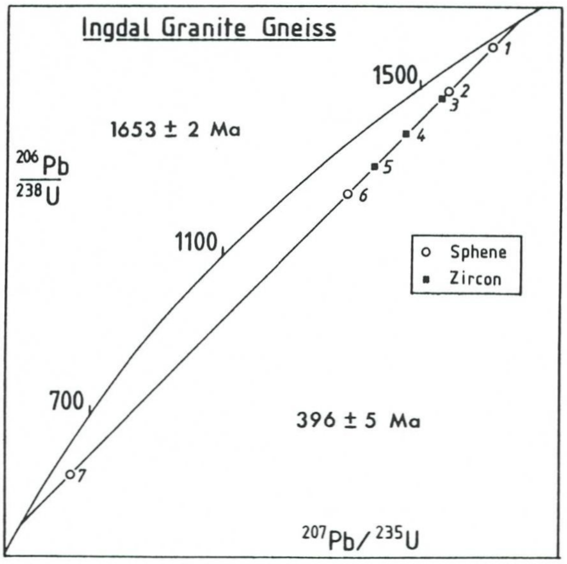

Fig. 14. U-Pb concordia diagram for the Ingdal Granite. From Tucker & Krogh (1988)

Mudstones are a subordinate facies of the Bjugn Formation, but important because of the presence of terrestrial plant fossils. At this locality Vogt (1929) and Høeg (1945) have described the species Hostimella and Psilophyton rectissimum indicating a Lower to Middle Devonian age for the Bjugn Conglomerate. Naked branch-systems of Hostimella, a few centimeters in size, may still be found in the mudstones at Døsvika (Fig. 12).

14:22	**15**	-	-	Leave Stop 11. Return toward Opphaug.
14:24	2	97.1	1.3	Left turn at Grøtan.
14:25	1	97.9	0.8	Junction, Center of Opphaug. Go straight on road which bends much in passing through the village.
14:27	2	100.2	2.3	Junction. Turn left, northeast toward Høybakken. Big Devonian hills on left.
14:32	5	103.7	3.5	Junction for Austratt. Stay straight.
14:33	1	104.8	1.1	Crushed retrograded Ordovician rocks close to detachment.
14:38	5	108.0	3.2	Junction. Turn right toward Høybakken.
14:41	3	109.2	1.2	Corner of Høybakken Harbor. Shore exposure near phone booth.

STOP 12: (10 minutes) Platy flaser mylonite of Ordovician diorite. The outcrop is situated just below the Høybakken detatchment which separates the Devonian sediments from the underlying Ordovician diorite (Seranne 1992) (Fig 13). The same detachment occur below all the Devonian basins in western Norway and seems to be a very important structure in the Caledonides of Norway. The detachment at Høybakken is dipping gently west under the Devonian sediments. The upper parts of the detachments consist of ultramylonite and mylonite, and the lower parts are underlain by protomylonites and mylonites of dioritic composition. The locality at Høybakken is situated just underneath the detachment in an Ordovician mylonitic diorite. The diorite has a west-plunging lineation and according to Seranne (1992) there are a lot of strain indicators all indicating a top-to-southwest sense of movement.

14:51	**10**	-	-	Leave STOP 12. Continue northeast along coast gravel road.
14:58	7	115.0	5.8	Junction. Turn left, northwest, away from coast toward Route 710 for Trondheim. Travel far inland on gravel road. Much flat dipping foliation in mylonitic Ordovician diorite.
15:04	6	118.2	3.2	Road cut on left.

STOP 13: (5 minutes) White Støren marble and calc-silicate. Shows gentle west-dipping foliation and strong E-W lineation. The shear sense along the lineation is top-west, consistent with observations in the region by Seranne (1992), indicating a ductile shear in the same sense as the more brittle fracture of the Høybakken detachment. About 1km north of here the the marble is quarried for industrial purposes.

15:09	**5**	-	-	Leave STOP 13. Descend toward highway 710 after big view.
15:12	3	119.8	1.6	Junction by lake shore. Turn right toward Trondheim on 710. Lots of trees and sheared Ordovician intrusive rock.
15:20	8	129.0	9.2	Hitra-Snasa Fault. Predominantly hard mylonite.
15:23	3	131.6	2.6	Junction. Route 715. Turn right toward Trondheim. Follow major transverse lineament.
15:26	3	134.7	3.1	Junction. Turn right on 718 toward Hasselvika. Platy rocks.
-	-	-	-	Finally on coast in real Proterozoic basement. Subhorizontal lineation.
15:37	11	145.3	10.6	Crossing Fiksdal. Quarries in quartzite high up valley.
15:44	7	151.1	5.8	Selsnes. Ordovician foliated diorite forms hills and points to north as at Valset Ferry.
15:46	2	153.0	1.9	Hofella inlet.
15:52	6	158.9	5.9	Fevåg Kai junction. Beyond here go through narrow pass through mountain. At pass possible stopping point for Agdenes type Proterozoic gneiss.
15:57	5	163.0	4.1	Green stripe shown on Rissa map as mica schist, but on this point is all basement gneiss.
16:01	4	165.9	2.9	Hasselvika picnic table at opening in steel fence on right.

STOP 14: (20 minutes) N to S Coastal section, Seve Nappe (?), Särv Nappe (?), and Baltica basement. Mica schist and amphibolite tentatively correlated with the Seve Nappe. Impure quartzite, amphibolite, and minor calc-silicate tentatively correlated with the Särv Nappe. Gneiss and amphibolite tentatively correlated with basement. Road cut to south across highway is typical basement gneiss with Scandian hornblende-bearing migmatite zones.

16:21	**20**	-	-	Leave STOP 14.
16:28	7	171.5	5.6	Big section of pink basement gneiss on coast. No parking.
16:30	2	172.6	1.1	Mock quartzite. Gray Ordovician intrusive.
16:31	1	173.2	0.6	Quarry on left. Ordovician intrusive in Lensvik syncline.
16:33	2	175.8	2.6	Junction by bridge. Right on 718 toward Rissa.
16:35	2	177.7	1.9	Junction 717 toward Trondheim.
16:37	2	179.6	1.9	Rein Kloster. Junction. Left on 717.

16:42	5	183.2	3.6	Mica schist of Seve Nappe at top of pass. Several cuts and a quarry in Seve. More mica schist for kilometers beyond quarry.
16:48	6	189.2	6.0	Turn right to Røberg.
16:50	2	190.9	1.7	Turn right at shore.
16:50		191.0	0.1	Proceed west to vicinity of old bell house at west end of jetty.

STOP 15: (10 minutes) Proterozoic Ingdal Granite Gneiss with flat foliation and strong lineation. The Ingdal granite was first mapped and described by Ramberg (1943). Later Tucker (1986) has mapped and classified it into three types, that all are thought to represent facies of a single intrusive body: fine-grained gneiss, medium- to coarse-grained gneiss, and a porphyritic variety. The Ingdal granite is a microcline-rich granitic gneiss with a characteristic red colour. In contrast to most of the gneisses in the Baltica basement, which are migmatitic, this is not. The Ingdal granite (or rocks that are very similar to it) occur over a large area in the basement both north and south of the Trondheimsfjord. Tucker and Krogh (1988) have studied the geochemistry and geochronology. They report a U-Pb age based on zircon and titanite of 1653±2 Ma from a rock collected across the fjord which is interpreted to represent the emplacement of the granite (Fig. 14). A lower intercept of 396±5 Ma is interpreted as the cooling of zircon and titanite below their blocking temperatures during the Scandian metamorphism.

17:00	**10**	-	-	Leave STOP 15. Turn right just away from shore on different gravel road.
17:03	3	192.8	1.8	Return to 717. Turn right toward Rørvik Ferry.
17:06	3	194.8	2.0	Statsbygd Junction. Sharp right for Trondheim.
17:08	2	196.9	2.1	Road cuts in Seve Nappe.
17:13	5	201.8	4.9	Rørvik Ferry (Ferries at 16:05, 16:40, 17:15, 18:25, 19:00). Outcrop lies near shore on north side of ferry terminal.

STOP 16: (??? minutes) Seve garnet amphibolite. If time permits we can examine another typical rock type in the Seve Nappe; This is a dark green relatively coarse-grained amphibolite with some felsic layers. Garnets up to 1cm across are common both in the amphibolite and in the felsite. The rocks are interpreted to be of volcanic origin. Note that this outcrop does not agree precisely with contacts shown on the geologic map, and was probably not exposed during mapping.

17:15	**2**	202.1	0.3	Enter ferry.
17:40	25	-	-	Leave ferry at Flakk.
17:42	2	203.0	0.9	Junction. End road log. Turn left on 715 and drive through middle of Trondheim with drop-offs at hotels..
18:02	20	-	-	End of trip at NGU.

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