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Talc deposits in Norway

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REPORT

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Talc deposits in Norway
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Summary:

Information about talc and soapstone deposits registered in NGU's different databases and various available literature have been collected and described in the present report. Around 400 deposits/occurrences are known, but the detail of the available information varies widely. By reading old field-books as well as old manuscript maps, etc., dating as far back as A.D. 1758, quite a lot of data has been found. The result of the work shows that most described talc in Norway is of ultramafic origin and is associated with serpentinites. The most common mineral association is talc + breunnerite. Different talc-provinces can be defined from the registered and non-registered data, the most important being Nord-Gudbrandsdalen, Altermark and Stølsheimen. While Altermark and Stølsheimen have been investigated in some detail with respect to talc as an industrial mineral, the Nord-Gudbrandsdalen talc province has been investigated both for milling talc and for soapstone used as dimension stone. Deposits that are probably extensive, but have so far not been investigated in detail, include the Lesjehorrungane deposits in the Nord-Gudbrandsdalen region and the Raudfjellet deposit in Nord-Trøndelag. The fractionated metakomatiites (pale green talc-chlorite rocks) of the southern part of the Palaeo-proterozoic Karasjok Greenstone Belt in Finnmark, northern Norway, possibly represents, by far, the largest accumulations of talc in Norway. These rocks are recently mapped, for the first time, but other critical information is, however, very scarce.

Keywords: Industrimineraler	Kleberstein	□
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Talk	□	Fagrapport

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1. INTRODUCTION

The present report is an overview of material within the databases and archives at the Geological Survey of Norway (NGU) per 1999. The work is financed by NGU and Norwegian Talc AS. A large number of talc-bearing rocks occur in Norway. Common for most of them is an ultramafic origin; only very few deposits of probable non-ultramafic origin have been encountered. Talc-bearing rocks are of interest for two major applications: 1) as an industrial mineral, and 2) as a dimension stone. For this reason, such rocks have been treated both by dimension-stone geologists and industrial-mineral geologists. As a result, the relevant data on the deposits has therefore been placed either in the dimension stone data base or in the industrial mineral data base.

Norway has a long tradition in quarrying talc-rocks. Before and during the Viking age soapstone was quarried for making cooking vessels, sinkers and weight for fishing lines and nets, spindle whorls etc (Fig. 1). Later it has also been quarried as a dimension stone for the use in church buildings, e.g. the Nidaros Cathedral. According to Skjelsvik (1989) old soapstone quarries exist in all counties in Norway, except for Vest-Agder and Vestfold. The main reason behind this early use was the ease of extraction and reworking of the material with simple equipment. Many old quarries are today protected because of the presence of heritage relics.

In the present report, the focus has been on presenting overviews for each of the counties. The intention of the present work has been to give an overview of talc in Norway and to facilitate the rapid location of the most interesting deposits and provinces. For more detailed information the reader is referred to the reference lists which follow the treatment of each county.

1.1 Sources of information

The data and information presented in this report have been collected from the following sources:

- NGU's database on industrial minerals
- NGU's database on natural stone (dimension stone)
- NGU Library reference data base
- NGU-Bergarkivet (old report archive within the NGU Library)
- NGU-Kartarkivet (the manuscript map and field diary archive at the Geological department, section for bedrock mapping)
- Published reports, journal papers, monographs, geological maps, etc.
- Unpublished field-diary notes, geological manuscript maps, etc.
- NGU's sample collection (both at NGU Trondheim and at Løkken)

In addition some information have been given to us by the courtesy of Mr. Gunnar Lee, Norwegian Talc AS, curator Eystein Jansen, Geological Museum, University of Bergen, and some information from the county geologist in Hordaland, Mr. Jomar Ragnhildstveit.

1.2 Historical uses of talc

Talc-rich rocks have been used by mankind for a long time. For example, cooking pots made of soapstone, a massive, talc rich rock, were made for as early as 1500 years ago (Garmo 1983). In the Viking age, pans were made from soapstone at several places in Norway, e.g. Sparbu in North-Trøndelag, Oppdal in South Trøndelag (Alnæs 1990). In Altermark, chimneys were made from soapstone from the 1600's up to the 1930's. Other historical uses of soapstone include lamps, weaving stones and gravestones. In the 11^{th}, 12^{th}, and 13^{th} centuries soapstone was used in the construction of many churches (Alnæs 1990).

Today, the most common use of talc is as a constituent in the following products (Brown 1973): ceramics, paper, plastics, rubber, paints, fertilisers, insecticides, pharmaceuticals and cosmetics. It is also used in more specialised products such as polish for rice, nails, white shoes, dusting powder for salami, roofing, car bodies, steel. A more comprehensive description of the many uses of talc has been given by Harben & Bates (1990). Norwegian industrial talc-products are used mainly in the paint industry. However, small amounts are also used in a great number of other purposes, e.g. fertiliser (by A/S Granite/Handøla Talc/Norsk Hydro).

1.3 Talc - the mineral

The mineral talc is a hydrous magnesium silicate with the theoretical formula $\mathbf{Mg_3Si_4O_{10}(OH)_2}$.

The mineral is a tri-octahedral mineral, belonging to the phyllosilicate-family (Deer et al. 1992). It has a perfect cleavage along the {001}-plane, which leads to a flaky habit. The interlayer bonding is very weak and the mineral has a very low hardness (1 on Mohs scale).

Talc has a pearly lustre and feels greasy. It is usually colourless or has a white, grey, pale to dark green, or pale red colour. In spite of these colours, talc becomes white when crushed to powder.

1.4 Type of deposits and their geneses

Worldwide, there are two types of talc deposits are of economic importance (Prochaska 1989):

1. **Ultramafite associated deposits**
2. **Mg-carbonate associated deposits**

Both ultramafites and dolomite/dolomitic marble occur frequently in metamorphic terranes. Deposits of industrial talc therefore exist in many parts of the world. In a mineralogical sense, talc is exploited from numerous types of ore, and the meaning of the sales-name "talc" is not always consistent with the mineralogical meaning of "talc" (Fig. 2; Karlsen 1995).

A common feature of many of the reported talc-rich rocks is their association with geological structures such as thrusts, faults, joints, shear zones and also with intrusions cross-cutting dolomitic marbles or serpentinites. Metasomatic alteration, governed by hydrothermal fluids, played important roles during the talcification process which led to formation of the talc-rich deposits.

Carbonate-associated deposits:

Talc-rich rocks formed from reactions between dolomite and silica are found in both regional metamorphic and contact metamorphic regimes. The following reactions were given by Prochaska (1989);

$$3\ CaMg(CO_3)_2 + 4\ SiO_2 + H_2O \rightarrow Mg_3Si_4O_{10}(OH)_2 + 3\ CaCO_3 + 3\ CO_2$$
Dolomite — Talc — Calcite

and

$$3\ CaMg(CO_3)_2 + 4\ SiO_2 + 6\ HCl \rightarrow Mg_3Si_4O_{10}(OH)_2 + 3\ CaCl_2 + 2\ H_2CO_3 + 4\ CO_2$$
Dolomite — Talc

When dolomitic marble has been intruded by granites, diabases etc., the contact metamorphic talcification can produce sizeable bodies of high-purity talc (Harben & Bates 1990).

As mentioned by Brown (1973), talc, commonly together with serpentine, can also be formed by the retrograde metamorphism of high temperature mineral assemblages including minerals such as tremolite, forsterite and diopside. This retrograde talc, formed during late stages of regional metamorphism, is the most widespread in USA according to Brown (1973). Talc derived from dolomite often has a chemical compostion close to the theoretical composition of talc, i.e. high content of Mg, and low content of Fe.

Ultramafite associated deposits:

Two types of processes are distinguished in the formation of talc rich rocks from ultramafites:
1. Metasomatic reactions between serpentinite and an introduced CO_2-bearing fluid.
   - Producing an ore dominated by a mixture of about equal amounts of talc and carbonate.
   - Such deposits are mainly associated with regionally metamorphic terranes.
   - The talc-rich rocks occur as rims around, or in shear zones within, serpentinites, or as solitary bodies which have totally replaced serpentinites. The serpentinites are usually associated with thrust faults in rocks of sedimentary or volcanic origin.

   The following reaction is suitable to explain the genesis (Sanford 1982):

   $$Serpentinite + 3\ CO_2 \rightarrow Talc + 3\ Magnesite/breunnerite$$

2. Metamorphic reactions between serpentinite and the surrounding country rocks.
   - Produce an ore dominated by talc (Brown 1973).

They are associated with either regional metamorphism (as above) or contact metamorphism caused by late intrusions.

Talc derived from ultramafic rocks, commonly carries quantities of Fe and Ni and, to a smaller extent, Cr in the lattice (Karlsen 1995).

Talc mined in Norway is derived from ultramafic bodies. Deposits from metamorphosed limestones are not known, though two deposits described in the present report might belong to this type.

A common mineral assemblage of the Norwegian deposits is 45 - 60 % talc, 35 - 50 % carbonate (usually breunnerite and magnesite), 0 - 5 % magnetite and 0 - 2 % chlorite. The abundance of carbonates shows that these deposits are metasomatic in origin, where CO_2 has been introduced to the bodies (process 1 above).

1.5 Definitions of common terms

Soapstone: A massive, soft talc-rich rock suitable for sawing, etc.

Steatite: a nearly monomineralic talc-rock with less than 1.5 wt-% each of CaO and Fe_2O_3, and less than 4 % Al_2O_3 (Harben & Bates 1990). It meets certain specifications for ceramic insulation bodies (Chidester et al. 1964, Harben & Bates 1990).

Steatitisation/talcification: Formation of talc-rich rocks.

Ultramafite: A rock consisting of ≥ 90% mafic minerals, for example serpentine, chlorite, amphibole, pyroxene, talc, olivine.

Ophiolite: A fragment of oceanic crust plus possible adjoining parts of the

underlying uppermost mantle that has been transported from its site of origin onto continental rocks, by orogenic processes.

1.6 Geological setting

The bedrock geology of Norway is dominated by igneous and metamorphic rocks, and three different suites can be defined (Fig. 3):

1) Precambrian basement complexes which form part of the Fennoscandian Shield
2) Nappe complexes, mainly metamorphic rocks, forming part of the Caledonian Mountain Belt
3) Late Carboniferous-Permian igneous rocks of the Oslo Graben

The Precambrian complexes
The bedrock geology of the Nordic countries (except Denmark) is dominated by a Precambrian basement complex, the Fennoscandian Shield. A succession of orogenic cycles (mountain building episodes) between 3500(?) and 900 Ma ago, constructed this resistant shield, forming a single block which extends from the Atlantic to the Urals. In early Precambrian times this formed part of the Pangaean supercontinent.

The Nappe complexes
The Nappe complexes, or the Caledonides, were formed by an orogeny (mountain building episode) that resulted from the closing of the Iapetus Ocean situated west of the Fennoscandian shield. During this orogeny, which culminated c. 420-430 million years ago, complex sequences of nappes were transported eastwards and emplaced onto the Fennoscandian Shield. The nappes were made up of sediments, volcanic materials and igneous rocks. Included in the nappes were remnants of ocean floor defining the former Iapetus Ocean. Such remnants of ocean floor, now situated within the nappes in Norway, are termed ophiolites. Many of the talc-deposits described in this report occur within such ophiolite fragments.

1.7 Classification of Norwegian talc deposits and talc bearing deposits

Based on the data collected for the present report the talc deposits and other mineral deposits where talc may constitute an important by-product can be classified into different groups, according to their rock associations. Between the groups listed there are both mineralogical and chemical differences. A documentation of these differences is, however, beyond the scope of the present work, and it will need some additional work to make a firm conclusion here. For the future understanding of Norwegian talc deposits this will, however, be of value, as will an adequate understanding of the geographic distribution of the different types.

The Norwegian talc deposits and talc bearing deposits (Fig. 4) can be classified as follows:

Talc and talc-carbonate dominated deposits:

A. Talc and talc-carbonate dominated deposits associated with alpine-type ultramafic/mafic complexes including ophiolite fragments

1. Talc-carbonate deposits associated with compositionally zoned metamorphosed solitary ultramafic lenses
    - Example: Altermark
2. Talc and talc-carbonate dominated deposits associated with the ultramafic parts of ophiolites and/or their erosional derivatives
    - Example: Åsårlia, NW of Otta, Nord-Gudbrandsdalen
3. Talc-carbonate dominated deposits possibly associated with ophiolitic metabasaltic lavas(?)
    - Klungen, Melhus, Sør-Trøndelag

B. Talc-carbonate dominated deposits associated with Early Precambrian ultramafic magmatism (Mg rich metakomatiitic lavas and dikes)
    - Example: Straumdalen, Langfjord (Sør-Varanger)

C. Talc-carbonate dominated deposits with an unknown precursor (Mid Proterozoic mafic/ultramafic dikes or lavas?)
    - Example: most of the deposits in Østfold and Akershus counties

D. *Talc-carbonate dominated deposits associated with gabbroic intrusions*
    - Example: Stolpelia, Misvær

E. *Dolomite associated talc or talc-carbonate deposits*

- Example: Nordland deposit in Rogaland (?)

Talc bearing deposits where talc may constitute an economic by-product:

F. Talc associated with massive sulphide deposits as a gangue mineral or in the wall rock assemblage

- Example: several Zn-Cu ore bodies in Folldal, Hedmark

G. Talc associated with hyperite hosted phosphate deposits where talc occurs both as a gangue mineral and in the wall rock assemblage

- Example: Ødegården, Bamble, Telemark

Most of the deposits described are of the types A1 and A2; others are appreciably more seldom.

1.8 Ultramafic rocks

Most of the talc-deposits in Norway are derived from ultramafic rocks. Per definition, ultramafic rocks consist of 90% or more of mafic (i.e. dark-coloured) minerals such as pyroxene, serpentine, amphibole, olivine, talc etc.

Originally, the ultramafic rocks are dunites, peridotites, or pyroxenites. Serpentinites and talc-bearing rocks are the alteration products of minerals within the primary ultramafic rocks formed by intrusion of a magma. Normally, serpentinisation is the first step in alteration, and lead to the formation of rocks consisting primarily of the mineral serpentine. In the process of serpentinisation, H_2O is added to the rock, and the primary minerals like olivine and pyroxene are transformed to serpentine-minerals. Three different serpentine minerals are common: antigorite, lizardite and chrysotile. These species are characterised by having different crystal shapes. Chrysotile is in most cases fibrous and is normally asbestiform. Chrysotile stands for around 95 % of the world production of asbestos. Antigorite is not fibrous and has a platy habit. Chrysotile and antigorite are formed under different pressure/temperature environment: chrysotile is common at lower temperatures and is often associated with the first alteration of ultramafic rocks. Antigorite is formed at higher pressures and temperatures and is a typical mineral formed during regional metamorphism. It is the most common serpentine species in ultramafic lenses in Norway.

Talc is stable at higher temperatures than antigorite, and serpentinites are commonly transformed to talc during progressive metamorphism. Carbonates like magnesite and breunnerite often occur together with talc. A pre-requisite for the formation of such carbonates is that CO_2 has been accessible from the metamorphic fluid.

There are several types of origin for talc-bearing ultramafic rocks;

1. Alpine-type ultramafic lenses where the traces of origin have been overprinted/obliterated by later deformation
2. Ultramafic rocks of ophiolitic origin.

In the first category, the talc-rocks commonly occur at the rim of concentrical zoned lenses, which contain serpentinite in the core. In the second category, the talc rocks occuring either within concentrical zoned lenses, within shear-zones of the ultramafic complex, and/or within ultramafic conglomerates formed by surface weathering of the ophiolite and subsequent deposition of detritus.

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2. FINNMARK

2.1 General introduction

The talc/soapstone potential in Finnmark, which covers an area of around 48000 km^2, has been little investigated. In the NGU-IMDS databases, 12 registered occurrences are spread over the entire county. In addition, the NGU Library reference database contains three references. The information in the various databases and referred literature contain very little about the talc/soapstone *potential* in Finnmark county.

Unlike the rest of Norway, Finnmark has extensive areas of Palaeoproterozoic and Archaean gneiss-greenstone belt terranes (Siedlecka & Roberts 1996). The various terranes occupy the peneplaned low mountain plateau to the south of the Caledonides plus a few tectonic windows within the Caledonides. With respect to talc/soapstone, the Mg-rich (i.e. cumulate) parts of komatiites and picrites, or their intrusive equivalents, are potentially the most interesting rocks, and are important constituents of the greenstone belts. The belts carry strong overburden over much of the Finnmarksvidda plateau and Syd-Varanger/Pasvik district. Outcrops are in general scarce, and outcrops of easily eroded rocks, like soapstone, etc., are very rare. Most talc/soapstone deposits are therefore probably to be found under lakes, bogs, marshes, etc.

Geological maps

Today prospecting on Finnmarkvidda is at a very low level due to fundamental and extensive conflicts with regard to the ownership/management and use of the land. The map basis, however, is much better today than only a decade ago. It is now possible to make much better target selection by comparing and contrasting the various map compilations from the Norwegian as well as the bordering Finnish and Russian sides. In addition to the 1:500,000 map of Finnmark county (Siedlecka & Roberts1996), NGU have recently issued several 1:250,000 scale and a large number of 1:50,000 scale maps based mainly on the Finnmark project (1982-1992). On the Finnish side there is a new 1:1 mill. map of the country plus many maps at various scales from Finnish Lapland. Deposit information from Finland will serve to tell exactly where in the greenstone belt stratigraphy and in what kind of rocks the talc/soapstone occurrences are hosted. The Kola Peninsula is also covered by a recently updated 1:500,000 scale map (Mitrofanov 1994).

In general the talc/soapstone deposits in Finnmark can be divided into two categories:

1) Precambrian deposits
   - Mainly associated by ultramafic extrusive rocks such as komatiite
   - This is the dominant group of talc rocks in Finnmark
2) Caledonian deposits
   - Some few deposits probably associated by gabbros and by Precambrian komatiite occurring in allochthonous position.

2.2 Talc/soapstone occurrences the Precambrian of eastern Finnmark (Sør-Varanger)

Talc/soapstone deposits in the Sør-Varanger district have been known for a long time, and prehistoric pottery is documented from one of the deposits ("Straumdalen deposit", Iversen 1990).

The deposits "Straumdalen", "Kjøøya" and "Sør-Leirvåg", see Fig. 5 for location, are three deposits all occurring in close association with the large and pronounced morphological lineament "Langfjord Fault" or "Langfjord Fracture Zone" (LFZ). This runs towards S o SSE from the southern side of the Varanger Fjord just SE of Bugøynes (Reusch 1892).

The Langfjord lineament may be interpreted as a large Late Archaean (?) fracture zone, subsequently reactivated, probably more than once. The protoliths for the Kjøøya, Sør-Leirvåg and Straumdalen talc/soapstone occurrences are, at least partly, Mg-rich komatiite flows (Straumdalen) or dikes (Sør-Leirvåg and Kjøøya). At Straumdalen, the ultramafic extrusives occur conformably within a basaltic (amphibolitic) sequence belonging to the Late Archaean Bjørnevatn Group (Iversen & Nilsson 1991, Iversen 1990, fig.9, etc.). The extent of talcification clearly increases over a 1 km distance from the east (mostly serpentinite) to the west where talc-rich soapstone can be seen in small quarries close to the fjord, i.e. close to the LFZ which follows the fjord (studied by LPN in 1994). Field relations of the two other occurrences are virtually unknown.

The LFZ is by far the most important zone for localisation of talc/ soapstone in Eastern Finnmark. Therefore, the bogs between Strand and Svanvik in the south (Dervajågi-Strandmyran-Grasmyra), and the bog covered isthmus between Sør-Leirvåg and Nord-Leirvåg on Skogerøya in the north may be possible targets for future prospecting.

The LFZ is further mostly covered by the Høybuktmoen Quaternary plateau between Korsfjorden (Kristinebukta) and Langfjorden (Straumsbukta). Prospecting is here unlikely or impossible due to the generally thick glaciofluvial plain and the proximity to the Høybuktmoen airport, etc.

Kjøøya
The Kjøøya occurrence is the northernmost of the three deposits and is localised to the island Kjøøya just SE of Bugøynes.

Wanvik (1985) briefly treats the talc/soapstone occurrences in a review report. He did not visit Kjøøya, but quotes unpublished information from S. Bakke (NGU) who visited the small island in 1982. There are two small occurrences of good quality, green and attractive soapstone. According to a local 'expert' *there are potentially larger deposits within the district* (this must be on the mainland as Kjøøya is only c. 0.4 km^2 in area). According to the map sheet Kirkenes (1:250 000) (Siedlecka & Nordgulen 1996) the talc/soapstone occurrence on Kjøøya is situated within tonalitic to granodioritic orthogneisses (TTG gneisses), far away from the nearest metasedimentary sequences. The soapstone occurrence therefore most probably represents a talcified komatiitic dyke.

Sør-Leirvåg
The deposit is localised to the fjord Sør-Leirvåg at the Island of Skogerøya.
Wanvik (1985) refers to the deposit list of Poulsen (1945), but does not give any details. The talc/soapstone locality is most probably situated within TTG orthogneisses (Siedlecka & Nordgulen 1996) and the protolith therefore probably is also a komatiittic dyke. The terrain is

strongly overburdened in the actual area. S. Føyn (manuscript map) mapped a c. 3 km long ultramafic ("amphibolite or serpentinite") dike running parallel to the Langfjord lineament (defined by the small fjords Nord-Leirvåg and Sør-Leirvåg) and situated 2 km to the ENE of this (Føyn 1937/38).

Straumdalen (Vardhaugen)
The deposit is localised not far from the northern end of Langfjord.
The occurrence was visited in 1994 by one of the present authors (LPN) and the following is mostly taken from the field diary:
There appear to be several minor overburdened pits scattered in the terrain, though the main worked occurrence is in an isolated field, with approximate size of 150 x 40 m, of talcified komatiite situated close to the sea (Iversen 1990, fig.9 and Iversen & Nilsson 1991). Soapstone, however, is also located nearly 900 m farther east, on the main komatiite branch. The komatiite is highly magnetic with a 100-200x susceptibility contrast with the enclosing amphibolites. Generally there are fairly sharp borders between komatiite and amphibolite, though occasionally they are transitional. In such cases, there is a passage, over c. 2 - 4 m, from basic amphibolite through ultramafic amphibolite (hornblendite) to moderately altered pyroxenite into serpentinised or talcified komatiite.

The main quarry is located at an elevation of 10-15 m in the steepest part of a knoll. The vertical inner wall is 5-6 m high and c. 4 m wide. Estimated quarried volume is only c. 10 m^3, and on the sea shore lies a 2-3 m^3 quarried block. The soapstone zone dips 60° - 70° to the south. Some 10 m south of the main quarry another working point in good quality soapstone occurs. Further, c. 35-40 m north of the quarry, and at the same altitude is a minor working with an inner wall 8-10 m wide x 2 m high. Only small blocks were worked here (possibly sinkers for fishing nets, and other items for local use) totalling not more than 2-4 m^3. Some 30 m north there is another small working. The total distance in which soapstone quarrying occurred is some 70–80 m (N-S). Along this zone there are parts with only partly talcified komatiite together with amphibolite and hornblendite. *The soapstone, everywhere where quarried, is, however, a massive, homogeneous, light talc-rich pot-stone with some carbonate and apparently little or no chlorite.* No microscope investigations have yet been performed. Lastly it should be mentioned that the Straumdalen and *Langfjorden* occurrences of Sverdrup (1969, p.9,10 and map enclosure) probably represent the same zone. The Langfjorden occurrence (no. 43), plotted on Sverdrup's map, on the peninsula between the outer part of Langfjorden and Korsfjorden does not appear to exist, and the only confirmed occurrence is on Hamnebuktfjell.

Hamnebuktfjell:

This occurrence, also shown in Fig. 5, is situated within or at the border of amphibolite (metabasalt) (Iversen & Nilsson 1991) and possibly represents a komatiitic flow. The occurrence was not localised during reconnaissance by Wanvik (1985), nor mentioned in the Høybuktmoen map sheet description (Iversen 1990), and is probably quite insignificant.

Though the above Late Archean komatiite derived talc/soapstone occurrences are quite insignificant by volume, as are the komatiites themselves (covering only c. 1 km^2 or less in area) (Iversen & Nilsson 1991, Iversen & Krill 1990), they represent a distinctive and hitherto non-investigated type among Norwegian talc/soapstone occurrences. The komatiites seem to be clearly different (e.g. in average richer in Mg) from the volumetrically more important Karasjok komatiites (Siedlecka & Roberts 1996) which are basically chlorite–amphibole rocks.

2.3 Finnmarksvidda (Karasjok greenstone belt)

The meta-komatiites in the Palaeoproterozoic Karasjok Greenstone Belt are, in terms of volume, the largest in Norway, covering some 80 km^2 (Barnes & Often 1990). They have invariably a metamorphic mineral assemblage of Mg-chlorite + tremolite ± antigorite ± carbonate ± olivine (Henriksen 1983, p.25), though more rarely serpentinised or talcified komatiites occur. There is an extensive literature on the Karasjok komatiites, especially stemming from the NGU Finnmark programme (1982-1992). During this period the whole greenstone belt was mapped at 1:50 000 scale. The most important references which might be useful in any future evaluation of the talc/soapstone potential are listed:

- Geological publications dealing with Karasjok komatiites: Wennervirta 1969, Henriksen 1983, Often 1985, Krill 1985, Barnes & Often 1990, Davidsen 1994.
- Combined geophysical-geological reports and publications: Midtun 1986, 1987, 1988, Nilsson 1988.
- maps covering areas with Karasjok komatiites:
  Often & Krill 1986, Krill & Often 1986, Nilsen 1986a,b, Henriksen 1984, Nilsson 1987, Siedlecka 1987, Roberts & Davidsen 1992, Roberts & Rice 1990, Skålvoll, 1972, Olsen & Siedlecka 1996, Siedlecka & Roberts 1996.

Rievdnesvadda (=Rievdnjesvadda)

This talc/soapstone occurrence is situated close to the main road E-6 between Lakselv and Karasjok, in a small komatiite flow near the western margin of the Karasjok Greenstone Belt, see Fig. 6 for location, (Skålvoll 1972, Henriksen 1984, Nilsson 1987, Midtun 1987).

The Rivdnjesvadda komatiite is essentially a serpentinised rock with some chlorite and hence, an anomalously Mg rich flow for the Karasjok belt, where most of the komatiites are chlorite-amphibole rocks as mentioned above.

The Rievdnjesvadda talc/soapstone occurrence(s) is probably located on or close to the margin of the ultramafic body, though no details are available. The occurrence itself is in the name list of Poulsen (1945), although the NGU IMDS database does not refer to any reports. No information is available about size and ore quality.

Assebakte

The word Assebakte is lappish and means *soapstone mountain/hill* according to Friis (in Helland 1893, p.149). Helland concludes that soapstone probably occurs in this place, but he gives no additional information. The NGU IM/NS database co-ordinates plot 1.0 km to the SE of the small tarn Assebakjav'rit, or c. 3 km to the SE of the place Assebakte, hence the name of the occurrence. Both the place and the tarn are situated on map sheet 2033-4 Iesjåkka (unpublished geological m/s map only), while the soapstone occurrence itself is situated on map sheet Karasjok (Nilsen 1986a), near the western margin of the map. The occurrence is further shown on the map of Skålvoll (1972), see Fig. 6.

The Bakkilvarri komatiite was first mapped by Wennervirta (1969), and in greater detail by Nilsen (1986a). In addition, the combined geophysical-geological reports and publication give valuable information on the distribution of the highly magnetic komatiite contrasting

neighbouring low magnetic amphibolite (metabasalt) and metasediments in this heavily overburdened terrain (Midtun 1986, p.22, etc., Midtun 1988, Nilsson 1988).

The reason for an occurrence of talc/soapstone or partly talcified, impure serpentinite, must be a local (?) enrichment of Mg in the thickest parts of the komatiite, perhaps proximal to the feeder channel(s). This is indicated by Wennervirta (1969, p.152-153), who reports metamorphic olivine in the rock, locally so abundant that it represents the main mineral in the komatiite. According to Wennervita, olivine (i.e. metamorphic olivine) is otherwise only locally present in the Karasjok komatiites. The reported variations in MgO contents in the Karasjok komatiites are generally large (21-35wt-%; Henriksen 1983, p.28-29), (18-37wt-%; Often 1985, p.81).

Talc/soapstone occurrences may be present also other places within or along the margins of the Mg richest parts of the Bakkilvarre komatiite. The potential is little known due to the thick Quaternary overburden. Ground geophysics (magnetic profiling) is the best tool to locate the margins of the komatiite and possible talc/soapstone deposits.

Guorbmet luobbal

The Guorbmet luobbal talc/soapstone, according to the IM/NS database occurs near the western shore of the lake Guorbmet luobbal (UTM 373/217), see Fig. 6, although it is not shown on the map-sheet Iddjajavri (Henriksen 1984). It may be speculated that the occurrence represents a continuation of the Gallujavrri ultramafic intrusion, which according to Henriksen runs into lake Guorbmet luobbal from the north. Geophysical maps, however, show that the highly magnetic intrusion bends orthogonaly to the east already about a km north of the lake (Midtun 1987, map 1, 3 and 6, etc.), and further indicate that the southern end of Henriksen's Gallujavrri intrusion is a separate minor intrusion.

This also applies to the talc/soapstone occurrence which is situated near the southern end of a 750 m long (N-S) magnetic band in nonmagnetic psammites, i. e. a small separate ultramafic intrusion.

According to the IM/NS database a few reports dealing with the occurrence should exist, but in spite of considerable efforts (223 NGU publications, NGU reports and NGU Bergarkivet reports checked by title, author(s), location, year, etc.) none have yet emerged.

2.4 Southern areas of the Karasjok Greenstone Belt

In the southern parts of the Karasjok belt, on map sheet Inari, 1:250 000 (Olsen & Siedlecka 1996), there are extensive areas of komatiites altered to pale green talc-chlorite rocks. The location, distribution and size of these rocks, which belong to the stratigraphically lowermost komatiites of the Gållebaiki Formation (Olsen & Siedlecka 1996), is shown in Fig. 7. So far, however, there are no written communications on these rocks in addition to the short description printed on the map. This descibes the actual metakomatiites as "white-spotted due to talc in the western areas of the map sheet", i.e. komatiites bordering or situated close the quartzites of the Skuvvanvarri Formation.

It should be noted that alone from studying the 1:250,000 map sheet Inari, these mainly talc-chlorite rocks, seem, possibly, to represent the largest accumulations of talc-rich, or talc

enriched, rocks in Norway as a whole, cf. Fig. 7. Individual zones/units have strike lengths of up to c. 10 km or more and outcropping widths up to 750 m. These rocks may therefore be totally unparalleled as raw material for talc with regard to size. The largest individual zone/unit is situated along the river Bavtajohka, north of the Anarjokka national park, whereas the remaining occurrences of this komatiite type are situated within the national park (Fig.7) and therefore not actual for prospecting.

A very rough tonnage estimate for the largest zone down to a depth of 100m would give: 10 000 x 750/2 x 100 = 375 Mill. M^3, or c. ***1Billion tons.***

If we assume that the rock in average contains 25 % talc and 75 % chlorite this means c. 250 Mill. tonnes of talc in-situ down to a depth of 100m. The talc grade may well in average be lower than this, but possibly locally also significantly higher where the protolith eventually has been an olivine rich cumulate.

So far this must be concidered as speculations and "playing with numbers", but the numbers are so high that the actual area certainly warrants a reconnaisance investigation to confirm or adjust the impression of vast tonnages and possibly also high grades.

Such an investigation will, however, in turn, quickly direct one in to the centre of the on-going debate on the management of both the "core-areas" of Lappish land in the inner parts of Finnmark in particular and in Norway as a whole in general.

The actual rocks probably belong to a group of fractionated komatiites, which is now well known on the neighbouring Finnish side of the border through the work of a research group from Turku University, Finland during the period 1992-1998, led by Prof. Heikki Papunen. The Pulja Belt and Hotinvaara area were among the key locations during these studies (H. Papunen. oral comm., Dec. 1999). These komatiites differs significantly in composition from the mainly non-fractionated and also well studied komatiites occurring farther north within the Karasjok Greenstone Belt (cf. Barnes & Often 1990, Often 1985). In the section of the 1:250 000 map sheet Inari shown in Fig. 7, the non-fractionated metakomatiites are shown as rock unit no. 12a and is characterised petrographically as a metamorphic amphibole-chlorite-olivine rock.

2.5 Finnmarksvidda (Kautokeino greenstone belt)

According to the IMDS database and NGU Library Reference database there are no talc/soapstone occurrences within the Kautokeino Greenstone Belt. There might, however, still be several occurrences scattered around, though komatiites are much less abundant in the Kautokeino belt compared to the Karasjok belt.

There is for example an occurrence of soapstone in the northern part of the *Vir'dnegiellasat* area (116/260) on map sheet *Suoluvuobmi* (Zwaan 1985). The occurrence is situated within a c. 250x700m large area of strongly sheared and talcified ultramafic rocks (Zwaan, pers. comm. 1999). Also 1 km to the SE of the occurrence, and 2.5 km to the SSE, respectively, there are strongly altered ultramafic intrusives according to Zwaan.

Further north, and close to the Alta river canyon (100/345), there are talc-chlorite schists of probable komatiitic origin.

In the south-western part of the Kautokeino belt there are also reports of talcified rocks. At the contact between a granitic rock and amphibolite, 4.5 km N of *Raisjavrre* a talc-serpentine rock has been found by Gjelsvik according to Holmsen et al. (1957, p.76).

2.6 Repparfjord - (Komagfjord) tectonic window

Vesterdalen and Beritsjord

In Vesterdalen and at Beritsjord, near Kvalsund *very talc rich schists* have been observed by Reitan (1963, p61). The schists are undoubtedly connected with reverse faults common in the valleys in this area according to Reitan who further recommends an investigation of their economic potential.

The actual occurrences belong to the volcanite dominated Nussir Group, a unit which occupies a significant portion of the window (Siedlecka & Roberts 1996).

Pharaoh (1985) reports laterally persistent ultramafic tuffs altered to serpentine schists or serpentinous tuffs (max 17 wt-% MgO) within the type area of the Nussir Group in the eastern part of the window (see also Roberts 1998 for location). Talcified ultramafic volcanics, however, seem to be sparse or absent in the type area. The ultramafic tuff horizons can be followed some 15 km further to the SW into the Porsa area as serpentine schists, but the ultramafics are not talcified (Nilsen & Nilsson 1996). The talcified rocks are probably therefore restricted to the most tectonically affected areas of the Nussir Group closest to the coast where Reitan made his observations.

2.7 Alta-Kvænangen tectonic window

There are both komatiites and ultramafic intrusions in the Alta-Kvænangen Tectonic Window, but to the authors' knowledge there are no known associated talc/soapstone occurrences.

2.8 Caledonian talc/soapstone occurrences in Finnmark

Vollstranda

The occurrence *Vollstranda* situated on the western side of Altafjord near the point where Altafjorden and Langfjorden meet. The occurrence has been known for a long time and is mentioned by Helland (1893, p149). According to the map sheet Hammerfest 1:250,000 (Roberts 1973) Vollstranda is situated in the Kalak Nappe Complex in garnet amphibole gneiss or gneissified, garnet-bearing psammite with amphibolite layers. The talc/soapstone is probably associated with the amphibolites. There is no information on the occurrence in the IMDS database nor in the Reference database.

Kunes

According to the IMDS database there are three talc occurrences at *Kunes* in Adamsfjord, but there are, however, no reports referred to.

When consulting the map sheet Adamsfjord 1:50,000 (Føyn et al. 1983) two of the three occurrences are apparently situated in "granitic and dioritic gneiss" (possibly TTG gneiss?) belonging to the Lower Laksefjord Nappe (a tectonic, allochthonous basement window). The last one is situated in a metagabbroic dike cutting the above gneisses. A komatiitic dike should therefore be a plausible guess for the origin of the protolith within these mainly felsic orthogneisses.

Kjelvik

According to the IMDS database there is a talc/soapstone occurrence at *Kjelvik* on the easternmost part of Magerøy, and there exists one or a few reports dealing with the occurrence according to the IMDS database.

The occurrence appears to be hosted in a unit of alternating metasediments (phyllite and siltstone), but an association with a minor gabbroic body belonging to the magmatic Honningsvåg Suite, a body not shown on the 1:50,000 map Skarsvåg (Roberts 1990), can not be ruled out. The distribution of metasediment hosted minor gabbroic bodies in the surroundings of the IMDS database co-ordinates favour the latter possibility. According to Roberts (1981) the occurrence is of insignificant scale.

Kongelvika

Sverdrup (1969, p.9) lists two densely spaced occurrences of talc/soapstone at *Kongelvika* on the point between Ryggefjorden and Kobbfjorden in Måsøy municipality. There are no other reports dealing with the occurrences according to the IMDS database. According to map sheet Honningsvåg 1:250,000 (Roberts 1998) the talc/soapstone occurs in a large area of various apparently Archean to Palaeoproterozoic gneisses. A komatiitic dike therefore seems to be a plausible protolith in this case too.

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3. TROMS

Troms is one of three counties where soapstone/talc presently is quarried on a regular basis. In Bardu, a soapstone quarry is exploited by the company Kleber AS. Examples of older exploitation of soapstone in Troms have been described by Sandmo (1997) and Bøe (1999).

3.1 Balsfjord municipality

Deposits associated by the Lyngen Ophiolite. No further information is available.

3.2 Bardu municipality

Steien soapstone and serpentinite deposit

Mapsheet Bardu 1432 I, coordinates 395425 7640705 (WGS84)
Locality: 400m due north of Øvre Steien farm, see Fig. 11.

According to Andreassen (1994) the rock is talc and chlorite bearing over an area of several square km. The composition is reported as highly variable, and the rock is strongly schistose in some places. Above the deposit, there is a schist containing serpentine and amphibole. The deposit is strongly overburdened. The deposits were visited by Gautneb in 1999 and is heavily covered by overburden. Its approximate size is 100 x 100 meters. Test quarrying of soapstone has been performed at several localities. Nidaros chatedral has also investigated the deposits for use in renovation. However, the soapstone was regarded as too densly cracked to be of interest. Gautneb (in prep) obtained the following brightness values:

FMX 54.,2 %
FMY 54,4%
FMZ 51.,4 %
R457 51.1 %

All measurements were made on the 60 to 140 mesh fraction after crushing.

3.3 Gratangen municipality

Lavika serpentine deposit

Mapsheet Gratangen 1432 III, coordinates. 986 277 (ED 50).

An ultramafic lens consisting mostly of serpentinite and metamorphic olivine (Karlsen 1988), but also small amounts of soapstone also occur at Lavika in Gratangen, see Fig 11. Minor quarrying has taken place. The lens is around 200 x 600 m and minimum 80 m thick. The soapstone often occurs as lenses within the serpentinite body according to Andreassen (1994). Kjølle & Lund (1999) concluded that the deposit has very limited potential for soapstone/dimension stone and is not regarded as a potential source of talc.

3.4 Lyngen municipality

Russelv soapstone deposit

Mapsheet Lyngstuva 1634 IV, coord. 704 587 (WGS 84)

Two small deposits are known and are localised in the Russelv river valley, see Fig 8. According to the description by Andreassen (1994) the deposits have no economic interest for soapstone production. This conclusion was also made by Hatling et al. (1971).

Serpentinite deposits at **Lyngseidet**

Altogether four deposits of serpentinite occur at the area around Lyngseidet (Andreassen 1994):
Rødberg in Kjosen
Mapsheet Lyngen 1634 III, coord. 626 195 (WGS 84)

Two small deposits just north-west of Lyngseidet
Mapsheet Lyngen 1634 III, coord. 7140 1960 (WGS 84)

A small deposit occurs at Klubbneset close to Lyngspollen
Mapsheet Storjord 1633 IV, coord. 6865 0520 (WGS 84)

None of these have reported talc, but the first mentioned deposit is large and could be evaluated further for talc. Kjølle & Lund (1999), who investigated the potential for dimension stone, concluded that the Rødberg is sizable and seems interesting, but the locality is unfavourable and the block size too small.

3.5 Målselv municipality

Grunneset soapstone deposit

Mapsheet Lenvik 1433 I, coord. 031 857 (WGS 84), see also Fig 9 for location.

The deposit, which covers an area of 250 x 300 m, has earlier been quarried for soapstone delivered to the Nidaros Cathedral in Trondheim (Mortenson 1965, Andreassen 1994). Nowadays, the company Kleber AS exploits the deposit. The deposit is described by Sverdrup (1962), Wiik et al. (1962), Vasshaug (1963), Mortenson (1965), Thorkildsen (1967), Andreassen (1994), Søvegjarto (1996a) and Kjølle & Lund (1999).

According to Wiik et al., the average mineralogical composition of the soapstone is 20% amphibole, 42% chlorite, 20% talc, 13% magnesite and 5% pyrrhotite. The low content of talc and the high content of amphibole make this deposit to be of very limited interest as a filler as the following brightness numbers clearly show (Gautneb in prep.):

FMX 40.7 %
FMY 41.3 %
FMZ 40.2 %
R457 40.2 %

All measurements were made on the 60 to 140 mesh fraction after crushing.

Møllerhaugen (=Nyborg) soapstone deposit

Mapsheet Målselv 1433 II, coord. 9785 7765 (ED 50), see also Fig 9 for location.
Soapstone of poor quality (for dimension stone) is located to ca. 1 km from the road towards Møllerhaugen (Andreassen 1994). The soapstone occurs as layers and lenses within a mica-rich schist.

Kleberberget soapstone deposit, Tillermoen

Mapped by Søvegjarto (1996b). No further information is available.

3.6 Sørreisa municipality

Nyeng (=Sørstraumen) soapstone deposit

Mapsheet Målselv 1433 II, coord. 386691/7671826 (WGS84), see also Fig. 9 for location.

The deposit has earlier been quarried for dimension stone to the restoring of Nidaros Cathedral. According to Gautneb (pers. comm.) the rock is medium- to coarse-grained and has a blue-greenish colour. The content of talc is rather high, and occasionally schlieren of almost pure talc occur. The deposit has a size of 80 x 30 meters. The visible part of the deposit is small, because of glacial overburden. The deposit is situated apporximately 1.5 km to the SW of Sørreisa church. Soapstone from this deposit was regarded as unsuitable for use in the Cathedral restauration, and, in addition, the talc content was concidered to be too low for milling according to Hatling et al. (1971). Presently the deposit is protected for any kind of exploitation, even sampling, due to its archaeological relics, and is part of a series of "tourist occurrences" called "fotefar mot nord" ("footpaths towards the north"). Gautneb (in prep.) has recently performed brightness measurements:

FMX 54.2 %
FMY 54.4 %
FMZ 51.4 %
R457 51.5 %

All measurements were made on the 60 to 140 mesh fraction after crushing.

Brokskardet soapstone and talc-deposit

Mapsheet Tussøy 1434 II, coord. 0425 1370 (WGS 84).
The deposit is reached by a walking 300 meters upwards along the rivers

Brokskardelv/Svarthullbekken, see Fig 9. Because the deposit is covered by overburden, it is difficult to get an overview of the size and geometry of the deposit (Andreassen 1994). According to Andreassen (1994), the rock has a variable composition, but locally it contains more than 80 % talc. There are also localities with small amounts of talc, and serpentine dominates. The soapstone, when observed, is too soft for dimension stone use but the high content of talc makes it interesting for filler uses (Andreassen 1994). Gautneb visited the deposits in 1999. The size was estimated to 100x100 meters. Brightness was measuered as follows:

FMX 66.4%
FMY 64.4%
FMZ 50.2%

R457 50.3%

All measurements on 60 to 140 mesh grainsize after crushing and removal of magnetic fraction by permroll separator

Finnhaugen soapstone deposit

The deposit has been visited and evaluated by Kjølle & Lund (1999) as a dimension stone. The result was negative.

3.7 Additional deposits

According to Helland (1893) soapstone occurs at the island Hinnøya. It has earlier been used at the Trondenes Cathedral. Similar rocks also occur at Sørstrøm in "Reisenfjord". Soapstone from this locality has been used for fishing sinkers.

Poulsen (1945) lists one additional deposit: Gullerfjord in Kvæfjord, but no description is given.

The deposit situated on the island Hinnøya, mentioned both by Helland and Poulsen, is probably the occurrence at Hemmestad shown in Fig. 10, whereas the occurrence at "Sørstrøm" must be the same as the Nyeng (=Sørstraumen) deposit in Sørreisa municipality.

3.8 Talc associated with massive Zn-Cu sulphide deposits

According to Lindahl (1981) the Rieppe massive Cu-Zn sulphide deposit in the in Nordreisa municipality in northern Troms contains some 10 % talc in average in the gangue. The Rieppe deposit belongs to the Caledonian Vaddas-Rieppe field of massive sulphide deposits. Dressing tests on the massive ore showed that talc had to be removed by flotation before the sulphides could be properly recovered from the ore. Therefore talc was concidered as a possible by-product to copper and zinc, and test scale talc concentrates were made. These contained at best up to 60-75 % talc according to semi-quantitative XRD-analyses made.

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4. NORDLAND

In Nordland, there are quite a large number of ultramafic lenses present in the two dominant nappe complexes: the Helgeland- and Rödingsfjället Nappe Complexes (HNC and RNC respectively).

Nordland has the only talc-mine in Norway in regular production, being located at Altermark, where the largest known deposits in Nordland occur. The talc deposits in Altermark, together with nearby deposits, define what has been termed the "Altermark talc province" (Karlsen et al. 1999a).

In addition to the deposits in the Altermark talc province, several deposits of soapstone as dimension stone are known. Most of these have been investigated by NGU and are described below. All registered talc occurrences in Nordland are associated with ultramafic lenses. The ultramafic lenses occur rather widespread throughout the country; many of them have not been investigated for their talc potential.

4.1 Tysfjord and Ballangen municipalities

Talc occurrences situated on map sheet Tysfjord (1:100 000) (Foslie 1931) in Tysfjord and Ballangen municipalities have been described by Foslie (1941), see Fig. 12 for location. Most of these occurrences are associated with minor serpentinite lenses, while one is associated with a mafic dike. The size of the serpentinite lenses varies from very small (<100 m^2) up to 40 000 m^2 according to Foslie (1941), who also registered that small lenses can be completely talcified, while the bigger ones always have a core of serpentinite, etc. The partly or totally talcified ultramafic lenses occurring within map sheet Tysfjord (1:100 000) are as follows according to Foslie (1941):

Name/location	size (m^2)	degree of talcification	comments
Ballangen municipality:			
1. Rauvassaksla	2400	total	two adjacent lenses
2. W of lake N. Bukkevatn	100	total	
3. N ridge of Filtind	25000	partial	mainly hornblende gabbro
4. S of Rånvassbotn	4500	partial	
5. W of lake Isvatn	1000	partial	
6. N of lake Langvatn	800	partial	
7. Rauvassaksla	400	partial	
8. W of lake N. Bukkevatn	400	partial	
9. S end of lake Geitvatn	100	partial	
Tysfjord municipality:			
10. SE end of lake Baugevatn	700	total	
11. Hesjetuva, Indre Tysfjord	7000?	partial	
12. NW of lake Fonnvatn	5000	partial	
13. Nikkaknausen	500	partial	

With regard to *no. 1* listed above, both of the two lenses are totally talcified, the larger measures c. 50 x 40 m.

The large and mainly hornblende gabbroic dike on Filtind, *no. 3* above, is 600 m long and 70 m wide. Here extensive zones of magnesite bearing talc schists are developed, especially along the footwall contact.

No. 11 Hesjetuva (also called "Sørfjorden") is situated only 400 m from the sea, at about 400 m above sea level. This lens has been visited by dimension stone experts from the Nidaros Cathedral a few years before 1940, but they did not find the stone suitable for their use. Hesjetuva was later visited by Hultin (1970) and subsequently by one of us (LPN) in 1978. Microscopic study of one of the 1978-samples shows a relatively fine-grained talc-carbonate rock composed of breunnerite (50-60 vol. %), talc (30-40 %) and magnetite (3-5 %).

No. 12 at the 898 m tarn, NW of lake Fonnvatn is 50 m wide and strongly talcified.

From the above it can be concluded that several of the ultramafic lenses listed may be interesting as raw material for talc. The mineral assemblage is mostly talc-magnesite-(tremolite)+/-(chlorite) plus minor disseminated oxides. The remote location of the deposits in wild mountainous terrain, however, is probably a decisive negative factor, and applies equally to practically all the listed deposits. Taken into account the rather limited size of the ultramafic lenses and hence their talc-carbonate mineralisations, the area as a whole would therefore probably have limited interest in talc prospecting.

4.2 Hamarøy municipality

In the municipality of Hamarøy, close to the Swedish border, there are large ultramafic-mafic bodies, probably representing remnants of a large ophiolite sheet, see Fig. 13 for location. The actual area, which has been mapped and described by Foslie (1942), continues with large ultramafic bodies on the Swedish side of the border where it has been mapped and described by Kautsky (1953). According to Foslie (loc. cit. p. 71, 75, 77 and map) there are three separate areas with large bodies of ultramafic rock, Ridoalkecåkka, Mellomfjell and the 903 m hill WNW of Mellomfjell. In addition there are several smaller bodies NW of the 903 m hill. In the following, short summaries are given, based on Foslies descriptions.

Ridoalkecåkka
There are two parallel, broad belts of serpentinite in the NE slopes of the mountain Ridoalkecåkka, and these run into Sweden. Both belts are extensively talcified along their northern margins. The northern belt is 3.5 km long and up to 700 m wide, the southern one only slightly thinner. The two belts merge in the west and constitute a corresponding level in an open synform.

Mellomfjell
On the Norwegian side of the border a 700 x 1200 m portion of an 8 km long and up to nearly 2 km wide serpentinite lens is exposed. The serpentinite lens, consisting mainly of antigorite with minor carbonates shows variable talcification in the form of veins and irregular portions. Exploitable talc was not, however, observed by Foslie.

903 m hill NW of Mellomfjell

In the 903 m hill in the SW slopes of the mountain Snjaskavarre there is a 400 x 1200 m large serpentinite lens. This resembles the lens in Mellomfjell. In the SW border zone, the lens is strongly talcified, partly as a network of talc-carbonate veins, but mainly as a thoroughly altered soft mass of talc and carbonate. The serpentinite carries abundant magnetite and relics of coarse tremolite needles.

Bortijavrri area

Some 400 m due E of the small lake Bortijavrri (752 m), there is a small and talcified serpentinite knoll. Another, similarly talcified, about 200 m long ultramafic lens occurs c. 1.5 km NW of the 903 m hill, between the 903 m hill and lake Bortijavrri. In the same area there are additional talcified ultramafic bodies which, however, were too small to be placed on the map.

It may be concluded that the ultramafic bodies in this area may possibly have a significant talc potential. However, they remain very little investigated. The area is covered by a modern 1:50,000 scale geological map (Brattli & Prestvik 1987) accompanied by a short published description (Brattli & Prestvik 1988). In spite of the very remote location, situated in wild mountainous terrain, the ultramafic bodies, and hence the talc-carbonate mineralisations, have such extensive dimensions that they definitely warrant a reconnaissance Survey. From Lake Bortijavrri to the nearest road in the NW (the road ends at the hydroelectric dam at the western end of lake Reinoksvatnet) it is a distance of 5 km as the crow flies. From the most remotely spaced location, border post 244A on the S limb of the Ridoalkecåkka ultramafic body, the distance to the same dam is 15 km.

4.3 Rana municipality and the Altermark talc province

The Altermark talc province, Fig. 15, includes the deposits located in Altermark, in Straumdalen, and in Kvanndalen. The geological setting of the Altermark area and deposit characteristics are described in detail by Karlsen (1995). The limits of the province to E and N is not known, while the Kvanndalen deposit (Karlsen et al. 1999a) probably defines the western boundary. Further to the west the metamorphism has been too high, and the ultramafites are dominated by enstatite and olivine (Karlsen et al. 1999a).

In the Altermark area, several big deposits occur within the Straumbotn Nappe (Søvegjarto et al. 1988), which is a part of the RNC, according to Gustavson & Gjelle (1991). The rocks are frequently folded by at least three deformational events, and a large scale fold (the Slettefjellet fold) is a dominant structure of the second generation folds. Peak metamorphism reached amphibolite facies during the second deformation event, close to the upper stability field of talc-carbonate (Karlsen 1995).

The talc-deposits in Altermark are all situated around, or are closely connected with, serpentinites, which dominate the up to 1 km long ultramafic lenses. The lenses are prograde zoned, containing antigoritic serpentinite in the core followed by talc-carbonate in the rim, and so-called "Blackwall rocks" (monomineralic chloritite, biotitite, smaragditite and

epidotite) at the boundary towards the country rocks. The ultramafic lenses are closely associated by amphibolite, which in some cases defines parts of mafic/ultramafic complexes.

In all the deposits in the Altermark area, the ore is defined by about equal amounts of talc and carbonate, while chlorite and magnetite, as well as local serpentine occur in trace amounts. The carbonate is compositionally zoned breunnerites with Mg-rich cores and increasing Fe/Mg ratio towards the rim.

In the following, only a short overview is given, based on the work by Karlsen (1995).

Altermark talc mine

The Altermark talc mine has been a major Norwegian supplier of talc since around 1934. The mine has been mined from four different levels. Despite that the mine is located close to the big ultramafic lens termed "Annabergan", only limited amounts of mining have taken place along this body. Instead, most of the mining has taken place further to the N, at talc bodies associated by several smaller ultramafic lenses.
Estimation of tonnages were given by Karlsen (1995). More updated information from the mining company indicates that the proven reserves of the mine are approximately 150,000 tonnes, probable resources 300,000, and possible resources 460,000 tonnes (Karlsen et al. in prep.).

Store Esjeklumpen

Store Esjeklumpen is an 800 m long and up to 180 m thick exposed ultramafite situated approximately 3 km SW of the present mine. The ultramafite is dominated by serpentinite, while talc-carbonate ore is exposed locally outside the serpentinite core. The occurrence of talc-carbonate ore was already known in the 1930's, when a small shaft was driven in the SW part of the ultramafic body. In 1990-1991, two diamond core-drilling programs were established by Norwegian Talc Altermark AS (Edvin Rian) to investigate the dimensions of the ore. The first programme formed the basis of a Civ. Eng. civil engineer (Holter 1990). The second programme was included in a doctoral thesis by Karlsen (1995), but is otherwise reported in internal reports by E. Rian and T.A. Karlsen. A total of 3,720 m was drilled in 1990-1991. Although quite a lot of drill-core information is lacking, an estimated tonnage of around 2.5 M tonnes, including both proven, probable and possible resources, is a quite realistic estimate.

Nakkan

The Nakkan deposit was found by airborne geophysics (Mogaard & Walker 1991), magnetic modelling (Karlsen & Olesen 1992, 1996) and subsequent diamond core drilling in 1991-1992 (Karlsen 1995). The minimum distance from Store Esjeklumpen is around 150 m, while the distance from the existing mine is around 3 km. As for the other talc-deposits in the area, the talc ore is situated as a rim around the serpentinitic core, but also within big joints that cut the serpentinite.
The upper parts of the Nakkan ultramafite have been investigated by drilling in 1992, 1996, 1997, 1998 and 1999 with a total sum of 163,10 m (E. Rian, pers. comm.). The lower levels have not been investigated. It is possible that the Nakkan ultramafite contains around 6 M tonnes of ore (Karlsen et al. in prep.). See also Karlsen (1995, 1996, 1997, 1999) for further information.

Lille Esjeklumpen

As in the case of the Store Esjeklumpen ultramafite, the talc-carbonate ore is exposed also around the Lille Esjeklumpen ultramafite. Though not investigated by drilling, there are no reasons to believe that this body does not contain talc-carbonate ore at the depth. It is probably rather similar to Store Esjeklumpen and Nakkan. Magnetic modelling (Karlsen & Olesen 1997) indicates that the magnetic body has a limited depth beneath the surface (<150 m). An exposure of talc-carbonate has also been found by the mining company (Edvin Rian) along strike, W of Lille Esjeklumpen. Even if the talc occurrence probably does not contain mineable reserves, it represents positive supports for the economic potential of the Lille Esjeklumpen-Straumdalen area.

Lille & Store Raussantind

The Lille & Store Rausanntind are two small (< 100 m wide) bodies of serpentine located around 700 m west of the present mine. Talc occurs in the rim around the bodies. Exposures are found on the eastern side of both bodies. Diamond drilling has recently been carried out by Norwegian Talc Altermark AS.

Rota

At "Rota", there is a small exposure of talc-carbonate. Magnetic ground measurments carried out by TAK/Norwegian Talc Altermark AS in 1991 indicated that no large serpentinite was associated with this deposit, inferring that it is a minor one. Previous drilling by Norwegian Talc AS has indicated that some limited amounts of talc exists at depth.

Langvannet

At Langvannet an old working exists within a talc-carbonate ore. Magnetic ground measurements carried out by TAK/Norwegian Talc Altermark AS, and diamond core drilling in 1991 proved that the amounts of ore is very limited.

Straumdalen, west of Altermark

A small exposure of talc-carbonate exists, and prospecting work was carried out by Holter (1990)/Norwegian Talc AS in 1990. Relatively large amounts of talc were found, but the deposit is probably sub-economic due to the location far from access roads and due to the negative topography. See Holter (1990) for details.

Kvanndalen, west of Altermark

The Kvanndalen deposit was found during talc prospecting in 1998 and is described by Karlsen et al. (1999 a, b). The deposit, which probably defines the W boundary of the Altermark talc province (Karlsen et al. 1999a), actually consists of three narrow small ultramafic lenses being separated by country rocks (Dalsegg 1999). The lenses occur at a similar tectonostratigraphical level as the Store & Lille Esjeklumpen and Nakkan in the Altermark area. Closely associated rocks are amphibolite and calcite-bearing rocks, as well as mica schists. The mineralogy of the ore is somewhat different than that of Altermark, since olivine is the dominant mineral in addition to talc and carbonate. Also, magnetite seems to

occur in slightly higher amounts that in the typical Altermark ore. The talc itself is rather idioblastic and coarse-grained, and could be a saleable product if it was posible to remove the other components (Karlsen et al. 1999a,b).

4.4 Skjerstad municipality

Stolpelia, Misvær

Locality: N of the farm named Stolpe in the Misvær valley, see Fig. 14.
Small pit in soapstone. According to Wennberg (1959) the deposit, which occurs within a gabbro, can be traced more than 200 m. The width is 20-30 m. The pit seems to have a length around 30 – 40 m and a width around 20 m. The soapstone is fine-grained and apparently of rather good quality. It contains much talc and little magnesite, but is rich in pyrite and contains some chlorite (Karlsen et al. 1999a). The deposit has been investigated by drilling by NGU (Lund 1986a, 1986b). It is possible that the deposit has been protected because of the existence of heritage relicts.

Misvær 2

A talc rock occurs around a large body of serpentinite (Karlsen et al. 1999a); see fig. 14 for location. The talc zone is found to be 8-10 m thick at one locality. At another locality it is only a few dm. Microscopic investigations of samples taken across the 8-10 m thick zone show that the ore contains talc, chlorite and amphibole. The content of amphibole makes this part of the ore uninteresting for exploitation.

Klette soapstone deposit, Skjerstad

Locality: 2-3 km N of Misvær chapel. According to Wennberg (1959), who investigated the deposit for dimension stone/soapstone purposes, the deposit has a variable soapstone quality. It represents an altered olivine-gabbro.

Høgset soapstone deposit, Skjerstad

Locality: unknown in 1992, but described by Wennberg (1959). According to Wennberg (1959) the deposit has a variable quality and contains asbestos and tremolite.

Djuposen soapstone deposit, Valnesfjord, Skjerstad

The deposit is described by Wennberg (1959) and the location is shown in Fig. 14. According to the author the deposit has some similarities to the Stolpelia deposit.

Skjerstad

Frigstad (1975) describes two areas of soapstone that are 80 x 40 m and 300 x 80 m, respectively. The soapstone is described as a thin layer, possibly 5-10 m thick, cored by serpentinite. As a dimension stone the quality is pore, as it is rich in sulphide and carbonate,

and as it has a pore weathering resistance. Because of fractures, it is not possible to produce blocks.

4.5 Hattfjelldal municipality

Ørjedalen soapstone deposit, Hattfjelldal

According to Nissen (1966) the deposit is around 250 m long (east-west direction) and has a maximum width of 40 m. The deposit makes a lensoid layer located above a greenschist which dips towards SW. The thickness of the soapstone, which is somewhat folded, is around 7 m. To the E, smaller quantities have been quarried. The thickness of good quality soapstone is less than 1 m.

4.6 Vefsn municipality

Bjørnålia, Mosjøen

Old soapstone-quarry: 100 m long, 50 m wide and 30 m deep; see Fig. 16 for location. The soapstone and the quarry occur along the western border of a serpentinite that continues 3-400 m towards S; altogether the ultramafic lens is around 600 m long. The soapstone is dark coloured and fine-grained. Microscopic investigation indicates that the soapstone is composed of chlorite and amphibole, while talc only occurs in very minor amounts (see Karlsen et al. 1999a,b for further details).

4.7 Hemnes municipality

Leirskarddalen

An old pit around 10 m and 2 m deep in soapstone/talc-carbonate, see Fig. 15 for location. The soapstone has probably been used for ovens, according to Helland (1893). The soapstone deposit is apparently rather small. The soapstone is a light coloured talc-carbonate rock that is rather similar to the Altermark type, with carbonates up to 2 cm big. Unfortunately, the rock contains fibrous amphibole in addition to talc and carbonate (Karlsen et al. 1999a).

4.8 Rødøy & Meløy municipalities

A great number of ultramafic lenses occur in these municipalities. A reconnaissance field study of the coastal area by Karlsen et al. (1999a) concluded that talc occurs rather seldom and in rather small amounts. The reason for this is that the metamorphic grade has been too high to stabilise the mineral assemblage talc + carbonate. Dominant mineralogy are enstatite

and olivine in various amounts, while sagvandites containing dominated by pyroxene and breunnerite occur in more eastern parts. In some cases talc occurs together with pyroxene and breunnerite, especially in the rim of zoned ultramafic lenses.

Lemstein, Ramskardet in Melfjord

Reconnaisannce work by Karlsen et al. (1999a) indicates that at least parts of the ultramafite at Ramskardet contains around 30% talc in addition to breunnerite/magnesite (~ 40%) and enstatite (~30%).

Hellarvika, Melfjord

A relatively coarse-grained magnesite-talc-enstatite lens, with an approximate width of 30 m and unknown length is located to Hellarvika (Karlsen et al. 1999a) in Melfjord.

Esjeholmene

Zoned ultramafite with talc-carbonate-enstatite in the rim and serpentinite in the core. The core is intruded by a vein of fine-grained white talc-carbonate rock with a thickness of 1-2 m (Karlsen et al. 1999a).

4.9 Alstahaug municipality – the Outer Vefsnfjord soapstone province

On many of the islands in the outer parts of Vefsnfjord, old soapstone quarries from the Middle Age are present, see Fig. 17 for location. In the present report this area is referred to as the Outer Vefsnfjord soapstone province. The soapstone was used as fishing sinkers, pans and ovens, according to Berglund (1999), who give an excellent overview of the historical parts and location of the quarries.

Geological setting

On the islands of Røøy and Haltøy talc rocks have been reported by Bang (1985). The talc is derived from ultramafic rocks.

Four geological main units are present in this area:
Røøy Nappe (uppermost unit)
Trolandet Group
Røøy Igneous Complex
The Flatøy Group
The Husvika Group
Intrusive granitoids (lowermost unit)

The Røøy Nappe is a thrust unit situated above the Husvika Group and, when present, the Flatøy Group. Within the Røøy Nappe the ultramafic/mafic rocks have been recognised to be parts of an ophiolite and is termed the Røøy Igneous Complex, RIC (Bang 1985); the RIC consists of several types of ultramafic bodies as well as gabbros. The ultramafic bodies consist of harzburgite with lenses and dikes of dunite and dikes of pyroxenite. A complex of layered and static gabbros is associated with the ultramafic rocks. Brecciated serpentinite

occur at the boundary between the ultramafites and the layered gabbro. More massive serpentinites occur along shear zones.

The RIC forms the basement for the Trolandet Group, which consists of conglomerates, schistose marbles and metapelites. The conglomerates include clasts derived from the underlying ophiolite. Four deformation events have been recognised, D_1–D_4, where the peak metamorphism (epidote-amphibolite facies) was interkinematic D_1-D_2. Talc-schists and soapstones occur along various shear zones in the Røøy/Haltøy area, generally between the serpentinites, or ultramafic fragments, and the underlying metasedimentary rocks. The talc-rocks are associated with D_2-thrusts.

Lauvøylandet talc deposits

Quarries and mines of soapstone from the Middle Age are known from several places at Lauvøylandet, including those located at the farms Remman, Haugen, Skavollen and Tro according to Berglund (1999) (Fig. 17).

Bang (1985) reports a talc-schist from Trolandet; the talc-schist is 1-2 m thick at the crossroad with the coordinates X869165, Y31090. Along the strike towards S, the talc-schist crops out several places with thicknesses 0-4 m to the coordinate point X868805 Y31210. It is not clear how this observation fits with the quarry/deposit – locations described by Berglund (1999) below. The talc rock consists of 60-80% talc and various amounts of serpentine, actinolite, carbonate, opaque minerals and olivine, according to Bang (1985).

Remman soapstone mine: According to Berglund (1999) a soapstone mine was opened at Remman in the year 1300 BC, and approximately 60 m^3 was exploited during a period of 300 years. The soapstone was primarily used for pans. Nearby, another quarry of soapstone exists which contains traces of younger exploitation. No data is available on the mineralogy or size of the deposit.

Haugen soapstone deposits
Six old workings or quarries are located to the farm Haugen according to Berglund (1999). Traces of pans and sinkers have been found. No data is available on the mineralogy and size of the deposit.

Skavollen soapstone deposits

Tro soapstone deposit: A small old working (pans) is located to a steep hillside ca. 15 m from the sea-side (Berglund 1999).

Røøya soapstone deposits: On the island of Røøy several smaller old workings are known, and two such workings were registered in 1977 (Berglund 1999).

Flatøya soapstone deposits. On the island of Flatøya there exist to smaller old workings with traces of pans (Berglund 1999).

Haltøy

On the island of Haltøy, 8 soapstone pits are known, located within the innermost parts of the bay of Trongvika. The biggest pit contains a 2-4 m wide and 25 m long ditch. This pit is called Hørtnaustan. The pits were mined for pans, but one of the pits was mined for the use in ovens as late as around 1930 (Berglund 1999).

According to Bang (1985), the soapstones are in contact with pelites belonging to the Trolandet Group. The soapstone is almost identical to that of Røøy/Trolandet, but are more coarse-grained. The size of this occurrence is not known.

Esøya

A soapstone quarry was located to the island of Esøya. From this deposit soapstone was mined for the use in the Middle Age church at Tjøtta (Berglund 1999). The deposit was visited by Karlsen (1991); the remains of the soapstone is in general not exposed due to the excavation, but on the hillsides the asocciated chloritite rock is visible. The potential as a talc-resource is very low due to small size. Just N of this soapstone quarry, on another very small island, another old quarry is present.

4.10 Brønnøy municipality

Stor-Esjeøya

Two pits were pans were made are located to this island, outside "Torget" (Berglund 1999). No further information of interest is available.

Nevernes, Velfjord

A talc-carbonate rock is located to the rim of a big serpentinised ultramafite. No detailed information exists.

Sømnes

A deposit of soapstone where pans were made is located to Sømnes (Berglund 1999). No further information of interest is available.

Vik

Another pan-locality is located to just N of the community of Vik, alomg Riksvei 17 (Berglund 1999). No further information of interest is available.

Mohaugen soapstone deposit, Arnes, Sømna community

A small soapstone deposit termed Mohaugen soapstone deposit, with reserves of 1500 – 2000 tonnes, is descibed by Heldal (1996). The deposit, which is located to Mohaugen at Arnes, is associated with one of several smaller serpentinite lenses in the area. The mineralogical content is as follows: talc (ca. 40%), antigorite (ca. 40%), carbonate (10–15%), chlorite, amphibole, and opaques.

4.11 Additional deposits

Poulsen (1945) mentions the following additional deposits:

Forvik, Tjøtta
Hessihompa, Saltdalen (see Fig. 14).
Fiskkjønmo, N. Rana
Steinhaugen, Drevja
Vikdal, Vefsn

Additional information from dimension stone data base:

Hellarvik, Sørfold (see Fig. 13)
Nyleng-Drosåsen, Skjerstad
Skardhamran, Skjerstad
Yttralia, Rana (see Fig. 15)
Ørfjellryggen, Saltdal (see Fig. 14)

Helland (1893) mentions the following occurrence:

Kolle, between Sømnæsbugten og Bindalsfjorden

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5. NORD-TRØNDELAG

Talc is known from several places in Nord-Trøndelag. Most, if not all, of the known occurrences are hosted within ophiolites. In the west, the well studied Leka ophiolite complex occurs with associated talc deposits on the island of Leka. In the east, ophiolite fragments occur mainly between the Seve and Køli main tectonostratigraphic level, e.g. the Raufjellet deposit in Snåsa, and the Sparbu deposits south of Steinkjer.

5.1 Steinkjer municipality

Sparbu talc-deposits

Talc-carbonate deposits from the Sparbu area in the Steinkjer municipality (Slipsteinsberget, Smulstuen and Bakaunberget) are well described by Mortensen (1973), (see Fig 21A-E for locations and details):

Common features for these deposits are that they all occur within zoned ultramafic lenses within the Gula Schist Group, which is otherwise composed of mica-schists, bitumeneous schists, metamorphosed sandstone, amphibolite and gabbro.

The zoning patterns of the ultramafic lenses are rather similar to zoned ultramafic lenses at Altermark in Nordland. They contain serpentinite in the core, surrounded by talc-carbonate-chlorite rocks and talc-schist. The talc-carbonate ore contains Fe-bearing talc and breunnerite as the primary minerals, and chlorite, magnetite and small amounts of sulphide as accessories and trace minerals. In addition, aggregates of coarsely crystalline smaragdite are found locally within the ore.

In addition to the deposit data given below, it should be mentioned that A/S Lilleberg Verk and Mortenson did some pioneer work on mineral processing; as early as 1938 the company built a test plant with a 75 kW melt-oven for melting of talc and serpentine under reducing conditions. The results were technically good, and a slag made up of Fe-free Mg-silicate as well as a product of metallic Fe with Ni, Co and Cr, were made. Unfortunately, the melt-oven burned down, and because of the war, no attempts were made to restart production.

At the same time a flotation plant were built, in order to separate talc, chlorite and magnesite, with following magnetic separation of magnetite from the magnesite concentrate. First, the talc and chlorite were separated from magnesite. Afterwards, the talc and chlorite were separated in another flotation circuit. From the chlorite a product termed 'gylden-talcum' (golden talc) were made. According to Mortenson (1973), all the products were of high quality, but unfortunately, the plant was destroyed without being fully brought on stream, at the beginning of World War II.

Slipsteinsberget

This deposit belongs to the second largest serpentinite massif identified in Sparbu (cf. Roberts 1997b). The ultramafic lens has an almost spherical outcrop and is approximately 170 –200 m in diameter (Fig. 21B). The deposit has a long exploitation tradition: pots of soapstone were made during the Viking era. Based on the size of the waste material, Mortenson (1973) inferred that 9000 – 18000 pots were made, partly for export. Nowadays, the Slipsteinsberget ultramafite is exploited for serpentinite as dimension stone. The talc-rocks are located to the

rim of the ultramafic lens, which is primarily composed of antigoritic serpentine. Mortenson (1973) gives the following numbers for the size of the different layers:

Chloritite: 0.1 – 1 m
Talc-schist: a few cm to 1 m
Talc-magnesite: 2 to 15-20 m

The main mineralogical content in the talc-magnesite rock is given above and in Fig. 21C. In addition, it can be mentioned that the sulphide concentrate consists of pyrrhotite and pentlandite, with an overall content of 0.7 % Co and 9.5 % Ni. The total Ni-content in the talc-zone is approximately 0.18-0.22 %, which is somewhat less than in the Altermark deposits. The size of remaining reserves of talc-rocks in the deposit is not known.

Smulstuen talc deposit

The deposit is located to Smulberget, west of Slipsteinsberget and around 300 m west of the rail-track, see Fig 21A for location and Fig 21E for details. The talc-zone is associated with a serpentinic lens as well as massive amphibolite and olivine-gabbro. Most of serpentinite has been altered to talc-magnesite. The talc-deposit lies almost horizontally. Mineralogical content and structure are identical with the deposit at Slipsteinsberget, according to Mortenson (1973). The tonnage of exploited material and reserves is not known.

Bakaunberget olivine-serpentinite lens

Despite a comparable geological setting as the Slipsteinsberget and Smulstuen ultramafic lenses, talc mineralisation has not been encountered here (Mortenson 1973). See Fig. 21A for location of the lens.

5.2 Leka municipality

Hundøyran talc-magnesite deposit, Leka.

The deposit is situated on the island of Leka in Nord-Trøndelag, Fig 18, within the Leka ophiolite complex (Prestvik 1980). The deposit was investigated by NGU in 1990 in a co-operation between NGU and Norwegian Talc AS. A total of 600 m were drilled in six holes (Olerud 1990). Two large horizontal lenses were detected. The "Upper lens" has an average thickness of 6.6 m and a probable tonnage of 0.89 M tonnes. The ore is very fine-grained and consists of talc (~50 %), breunnerite (~44%), chlorite (~2-5 %) and chromite/ferrite-chromite (~2-3 %). The whiteness of milled products is in general < 70 %, while smaller areas have whiteness up to around 75%.

5.3 Snåsa municipality

Raudfjellet (Snåsa) - Verdalsfjellene

The large *Raudfjellet ophiolite fragment* (c. 2x7 km) together with several minor ultramafic ophiolitic bodies along a 15 km distance to the SW of Raudfjellet (Fig. 20) have been mapped, described and sampled by State geologist S. Foslie in the years 1933-35. In addition to the valuable sample collection, Foslie's field diaries contain a wealth of relevant information, also with regard to occurrence of talc/soapstone. The very valuable field

material, kept in the NGU Archives, was never published, but by the time of his death in 1951 Foslie had compiled 8 manuscript maps covering most of the Grong district and neighbouring areas to the south, in scale 1:100 000, ready for printing. All 8 map sheets were published by NGU in the years 1957-1960. The map sheets Jævsjøen (Foslie 1959a) and Bjørkvassklumpen (Foslie 1959b) cover the actual area along the national border.

In his field diary for 1934, vol. I, p. 117, Foslie reports about "very wide talcified zones, though always impure with abundant carbonates" near the gabbro/serpentinite border of the Raudfjellet body (see Foslie 1959a). In other places in his 1934 field diary (e.g. in vol. I, p121), he reports about "outcrops of a lot of variably talcified serpentinite" in the same body. From Foslie's field diaries and accompanying sample collection, one can imagine large amounts of talc-rich soapstone outcropping along the gabbro/serpentinite border of the Raudfjellet body.

More recently, the Raudfjellet body has been remapped by the Swedish geologists S. Bergman and H. Sjöström as part of the general mapping and compilation of map sheet Gjevsjøen, 1:50,000 (Sjöström & Roberts 1992). There are, however, no written communications on their observations and interpretations. Bergman & Sjöström, however, were probably the first to recognise the Raudfjellet body as an ophiolite fragment.

Because of a planned very large extension of the Gressåmoen National Park which will include both Raudfjellet and several other ultramafic bodies, the land manager, Statskog (=the Norwegian forest administration), is currently undertaking an investigation of the economic potential of that part of their land areas which will fall within the boundaries of the new national park, (cf. information on this work in the Steinkjer-based newspaper *Trønder-Avisa*, 6. and 7. July 1999).

5.4 Lierne municipality

Nordli (areas south of Murusjøen)
Foslie located and mapped some 50 ultramafic bodies on map sheet Nordli 1:100 000 (Foslie 1959c). A few of larger bodies are shown in Fig. 19. These bodies are much smaller than the Raudfjellet body. The largest one, ***south Skograudberget*** has an irregular outcrop measuring c. 450 x 450 m. Occurrences of talc/soapstone may occur in the border zone of this body. It should be mentioned here that a very detailed study of the ultramafite rich Muruhatten – Lillfjellet area, located some 1 – 2 km on to the Swedish side of the national border north of lake Murusjøen, has been conducted as part of a Ph.D. thesis (Du Riez 1935). The Muruhatten body is mapped and investigated in great detail, and Du Riez (loc. cit. p 170-71) has e.g. located soapstone widths here up to c. 8 m. The soapstone is in general rich in talc (an analysis showed 92.6 % talc), and the mineral assemblage is chlorite and talc or actinolite and talc. Carbonates rarely occurs in the soapstones along the margins of the Muruhatten body. The Muruhatten study has direct relevance to the long line of ultramafic bodies in the Kvesjøen – Murusjøen area and further south of these lakes on the Norwegian side of the border since these ultramafites seem to follow broadly the same stratigraphic level. According to Drs. Sturt & Ramsay (NGU), who currently are revising the tectonostratigraphy of the Nordli area, the ultramafic lenses, which represent ophiolite fragments, occur either at the Seve/Köli boundary or are tectonically displaced slightly lower down into the Seve unit.

5.5 Additional deposits

According to Helland (1893) the following talc/soapstone deposits occur in Nordre Trondhjems amt (=Nord-Trøndelag fylke):

Inderøy

Landstadmarka (Sparbu). This was worked extensively in the Viking period. There are extensive sub-surface workings. The deposit has to be identical with Slipsteinsberget described above.

southern parts of **Sparbu**

Barkaldsberg and other places along the Borgenfjord. Probably resembles Smulstuen/Bakaunsberget, or represent additional nearby occurrences.

Monen (=Mona), Snåsa. Talcstone has here been excavated in a hill belonging to the farm Mona situated c. 3 km ESE of Snåsa centre.

Mo in Fosnes

Poulsen (1945), in his list of talc/soapstone occurrences, reports five of the above deposits. Compilations of industrial minerals deposits in Nord-Trøndelag have been made by Gautneb (1991) and Kjølle (1996) but do not provide any further information.

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6. SØR-TRØNDELAG

The Trondheim Nappe (Wolff 1979), which dominates large parts of Sør-Trøndelag, hosts some ultramafic lenses that include talc-rocks. Some of these talc-rocks define deposits, of which some have old mining histories, primarily related to excavation of soapstone for the Nidaros Cathedral. The metamorphism in the Trondheim Nappe varies from lower greenschist facies to higher almandine-amphibolite facies.

6.1 Melhus municipality

Klungen soapstone deposit

The Klungen soapstone deposit, described by Heldal et al. (1998), located approximately 10 km south-west of Trondheim, has earlier (during the Middle Ages and between 1890-1910) been quarried for dimension stone used in the Nidaros Cathedral. The location of the deposit is shown in Fig. 22. At present time, the deposit is being investigated as a possible source for building stone for the future restoration of the cathedral. According to Heldal et al. (1998), the soapstone deposit is formed as a plate with a thickness between 7 and 20 m, but with an exposed length probably more than 1000 m. Around 70% of the deposit is termed "carbonate rich" and consists of ~30% carbonate (dolomite, magnesite/breunnerite), ~30% fine-grained talc and ~30% chlorite, and ~10% magnetite/pyrite and pyrrhotite. The remaining 30% of the deposit is termed 'carbonate poor' and contains ~35% talc, 15% amphibole, 10% chlorite, 10% carbonate, 10-15% serpentine and 10-12% oxides and other sulphides.

Medieval quarries occur across a substantial part of the deposit, and archaeological excavations are now being carried out. These sites are, according to the law of cultural heritage, automatically conserved. Thus, permissions for prospecting/mining in the area would be difficult to obtain. Furthermore, such activities would easily be in conflict with farmland and nearby residential areas.

6.2 Røros municipality

Talc deposits are located to ophiolitic ultramafites in the areas to the east and south-east of Røros – the mining town, see Fig. 37 for location.

Raudhammeren massif

The ultramafic ophiolite fragments east and south-east of Røros are among the largest in the country (Sigmond et al.1984, Nilsen & Wolff 1989, Rui 1981a,b, Nilsson et al. 1997), but their talc/soapstone potential has not been assessed in detail.

Talc-rich soapstone has locally been developed in the border zone of these ultramafites. No known occurrences exist along the borders of the largest massif, the 15 km^2 *Feragen* mantle tectonite body, but the second largest massif, the thoroughly serpentinised 5 km^2 *Raudhammeren* body, locally shows development of soapstone along its western and southern margins.

Parts of the c. 12 km long border zone was here briefly investigated and sampled in connection with geological mapping of the entire Raudhammeren body at the scale of 1:5000 (LPN 1997 and 1999, unpublished). Along the southern margin of the body, just to the east of the historic, small Sara sulphide mine, there is a 6 m wide outcrop of soapstone in the border zone of the ultramafite. The soapstone gradually passes into normal serpentinite towards the NE. Towards SW, the soapstone zone has a tectonic border (not exposed) to a hydrothermally affected ophiolitic(?) metagabbro. Based on observed outcrops the width of the soapstone altered zone may here be as much as c. 10-15 m and the length at least 300 to 400 m, possibly much more, but with somewhat irregular degree of alteration (LPN field diary and map 6.8.1997 + 9.9.1999).

In addition a strongly talcified serpentinite (soapstone) is developed locally along the W margin of the Rauhammeren body in the Lossius sulphide mine area, e.g. visible on an outcrop located c. 60 m to the NE of the main adit of the old sulphide mine.

In an old NGU Bergarkivet report (anonymous 1934, p.3) soapstone from Raudhammeren is briefly mentioned, based on available samples. However, the author does not appear to have visited the actual place(s). The author reports about "a very dense and homogeneous stone, with much 'pure talc' in it".

Litjgråberget

The same author (anonymous. 1934, p.1,2) also reports occurrences of talc-rich soapstone rimming the 150x750 m large *Litjgråberget* serpentinite lens, located just to the SE of the place Ensomhet in Møllmannsdalslia SE of Røros (see also Rui 1981a). The stone is "fat and soft with numerous veins of pure talc". Coarse grained dolomite occurs sporadically, and over the entire talc zone brownish magnesite (i.e. breunnerite) occurs as disseminated, variably sized crystals. The contents of magnetite and chromite is reported to be low. The width of the soapstone is reported to be c. 5 m. The best outcrops seem to be near the W or SW end of the serpentinite lens where c. 100 m of soapstone is exposed in the strike direction (c.f. Rui's map; Rui 1981a).

6.3 Additional deposits

Helland (1893) mentions the following additional deposits:

1) **Kletten**, Oppdal municipality
2) **Djevelvatnet** (=Gjevilvatnet), Oppdal municipality
3) **Bratset**, Rennebu municipality
4) **Øie**, near Øysanden, Melhus municipality (see Fig. 22 for location)
5) **Bakkaunet**, Trondheim. Today inside of the city of Trondheim (see Fig. 22 for location). Difficult access due to nearby building, etc., but several detailed descriptions exist in addition to that of Helland, e.g. the description of Kjerulf (1871) accompanied by detailed illustrations.
6) **Rokstad**, Singsås
7) **Grytdal**, Rognes in Gauldalen, Midtre Gauldal municipality. Located c. 2.5 km from Rognes railway station.
8) **Bønes**, at the mouth of Budalen valley, near Rognes in Gauldalen, Midtre Gauldal municipality.

9) **Solem in Budalen**, Midre Gauldal municipality.
10) **Auneøyen**
11) **Børgseskogn** (=Børgeskogen?)
12) **Grøtåsen**, Horg

Additional information from the NGU Library reference database:
13) In the district between Gauldalen and Kvikne, the Gula amphibolites frequently carry mafic and ultramafic ('alpine-type') inclusions. These show metamorphic mineral assemblages, and talc-chlorite schists and serpentinites occur among the assemblages (Nilsen 1974).

Additional map sheet information:
14) **Risberget**, Oppdal municipality. Soapstone-amphibolite in garnet- and hornblende bearing mica schist according to Krill (1987).

Additional NGU Report information:
15) **Hornet/Horne sæter**, Oppdal municipality. The 4 m wide deposit is situated 768 m above sea level. The mineral assemblage is magnesite/breunnerite (18-78%) and talc (12-70%) plus minor amounts of Fe-bearing dolomite (9-13%) and very small amounts of chlorite (0-2%) according to Torstensen (1982).

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7. MØRE OG ROMSDAL

From the various available references, the following talc/soapstone deposits in Møre og Romsdal county can be presented.

7.1 Sunndal municipality

Lilleglupen deposit

The deposit is located at an altitude of 1500 m a.s.l. just NE of the mountain Store Aurhøa, 5 km west of Grøvudalen in Sunndal (Stadheim, field diary 1939, Korneliussen 1982). See Fig. 24 for location. The talc occurs within an ultramafic lens, 4 – 500 m long and around 200 m wide, that defines a characteristic hill. The ultramafic lens is situated within garnet-mica-schists belonging to the Blåhø-unit. Chromite occurs within the ultramafic lens and has been the object for earlier mining. The ultramafic body consists of a serpentinised dunite, with variable content of talc, carbonate and amphibole. The content of talc and carbonate is usually 10-15%, but locally, and mainly in the rim zone, a content of 50% occurs (Korneliussen 1982). In addition to the talc mineralised lens described by Korneliussen (1982) there is a 100x450 m long, talcified lens 1 km to the ESE of Lilleglupen. Stadheim mentions chrysotile (asbestos) associated with a serpentine-talc-carbonate-"pale hornblende" assemblage. The "pale hornblende" is tremolite, and it occurs as long needles according to Stadheim.

Storskarhøa talc deposits (map sheet 1419-IV Aursjøen and 1419-I Storskrymten). There occur several ultramafic lenses in the steep western slopes of mountain Storskardhøa (1871 m; see Fig. 24). Several of the lenses show talc-carbonate-tremolite/anthophyllite mineralisation in the outer zones with sharp borders to a core region of a serpentine-tremolite assemblage. The largest mapped lens measures c. 100 x 400 m and runs from the NW to the SE between 1600 m and 1690 m. a. s. l. (information from LPN field notes 1988).

Grøvudalen talc deposit(s): According to Vollmer (1985 and unpublished manuscript map 1983) there are several ultramafic lenses in Grøvudalen, north of the tourist hut Grøvudalshytta. Among these there is a strongly talcified lens situated 1.75 km to the NE of the tourist hut (cf. Fig. 24 for location). It measures roughly 75x150 m.

Koppungen talc deposit (map sheet 1419-I Storskrymten and 1420-II Romfo): According to LPN (field diary 1988) there is talc-carbonate-tremolite alteration observed within the largest ultramafic body situated in the northern slopes of the mountain ridge Koppungen, see Fig 24 for location. In addition to chromite pitting, there seems to have been some talc prospecting in this area. Vollmer (1983) also reports talcified ultramafites from this area.

Scott (1967 and manuscript map) has additional information on ultramafic lenses in the Dovrefjell region, adjacent to Vollmer's mapping area. The westernmost part of Scott's mapping area is situated in Møre og Romsdal county.

7.2 Halsa municipality

Hjelmkona: According to Smith (1941) the ultramafic body located north of the highest peak of the mountain Hjelmkona (849 m), see Fig. 23 for location, contains some soapstone along the margins of the 150x500 m large lens. The lens has been mapped in some detail by Moore (1977) who characterises the bulk mass of the body as a carbonate harzburgite (=sagvandite) consisting of 10-30% orthopyroxene, 5-70% olivine, 0-20 % phlogopite and carbonate (5-60%) with lesser amounts of tremolite (0-15%), talc (0-30%), etc. Moore doesn't emphasise talcification along the margins of the body, as does Smith, but instead he emphasises the development of a tremolite-rich alteration zone along parts of the margins. The measures given by Smith were confirmed by LPN who has mapped the outline of the body at the scale of 1:5000 (LPN field diary + map 1988).

7.3 Additional deposits, Møre og Romsdal

A great number of other deposits are mentioned in the literature, but only very limited amounts of information are available on these.

Deposits referred to by Helland (1893) are as follows:

Sunnmøre district:

1) **Haram** (Sunnmøre)
2) **Lepsøy** (Sunnmøre)
3) **Kleberstenhammer**, Østrem, Borgund (near the town Ålesund)
4) **Oksenøy**, Borgund
5) **Otterskind**, Norddalen
6) **Dalsbygda**, Norddalen
7) close to **ytre Dalsviken**, Norddalen
8) **Rødbergvik**, Sunelvsfjorden
10) **Helset**, Volda
11) **Vanelvsdal** (Vanylven?) (associated with asbestos)
12) **Bjørkedalen**

Nordmøre district:

13) **Grudal** farm (=Grødal farm), situated just to the west of Grøa, Sunndal
14) **Vingula**, Surnadal
15) **Fiske**, Surnadal
16) **Krogvassdalen**, Surnadal
17) **Rensli**, Rindal
18) **Vindalen**, Todalen

Additional deposits according to Poulsen (1945):

19) **Harane** (a misspelling for Haram??)
20) **Lysøya**, Østheim
22) **Østheim** (possibly same as Østrem??)
23) Hekel

7.4 References, Møre og Romsdal

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8. SOGN OG FJORDANE

8.1 Bremanger municipality

Kleberga

Source of information: Fure (1996).
Location: Close to Davik, Nordfjord (Fig. 25).
Deposits: Småkleberen, Storekleberen, Sørekleberen, Deposit E, Gullhaugen
Type: Zoned ultramafic lenses with serpentinic cores.
Tonnage: The size and tonnage of the deposits, as interpreted by Fure (1996), are given in Table 1. Much of the talc ore may be less than 4 m in thickness.
Quality: Talc-carbonate ores.

Some veins with asbestiform tremolite have been located, but it is not clear if these occur in such amounts that makes exploitation impossible. As pointed out by Fure (1996), the major element chemistry and mineralogy of the ore (except for the tremolite veins) are rather similar to samples from Altermark. Whiteness measurements (Fure 1996), however, gave very low values (~ 47 – 72 %, magnetically separated). Whiteness-numbers are strongly dependent on 1) if the samples are weathered or not, and 2) the preparation-method. Sampling of talc is a difficult task since talc-bearing rocks often have a brownish-yellowish weathered surface due to the breakdown of iron in carbonates, olivine etc. Inspection of the samples studied by Fure (1996) showed that they were not fresh enough to achieve correct whiteness numbers, and as pointed out by the author: drilling might be necessary to collect pure samples.

Table 1: Talc deposits south of Nordfjord. From Fure (1996).

Deposit area	Deposit	Size of ultra-mafic lens	Tonnage of talc-rocks	Talc-content	Major secondary Mineral
Kleberga	Småkleberen	240 x 60m	180 000	50	Carbonate
Kleberga	Storekleberen	230 x 70m	230 000	55	Carbonate
Kleberga	Sørekleberen	450 x 90m	580 000	55	Carbonate
Kleberga	Deposit E	150 x 40m	?	38	Carbonate
Kleberga	Gullhaugen	Small !	?		

8.2 Vik municipality

Stølsheimen

Mining in Framfjord (see Fig. 26 for location) took place from the early 1930's up to the 1970's, by Norwegian Talc AS. Due to lack of exhaustion of mineable ore in existing mines, the mining stopped. Later prospecting by NGU did not succeed in finding additional deposits in Framfjord. Due to the lack of raw material, a prospecting programme was carried out in the area Framfjord-Stølsheimen in the period period 1981-1990 by NGU. The work is reported in

reports by Bakke (1982, 1986a, -b, -c, -d; Mogaard & Håbrekke (1983); Aarfloth (1984); Trønnes (1988); Karlsen (1990a, -b); Olerud (1990).
The programme led to the discovery of some new deposits in Stølsheimen.
The Stølsheimen talc deposits, situated south of Sognefjorden (Fig. 27), were discovered by geophysical and geological prospecting followed by core drilling by NGU in co-operation with Norwegian Talc AS in the years 1981-1990.
Magnetometric measurements from helicopter (Mogaard & Håbrekke 1983) led to the discovery of two large ultramafic lenses (Bjørnshaugen & Valsvikdalen ultramafites) with associated talc mineralisation which could be added to the already known deposits occurring around the exposed ultramafites (Lille & Store Raudberget, Fig. 27);

Valsvikdalen (deep-seated)
Bjørnshaugen (deep-seated)
Raudberget (exposed)
Vetle Raudberget (exposed)

More than 16,000 m have been drilled in Stølsheimen. The three first mentioned ultramafic bodies were investigated by drilling in the years 1984-1985 (Fig. 27, Table 2). Several large intersections of talc-carbonate rocks were found (Bakke 1986 a), allowing the total resources of talc from all deposits to be estimated (Table 3).

Table 2: Locations of core drilling in Stølsheimen 1984 – 1985. All later drilling have been performed at the Raudberget talc deposit.

	Bjørnshaugen	Raudberget	Valsvikdalen	Others
No. of drill holes	14	9	6	3
Metres drilled	5142 m	1716 m	1712 m	489 m

Bjørnshaugen talc deposit

A great number of talc intersections at different structural levels was found by the drilling in 1984-1985. The geometry of the deposit is generally very complex. Bakke (1986a) suggested that the occurrences of talc-rocks at different levels were caused by folding. Alternatively, the deposit consists of several ultramafic lenses. The Bjørnshaugen deposit is perhaps the largest deposit in the area, but the access is somewhat more difficult than the Raudberget deposit.

Valsvikdalen talc deposit

From the present investigations, the talc rocks at the Valsvikdalen deposit primarily seem to be situated around a single serpentinite lens that might be around 450 m in the north-east-south-west direction and about 250 m thick. Parts of the talc-carbonate ore is situated just below the surface, or even at the surface at one locality.

Raudberget talc deposit

In 1986-1988 the Raudberget talc deposit was investigated in further detail. This deposit was chosen partly because it was the deposit that was easiest and most economic to open. The Raudberget talc deposit is situated in the rim of the Raudberget ultramafite, which is dominated by antigoritic serpentinite with relics of older rocks. The talc deposit occur on the

south-eastern side of the ultramafic lens and has a length of at least 500 m along strike. The north-eastern part of the talc deposit has been investigated in details by drilling. Since 1984 around 9000 m have been drilled at the deposit. The *bottom ore*, which is the lowermost ore, has a thickness of 10 - 30 m. The detailed investigated area of the Raudberget deposit was estimated to contain at least 5.27 mill. tonnes of talc-carbonate by Trønnes (1988). The *bottom ore* - the target for the test-mining, was interpreted to contain about 70 % of the total tonnage. In 1990 the Raudberget talc deposit was opened for test mining. Additional investigations were carried out by Norwegian Talc AS/Norwegian Holding in 1992 and 1994. New tonnage estimations have been made later by Norwegian talc AS, but this information is not included here.

Mineralogy

The ore has the following general composition (Karlsen 1990a): Talc (50-60 %), carbonate (40-50 %), chlorite (0-2 %), spinels (0-2 %). In addition antigorite is present in the vicinity of serpentinite bodies.

In general, three types of carbonate are present: breunnerite (mostly), magnesite and dolomite. In the *bottom ore*, chemically zoned breunnerite and magnesite are the most common types while dolomite is seldom present. Two types of spinel are present: Firstly, large grains (up to 4 mm) of ferrite chromite with cores of chromite, and secondly, small (up to 1 mm) grains of magnetite. The composition depends on the structural occurrence of the sample. Near the serpentinitic core the antigorite and spinel contents increase, while chlorite is slightly more abundant near the blackwall rim. Small parts of the ore are polluted by hematite giving a red colour.

Table 3: Tonnage of talc-carbonate rocks in Stølsheimen as estimated by Bakke (1986 a).

Deposit area	Deposit	Tonnage
Stølsheimen	Rauberget	14 000 000
Stølsheimen	Lille Rauberget	23 000 000
Stølsheimen	Valsvikdalen	2 700 000
Stølsheimen	Bjørnshaugen	19 000 000

Comments:
The geological investigations in the Stølsheimen area have proven that considerable resources are present. even if they are probably smaller that originally estimated. Detailed investigations by test-mining have shown that the deposit geometry is more complex than previously known, and there are some considerable question marks concerning quality of the ore.

Despite all previous investigations, the area has not been completely investigated and evaluated. For example, the geometry of the Bjørnshaugen and Valsvikdalen deposits is not fully understood, and a possible difference in ore quality, and the reasons for such a difference, between the deposits have not been studied. In addition, some ultramafic bodies are present that are not described by the earlier investigations, although these bodies probably are much smaller. The ultramafite bearing phyllonite rock continues towards south and could host unknown deposits.

The Rauberget deposit is situated a rather long distance from the sea, and transport is both long and difficult on the present road. The county geologist of Sogn og Fjordane has recently put forth an idea to build a tunnel from Nærøyfjord to Framfjord. If such a plan was realised it would be important to check up the potential for deposits in the Framfjord area and the northernmost part of the Stølsheimen area.

Framfjord

In Framfjord, historical mining took place at the following sites: *Johilleren*, *Kalveskår-mine*, *Dale-mines*, *Katlaberget*, *Gammelgruven*, *Ørneredet*, *Skredhamrane* and *Klev*. The old mines are regarded as either worked out or impossible to mine. In the literature, the names *Hatleberg* and *Hellenes* occur (e.g. Helland 1893). These names represent the northern continuation of the soapstone at Dale.

At the *Storegjelet* deposit a tonnage of 40,000 tonnes is described. Difficult access is the primary reason why the deposit has not been mined. According to report *BA 7473* there is also a deposit at *Kleivane*, but the access is also difficult at this deposit.

A great number of old reports exist from the mining and prospecting activity in Framfjord, and the reader is referred to these for further reading (reports are anonymous): BA 7474, BA 7473, BA 7471, BA 7472, BA 7470, BA 7475, as well as Ross (1962). More recent reports are those by Bakke (1982), Torstensen (1981, 1982) and Sindre (1986). In addition some reports deal with processing (Sandvik, 1984; Ljøkjell, 1988).

The area between Framfjord and Stølsheimen

Some presumably smaller deposits occur in the area between the well known deposits in Stølsheimen (Raudberget, Bjørnshaugen etc.) and Framfjord, for example *Vidarshaug* and *Kleberget* (Gunnar Lee, pers. comm. 1999), but mapping and diamond core drilling would need to be carried before the potential is identified.

8.3 Leikanger municipality

Åfedt: Strand (1963) investigated this deposit, which is situated around 4 km from Feios at the southern side of Sognefjord in the Leikanger municipality (Fig. 26). The deposit was investigated for dimension stone purposes. Soapstone occurs in several exposures within phyllitic mica-schist over a distance of 250 m. The deposit is cut by faults. In all soapstone exposures, impurities of country rock, mostly consisting of quartz, were identified. Soapstone of good quality occurs in only negligible amounts.

Industrial mineral use of the talc-rocks has not been evaluated. To achieve an overview of both quality and size, detailed mapping and drilling is necessary, according to Strand (1963).

8.4 Additional deposits

Below are names of additional deposits mentioned by Helland (1893):

1) **Gaupne, Luster**, inner part of Sogn.

2) **Svanøy** (on the western part of the island), Flora (earlier: Kinn) municipality, Sunnfjord. According to Kolderup (1928, p.92 and 176) soapstone occurs at the outlet of lake Stryvatnet in the form of several small bosses. The quality varies much, and remaining quantities were limited at the time of Kolderups visit. Some parts of the soapstone are rich in serpentine, whereas other parts are enriched in carbonate plus significant amounts of sulphides.

3) **Råeim** (Råheim?), Viigs sokn, Indre Holmedals parish, Dalsfjorden tract, Sunnfjord.

4) The tract (zone) **Langeland-Utvik-Breimsvatn**, Nordfjord.

5) **Svinestranda** (a 1140 m high mountain at the border between the municipalities Stryn (earlier: Innvik) and Gloppen) located 2100 feet (=659 m) above sea level, Nordfjord. Soapstone is here associated with green schists.

6) **Rødfjellseggen**, located 2190 feet (=687 m) above sea level, Nordfjord.

7) **Åshammer** (near the farm with the same name) in Eid parish, Nordfjord.

8) **Hougen** (near the farm with the same name) in Innvik sokn, Nordfjord.

There are, in addition, a number of other deposits taken from various sources:

9) **Eggum:** According to rumours there is one deposit at Eggum. No details are available.

10) **Feios**: A possible deposit. No information is available from our sources. There might be a Bervesenet-report available.

11) **Inner Hafslo**: Soapstone is known from several places in Luster. The soapstone has been used at the Dale Church in Luster.

12) **Inner Lustrafjorden**: On the northern side of the inner part of Lustrafjorden there are some localities of talc-bearing rocks according to rumours.

13) **Hyllestad:** Frimannslund (1972) investigated some ultramafites in Hyllestad. No mentionable talc deposits were, however, described. According to Kolderup (1928) talc and soapstone occurs at Sellevoll in Hyllestad, located not far from the well known occurrences of Ti-bearing iron ore. Test mining has been carried out both on the talc and soapstone, but available reserves were too limited for a more regular mining operation.

14) **Bortneim:** At Bortneim in Dalsfjord, W of Dale, an occurrence of talc have been test mined, but with little success. Hornblende-asbestos here occurs together with the talc (Kolderup 1928).

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9. HORDALAND

A great number of talc-bearing mafic and ultramafic rocks occur in the county of Hordaland. In fact this county is unparalleled with regard to the number of occurrences, but many or most of them are small and have only a limited potential. In addition several deposits are formed from hydrothermal alteration of relatively Mg-poor diabase dikes and thereby have only a low talc content. Deposits can be divided into two principal groups: Precambrian and Caledonian deposits. The Precambrian deposits (> 1000 Ma) are found within the northwestern part of the Bergen Arc, in the Nordhordaland area, and in the Odda-Sørfjorden area in Hardanger. The deposits are predominantly dark, chlorite rich with minor amounts of carbonate, whilst the deposits in the Odda area are purer, talc-rich, but are generally small in size.

The Caledonian deposits are of Cambro-Silurian age (540-420 Ma) and, with few exceptions, they are talc-rich with carbonate veins, and contain various amounts of serpentine. The deposits are in various degrees attached to serpentinites, and are essentially believed to represent zoned serpentinite-talc deposits of the alpine type. However, some deposits do clearly represent altered ultramafic conglomerates. The Caledonian deposits occur in three areas: within the phyllite formations between Vikafjellet and Sognefjorden (mostly in Sogn og Fjordane county), in the outer Bergen Arc (Fensfjorden-Osterøy-Samnanger-Os) and in the Hardangerfjord-Sunnhordland area.

Most of the information here presented is taken from Helland (1893), with some additional information from Poulsen (1945), the NGU IM/NS databases, etc.. In addition, valuable information are found in regional descriptions with detailed maps from the beginning of the century, e.g. Rekstad (1907) for the Folgefonn peninsula and C.F. Kolderup (1915) in the case of the Samnangerfjord-Sørfjord area, etc. The maps accompanying these publications are still the key references in locating occurrences of serpentine plus associated talc and soapstone.

9.1 Samnanger municipality

A very detailed description of the occurrences of serpentine, talc and soapstone in the tract between Sørfjorden (south of Osterøy) and Samnangerfjorden is given by Kolderup (1915). Most of these deposits are situated in Samnanger municipality. The northernmost ones, however, are located within the Vaksdal municipality.

Kvernes (=Kvernnes or Kvenes) soapstone deposit

Also referred to as Skudevigens soapstone quarry; see Fig. 29 for location. The soapstone has been frequently used during the 1880's as building stone in Bergen, e.g. for the stock exchange, and post-office buildings (Lauvstad 1973). The ore is foliated and consists predominantly of talc and carbonate. Most of the deposit is exploited, and reserves are considered to be limited.
The soapstone is up to 10 m wide and is followed along strike for some 30 m. The working level in the year 1893 was 16 m under the entrance level (entrance cut). From this level, high quality, attractive soapstone was quarried. In addition to soapstone, veins of pure green talc occur. Magnesite occurs as veins in the soapstone. The soapstone is also here associated with serpentinite occurring in a knoll. Soapstone also occurs some 150m to the north of the quarry described, but is not worked at this latter site.

Årland (=Ådland) soapstone deposit

Location near Årland road junction (on the property of the Årland farm, near the border to Hisdalen), along the then new road (cf. Helland 1893) between Trengereid (at the bottom of Trengereidfjord) and Årland in Samnanger (see Fig. 29 for location). Serpentine-rich talc-carbonate type, used as building stone. The deposit is partly covered by the road construction.

Other deposits of similar type are located at **Sandvik, Leitet, Raudskolten** and **Nygård**. Most of these deposits are poorly investigated, but are essentially of small size. From the Sandvik deposit, soapstone was delivered to "Munkestova" in Bergen (Lauvstad 1973).

The **Fagerbotn** soapstone (Skår 1995, Alnæs 1996) differs from the other, in being dark, coarse-grained and does not contain carbonate. This rock is probably an altered pyroxenite within the Gullfjellet Gabbro. Chlorite and quartz are common minerals in addition to talc.

Additional deposits in Samnanger municipality include according to Helland (1893) (see location in Fig.29):

1) "**Årland-2**" (=Ådland-2). Another soapstone deposit at Årland farm..

2) "**Årland-3**" (=Ådland-3). Yet another soapstone deposit at Årland farm

3) **Haga**. Near the farm Haga on the opposite side of Ådlandsfjorden (=Samnangerfjorden).

4) **Rauvatn**, Samnanger. At lake Rauvatn under the mountain Raunipen

5) Between **Gaupholmen and Barmen**. Only poor quality stone at this place.

Additional:

Raudskolten (=Raudaberget?) soapstone deposit, east(?) of Haga. This is possibly the same as the deposit located ca. 2- 2.5 km N of Haga.

Soapstone deposits here seem to follow the line (from S to N): Gaupholmen-Kvernes-Årland-Raudvatn-Hana. Another eastern line includes the Haga soapstone deposit, deposits between Langeland and Træet as well as that at Fidjevatn (cf. Fig. 29).

9.2 Osterøy municipality

Bruvik (=Brudvik), Sørfjorden, SE corner of the big island Osterøy (Fig. 29). Here several minor occurrences are situated on the Brudvik parish farm according to Helland (1893). These have been tested, but none of them could provide high quality stone in sufficiently large blocks.

Storavatn (Storevatn), some 5 km Osterøy.

9.3 Bømlo municipality

Sele deposit

Located to the south of Nøklingfjorden (=Lyklingfjorden) on the island of Bømlo (Fig.32). The soapstone is regarded as a hydrothermally-altered diabase dike.

Østenvindhaugen talc deposit

Located to Østenvindhaugen, Uren, Bømlo. The soapstone is a pale "mixture" of talc and "talcspat". A dark grey soapstone, probably an altered diabase, is also associated with the former, as is some dark green serpentinite.
Additional information on these two occurrences are to be found in the monograph of Reusch (1888).

Sønstebøvågen: Soapstone occurs at Sønstabøvågen located some 5 km SW of Bremnes (Fig. 32). The stone is talc-bearing, but schistose and therefore unfit for use as dimension stone.

Espevær: An occurrence of soapstone is also located to the small island named Espevær after the fishing station off the coast of southernmost Bømlo (see fig. 32 for location).

9.4 Vaksdal municipality

Hana soapstone quarry
Hana soapstone quarry is located c. 3.5 km SW of Bruvik at Osterfjorden (see Fig. 29 for location). The soapstone is hosted by mica schists. The quarry is situated in a steep slope towards the fjord. The maximum width of the soapstone, judged from the quarry dimensions, has been ca. 4m. The stone has been known for its good quality and therefore was used in public buildings as well as monuments. Quarrying towards depth, however, has shown that the soapstone zone is wedging out and becoming more schistose.

Staveneset soapstone occurrence. Located some 1.5 km to the NE of the Hana occurrence (Fig. 29).

9.5 Os municipality

Several deposits occur in the Os area (Fig. 29), most of them small in size. Furthermore, several of these deposits contain pot-marks and/or signs of medieval building stone extraction. These deposits include Røtinga , Vargavågen , Moberg, Lysekloster and Lonane.

The **Moberg** (=Ytre Moberg) deposit consists of soft soapstone.

At the **Lysekloster** deposit an old quarry is located to the Lysekloster mansion in Os. The quarry has been established within impure talc schists. It is still visible at the road some distance to the north of the ruins of the medieval Lysekloster monastery. The deposit seems to be exhausted for good quality stone.

The Hatvig deposit occurs at the border between the two farms Hatvig (=Hattvik) and Malde (=Moldegård?). The soapstone deposit occurs in a 40m long, 25m wide and 10m high knoll. The soapstone has a high content of magnesite. This occurrence may well be the same as the occurrence Lonane, or a separate one situated close to the latter mentioned.

The **Vargervåg** deposit represents a continuation of the Hatvig deposit, i.e. it is lying on the same line as the above occurrence. An old quarry is here situated close to the sea on the north side of the bay of Vargervåg.

9.6 Jondal municipality

Krossdalen (Drebrekke) deposit

Krossdalen, Drebrekke, Jondal, Hardanger (see Fig. 30 for location). Very pure soapstone consisting mainly of large flakes of pale talc. In earlier days extensively used for local purposes as the making of pipelines, baking-stones, etc.

Reppa

Location in the mountain Reppa, SE of Torsnes seter according to Rekstad (1907). See Fig. 30 for location in addition to the map in Rekstad treatise. In a cave here named Reppaholet talc-chlorite schists occurs. Used for local purposes in old times according to Rekstad.

9.7 Lindås municipality

Chlorite- rich, Precambrian deposits occur at **Lygra, Alversund, Sletten** and **Eikangervåg** (Helland 1893) (see Fig. 28 for location).

Lygra soapstone deposit

Two soapstone quarries, mined in the period 1900 – 1930, is located to the north-eastern part of the island Luro (=Lurøy or Lygra) in Lindås. They have been described by Skår (1995). The size of the deposits is difficult to tell because the quarries are filled with water.

Among other deposits are **Raudholmen**, a Caledonian occurrence on an islet just off the NE coast of the Lindås peninsula (Fig. 28).

9.8 Radøy municipality

The occurrences on the islands **Floni** (=Flona) and **Toska** (=Torsken) (Fig. 28) are similar chlorite-rich Precambrian soapstone deposits as the ones mentioned above.

9.9 Meland municipality

Flatøyni (=Flatøya or Fladøen)
There are two similar occurrences of soapstone as the above mentioned on the small island of Flatøyni situated SE of Alverstraumen (Fig. 28).

9.10 Kvam municipality

Høiviken talc deposit

Underground mining of ultramafite-associated talc took place at the Høiviken talc deposit. The Høiviken talc deposits are situated at the western side of Fiksesund (Fig. 30). According to Bugge (1941) the talc-deposits occur in three different ways along the western side of Fiksesund and in Steinsdalen: (i) along the border of serpentinites, (ii) along faults in the greenschist and (iii) as layers in the greenschist

The mines were named "Gamle gruben" and "Jakobs gruve".
The deposits are of ultramafic origin and associated by serpentinites (Bugge 1941, 1942 a & b, 1943).

Gravdal

The soapstone occurrence is located south of Mørkevåg and north of Bergedal, just west of the centre of the island Varaldsøyna in the Hardangerfjord (see Fig. 29 for location). Two relatively large quarries (8x14 m and 10x14 m respectively) in Caledonian deposits have here been worked historically. In general, the stone seems to be strongly schistose, and good quality stone occurs only close to the sea shore and from here on disappearing into the sea. The soapstone level occurs within chlorite schists of considerable widths. Soapstone from this locality has been used as building stone for Norges Bank in Bergen.

9.11 Odda municipality

Skare (=Skåre) soapstone deposit (Fig. 31)

Investigation by drilling was done by NGU, and is reported by Vanebo (1973) and Frigstad (1974). The investigation was done in co-operation with Nidaros Domkirkes Restaurerings-arbeider. The deposit has the dimension 10x30x88 m and is situated in a fracture zone that cuts an amphibolite (Frigstad 1974). The deposit contains talc, dolomite and chlorite as the primary minerals. Veins of quartz, etc. precludes blocks larger than 1 m^3.

9.12 Kvinnherad municipality

Holmedal (Gråtuten) deposit

Located NE of Holmedal on the W side of Matersfjorden (southernmost part of the Folgefonn peninsula), see Fig. 32 for location. Soapstone starts at 500 m.a.s.l. on the mountain Gråtuten and continues all the way to the top of the same mountain, but with a few discontinuities. The soapstone is dark and partly contains coarse-bladed chlorite.

In **Kvinnherad** there are some Caledonian, small deposits, with many potmarks etc: *Bussevik, Kvitebergsvatnet and Nettland* (Fig. 29) as well as the Precambrian *Digraneset* occurrence .

The **Nettland** deposit is located to Indre Nettland (farm), Hatlestrand. A very much used quarry in old days. One of the pits is around 40-50 m deep. The soapstone zone continues towards the south-west towards Bussavik/Bussevik.

The Kvitebergsvatnet deposit is located to Kvitebergsvatnet, Ølve. The soapstone runs along the lake Kvitebergsvatnet and across the hill to the farm Nettland.

Digraneset is located on the N side of Maurangsfjorden (Fig. 30).

Ingafjell, a soapstone occurrence in the Precambrian basement (Fig. 31). Local production in earlier times according to Rekstad (1907) and Sigmond (1978); (cf. also Nordrum & van der Weel 1981). According to Rekstad (loc. cit.) the soapstone, which is basically a talc-chlorite schist, occurs as a layer in granite.

Hisdalen is a Caledonian deposit located on the western side of the island Varaldsøyna (Varaldsøy) in the Hardangerfjord (Fig. 29).

Etne municipality

Miljafjellet: Located to Miljafjellet (=Mildefjell), Skånevik, Etne (Fig. 32). A Precambrian deposit.

Tysse and **Gjuve**: According to Rekstad (1907), soapstone occurs in extensive amounts at Tysse on the northern side of Åkrafjorden (Fig. 31). The soapstone here is a dark greenish-grey and hard chlorite-rich rock most suitable as building stone. Further more soapstone is also occurring at Gjuve in Åkrafjorden (Fig. 31) according to Rekstad (loc.cit.).

9.13 Tysnes municipality

Russøyna and **Litla Vernøyna** deposits: At the small islands Russøyna and Litla Vernøyna (Fig. 29), Caledonian talc deposits occur. No further details are available.

9.14 Additional deposits

According to Helland (1893), with some additional information from Poulsen (1945) and the NGU IM/NS databases etc., the following additional occurrences can be mentioned:

1) **Lonevågen** (same as Sognevågen?), on the island Osterøy, Osterøy municipality (Fig. 29).

2) **Hop** (farm) in Fana, at lake Nordåsvatnet (Fig. 29).

3) **Fuse**, possibly same as Vågnipan, E of Baldersheim (cf. Qvale 1978), see Fig. 29 for location.

4) **Samlenes**, Jondal, Hardanger (Fig. 30). The soapstone occurrence is located to the relatively low isthmus to the east of the Samlenes peninsula, east of the mountain Samlen (Thommasen 1979). A high quality light grey stone with a high talc content is here occurring according to Rekstad (1907).

5) **Åkre** (=Åkra). Possibly the same as Ingafjell, or a separate occurrence located south of the Ingafjell occurrence. See Fig. 31 for location.

6) **Tåneset** (Rosendal). Soapstone occurs at Tåneset c. 2 km NW of Rosendal (Fig. 32).

7) **Kvitno** (=Kvitnå) (farm), W side of Sørfjorden, Hardanger, Ullensvang municipality (see Fig. 30 for location). Soapstone occurs in a max. 2 to 3m wide zone. Two quarries are located in the soapstone zone which trends WSW near the farm. The one quarry is situated 40 m.a.s.l. and ca. 100 m from the farm, whereas the other is situated 100 m.a.s.l. and ca. 300 m from the farm. A very good quality, light grey stone with a high talc content according to Rekstad (1907).

8) **Loberget**, very close to Kvitno farm. Soapstone in a stock formed mass, c. 2m wide. Located 85 m.a.s.l.

9) **Skjeldås** (=Skjoldås?). Located in the mountain side high above the farm Skjeldås, E side of Sørfjorden (Fig. 30).

10) **Skjoldås**. Possibly the same as the occurrence Skjeldås above. Here is an abandoned mine with extensive depth according to Helland (1893).

11) **Digranese**t. Here is also an abandoned soapstone mine with extensive depth. Should not be confused with the occurrence with the same name located on the north side of Maurangsfjorden (Fig. 30).

12) **Hanakamb** (=Hanekam). At the foot hill of the mountain Hanakamb (the peak is located 2 km to the NNW of the Kvitno farms), W side of Sørfjorden (Fig. 30).

13) **Mouge** (=Måge),(farm), see Fig. 30 for location. A quarry was still in production in 1830. A very good quality light grey stone with a high talc content according to Rekstad (1907).

14) **Bleie** (abandoned mine, extensive depth) (Fig. 30).

15) **Eikenes**, Maurangsfjorden (Fig. 30). Here, an altered dunite has been quarried and no real talc bearing soapstone. The stone has, however, been used as a soapstone on several occasions.

An additional talc/soapstone occurrence according to the NGU Library reference database is:

16) **Tveit** mine (Anonymous in NGU-report Ba 1400). Not located.

And according to the IM/NS databases, etc.:

17) **Gullfjellet**, Bergen municipality. Not located.

Additional deposits where information is lacking:

18) **Sandvik** soapstone deposit. Not located.

19) **Leitet** soapstone deposit, close to Riksvei 7. Not located.

20) **Nygård.** A soapstone deposit, close to Fylkesvei 134, east of Nygård. Not located.

9.15 References, Hordaland

Alnæs, L. et al. 1996: Laboratorieprøving av kleberstein. Fagerbotn kleberstein. STEINFORSK –RAPPORT 95099.

Anonymous 19??: Tveit grube. NGU Ba 1400.

Bugge, A., 1941: Geologisk oversikt over talkfeltene på vestsiden av Fiksesund og i Steindal. Bergarkivet report no. 6201. Geological Survey of Norway.

Bugge, A., 1942 a: Geologisk kartlegging ved Høiviken Talkforekomst, Hordaland. Bergarkivet report no. 6203. Geological Survey of Norway.

Bugge, A., 1942 b: Uttalelse om Høiviken talkforekomst i Fiksesund. Bergarkivet report no. 6202. Geological Survey of Norway.

Bugge, A., 1943: Geologisk kartlegging av Høiviken Talkforekomst, Hordaland. Bergarkivet report no. 6204. Geological Survey of Norway.

Frigstad, O.F., 1974: Geologisk undersøkelse av en klebersteinsforekomst ved diamantboring. Skare, Odda, Hordaland. NGU-report 1182. Geological Survey of Norway.

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Kolderup, C.F. 1915: Fjeldbygningen i strøket mellom Sørfjorden og Samnangerfjorden i Bergensfeltet. Bergens Museums Aarbok 1914-15, Nr. 8., 257 pp.

Lauvstad, N., 1973: Samnanger, saga um bygdi, gardane og ættene.

Nordrum, F.-S. & van der Weel, D. 1981: Mineral, stein, og ertsforekomster innen kartblad Sauda 1:250 000.

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Ragnhilstveit, J. & Helliksen, D. 1997: Gologisk kart over Norge; berggrunnskart Bergen – M 1:250 000. Geological Survey of Norway.

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Thommasen, T. 1879: Geologiske undersøgelser paa Folgefonns Halvø. Nyt Magazin for Naturvidenskaberne, vol 24, p. 273-288.

Vanebo, J., 1973: Teknisk rapport fra diamantboring, Skare, Odda, Hordaland. NGU-report no. 1182/A. Geological Survey of Norway.

Only limited information exists about talc-bearing rocks in Rogaland in NGU's databases, although several old soapstone quarries and workings are located in the county. The database of the Archaeological Museum in Stavanger contains data on soapstone. Nidaros Domkirkes Restaureringsarbeider has visited many of these deposits, and data has been given in a separate report (Storemyr 1998) and summarised in Table 4. Most of the deposits are concentrated within an area close to, and partly within, the town of Haugesund as shown in Fig. 32. This report forms the basis for the description given in the table below. The soapstone was primarily used as dimension stone for churches. The Nordland quarry is one exception. According to Storemyr (1998), this quarry was excavated for talc from the end of the 1800's to around 1946-47. In the 1930's there was an intense activity with up to 20 men at work. The quarry was partly run by the company Jacob Kjøde. Blocks were transported to the harbour and transported to Germany for milling. It is worth noting that the ore is possibly derived from dolomite. This implies that the talc may have low contents of iron, chromium and nickel.

Table 4: Talc-deposits in Rogaland. Source: Storemyr (1998).

Deposit	1:50 000 bedrock-map (Topo map in brackets)	UTM-coord	Type	Mineralogy	Size of deposit	Possibilities for mining
Tømmervik	1113 I	873/978	Soapstone from UM			
Søre-Dyrsnes	1113 I	869/978	Soapstone from UM	Light-coloured talc-carbonate	50-60 m long quarry, 2-5 m wide	Limited
Nore Grønevik	1113 I	869.5/963	Soapstone from UM	Light-coloured soft talc-carb + sulphide	25 X 7 m	None
Sandmyr	1113 I	872/960	UM Soapstone	Talc-carb + some trem	20 x 12 x 2-3 m quarry	Very limited
Ilibrotet	1113 I	873/945	UM Soapstone (?)	?	?	None
Grønhaug	1113 I	899.5/925	UM Soapstone	Grey talc-carb	5 x 5 m quarry, 1-3 m high	Very limited
Tolgetjødn	1113 I	888/923.5	UM Soapstone (?), possibly shear-zone related	?	?	None
Varaberg	1213 III	107/491	UM Soapstone	Talc-carb ± trem	50 x 20 m quarry	Maybe possible
Nordland	(1212 I)	255/270	Dolomite associated	White, massive talc	50-60 m long and 10-15 m high walls of a quarry. Also underground mining	Probably very limited

10.1 Additional deposits

According to available sources there are several additional talc/soapstone deposits in the county of Rogaland;

According to Helland (1893) these are:

1) **Ertenstein**, Rennesøy municipality. Hosted by metasediments. According to Dahl (1981) seemingly exhausted (see loc. 33 for location).

2) **Fjøløen** (=Fjeldøen) near Utstein Kloster. Hosted by metasediments (Fig. 33).

3) **Grønhaug**, Skåre east of Haugesund town. Hosted by metasediments. This deposit is also mentioned above (Fig. 32).

4) **Tysvær**, SE of Haugesund.

5) **Grytenuten** in Jelse, Suldal municipality (Fig. 32).

6) **Rødne** (=Rydne), Jelse (Fig. 32). Near the Rødne farms, located at the fjord in the foot hill of the mountain Grytenuten. Here a 1m wide layer of pure talc schist occurs.

7) **Seldal**, (=Seldalsvatnet), Høle (Fig. 34).

8) **Matingsdal** (farm), Ogna. A fine soapstone is here associated with a gabbroic rock. The occurrence is one alen (glds) wide (=c. 0.6 m).

Additional ones according to Poulssen (1945):

9) **Tjeldøen** (might be the same as Fjeldøen above(?).

Additional ones according to the Industrial minerals . /Naural .stone databases:

9) **Gjermstad** talc deposit, Eigersund municipality. This occurs within the Egersund anorthositic Province (Fig. 34). Possibly mistaken/confused with an occurrence of kaolinite or white anorthosite?.

10) **Hegrestad** talc deposit, Eigersund municipality. Occurs within the Egersund anorthositic Province (Fig. 34). Possibly mistaken/confused with an occurrence of kaolinite or white anorthosite?.

11) **Gåsland**, Haugesund municipality, 2.5 km due east of the Haugesund church (Fig. 32).

12) **Malmbukta**, Haugesund municipality (Fig. 32).

13) **Rømelien**, Sandnes municipality (Fig. 34).

14) **Nuten**, Sandnes municipality

Additional talc occurrences registered in the NGU Library reference database:

15) **Nordland**, Høle (Fig. 34). According to Mortenson (1945) the location is in the hills which can be reached by following a 4 km long road from the east end of Tengesdalsvatn. *This is a rare type of occurrence for Norway as talc/soapstone here is formed by metasomatism of dolomitic calcite marble.* The deposit and its mode of occurrence are described in detail by (Mortensen 1945). According to Dahl (1981) there has here been production during shorter periods covering a time span of several centuries, – more recent ones around 1900 and in the 1930's. All together c. 500 m^3 rock has been quarried, most of which has been used as "talc" of various qualities. The talc occurs as pure, pale green and irregularly folded layers, interbedded with layers richer in chlorite or even chlorite and mica. The entire lensoid deposit is surrounded by granites. Remaining talc in the quarry is strongly cracked according to Dahl (1981). According to Mortensen (loc.cit.) minor layers or lenses of serpentine or talc occurs in the marble, but they have always shown to be small and little persistent. Mining has been concentrated basically on these minor accumulations of talc. Bugge (1929) reports up to 60 cm wide bands of light talc within a 5-6 m wide zone of chlorite schist within a 15x15 m cut in the quarry.

Additional deposits with detailed information according to Dahl (1981):

16) **Reianes**, westernmost Rennesøy (c. 5 km to the W of no. 1) (Fig. 33).

17) **Tolgetjødn**, near Haugesund town (Fig. 32).

18) **Litla Tolgetjødn**, near Haugesund town.

19) **Lusamyr**, near Haugesund town (Fig. 32).

20) **Dam**, N of Haugesund (Fig.32).

21) **Ilibrotet**, N of Haugesund (Fig. 32).

22) **Austrheim**, N of Haugesund (Fig. 32).

23) **Sandmyr**, N of Haugesund.

24) **Nora Grønevik**, N of Haugesund (Fig. 32).

Either no. 23 or 24, or possibly both, may be the same as the database-registered no. 12 (Malmbukta). The occurrence Malmbukta plots half-way between the two (cf. also the geological map sheet Haugesund, 1:50 000 (Jorde et al. 1993), on which the Sandmyr serpentinitic lens (c. 40x70 m large) is shown). The Sandmyr talc/soapstone occurrence is probably therefore confined to the border zone of this lens.

25) **Tømmervik** (=Tømmerhammar), Førland, N of Haugesund (Fig. 32).

None of the 25 named occurrences above are currently in production. Most of them are small or very small, and several in addition probably partly or fully exhausted. No. 15 represents an exception with regard to genesis as this is a deposit not formed in a purely ultramafic, but in a carbonate environment through metasomatism.

10.2 References, Rogaland

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Storemyr, P., 1998: Prosjekt restaurering av Stavanger domkirke – undersøkelse av steinbrudd. Nidaros Domkirkes Restauringsarbeider.

11. VEST-AGDER

There are no known talc/soapstone occurrences in the county of Vest-Agder.

12. AUST-AGDER

Information on talc/soapstone occurrences in Aust-Agder is sparse. There are, however, several old soapstone quarries/workings given in the following list extracted from Skjelsvik (1997):

Åmli:
Vime Østre

Vegårshei:
Myre østre

Froland:
Plassen av Horv
Blakstad Nedre
Brattlandsåsen
Sparsås

Arendal:
Tykkeris av Øystad
Ginnestad

Grimstad:
Tøra

Lillesand:
Hisåsen
Vatne (1)
Vatne (2)
Vatne (3)
Gitmark (1)
Gitmark (2)
Gitmark (3)

Common for all the deposits above is that they were excavated for pans in the Middle Ages. There is only limited information available on size and quality of the deposits. The reader is referred to Skjelsvik (1997) and references therein.

12.1 Reference, Aust-Agder

Skjelsvik, E., 1997: Klebersteinsbruddene i Aust-Agder. Årsskrift 1997 (vestre Moland og Lillesand historielag), Hefte no. 5. Lillesand: Historielaget.

13. TELEMARK

According to Helland (1893) there are a few talc/soapstone occurrences in Telemark county (the old name is Bratsberg Amt), but details on location and composition are scarce.

There have been pot-stone workings in *Dyrlandsgrenden in Åmotsdal* in Seljord municipality and soapstone on property of the farm *Bøen* in Tinn municipality. Bøen or Bøengrenda is located on the southern side of the river Tinne between the lakes Tinnsjå and Heddalsvatn.

The pot-stone occurrence at *Tveitan* in Tinnegrend, is located ca. 3 km east of Lake Heddalsvatn (Hysingjord 1962). According to Hysingjord's field report, the soapstone occurrence is associated with a poorly exposed mafic dike that can be followed for ca. 1 km as a depression or joint in the terrain. The width of this dike is only around one m and is therefore of low interest for future exploration.

Morton (1960) describes talc from the famous *Ødegården* phosphate deposits, which contain some talc in the phosphate ore itself, or in the wallrock. The predominant type of ore, occurring in veins, has phosphate lenses in the centre, surrounded by a dense mass of phlogopite and enstatite, where the latter is often pseudomorphosed by talc. The wallrock is frequently altered to a soft green rock, and there are two types with slightly different mineral assemblage:
1): scapolite-hypersthene-plagioclase-talc-epidote-ilmenite-rutile-apatite, or
2): scapolite-rutile-biotite-clinoenstatite-talc-apatite.

Neither the talc within the apatite ore itself, nor that in the wallrock, would appear to have any economic potential. This both due to the general unfavourable mineral assemblage in which the talc occurs, and the talc grade in the apatite ore and the wall rock assemblages.

13.1 References, Telemark

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Hysingjord, J. 1962: Rapport vedrørende befaring av klebersteinsforekomst Tveitan, Tinnegrend, Telemark fylke. NGU Bergarkivet report 544, 2p.

Morton, R.D. 1960: The Ødegården phosphate deposits. In: Neumann, H.: Mineral occurrences in southern Norway. Guide to excursions no. A 15 and C 12. International Geological Congress, XXI session, Norden 1960. NGU 212, p.13-16.

14. VESTFOLD

There are no known NGU-registrations of talc/soapstone occurrences in the county of Vestfold, which is almost totally occupied by alkaline intrusive and extrusive rocks of the Permian Oslo Rift.

15. BUSKERUD

The county of Buskerud has a few talc/soapstone occurrences. Two of these occurrences are briefly mentioned by Helland (1893):

On the mountain *Slottet* (translates: "the Castle") in Ådalen, there is a soapstone quarry, though insignificant, Helland notes.

On the property of the farm *Skarteim (=Skartum)* near the valley centre Prestfoss in Sigdal, there is a pot-stone pit which was quarried in the 17th century.
Additional information concerning these two occurrences is not available.

A search in the NGU Library reference database, for Buskerud county, resulted in only two literature references (Daumann 1905; Jøsang 1960), both pointing to talc in the classical *Modum* area. The Modum area, is especially known both for its deposits of Co, but also for its unusual serpentine - magnesite deposits. The serpentine – magnesite rocks were extensively investigated by O. Jøsang (1960, 1966). Talc-rich rocks were apparently developed only in the marginal zones of the serpentine-magnesite bodies, which are themselves only of minor size. According to Jøsang (1966), the magnesite-serpentine bodies are surrounded by a thin 'layer of talc', and the closest few dm of the country rocks always contain variable amounts of talc. The talc, further, is impure (Jøsang 1960). Within the interior of the magnesite-serpentine bodies talc is only a minor constituent or absent. It therefore seems clear, from the above, that the talc potential is very limited and not worth considering for economic purposes.

Further, there are relatively large areas occupied by talc bearing albitized breccias, in association with the serpentine-magnesite bodies. These breccias, in fact, occupy much larger areas than the latter bodies. It is unlikely that they will have any economic significance, due to the unfavourable mineral assemblage albite-talc-quartz, plus presence of various other minerals as hematite, titanite and rutile (Jøsang 1960, 1966).

15.1 References, Buskerud

Daumann, E. 1905: Magnesit från Snarum.Bihang till Jern-Kontorets Annaler. Häft 5, p. 222-225.

Helland, A. 1893: Tagskifere, heller og vekstene. NGU 10, 178 pp.

Jøsang, O. 1960: Serpentine-magnesite deposits at Modum. In: Neumann, H.: Mineral occurrences in southern Norway. Guide to excursions no. A 15 and C 12. International Geological Congress, XXI session, Norden 1960. NGU 212, p.5-8.

Jøsang, O. 1966: Geologiske og petrografiske undersøkelser i Modumfeltet. NGU 235, 148 pp. + photographic plates + 2 map enclosures in scale 1:20 000.

16. AKERSHUS

The county of Akershus has, according to the NGU industrial minerals and natural stone (IM/NS) databases, five, registered talc/soapstone occurrences. They are all situated in the eastern part of the county, in the municipalities Aurskog-Høland and Sørum. All the occurrences occur in the early to mid Proterozoic Romerike gneiss complex, and they are all plotted on the 1:250 000 scale bedrock map sheet Oslo (Berthelsen et al. 1996, see Fig. 35 for location). According to the IM/NS databases (NGU 1990) only one out of the five occurrences (*Mostuene*) is dealt with in NGU report(s) or NGU/Bergarkivet report(s)(see later). Helland (1893, p.114-115) briefly describes several occurrences, but partly he gives only very approximate locations. This makes the identification and comparison with today's NGU registered occurrences, which partly have other names and co-ordinates, a rather time consuming effort.

Helland notes that, on the farms *Sætre* and *Åmot* at Setskog, within the Aurskog-Høland municipality, there is a soft rock (talc schist) which earlier has been used for pottery, etc. This might be either the *Aursetsjøen* deposit, the easternmost of the NGU-registered ones, or the neighbouring deposit at *Langsjøen*, situated east of the farm (or place) Åmot. The two farms are located half way between the two NGU-registered occurrences, and may represent a third, though unregistered, occurrence.

Helland's *Fallet* occurrence, taken from the NGU bedrock map sheet "Fet" (1:100 000) (Kjerulf 1880), does not coincide with any of the NGU-registered occurrences. Fallet is situated to the east of the southern end of Lake Bjørkelangen. Some 3 km NW from here on the opposite side of the lake, is situated the nearest NGU-registered occurrence, *Grepperud.* The two clearly represent two different occurrences and not only a change of name. On the topographic map sheet 2014-4 "Bjørkelangen", (scale1:50,000), there are two quarries marked at the place Fallet. These might represent modern extensions of the old soapstone quarries.

Helland's occurrence *Mostuerne,* has also been taken from the map sheet Fet (to-day's spelling is *Mostuene*). The pot-stone occurrence is situated c. 500 m to the ENE of the top of the hill Piggåsen and c. 2-3 km south of the town/suburb Sørumsand. According to the NGU databases, the Mostuene talc/soapstone occurrence is the theme of one or several NGU reports or NGU/Bergarkivet reports. So far, however, it has not been possible to trace this material by means of interactive data search. It remains thus, to make a manual search through the many thousands of reports within the NGU archives. It should also be mentioned that the mafic and ultramafic rocks of the Sørumsand area have been the subject of a thesis at the University of Oslo (Veisal 1988). This work is probably also a good source concerning the actual soapstone deposits in this area (Mostuene, Gullsmedås/Fjellet (Kjellet), and potentially also on others). Possibly also Holtedahl (1942) gives valuable information from this district.

The *Guldsmedås* occurrence, is also marked on the old map sheet Fet. The top of the hill Gullsmedås is located 2.5 km SE of Sørumsand railway station. According to Helland, who refers to the map sheet Fet, the soapstone occurrence is situated east of the summit. This may, perhaps, be the same as the NGU-registered *Kjellet* occurrence, which plots between the top of the actual hill and the farm Fjellet to the ESE. It seems reasonable that Kjellet is a misspelling for Fjellet, and that the soapstone occurrence, which according to the NGU databases is situated in the forest c. 750 m to the WNW of the farm Fjellet, is called after the nearest farm (c.f. map sheet 1914-1 "Fet", scale 1:50 000). There is a possibility that Gullsmedås and Fjellet represent two different occurrences some 1-1.5 km apart.

The occurrence *Folvelsæteren*, is, according to Helland, situated 8 km to the ESE of Haga railway station at the river Glåma. This location coincides well with a soapstone occurrence plotted on the recently published 1:250 000 scale map sheet Hamar (Nordgulen 1999). The occurrence, however, is not registered in the NGU IM/NS databases.

The overall poor fit between the soapstone occurrences mentioned by Helland and those in the NGU IM/NS databases, indicates that several occurrences apparently exist in addition to the NGU-registered ones. Indeed, the whole region might well be classified as a well-delineated talc/ soapstone province with extent c. 30 km E-W and c. 25 km N-S. Helland, unfortunately, in his treatise has very sparse information about petrography/quality as well as quantity of the soapstone occurrences in Akershus county.

16.1 References, Akershus

Berthelsen, A., Olerud, S. & Sigmond, E.M.O. 1996: Geologisk kart over Norge, berggrunnskart OSLO 1: 250,000. Geological survey of Norway.

Helland, A. 1893: Tagskifere, heller og vekstene. NGU 10, 178 pp.

Holtedahl, O. 1942: Geologi. *In*: Bjørke, O. (ed.) Sørum Herred, p. 35-54.

NGU 1990: Registreringskart for Industrimineraler / Natursten. M 1:250 000, kartblad OSLO / KARLSTAD / UDDEVALLA. Geological Survey of Norway.

Kjerulf, T. 1880: Rektangelbladet "Fet", berggrunnsgeologisk kart. M. 1:100 000. Norges geologiske undersøgelse. (*NB! This map, unfortunately, has not been available at the NGU-library or NGU-map archive during the course of the present work*).

Nordgulen, Ø. 1999: Geologisk kart over Norge, berggrunnskart HAMAR 1:250,000. Geological Survey of Norway.

Veisal, T. 1988: En geologisk undersøkelse av Sørumsand området med hovedvekt på de mafiske og ultramafiske bergartene. Cand. Scient thesis, University of Oslo, Geologisk fellesråd.

17. OSLO

There are no known NGU-registrations of talc/soapstone occurrences in the county of Oslo, the area of which equals the municipality of Oslo and is several times larger than the urban city area. The ca. 450 km^2 land area is occupied by Permian magmatic rocks (both intrusives and extrusives) in forested areas to the north, mostly Cambrian and Ordovician sediments in the city areas and Proterozoic gneisses in the suburban and forested areas in the south-east.

18. ØSTFOLD

Within the county of Østfold there are twelve registered occurrences of talc/soapstone in NGU's industrial minerals and dimension stone databases. Nine of these are so densely spaced (within an area of 5 x 10 km) that they constitute a small, but distinct talc/soapstone province, situated in the municipalities of Marker (to the north) and Aremark near the Swedish border (NGU 1990), see Fig. 36 for location. The province continues towards the SE into the Store Le tract in Sweden where talc is also reported, e.g. at the place *Kabuholta* located some 500 m only from the international border. All the Norwegian and also the Swedish occurrences are confined to a narrow NW-SE trending belt, the Ørje mylonite zone which is bordered, on both sides, by generally less deformed, early to mid Proterozoic gneiss complexes (Berthelsen et al. 1996).

The Marker-Aremark province has been known for a long time. It is briefly mentioned e.g. by Kjerulf (1879) and described in more detail by Helland (1893). Most of the occurrences are also marked on the manuscript map "Aremark" (Rekstad 1919). According to the registration map and databases (NGU 1990), only one out of the twelve occurrences in Østfold (the *Solerudberget* occurrence) has been described in a NGU report. The reader is advised to refer to the enclosed deposit lists and the topographic map sheet 2013-4 "Øymark" for a proper geographical orientation, and the localisation of these potentially economic deposits.

According to Helland (1893) the pot-stone deposits are grouped around the northern end of the large lake Stora Le, the major part of which is situated on the Swedish side of the border. The deposits are very large; they have both considerable width and strike extents. In spite of the apparently very significant talc/soapstone potential, there is, however, very little information on the petrography of the deposits, in the work of Helland.

18.1 The zone Funken-Kornelius sæter

This southern zone, running SSE-NNW, is 3 km long and situated between *Funken* (to the south) and *Kornelius seter (=today's Høgås occurrence?)*. The main layer has a reported thickness of 51 m, with a subordinate c. 5 m thick layer on the foot wall side at Funken. At the northern end, at Kornelius sæter, located on the shore of Stora Le Lake, the width is 25 m. In between, there are smaller, partly overgrown diggings in soapstone. The soapstone at *Bøen sæter (=today's Smørtjernet occurrence?)* occurs c. 2 km to the WNW of Funken, and thus slightly to the west of the main zone.

18.2 The Solerud-Viken zone

This ca. 1 km long zone, is also running SSE-NNW, has a reported thickness of 'not less than 50 m'. There are several old workings along this zone, and the soapstone has an uncommon, attractive deep blue colour, probably due to its mica content. Other soapstone deposits in the vicinity include those at *Herrud, Stusrud* and *Solerudberget*, and to the SE of the zone the *Styggmyr* occurrence is found. This occurrence lies in an area termed *Kisleberg* on old topographic maps, and the word kisleberg (local dialect) translates to *soapstone hill.* According to the NGU-databases there are one or more NGU report(s) and/or NGU Bergarkivet report(s) dealing with the Solerudberget occurrence, but it has not been possible to locate such report(s) using available data base search.

The *Fluetjern* soapstone occurrence ("*Kisleberg vekstensdrag*") is situated in the northernmost part of Marker municipality. The old term is kept on the modern topographic

map 2014-3 "Rødenes" (1:50 000) where the area surrounding the soapstone deposit is named *Kisselbergmosen.* The deposit is hosted by a migmatitic, muscovite-biotite gneiss belt, dominantly of assumed supracrustal origin (Skjernaa 1984). This belt is situated in the Romerike Complex to the north-east of the Ørje Mylonite Zone and is sub-parallel to the latter (Skjernaa 1984, Berthelsen et al. 1996). The width of the soapstone occurrence or zone is estimated to be 'several hundred feet', and 'there has been much working, here in old days' according to Helland (1893). The rock is partly dark, hard and chloritic and partly pale, soft and talc rich. The latter has of course been the one mostly used and is the main material found in the spoil-tips. The good stone shows local spots of pyrite, it is further coarse leaved and shows nicely radiating sheaves, etc.

The *Stakkestad (=Stakkestadberg)* soapstone occurrence is situated within the borders of Halden town, close to the Swedish border, and the *Stiksvatn* occurrence some 12 - 13 km to the north of the former (NGU 1990).

According to old and unspecified sources (referred by Helland 1893) pot-stone has also been found in the Rakkestad and Eidsberg areas in the central parts of Østfold county. Information about locations, however, appears to have been lacking, or even already lost, at the time Helland wrote his treatise more than a century ago.

18.3 References, Østfold

Berthelsen, A., Olerud, S. & Sigmond, E.M.O. 1996: Geologisk kart over Norge, berggrunnskart OSLO 1 : 250 000. Geological Survey of Norway.

Helland, A. 1893: Tagskifere, heller og vekstene. NGU 10, 178 pp.

Kjerulf, T. 1879: Udsigt over det sydlige Norges geologi. Den Kongelige Norske Regjerings Departement for det Indre, Christiania (Oslo), 262 pp.

NGU 1990: Registreringskart for Industrimineraler / Natursten. M 1:250 000, kartblad OSLO / KARLSTAD / UDDEVALLA. Geological Survey of Norway.

Rekstad, J.B. 1919: Geologisk manuskriptkart "Aremark", M. 1:100 000. Geological Survey of Norway.

Skjernaa, L 1984: RØDENES, 2014 III – berggrunnsgeologisk kart M. 1: 50,000. Geological Survey of Norway.

19. HEDMARK

19.1 Nord-Østerdalen

Introduction

The ultramafic rocks in the Nord-Østerdalen region are a direct eastern continuation of those in Nord-Gudbrandsdalen, as can clearly be seen in the overview map in Nilsson et al. (1997, p.11 shown here as Fig. 37). These are isolated fragments, of essentially upper mantle ultramafites, belonging to the highly dismembered Vågåmo Ophiolite Complex or serpentine conglomerates/sandstones derived from this complex.

The ultramafic bodies are concentrated in the area from Hornsjøhø-Haverdalen, at the Hedmark-Oppland county border in the west, and extend eastwards. Following the valleys Grimsdalen and Folldalen to Alvdal, their trend swings into a more NNE-SSW direction following the western side of the main valley to Tynset and Tolga before entering the Røros district in Sør-Trøndelag county.

As in Nord-Gudbrandsdalen, deposits of talc/soapstone in Nord-Østerdalen are located at the serpentine conglomerate level (the Otta Conglomerate) or its ultramafic substrate.

Reinsliåsan-Stoberget zone

This zone has recently been investigated by Hjerkinn Næringsselskap in collaboration with NGU. Results are reported by Olerud (1993).
The Otta Conglomerate here, which is strongly talcified, occurs stratigraphically somewhat up-sequence, in the Lower Sel sediments, from the contact of the ultramafic ophiolite fragments as shown on the map of Nilsson et al. (loc. cit.). The ultramafites (Raudkletten, Døltjørsætri and other lenses) and the related talcified conglomerates are here separated by a relatively thick sequence of phyllites of the Sel Group.

Reinsliåsan deposit

The *Reinsliåsan*, or just Reinslia; deposit (Fig. 37) has earlier been quarried for soapstone with a very high content of talc (80-95 %). The talc/soapstone potential is large, since the ultramafic conglomerate here constitute a ca.3 km long zone with enlarged thickness (150 – 1000 m width (Dighem Survey, 1982). The terrain is strongly to totally covered by overburden but the zone gives a strong positive anomaly on aeromagnetic maps. The mineral assemblage of the soapstone is *talc-magnesite-chlorite-(magnetite)*. The magnetite contents is reported to be relatively high in parts of the rock, hence the coincidence with the strong positive magnetic anomaly. In addition to geology, mineralogy, bulk chemistry, etc., results from ore dressing pilot tests (whiteness, etc.) are also reported by Olerud (1993). As mentioned above, the ore is very talc-rich, but whiteness tests have given rather disappointing results. Further talc prospecting was therefore not recommended by Olerud (1993).

Stoberget deposit

The *Stoberget* soapstone occurrence west of Reinslia (Fig. 37) is a small and inhomogeneous occurrence, which will not be dealt with in detail here. It is not suitable for block stone due to the inhomogeneous nature, and it is also too small and quality too uneven for talc production according to Olerud (1993, p.13).

Strålsjøen-Einunna zone

The Strålsjøen-Einunna talc/soapstone zone is apparently situated within the Gula Gp. in the Einundalen-Savalen tract (Fig. 37) and therefore does not appear to belong to the Vågåmo ophiolite or its derivatives. This is a narrow zone, known for centuries, and exploited for local usage (fireplaces, etc.). In the NE end, at the *Grøtberget* lens, only serpentinite was observed. The next occurrence is at *Strypet* (which in local dialect means saddle point or pass point) north of Strålsjøen in a bog (?). The soapstone occurrence was not located during reconnaissance in the area, but it is definitely located marked on the map of Marlow (1935), both with regard to size and to location. In the central portion, at *Svartlia* south of Strålsjøen old soapstone workings are reported (Helland 1893, p.117; Braseth 1995, p.155). Further towards SSW, talcified serpentinite occurs in several road-cuts along the Folldal-Strålsjøen-Savalen road just opposite the place where the river Einunna makes a 90° bend. The southern end of this zone is represented by the *Klebermyran* (name translates soapstone bogs) occurrence situated on the western side of the river Einunna.

***Brekkebekkdalen-Straumsåsen-Styggberget-Fåset-Fåsteen** zone*

This is a very well known zone consisting of separate occurrences of the Otta serpentine conglomerate and fragments of its ophiolitic substrate (Fig 37). At *Brekkebekkdalen*, or Steivanglia, the conglomerate forms a c. 200 m long N-S trending ridge in the terrain and with a width of at least 25 m (Helland 1893, p.116; Braseth 1995, p.155). The northern part is non-talcified serpentinite conglomerate, whereas the southern part is strongly altered to soapstone, and with a very sharp E-W running border between the two (Olerud 1993, p.14). The soapstone has been exploited for more than a century and used both in dimension stone production, mainly for the typical "Østerdals" fireplace, and production of small blocks (60 kg) for use in soda melting at the Moss cellulose factory (Braseth 1995, p.155-157). According to Olerud (1993) the soapstone is unsuitable as raw material for talc production due to the dark colour.

Straumsåsen (other names: Brennåsen or Bua) is the NNW continuation of the Brekkebekkdalen deposit, and located 6 km to the NNE. According to Helland (1893, p.118) the length of the soapstone altered conglomerate is c. 200 m and the width c. 15 m, locally possibly somewhat more. Helland reports about a rather extensive and continuous production, with work in the quarry/-ies 'every year during the last 104 years', i.e. in the period 1789-1893. The stone is relatively easy to work, and 'may be cut with an ordinary saw' says Helland. After Helland's monograph, several NGU-Bergarkivet reports were written dealing with the Straumsås deposit (anonymous 1918 with reports referred therein, Hysingjord 1970a). Olerud (1993, p.14) regarded the width to be at least 50 m, and recommended the deposit evaluated for block stone quarrying. Furthermore, he regarded the soapstone as too dark as raw material for talc production. A/S Granit excavated a test pit (1994/95), but unfortunately, the quarried blocks fell apart too easily, due to a series of very fine fissures and veinlets containing pure, coarse grained, pale sea-green talc. The test pit was therefore quickly abandoned.

The *Styggberget* ultramafic body located some 2 – 2.5 km further to the north is marked on the map by Nilsen & Wolff (1989), but otherwise this occurrence is not well known from the literature, nor from the different NGU archives or databases. The ultramafite, consisting of serpentinised harzburgite with enclosed dunite bodies, were located and mapped in detail by Sturt & Ramsay (NGU) during the summer 1999. Notably talcified serpentinite was not, however, encountered during this mapping.

According to Pram (1758), cited in Helland (1893, p121), there is an occurrence at *Fåset* in Tynset which he characterises as 'the nicest and purest soapstone I ever saw, dark grey to nearly black, and nearly without veins, etc'. This might be a separate occurrence along the northern continuation of the Straumsåsen-Styggberget zone. There are no other sources of information on the "Fåset" occurrence in addition to that of Pram. A magnetic anomaly in the southern part of the Fåset area may, however, perhaps mark the site of the soapstone occurrence, because the location, form, size and strength of the anomaly indicate connection along the weakly curved line *Brekkebekkdalen-Straumsåsen-Styggberget-Fåset-Fåsteen* (NGU 1982).

The well-known *Fåsteen* ultramafic body and its surroundings have been mapped in large detail (1:5000 scale) in 1996 by Sturt, Ramsay & Nilsson, however, without tracing any occurrence of soapstone in the hanging wall zone. Soapstone occurrences should, however, not be completely ruled out in this case because the hanging wall contact of the ultramafic body with Sel Group phyllite sedimented directly on top of it is only occasionally exposed. By analogy with the Nord-Gudbrandsdalen region (e.g. the Sagflaten-Åsåren area on Tolstadåsen) Fåsteen is a body that might well have suffered tropical weathering of the uplifted and eroded surface and hence formation of talc/soapstone.

Tronfjell area

In the narrow gorge east of *Midtkletten* (c. 2 km N of Tronsvangen) within the borders of the Tronfjell gabbroic massif a small occurrence of talc occurs. Test mining has been carried out, but the occurrence has proved both too small and not pure enough for industrial use (Marlow 1935, p.22). The Tronfjell massif has recently been remapped and described in detail (Wellings 1996). A summary version has also been published (Wellings & Sturt 1998). At Tronkalven, a separate smaller mountain massif constituting the northeastern part of the Tronfjell massif, "serpentine" is registered in the NGU IM/NS database. Talc/soapstone may possibly also be associated with this serpentine(?).

Tynset-Tolga-Os tract

This large district north of Alvdal hosts several fragments of mantle tectonite (ultramafic rocks from basal zone of ophiolite) belonging to the Vågåmo Ophiolite as well as locations of the Otta serpentine conglomerate (see Fig. 37). The best known soapstone deposit in this district is probably the one located close to the road to Vingelen, between the road and the small stream in *Kverndalen* (Holmsen & Holmsen 1950, p.20-21). At the nearby *Eidsfossen* (a waterfall in the river Glåma) serpentinite is reported in the NGU-industrial minerals database, but there are no records of soapstone there.

Kvikne area

The soapstone quarries at *Grøtli* SE of Yset in the Kvikne area, are described, in a fairly detailed manner, by Helland (1893, p18-19). Geologically the locality is situated within the Gula Group (Nilsen & Wolff 1989), but the details of the geological setting have not been investigated in modern times. The protolith is neither the Vågåmo Ophiolite nor the Otta serpentine Conglomerate, but a hitherto unknown(?) rock of ultramafic/mafic composition (possibly a somewhat uncommon rock like a clinopyroxenite or a komatiite?). It should be noted that Helland (1893, p.118-119) recognised a clear difference in general appearance and mineralogy between the Grøtli soapstone and the ophiolite-related ones described above (the "ordinary soapstones" in Helland's comparison). Helland speculated about the origin of the Grøtli soapstone and mentions a clinopyroxenite ("diallage") as a possible precursor. The stone is harder to cut than "ordinary soapstones", but it has no magnesite and is "praised for its good properties" by Helland.

The soapstone occurrence at *Bubakk,* east of lake Stor Børsjøen in Kvikne, is among the more famous ones in Norway because soapstone from this locality has been used for building (?) and repair of the medieval Nidaros Cathedral in Trondheim (Alnæs 1994). The oldest workings may be as old as early as iron age (ca. 600 years BC) or possibly even older (Braseth 1995, p.16-17). The Bubakk occurrence is also situated in the Gula Group (Nilsen & Wolff 1989), and probably belongs to the same type of soapstone deposit as the Grøtli occurrence. Because soapstone from the Bubakk quarry until recently has been used in the restoration of the Nidaros cathedral, there is a lot of information on the occurrence: e.g. Hysingjord 1970b, Frigstad 1973, 1975 and Alnæs 1994, p.337, 342, 363 and appendix 3, etc. The size of the strongly overburdened and soapstone altered ultramafic lens is c. 45x75 m with a 23x40 m serpentinite core according to interpretation based on diamond drilling (Frikstad 1975).

Though the soapstone is partly talc rich and fine, the size of the ultramafic body, archaeological interests and the use for cathedral restoration, however, totally precludes an industrial use of the Bubakk ultramafic body.

The main value of the Grøtli and Bubakk occurrences in talc prospecting are as indicators of similar, but larger and hidden talc/soapstone deposits within this portion of the Gula Group. In this respect the geophysical signatures of the two known bodies will be of great importance, then, almost certainly, eventual new deposits will be bog or moraine covered without outcrops (otherwise they would probably have been known since long ago like the above two).

19.2 Talc-soapstone deposits in Hedmark in addition to those in Nord-Østerdalen

According to Helland (1893, p.115), there is a soapstone occurrence on *Munkesjøfjell* east of lake Ossjøen in Trysil. Further details are not available. The mountain Munkesjøfjell consists of a sheet of Vardal Sandstone (part of the Osen –Røa Nappe) thrust on top of Proterozoic granite with a thin, autochthonous sedimentary cover (Siedlecka et al. 1987, Wolff et al. 1995). The Caledonian nappe front runs around the mountain on all sides except to the NW where this outlier is connected with the main mass of the actual sparagmite nappe. It is however not clear if the soapstone deposit is situated in the Vardal Sandstone, or if it is hosted by the adjacent basement granite. The latter is the more plausible host as the sparagmite nappes rarely contain talc/soapstones or their precursor rocks.

19.3 Talc associated with massive Zn-Cu sulphide deposits

The different NGU archives and databases plus other available sources (see literature list) do not contain additional information about talc/soapstone deposits in the county of Hedmark. Talc is, however, generally an abundant constituent in many of the sulphide deposits, both in Hedmark and in the rest of the country. The massive sulphide deposits in Folldal in Hedmark has recently been investigated in detail (Bjerkgård & Bjørlykke 1994, Bjerkgård 1995), and therefore used here as an example. Talc in the gangue and wall rocks of the massive sulphide deposits are of a different origin compared to those so far treated in this report. Both the talc, Zn and Cu are products of hydrothermal activity at the sea floor and within the oceanic crust. Such talc is low in iron, but occurs intimately associated with magnesium-rich chlorite. Talc from a similar deposit is extracted as a by-product in Cu-Zn production at Garpenberg, Sweden.

Søndre Geitryggen, Folldal

This is an old Zn-Cu mine which was closed down in 1965. Parts of the wall rock, on the foot wall side, is constituted of a heavilly sulphide mineralized quartz-talc-chlorite-carbonate schist relatively rich in talc (cf. e.g. Bjerkgård & Bjørlykke 1994, p.219 and 229-230). This particular part of the wall rock is some 200-300 m long and 2-15 m wide (Bjerkgård 1995, Bjerkgård & Bjørlykke 1994).

Svartåsen & Bjørkåsen, Sivilvangen

Locality: southwest of Tynset, at the southern end of the lake Savalen. Talc is here an important constituent of the gangue in sphalerite ore (Bjerkgård 1995).

Trøfloen, between Tynset and Tolga

Talc is here associated with Zn-ore, as above (Bjerkgård 1995).

It should lastly be mentioned here that talc has been localised and investigated as a possible by-product also at other pyrite-Cu-Zn deposits in Norway, among these the Vaddas massive sulphide deposit in northern Troms (see under Troms county).

19.4 References, Hedmark

Alnæs, L.-I. 1994: Kvalitet og bestandighet av naturstein. Påvirkningsfaktorer og prøvemetoder. Dr.ing. thesis, Norwegian Institute of Technology (NTH), 438p + appendix.

Anonymous 1918: Promemoria angående Strømsaas Kleberstensbrudd pr. Auma st. NGU Bergarkivet report no. 365, 4 p.

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20. OPPLAND

20.1 The Nord-Gudbrandsdalen region

Introduction

The northern part of the valley Gudbrandsdalen, with its main tributary Ottadalen, is regarded as the classical type area for talc and soapstone deposits in Norway. Quarrying in this area is much older than in the two other main talc/soapstone provinces in Norway, i.e. Stølsheimen and Rana. The actual area is situated practically in the middle of southern Norway with long transport distances to the nearest harbours (150 km to Åndalsnes in the NW and ca. 280 km to Oslo in the S). The valley district or region is named Nord-Gudbrandsdalen, or just "norddalen" in local dialect.

Despite the considerable distances to the sea, the soapstone deposits were already known by the Vikings, or even by their "iron age" ancestors, as revealed by remnants of broken pottery, etc. There are reports of extensive pot-stone production as early as the the 16th century when, in 1738 or –39, an unspecified, large quantity of soapstone, at least according to current mining conditions, was mined in the Åsåren quarries NW of Otta. The soapstone was transported c. 150 km to nearest harbour at the Romsdalsfjord (Pram 1758). A century ago, the majority of the soapstone occurrences known today were already known as shown by the detailed account on slates, schists and soapstones from 1893 by Professor Amund Helland. This was at a time when deposits in Stølsheimen were not yet known, and known occurrences in the Rana district were mentioned only by a single sentence in Helland's treatise.

Talc / soapstone mining and quarrying in modern times

Modern talc mining and soapstone quarrying started when the company *A/S Østlandske Stenexport* was established and around 1915/16 began their mining and milling operations at the large farm Bårstad at Lalm in the Ottadalen (river Otta valley). Land areas of neighbouring farms and smallholders farms were also included in the site for the operations. Already in 1918 there were extensive sub-surface mining operations going on in the mine (Fjellanger 1918). In the first few years, transport conditions down the steep hill from Bårstad to Lalm and further along the river Otta valley to the railway station at Otta centre (21 km in all) using horses, and to a minor extent also lorries, was the real bottleneck preventing a rapid increase in production. A ropeway was therefore soon considered the necessary solution to the severe transport problems, and one was built and ready for use in 1920. It followed the 6.8 km straight line from Bårstad due east above the crest of the mountain Tolstadkampen (c. 1020 m) and down the Selsrusten valley to Sel railway station in the main valley NW of Otta. The ropeway permitted a multiple increase in production. Proven + estimated talc reserves for milling were considered practically unlimited in the beginning (e.g. Münster 1916), and production quickly escalated to several tens of thousands tonnes annually. In 1934, five major production levels in the mine were established, with a number of sub-levels (Fjellanger 1934). Production of milled talc went on continuously until 1990 when the old mill was closed and dismantled. The dressing operation was kept unchanged during the whole lifetime of the mill. The flow sheet was quite simple; a weak field magnetic separation of magnetite, the only mineral to be removed in the process, was in operation. During the final years of production, milling was based on wreckage from decades of stone production (mainly fireplaces) accumulated in large dumps at the Sagflaten factory near Sel.

There are very few published accounts from the mining period and also later which show geological conditions in the mine. As far as known by the authors, the only published paper showing maps of the Bårstad mine is Professor C. Oftedahl's article from 1969. Fig. 41A and B shown here are taken from this publication. Oftedahl acted as a consultant for A/S Østlandske Stenexport for several years during the 1950's and -60's.

General geology

Some 60 years ago, Trygve Strand, who was then a mapping geologist at NGU, started work on the 1:100 000 sheets Sel and Vågå. Strand, over the years, made a very respectable work and made a very good basis (e.g. Strand 1951a, 1964) for later generations of geologists to work in this rather complicated region in the Caledonides. One must especially have in mind that this was a long time before ophiolites had been discovered, mapped, debated and the general build-up of these rock associations had become familiar to the geological world.

The understanding of the geology of Nord-Gudbrandsdalen has increased tremendously after Professors B.A. Sturt & D.M. Ramsay started their work in the region about 1985. Within a few years, they has established a tectonostratigraphy which has shown to be valid not only for the Nord-Gudbrandsdalen region, but for the entire southern and eastern part of the Trondheim Nappe Complex. Though the main emphasis of their efforts was on the tectonostratigraphy, their findings are also highly valuable for the talc/soapstone industry. Their work which has been presented in a series of papers, partly together with co-workers, are listed in the following: Sturt et al. 1997, Sturt & Ramsay 1997, Nilsson et al. 1997, Sturt et al. 1995, Bøe et al. 1993 and Sturt et al. 1991.

One of their major findings in the region was the existence of a highly dismembered ophiolite, the Vågåmo Ophiolite Complex, originally emplaced above the Heidal Group. The relation of this complex to the high-grade Heidal Group meta-psammitic substrate and the low-grade Sel Group metasediments deposited at the top of both the ophiolite and the Heidal Group was a discovery of equal importance. The Sel Group consists mainly of phyllites with minor conglomerates. There are three distinct varieties of conglomerate of which the serpentine conglomerate (the Otta Conglomerate) is the only important one for the talc/soapstone industry. The soapstones are essentially developed in the ultramafic (serpentinite) lower parts of the ophiolite and from serpentinous conglomerates and sandstones derived from the ultramafic rocks.

The best talc/soapstone deposits are generally the ones developed at the contact between the ultramafic part of the ophiolite and the serpentine conglomerate lain down above it. This is due to the formational conditions in the Ordovician when the continent Baltica was situated in the then tropical zone. Weathering of the ultramafic rocks then proceeded under tropical conditions, facilitating talc formation during subsequent metamorphism.

Table 5: Some published production numbers of talc and soapstone from A/S Østlandske Stenexport (from 1980 part of the company A/S Granit). Localities: 1) Bårstad mine, Lalm in Nord-Gudbrandsdalen (talc), 2) Åsårlia quarry, 8 km ESE of Bårstad (soapstone).

Year	Production (in metric tons) Talc	mt-cons.*	Soapstone	Source of information
1963	c. 20 000	c. 500	c. 600	Sverdrup 1967, page 14, 48
1964	?	?	c. 650	Sverdrup 1967, page 14, 48
1973?	c. 35-40 000			Industrial Minerals, January 1975
1978	c. 35-40 000			Industrial Minerals, September 1979
1980?	c. 11 000		c. 500	NOU 1982 : 24, page 52
1982	50 000**			Industrial Minerals, December 1982, page 63
1991	c. 25 000 ***			Industrial Minerals, January 1991, page 20

* by-product magnetite concentrate

** total capasity A/S Granit (both at Lalm and at Kvam)

*** total capasity, A/S Granit (Lalm operation only)

Table 6: Some published production numbers of talc and soapstone from A/S Smestad & Sætre (from 1980 Kvam talc A/S). Locality: Klefstadlykkja mine, 8 km north of Kvam centre.

Year	Production (in metric tons) Talc	mt-cons.	Soapstone	Source of information
1973?	c. 25 000			Industrial Minerals, January 1975
1978	c. 25 000			Industrial Minerals, September 1979
1980?	c. 5 000			NOU 1982 : 24, page 52
1991	0?			Industrial Minerals, March 1992
1993	4000-4500			Karlsen (1995)
1994?	c. 3-5000			Industrial Minerals, December 1995 (S.Olerud)
1997	c. 7000**			Industrial Minerals, November 1998 (T.A.Karlsen)

** milled quantity

Geology, mineralogy and geochemistry of talc/soapstone deposits in Nord-Gudbrandsdalen: references to open file reports.

There are a number of unpublished reports concerning the talc/soapstone deposits in the actual region. The older ones are registered in the NGU Bergarkivet report series and the more recent ones, from the 1970's onwards, in the NGU-report series.

Mine superintendent for Eastern Norway, Geir Strand, in 1963, made a review report on the talc/soapstone industry describing the current state of the industry including statistics on production numbers, comments on various aspects on the mining operations, etc. plus proposals for future development.

In 1979 NGU started a 4-year mapping and prospecting programme in co-operation with the 7 municipalities in the Nord-Gudbrandsdalen region and the Oppland fylkeskommune. In the beginning, scope and targets were rather wide, but during the years attention was focused more and more toward specific exploration targets of which certain talc/soapstone deposits were emphasised. A detailed summary of the programme, why and how it started, the course of its activities, etc. is given by the programme manager Einar Tveten (Tveten 1984).

During the programme, much work was carried out on the talc/soapstone deposits. Extensive reconnaissance reviews covering practically the entire region were made by Torsteinsen (1982) and Nilsson (1983). In addition, work focusing specially on the Råsdalsfjell - Åsårlia – Nysetri - Fredheim(=Rusti) area NW of Otta was carried out (Rønning & Nilsson 1983; Nilsson & Rønning 1984). In this latter area, A/S Østlandske Stenexport (from 1980 A/S Granit) was quarrying pot-stone in the Åsårlia quarry which around 1980 had very limited reserves. After the Nord-Gudbrandsdal programme period, NGU continued work in the area on commission for A/S Granit.

In addition NGU also carried out talc/soapstone prospecting work farther south, at the Klefstadlykkja talc mine in Kvam (Rønning 1982) plus work in the Skarsroi area just west of Lalm centre (Rønning et al. 1983). Recent regional geological work in the Kleftstadlykkja area shows that the talc-serpentine rocks are developed from ultramafic fine-conglomerate and sandstone (Ramsay and Sturt 1998). It is of interest that this stratabound deposit is up-section from the Sel-Heidal Gp. boundary.

The reports referred to above, all essentially written in the period 1982-84 and originally confidential material, are now open file reports. *The reader is therefore advised to refer to these reports in order to obtain an overview of the talc/soapstone deposits in Nord-Gudbrandsdalen. The contents of the reports cover geophysics, petrophysics, general geology, petrography, mineralogy/mineral chemistry, estimates on size, quality, etc. and with abundant map enclosures.*

The company A/S Granit has its major ground rights, activities and interests in the hills between the main valley Gudbrandsdalen and the side valley Ottadalen.

Outside of this area there is ***a very large talc potential*** *which is only partly investigated, in the* ***Lesjehorrungane*** *area north of Lesja in Nord-Gudbrandsdalen.*

In the ***Hornsjøho-Haverdalen*** *area in the Dovre-Grimsdalen tract, at the watershed between Oppland and Hedmark counties, there is further a* ***potential for very pure talc*** *in zones*

surrounding the larger and smaller serpentinite knolls and bosses in this area, see next section.

Characterisation of the talc ore/soapstone in Nord-Gudbrandsdalen

Nilsson (1983) made an overview of the petrography of the ultramafic rocks in Nord-Gudbrandsdalen based on field studies including reconnaissance mapping, thin section modal analyses and XRF major and trace element analysis of several hundreds of samples from the region (loc. cit. *Tegn. –25, -26, etc.*). See Fig. 38 and 39 for location of the actual rocks.
A list of specific deposits is given at the end of this chapter. For more details on these deposits, see Nilsson (1983). The following simplified summary is based mainly on Nilssons findings:

1) The Jotun Nappe:

The Jotun Nappe contains numerous ultramafic bodies as minor lenses, stocks(?) and layers in layered igneous rocks (dismembered layered intrusions(?)). Petrographically they span from dunites and peridotites to olivine-free pyroxenites and hornblendites. All the rocks have suffered granulite facies metamorphism and show a dry high grade mineral assemblage. However, in the border zones of the nappe, a superimposed Caledonian(?) retrogression has caused a weak serpentinisation of the ultramafic bodies. Modal analyses showed maximum 10-15 vol-% serpentine in the investigated rocks, but serpentinisation seems to be locally stronger, e.g. in the Sjodalen area. Talcified rocks are however only sporadically met with along the north western margin of the nappe (Nilsson 1983, Figs. 25 and 26). Here the minor occurrences Visa , Glitra and Skautflyi are situated, see Fig. 38 and 40.

The known talc/soapstone occurrences within the Jotun Nappe are very few and very small. The talc/soapstone potential within this geological unit therefore, seems to be so small that it can be neglected for all industrial purposes.

2) The Western Gneiss Region:

The north westernmost part of the Nord-Gudbrandsdal region constitutes but a small part of a geological province known as the Western Gneiss Region. Here steeply down-folded, narrow metasedimentary bands and slivers occur in the orthogneisses. The metasediments contain abundant ultramafic lenses (see Fig. 38 for location). Current interpretations tend to include more and more of these sedimentary sequences in the Caledonian nappes. Their tectonostratigraphic positions are, however, not yet fully understood.
In general, the ultramafites show a higher-grade metamorphic mineral assemblage than those in the Otta-Vågå tract (Trondheim Nappe Complex), but a clearly lower grade when compared with those within the Jotun Nappe.
Although metamorphic olivine and enstatite may occasionally be present, tremolite is undoubtedly the most characteristic metamorphic mineral in these ultramafites, compared to those further to the east. Talc-carbonate alteration is the common alteration observed, whereas serpentinisation is only occasionally met with in this tract. The typical ultramafic body is a dunite or harzburgite (possibly an ophiolite fragment?), partly altered only in the core area, but with an extensively altered border zone. The typical border zone alteration assemblage is: **talc-chlorite-magnesite/breunnerite-tremolite/(anthophyllite)** in varying proportions, but

generally with **talc** and **tremolite** as the most important ones by volume. In addition there is usually a few % secondary magnetite, some relicts of chromite, and rarely sulphides.
There is probably a talc/soapstone potential in this part of Nord-Gudbrandsdalen, but there are severe challenges to overcome. The ultramafic bodies are, with a few exceptions, rather small and/or remotely situated. In addition it can be observed that even the zones richest in talc consist of a mixture of the minerals mentioned above. Furthermore, microscope investigations show that talc and chlorite are occasionally strongly intergrown.

If we include the *Lesjehorrungane ultramafites* in the Western Gneiss Region, they would seem to have the best talc potential when it comes to tonnage alone (see Nilsson 1983, Fig. 11). Tonnage can here be calculated in millions of tonnes. At the locations Sjongsosen and Sjong setergrend, modal analyses of representative specimens have shown that talc contents may reach 40-60 % of the rock composition (S. Bakke, pers. com. 1983). Several other places in Lesjehorrungane have also been investigated and sampled, especially south west of Tandesætri, but talc contents here reached maximum c. 30-40 % in modal analyses of representative specimens. However, there might well be local areas somewhat richer in talc than indicated by the numbers cited above. According to old descriptions by Bjørlykke (1905, page 356, 367-369) and Carstens (1918, page 29-33) they have both observed talc-rich soapstone at several locations, especially in the western areas of Lesjehorrungane.

The mineral assemblage in Lesjehorrungane as a whole is rather complex. The maximum (prograde) PT assemblage has been forsterite-enstatite-tremolite-chlorite. This assemblage has partly suffered talc-carbonate alteration and partly serpentinisation during retrogression, therefore the metamorphic mineral assemblage all together consists of talc-carbonate-serpentine-chlorite-forsterite-enstatite-tremolite. The assemblage in the most favourable rocks is *talc-chlorite-carbonate-enstatite-tremolite*. Talc is partly intimately intergrown with chlorite, and the two minerals occur partly side by side as separated flakes and clusters.

Lesjehorrungane is situated in an area with mountain dairy farming (mainly sheep). In addition the area is an important passage for wild reindeer a few times a year. It is however not a nature resort without significant traces of human activity. There are several roads, a very large reservoir for hydroelectric power stations (lake Gautsjøen), a high-voltage transmission line, etc. in the area. The tectonostratigraphic placement of these sepentinites is inadequately known, and more work is required before reasonable correlations can be proposed.

We can therefore summarise that the talc potential in Lesjehorrungane is very large and possibly attractive if the talc can be satisfactorily extracted, transport problems solved and environmental and eventual other area conflicts properly addressed.

3) The Trondheim Nappe Complex

The main talc/soapstone potential in this geological unit within the Nord-Gudbrandsdalen region are connected with the Vågåmo Ophiolite Complex described above. The complex is highly fragmented or dismembered. An overview of the distribution of these fragments is given in Nilsson et al. (1997, p.11, here shown as Fig. 37). As mentioned above, the best talc/soapstone potential is generally near the contact between the ultramafic part of the ophiolite and its cover of serpentine conglomerate or sand. Outside the area where A/S Granit have their interests we will here point the attention to the Hornsjøhø-Haverdalen area earlier mentioned. Here there are one relatively large (Raudhamran: c. 0.4 km^2) and several minor ultramafic bodies, together at least 14 separated bodies (see Nilsson 1983, Tegn. –18). These

bodies are serpentinites with rather pure talc in the border zone. Investigated samples have shown pure talc schist and massive talc with >95 % talc and <5% chlorite in a 5-10 m wide border zone of one of the smaller ultramafic lenses (c. 25 x 50 m large lens). The talc potential for this area is not yet estimated. Most of the ultramafic bodies have only been the subject of reconnaissance mapping. The largest (Raudhamran) body may have a significant talc potential in the border zone which, however, is totally overburdened. Drilling, eventual trenching/pitting, is clearly needed here to proceed with the question of the talc tonnage. There is a road to a schist quarry (the Storvassbergert quarry) just north of the serpentinite field, but this is open only during summer time. The high altitude (1300 – 1500 m.a.s.l.) is clearly a negative factor for talc/soapstone quarrying operations. In addition environmental problems (the proximity to the adjoining Rondane National Park) may be another obstacle.

We can thus summarise that the Hornsjøhø-Haverdalen area has a potential for very pure talc in the border zones of the many serpentinite bodies in this area, but so far this potential is very poorly investigated. Eventual climatic and environmental problems should be kept in mind for this area too.

The common mineral assemblage of the talc/soapstone deposits in the Trondheim Nappe Complex is *talc-chlorite-breunnerite±dolomite.* Chlorite is usually a green Mg-Fe clinochlorite, breunnerite is always of a coarse grained well crystallised variety, whereas dolomite occurs in aggregates of a very fine grained variety.

There is usually a transition zone between pure serpentinite and serpentine free talc/ soapstone. The width of this zone can vary from a meter or so, to several tens of m. Sometimes there are whole ultramafic bodies with this mixture, i.e. neither serpentinites nor soapstones *per se.*, but something intermediate between the two.
In addition, some of the soapstone altered serpentine conglomerates have a high *quartz* content (± 30 %) that makes the stone completely worthless as raw material, e.g. the zone at Råsdalsfjell NW of Otta. The assemblage here is *talc-quartz-(tremolite)-(chlorite)-(oxides)* and has nothing to do e.g. with listwaenites. This rather odd mineral assemblage is probably due to two completely different sources during formation of the serpentine dominated and rather hybrid, polymict conglomerate. One source is purely ultramafic, i.e. contributing only ultramafic detritus (pebbles, cobbles, gravel and sand) from the ultramafic part of the Vågåmo Ophiolite, whereas the other source, providing the quartz detritus, might be a Heidal Group meta-psammite. Bøe et al. (1993) show how many of the conglomerates may in fact have a mixed assemblage of source rocks. This shows that when one is dealing with talc-serpentinite rocks, which have a sedimentary origin, the study of the sedimentary features including information regarding clast types (conglomerates) or the petrography of the sand fraction are features which are also important in a prospecting strategy.

The following is a list of talc/soapstone occurrences in Nord-Gudbrandsdalen described or mentioned by Nilsson (1983):

Blankåhaugen, Skjåk
Bårstad, Vågå
Dale, Sel
Darthusseter, Vågå
Dyratjørni,
Dørkampen, Skjåk
Finna ved Øyagarden, Vågå
Fredheimsbruddet, Vågå
Grandalen, Sel
Grota, Lom
Grotli, Skjåk
Guttormstjern, Sel
Halvfarhøi Gruve, Lesjehorrungane, Lesja
Haugsetra, Nord-Fron
Heidal, Sel
Holepiggen, Sel

Hovdestulfjellet, Bøverdalen, Lom
Huguvardtjern, Skjåk
Høggøymen, Skjåk
Høgsetrene i Heidal, Sel
Kjerringtjørni, Skjåk
Klefstadlykkja, Nord-Fron
Kleppdalen, Lom
Knutshøi
Kollen-Tandsetri
Krosshø, Skjåk
Megardsåsen, Vågå
Mjølrakkhaugane
Nordsetrene, Vågå
Nysetri, Vågå
Ormhaugen, Vågå
Raudberget ved Raudalsvatnet, Skjåk
Raudbergi i Lesjaskog, Lesja
Raudhamran, Haverdalen, Dovre
Raudhøgda, Skjåk
Raudnebb, Vågå
Reiggehaugen, Vågå
Råsdalsseter, Sel
Senda, Vågå
Severine Skjerp, Lesjehorrungane, Lesja
Sjongsosen, Lesjehorrungane, Lesja
Skarsroi, Vågå
Skytningen, Vågå
Svarthovda, Dovre
Svarttjern, Tolstadåsen, Vågå
Tallerås, Dovre
Tessekrokene, Vågå
Tristeinen, Vågå
Ulevollen, Sel
Vangstjern, Sel
Veggemskampen, Sel
Veslehorrungfeltet, Lesja
Veslegrovåi, SW of Otta, Sel
Vesleknatten
Vistdal, Vågå
Viste, Vågå
Åsårlia, Sel

20.2 Oppland outside the Nord-Gudbrandsdalen region

Within the Oppland county there are very few talc/soapstone deposits, outside the main province in Nord-Gudbrandsdalen. The few additional ones are in the south (Jevnaker and Hadeland) and the west central part of the county in the Valdres district.

Jevnaker area

According to Helland (1893, p.119-120) there is a small pot-stone occurrence at the property of the farm *Øvre Berger*, 2 km WNW of Randsfjord railway station at Jevnaker. There are two small quarries here. Both widths (around 2 m) and strike lengths, of the deposit, are very limited, and the further raw material potential was therefore considered to be quite insignificant by Helland. The stone itself, however, is attractive bluish grey, with a little mica, and it has been used in the building of at least two monumental buildings, the Kreditkassen banks in Oslo and Bergen. In NGU's IM/NS databases, this occurrence goes under the name *Brenteberg* soapstone deposit. The occurrence has been briefly treated in a paper by Stenberg (1991).

Hadeland district

Close to the farm *Næs (=Nes)*, situated at Lake Randsfjorden in the Gran municipality (as well as at other places in the Hadeland district), there are good soapstones according to Kraft, referred to in Helland (op.cit., p. 120). However, Helland gave no additional information. The farm Nes is situated just at the border between Cambrian alum shale and Proterozoic gneiss according to the map of Holtedahl & Schetelig (1923). There is, however, no information, either on the map or in the accompanying map sheet description, on soapstone occurrences

here or at other places in the Hadeland district. Further, there is no information in the different NGU databases on soapstone, in this district.

Valdres district

According to Helland (loc. cit., p.120) there may also be occurrences of soapstone in *Røddalen* in Vestre Slidre in the Valdres district. The rather vague statement by Helland combined with a total lack of information in the NGU databases, should indicate that this is probably not an important occurrence. However, the very conscientious geologist Trygve Strand, who mapped the whole district, has also treated the actual soapstone deposit (Strand 1950 and 1951b, p.45-46). According to Strand the *Kjøsalia* soapstone occurrence in Rauddalen is situated within metasedimentary rocks of the Precambrian basement complex. The host rocks are classified as "quartzite rich in mica and mica-schist rich in quartz". Herein, is a 13 m wide zone of hornblende-chlorite schist and soapstone where 7m. is soapstone occurring in two belts or layers, 2 and 4 m thick respectively, and separated by a meter thick layer. A sample from the thinner layer turned-out to be a low quality chlorite rich stone, whereas a sample from the thicker layer showed to be a very pure, talc-rich soapstone, without carbonates. There may, however, be compositional differences within each of the belts, as Strand points out. Soapstone has been quarried here in ancient times, and is described in historical documents by both Kraft and Helland, according to Strand. In 1917-1918 the quarry was worked using "modern machinery", and ovens, open fireplaces, blocks and bricks were made. The soapstone was known for its good quality and was easy to work.In more recent times the talc/soapstone deposit at Kjøsalia has been treated in a local historical yearbook (Dæhli 1992).

Espedalen area

Soapstone also occurs in Espedalen (a tributary to Gudbrandsdalen) according to Dietrichson (1945, 1950). The occurrence, named Venliens soapestone quarry, is situated on the SE side of the northernmost part of Lake Espedalsvatn (cf. Dietrichson loc. cit., fig. 1).

20.3 References, Oppland

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21. CONCLUDING REMARKS

- Norway contains a large number of talc/soapstone deposits.

- The existing knowledge of the deposits is rather low, with the exception of the areas Stølsheimen, Altermark and Nord-Gudbrandsdalen, which so far have been the most obvious and productive talc provinces.

- Areas that possibly contain large quantities of talc include Lesjehorrungane in the Nord-Gudbrandsdalen region and the Raudfjellet deposit in Snåsa, Nord-Trøndelag.

- One of the two varieties of metakomatiite shown on map sheet Inari (cf. section of the map in Fig. 7) is basically a pale green talc-chlorite rock. The size of this rock, with individual zones/layers up to c. 10 km long and 750 m wide, possibly makes it by far the largest source for talc in Norway. There are, however, no written communications, neither on the grade and quality of this metakomatiite as a possible raw material for talc, nor on more general quantitative (modal) petrography.

22. ACKNOWLEDGEMENTS

We would like to thank the following persons:

Chief geologist, Prof. Dr. B.A. Sturt for commenting on the geology of Nord-Gudbrandsdalen and Hedmark, as well as for improving the English for a large portion of the m/s.

Section Leader, mineral resources, Dr. Nigel Cook, for correction of English language and for proof-reading the final manuscript.

Department Engineer Rolf Lynum for preparing most of the figures.

Researcher Håvard Gautneb for providing detailed unpublished data from Troms County.

23. INDEX of talc-deposits and occurrences

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Figure 1: Soapstone pot from Gjestad, Fet in Hordaland. Source: "Piggåsen soapstone quarry" at World Wide Web.

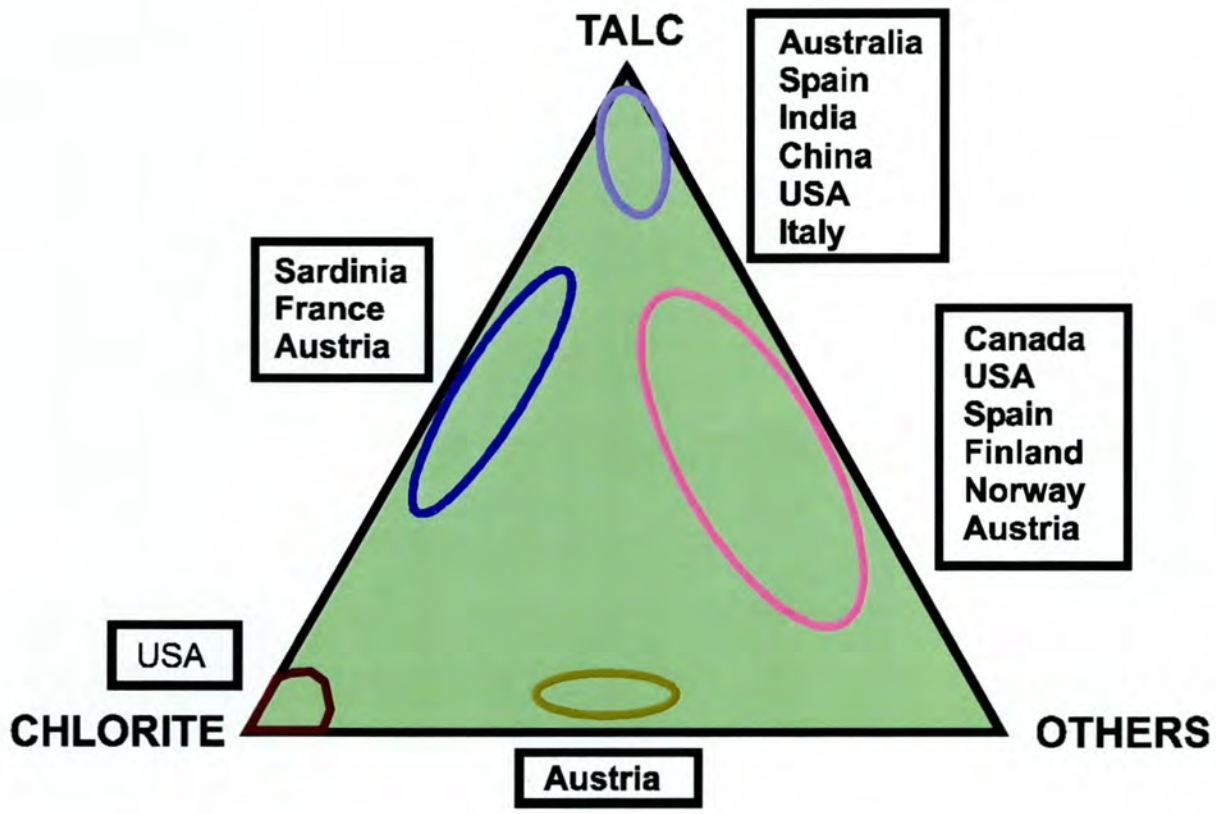


Figure 2: Simplified mineralogical composition of talc ores. Modified from Fourty (1999).

Scandinavian Caledonides

Tectonostratigraphy

Fig. 3

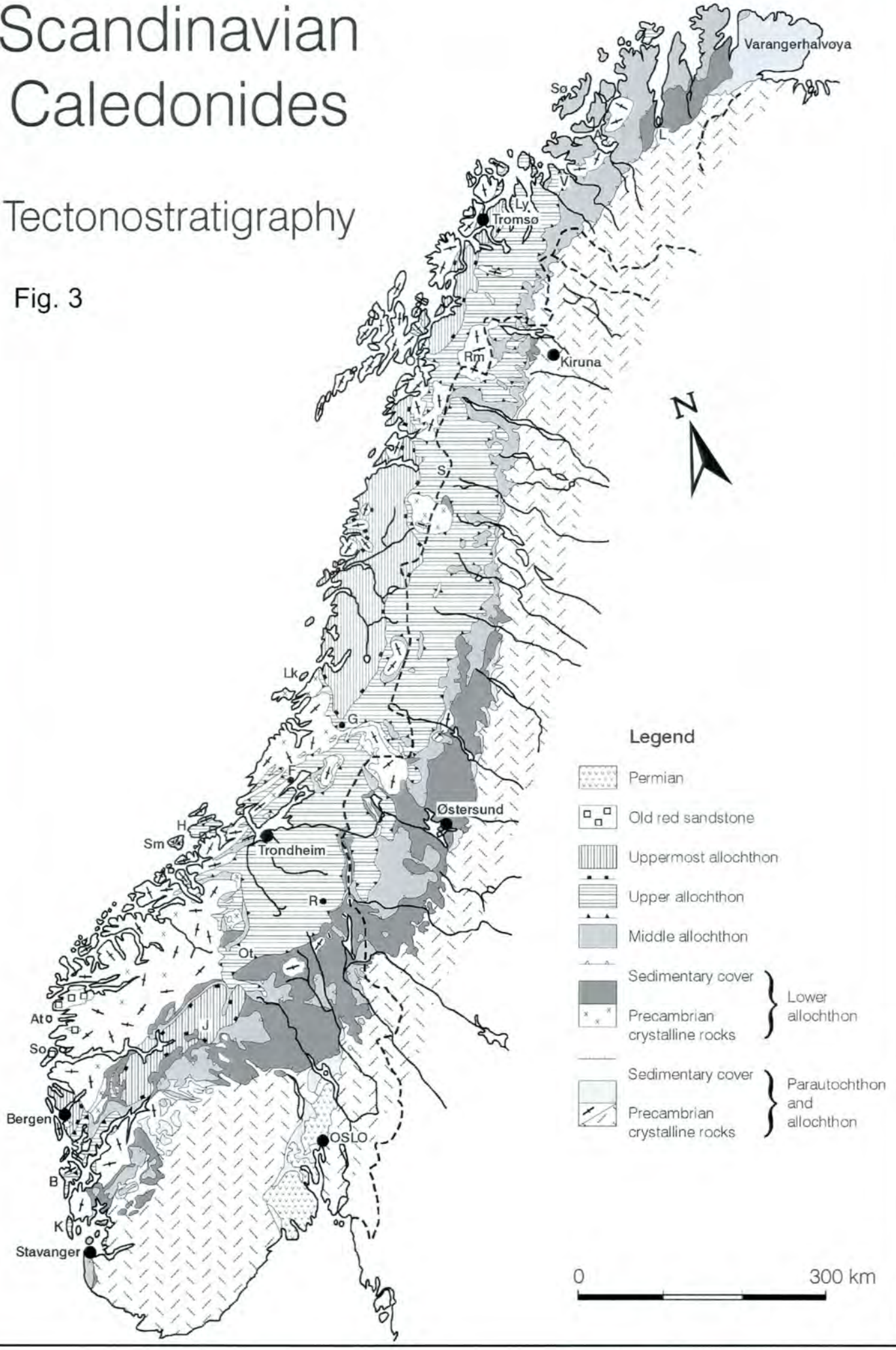


Fig. 4A: Counties and main cities in Norway

Fig. 4B: Registered talc/soapstone deposits in Norway

Figure 5: Talc / soapstone occurences in Sør-Varanger, eastern Finnmark, Finnmark county.
Map sheet KIRKENES, 1:250 000 (Siedlecka & Nordgulen 1996).

Figure 6: Talc / soapstone occurences in Karasjok Greenstone Belt, Finnmarksvidda, Finnmark county. Map sheet Karasjok, 1:250 000 (Skålvoll 1972).

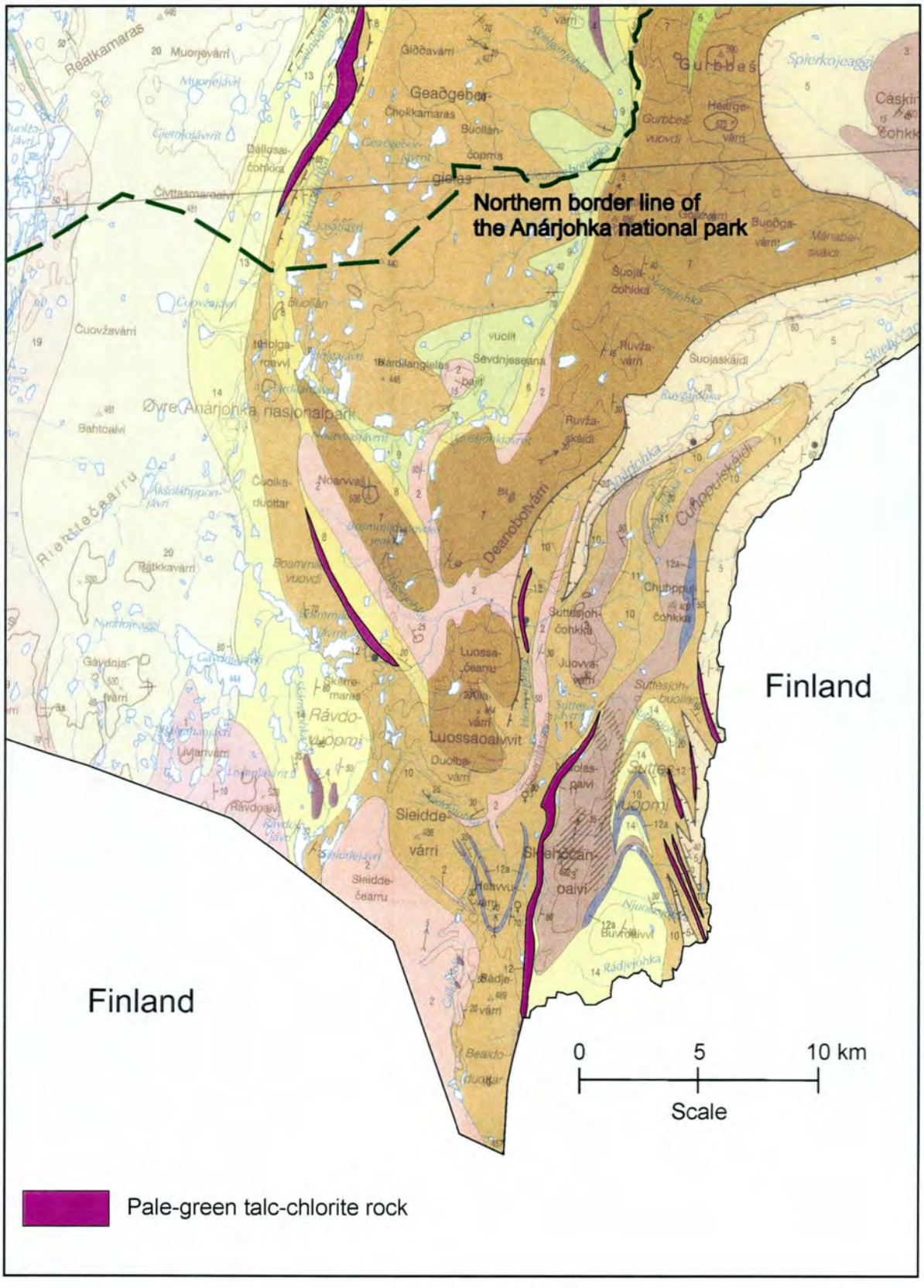


Figure 7: Talc bearing metakomatiites (unit 12), southern part of Karasjok Greenstone Belt, Finnmarksvidda, Finnmark county.
Map sheet Inari, 1:250 000 (Olsen & Siedlecka 1996).

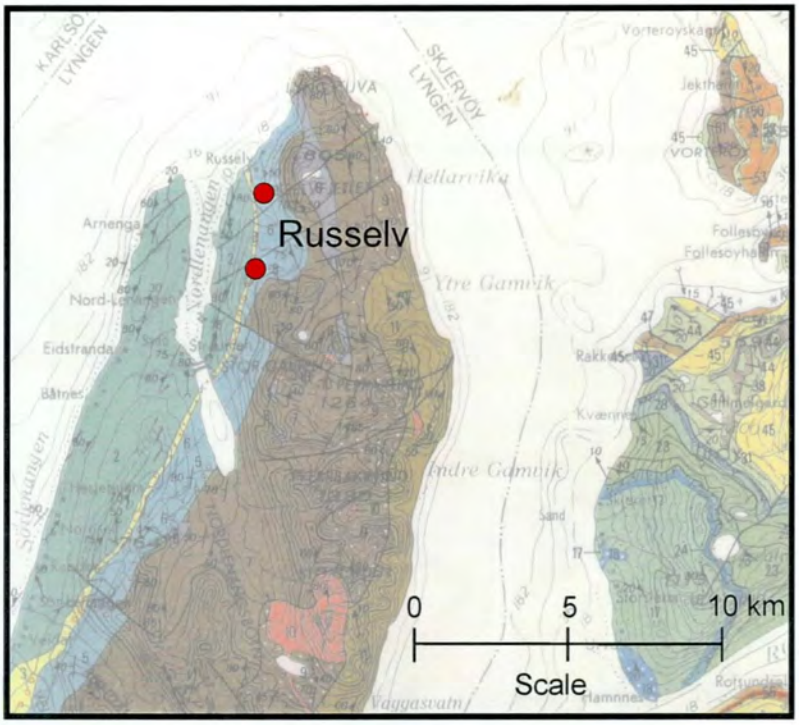


Figure 8: Talc / soapstone occurences in northern Troms
Map sheet NORDREISA, 1:250 000 (Zwaan 1988)

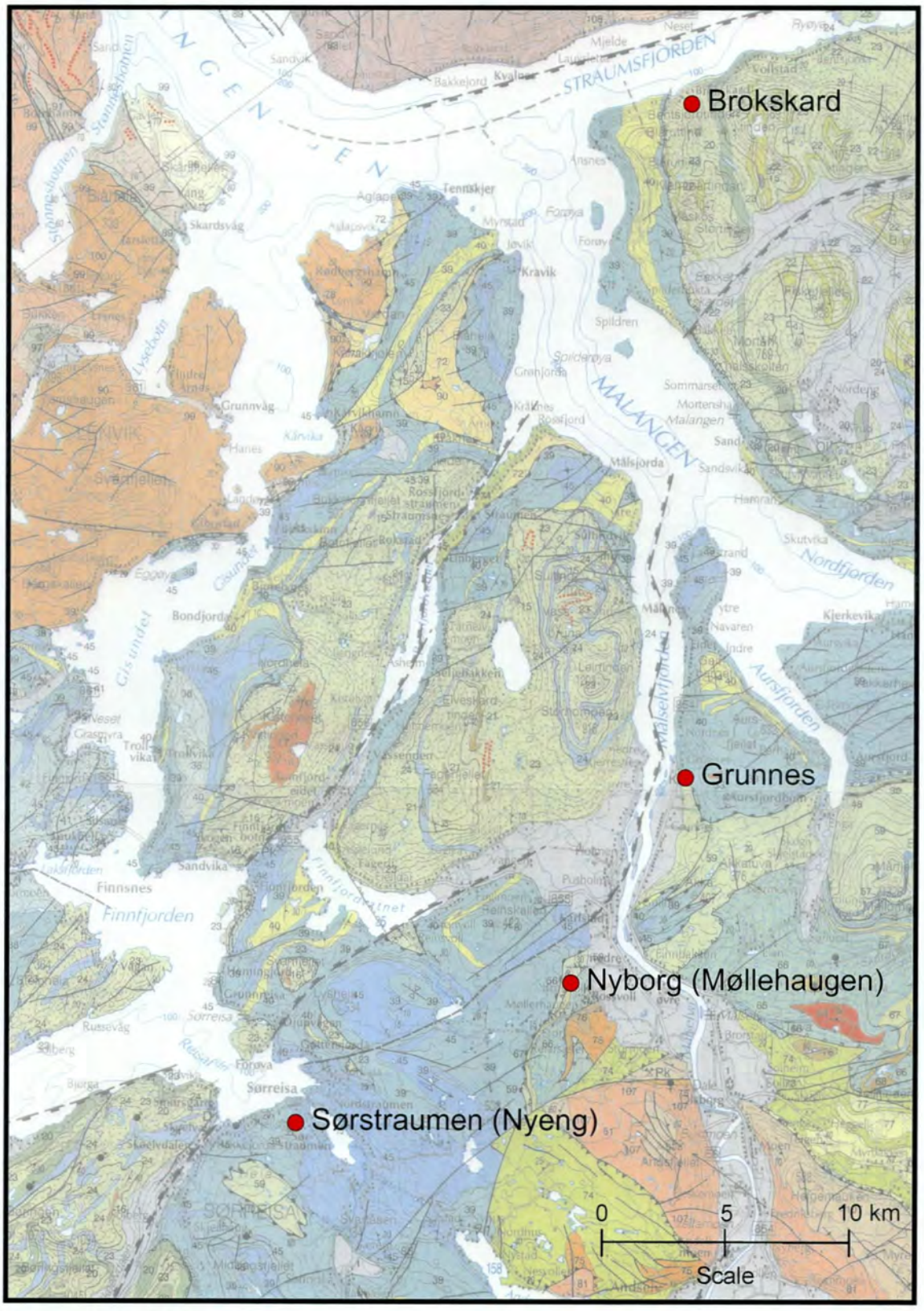


Figure 9: Talc / soapstone occurences in central Troms
Map sheet TROMSØ, 1:250 000 (Zwaan, Fareth & Groogan, 1998)

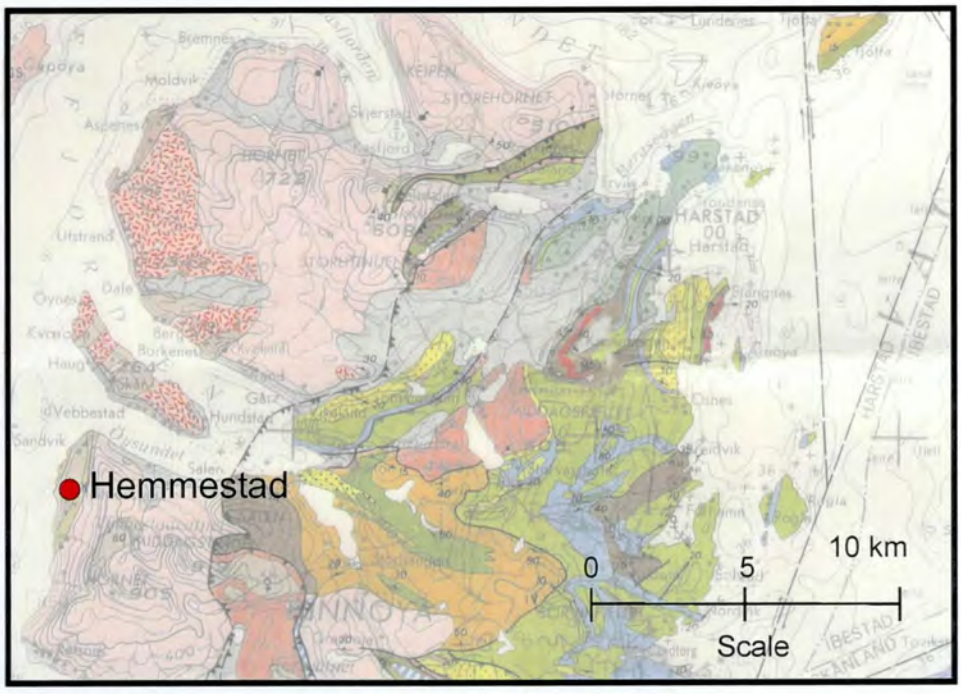


Figure 10: Talc / soapstone occurences in southern Troms
Map sheet NARVIK, 1:250 000 (Gustavson 1974)

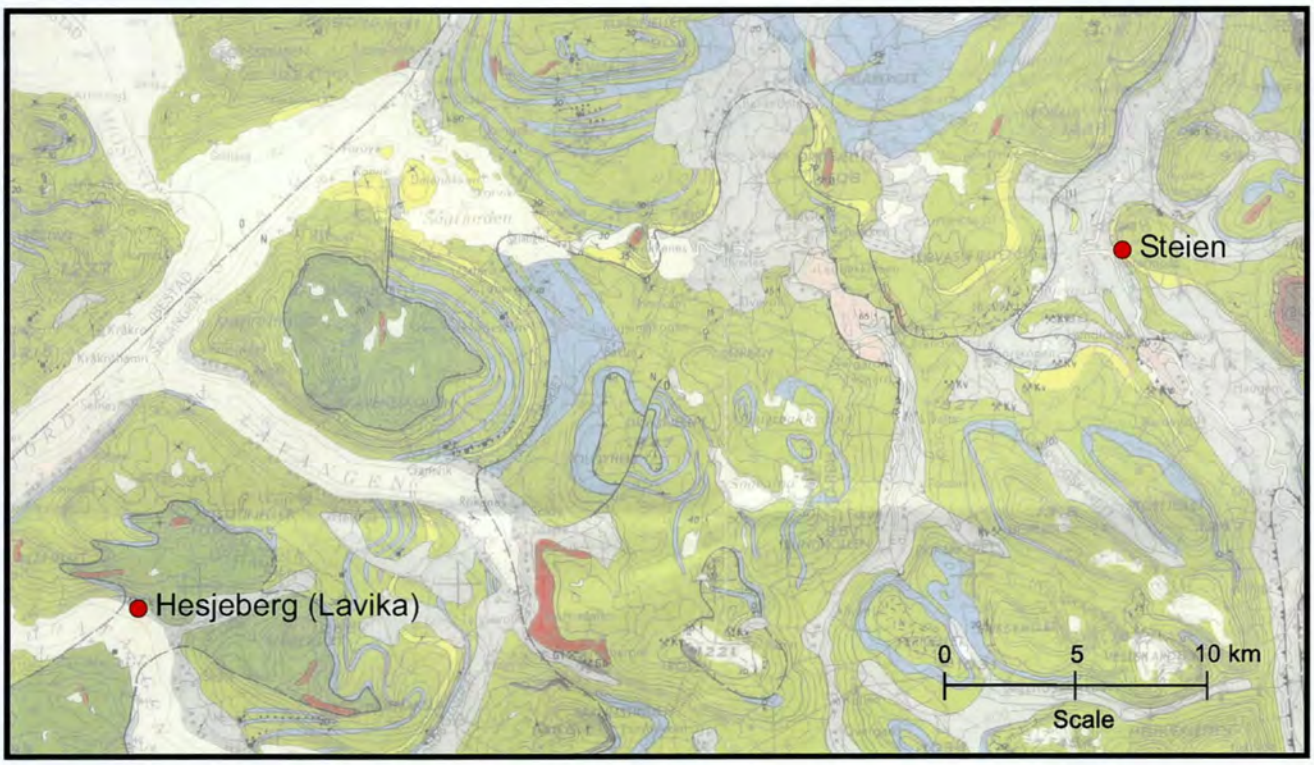
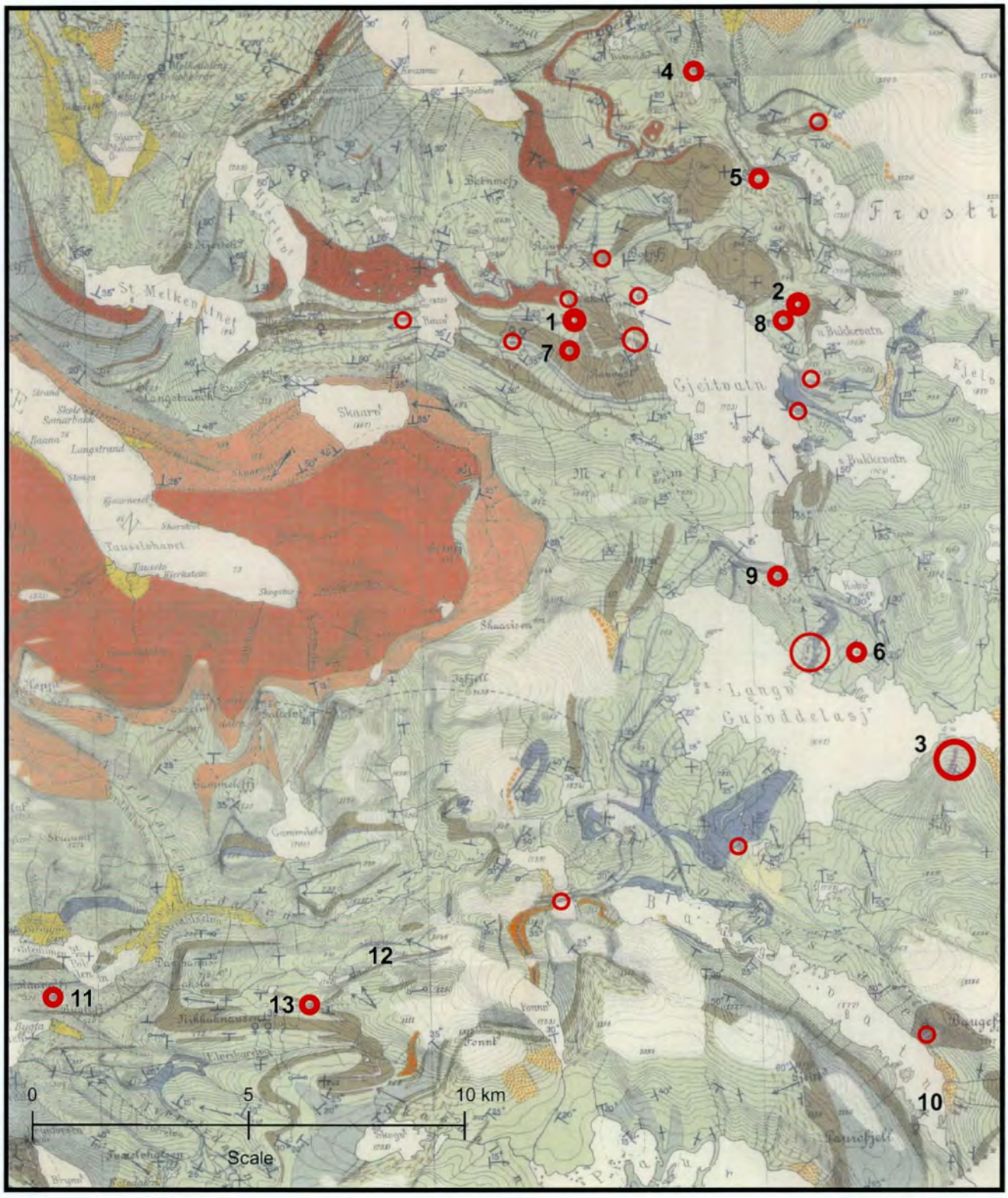


Figure 11: Talc / soapstone occurences in southern Troms
Map sheet NARVIK, 1:250 000 (Gustavson 1974)



The circles marking the serpentinite bosses indicate degree of talcification in the following way:
○ insignificantly ◎ partly ● totally talcified

Figure 12: Talc / soapstone occurences in northern Nordland, map sheet TYSFJORD, 1:100 000 (Foslie 1931). NB! Scale is here reduced to c. 1:135 000.

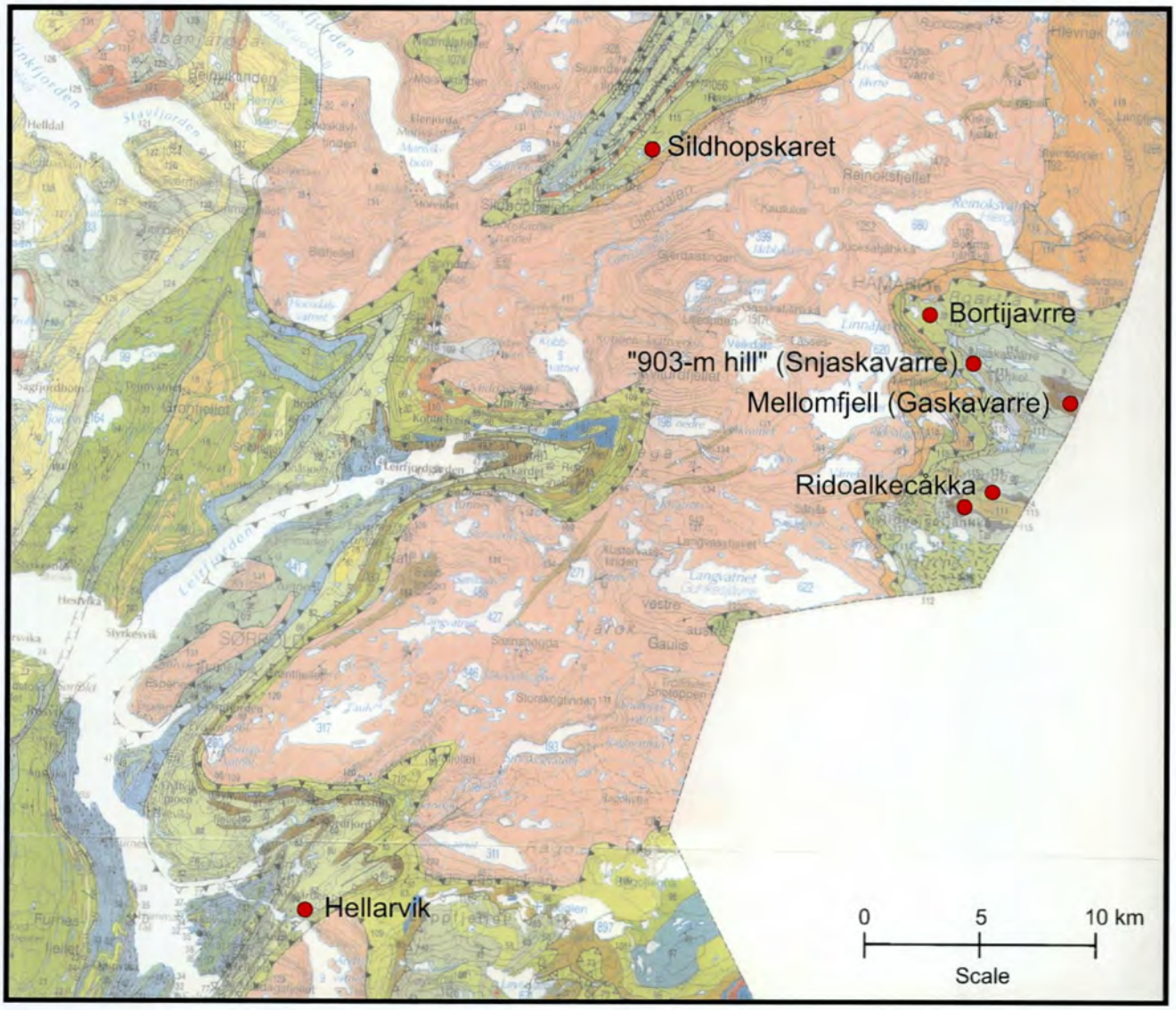
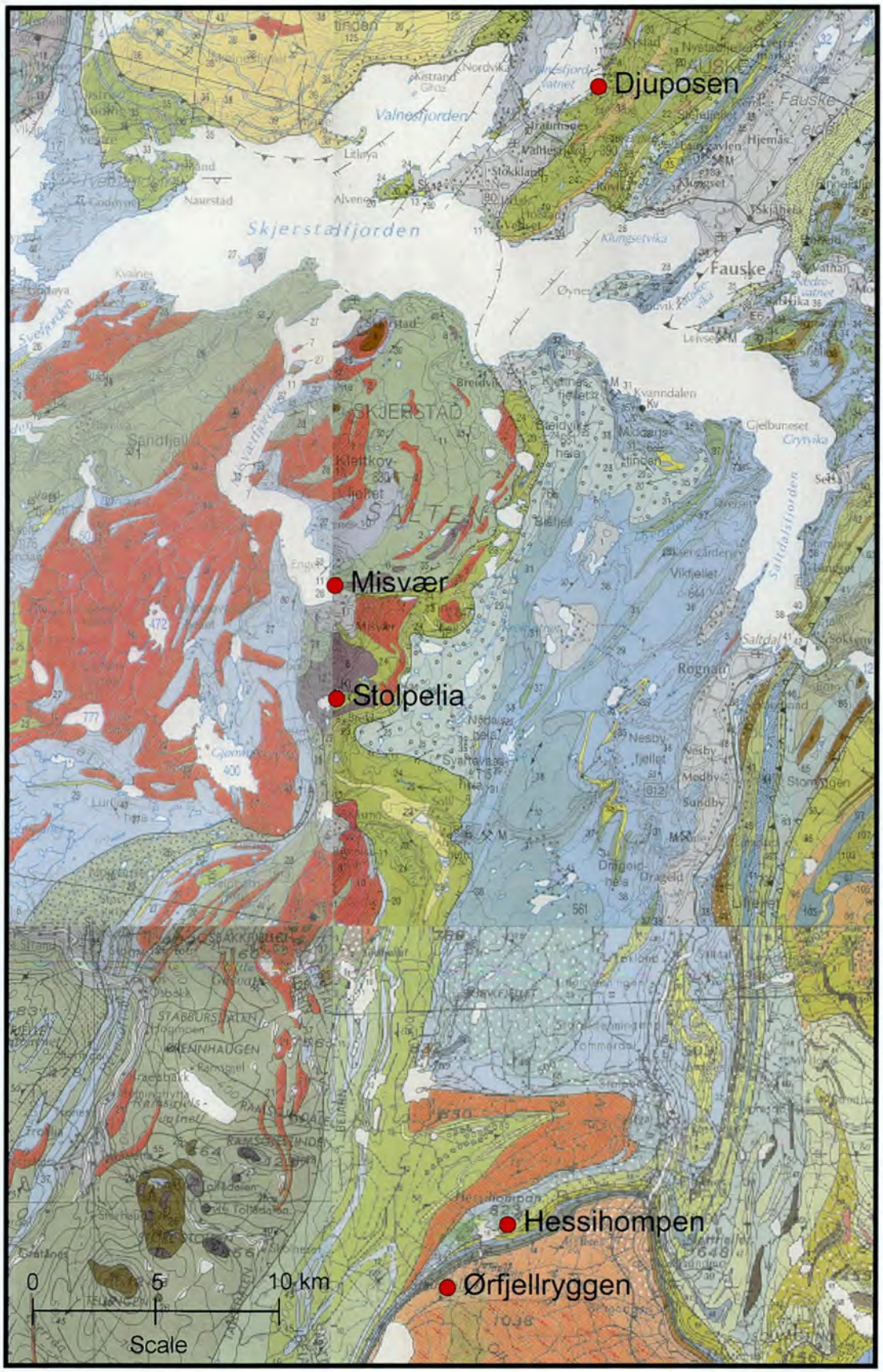


Figure 13: Talc / soapstone occurences in north central Nordland
Map sheet SULITJELMA, 1:250 000 (Gustavson 1996). NB! Scale is here reduced to c. 1:285 000.



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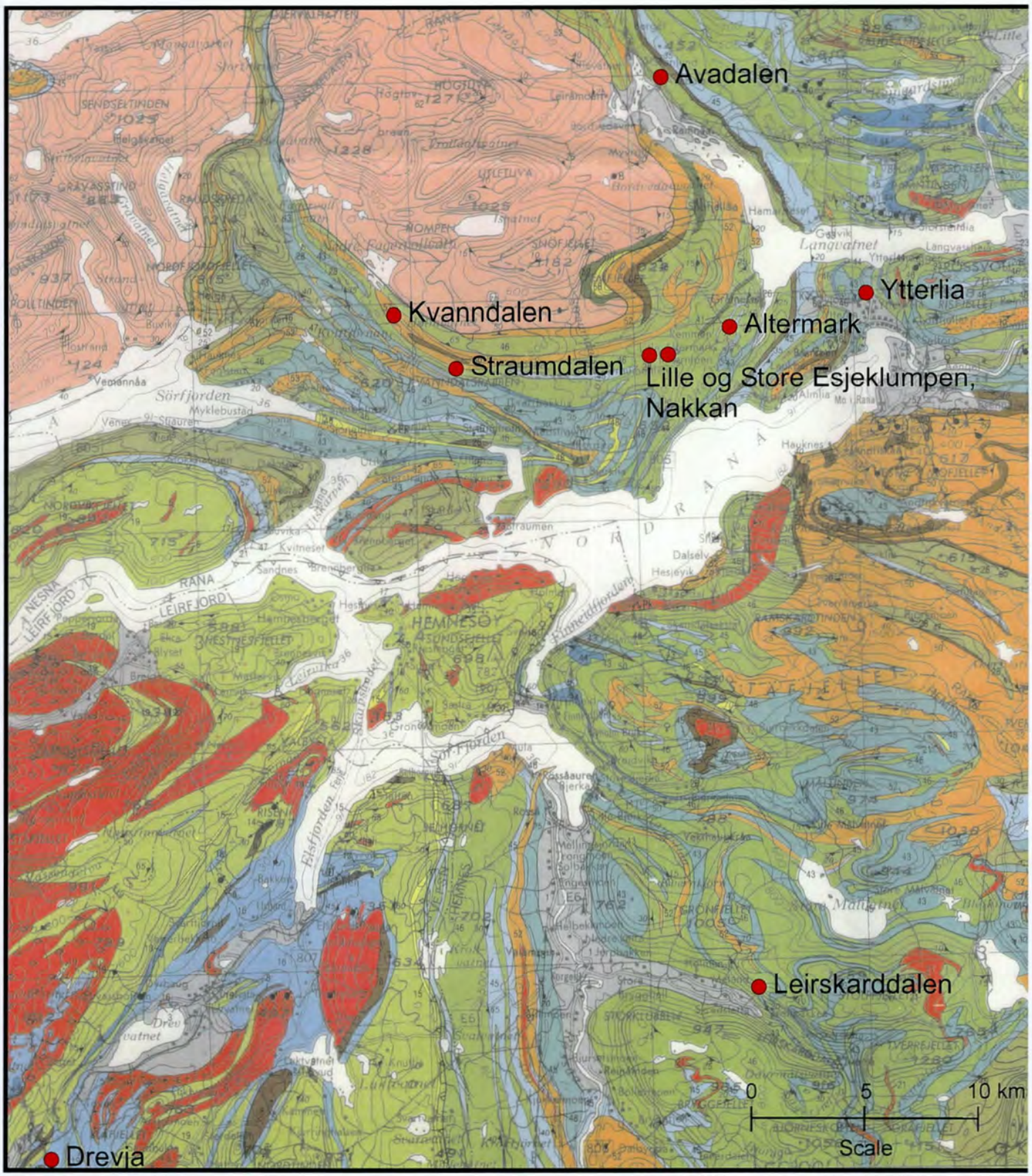
SALTDAL (SE) (Gjelle 1988), MO I RANA (SW) (Gustavson & Gjelle 1991)
and BODØ (NW) (Gustavson & Blystad 1995), all 1:250 000.



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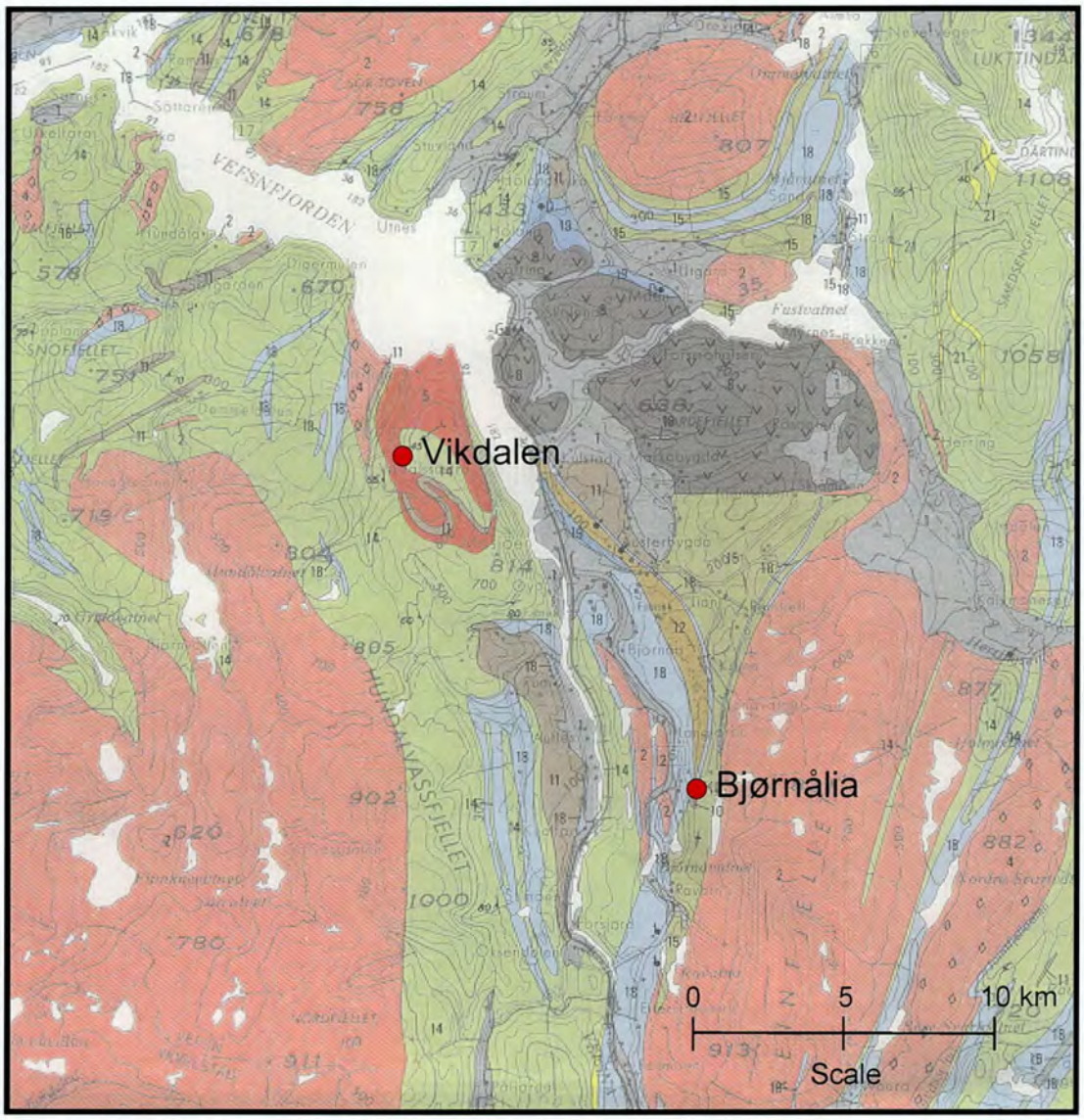
Map sheet MO I RANA, 1:250 000 (Gustavson & Gjelle 1991)



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Map sheet MOSJØEN, 1:250 000 (Gustavson 1981)

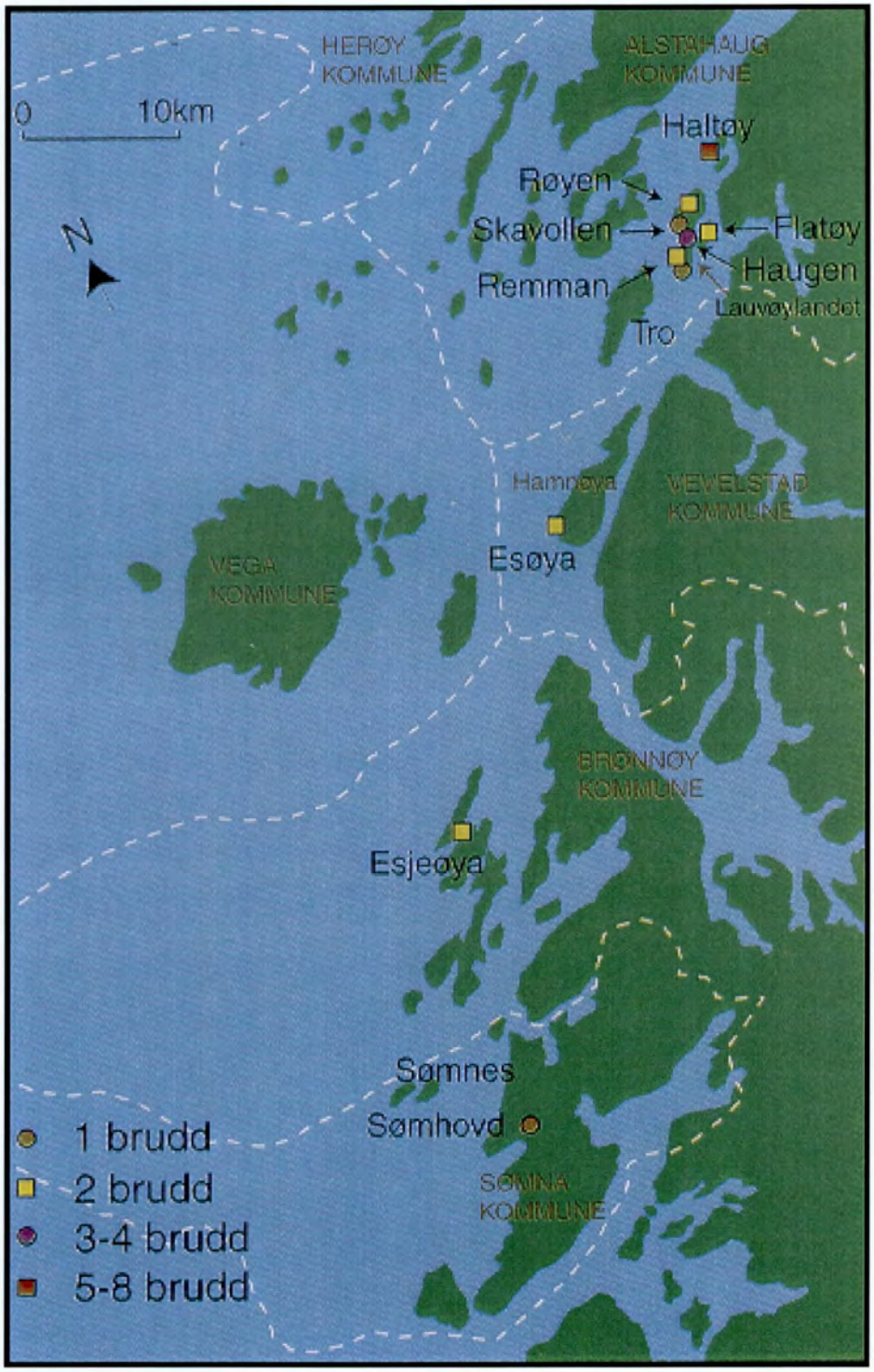

Figure 17: Outer Vefsn fjord talc province
Ottar 2/99, Tromsø Museum (Birgitta Berglund, p.13-24)
Map scale c. 1:45 000

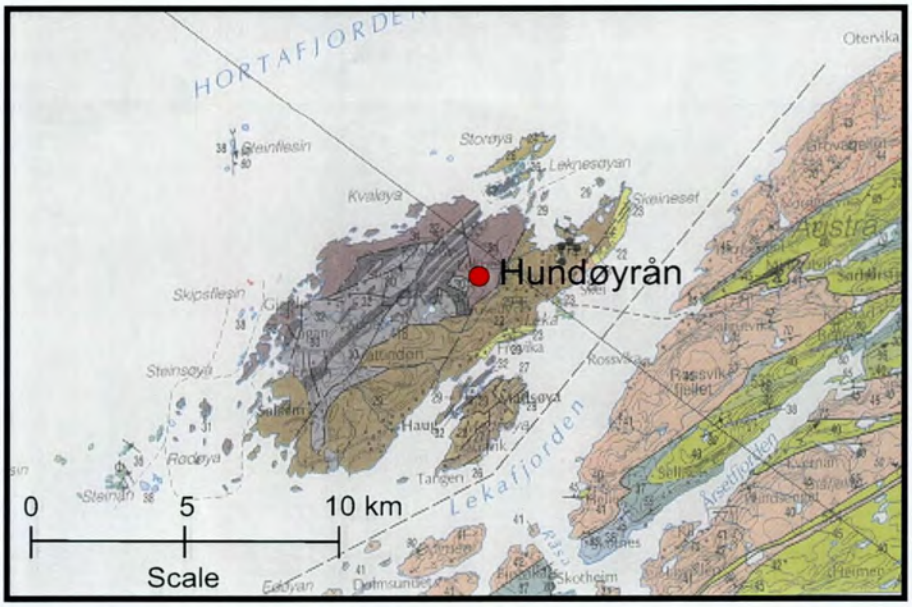

Figure 18: Talc / soapstone occurences in northwesternmost Nord-Trøndelag
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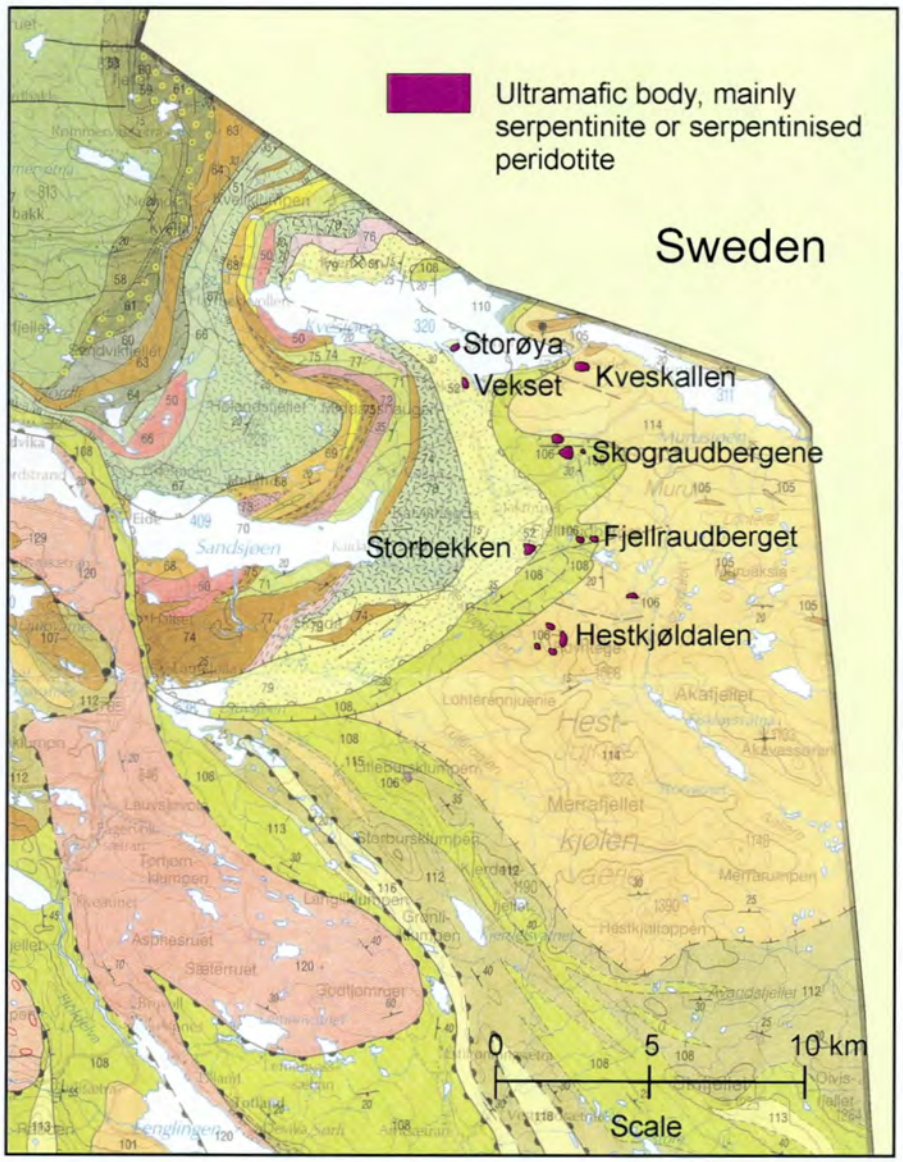

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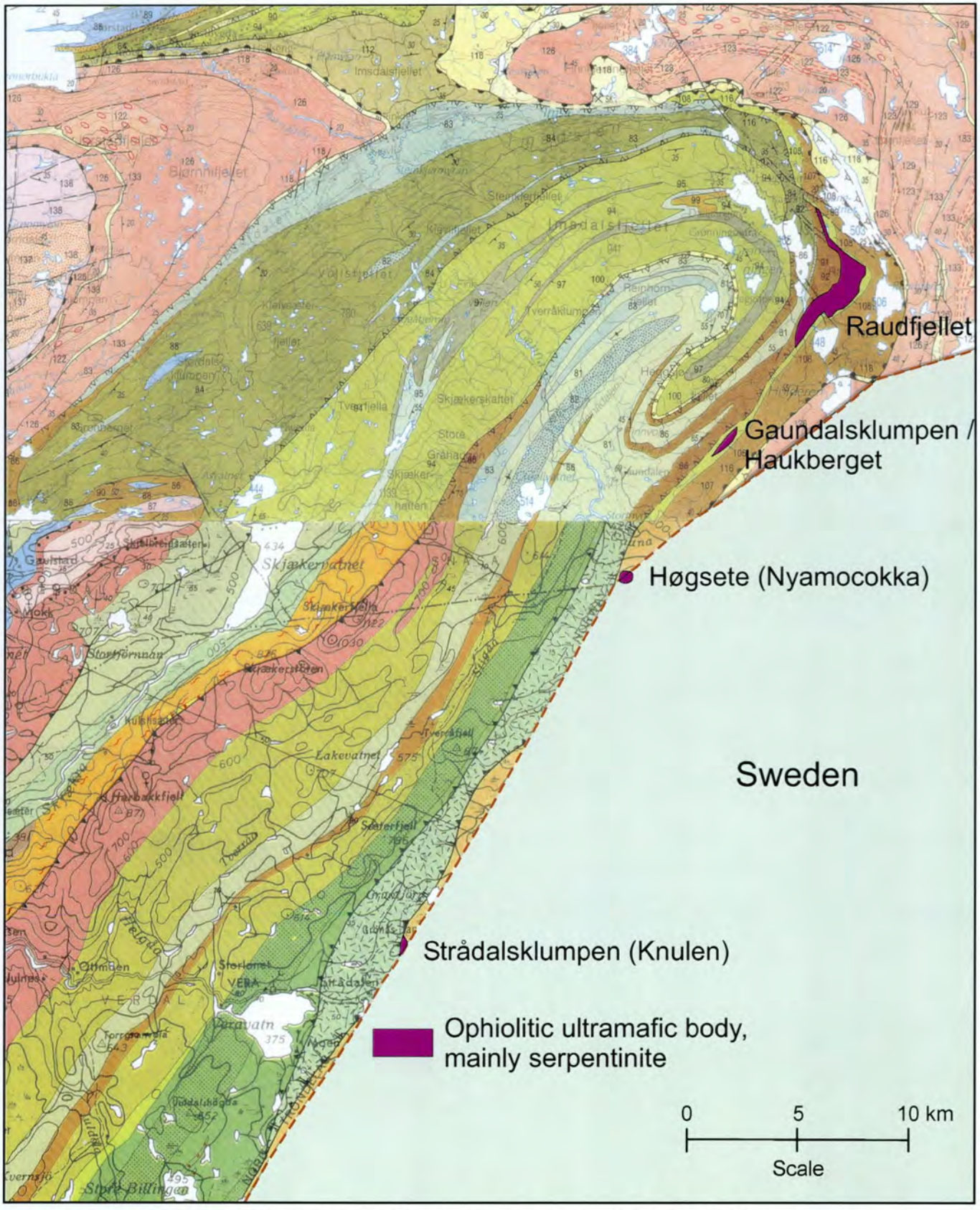


Figur 20: Ophiolitic ultramafic bodies in the Snåsa - Verdalsfjellene area. Map sheet Østersund, 1:250 000 (Wolff 1977) to the south, and Grong (Roberts 1997a).

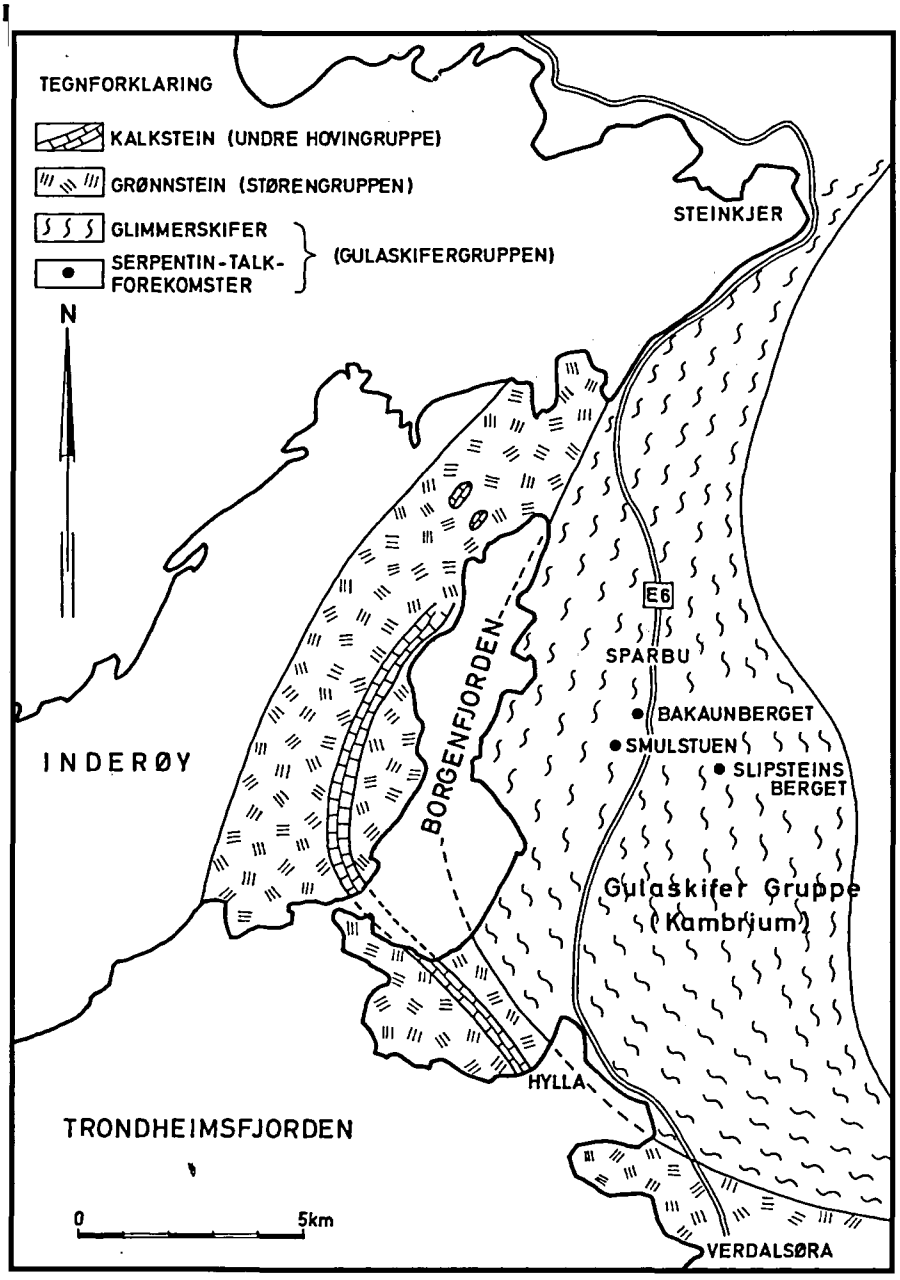


Figure 21A: Geological sketch map of the Sparbu area showing the locations of talc deposits / ultramafic lenses. Modified from Wolff (1964), Mortenson (1973) & Roberts (1997b).

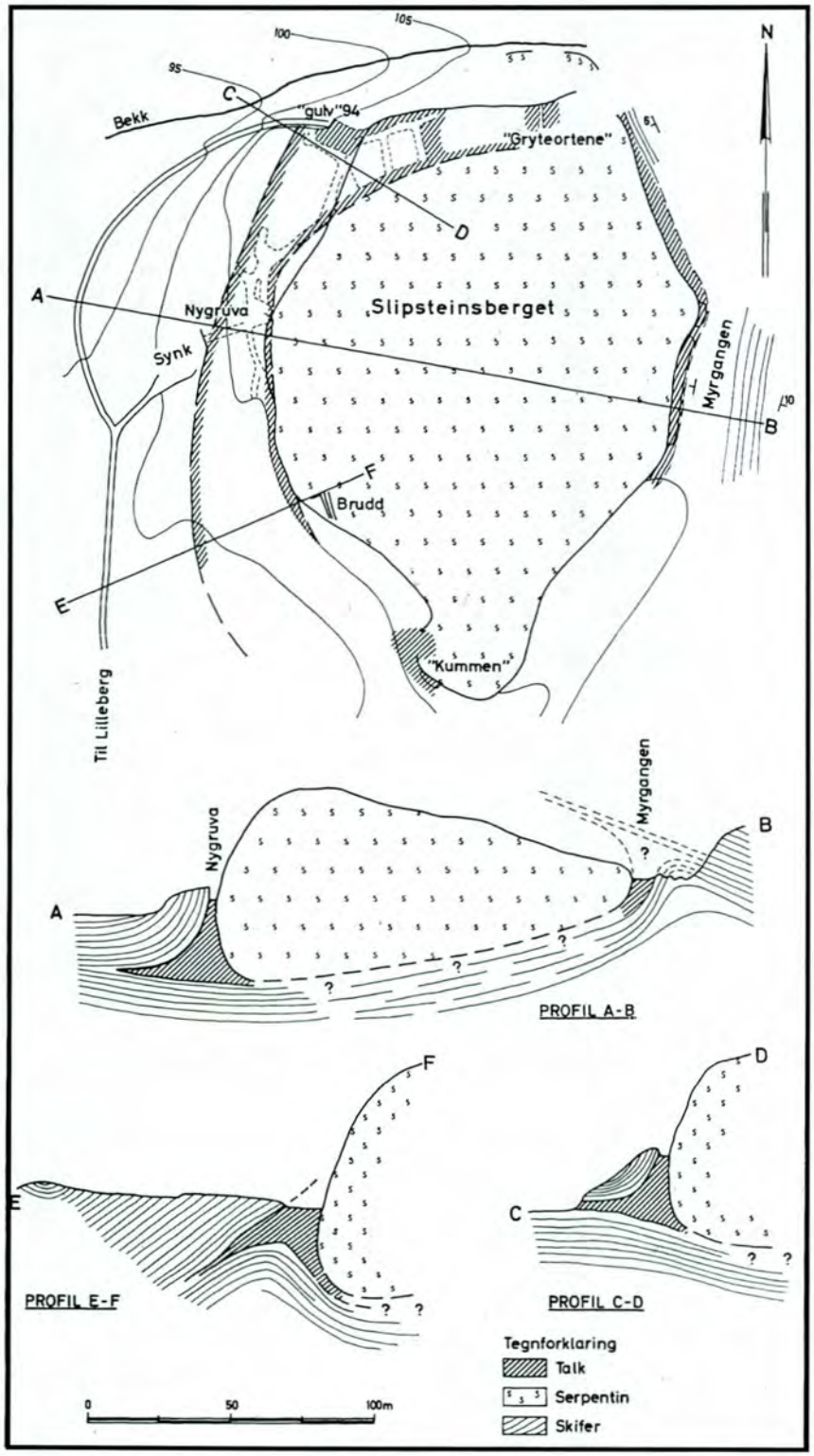
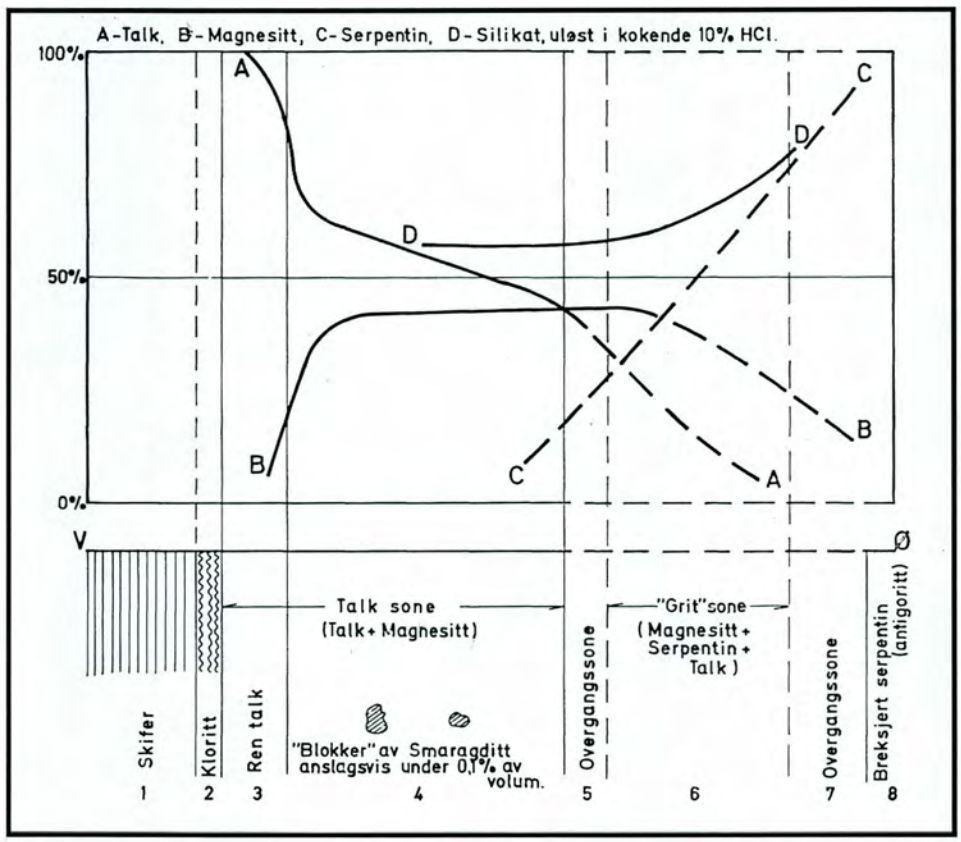


Figure 21B: Geological sketch map and profiles of Slipsteinsberget (From Mortenson 1973).



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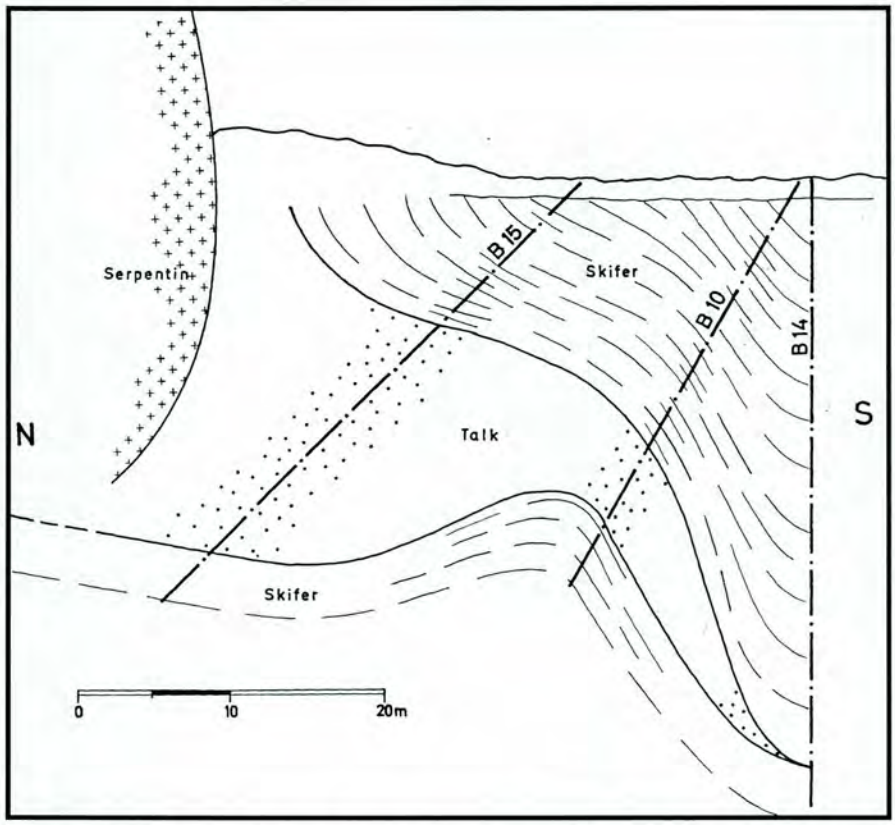

Figure 21D: Profile through the talc-zone, around 70 m east of "Nysynken" (from Mortenson 1973).

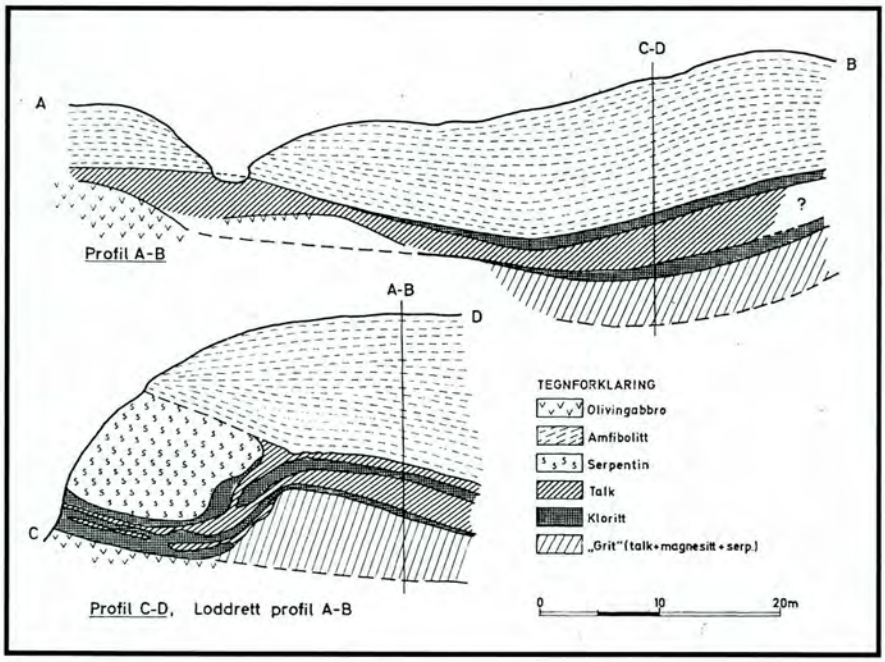

Figure 21E: Profiles through the Smulstuen talc deposit.

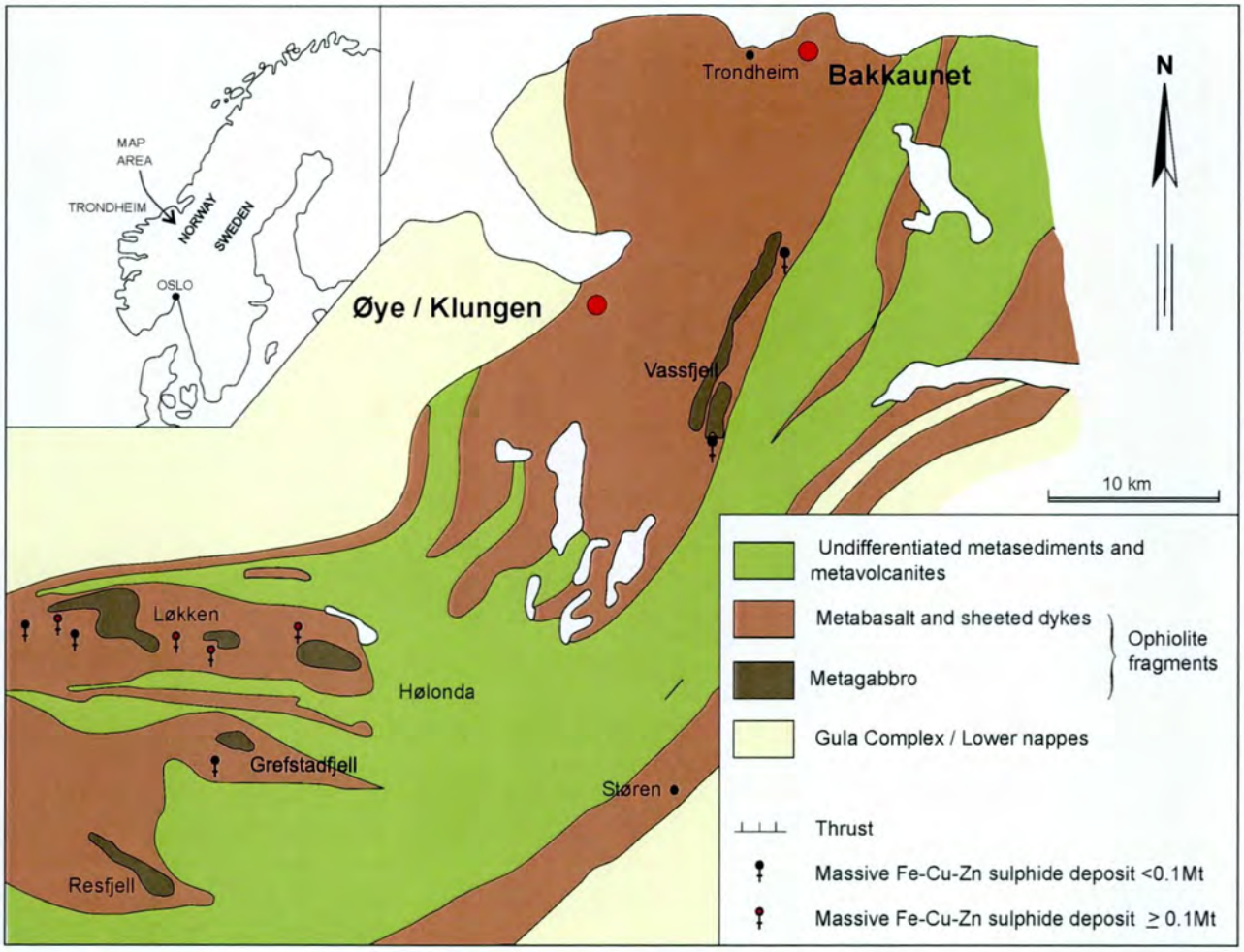

Fig. 22: Simplified map of the western Trondheim district, Sør-Trøndelag county, showing the location of ophiolite-hosted massive sulphide deposits as well as talc/soapstone deposits at Øye/Klungen and Bakkaunet, Trondheim (from Grenne 1989 with talc/soapstone deposits added)

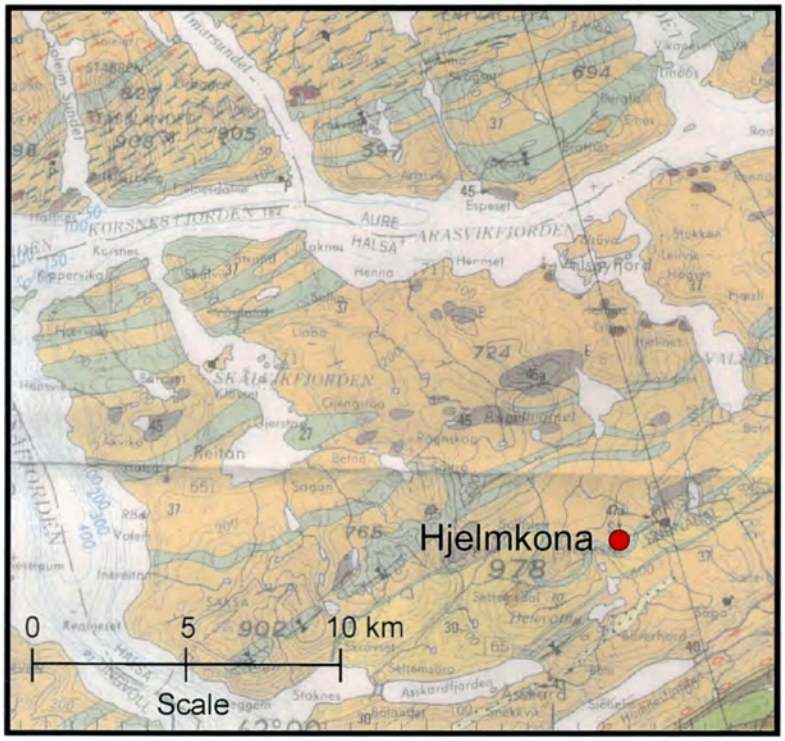

Figure 23: Talc / soapstone occurences in Nord-Møre district, Møre & Romsdal county.
Map sheet KRISTIANSUND, 1:250 000 (Askvik & Rokoengen 1985)

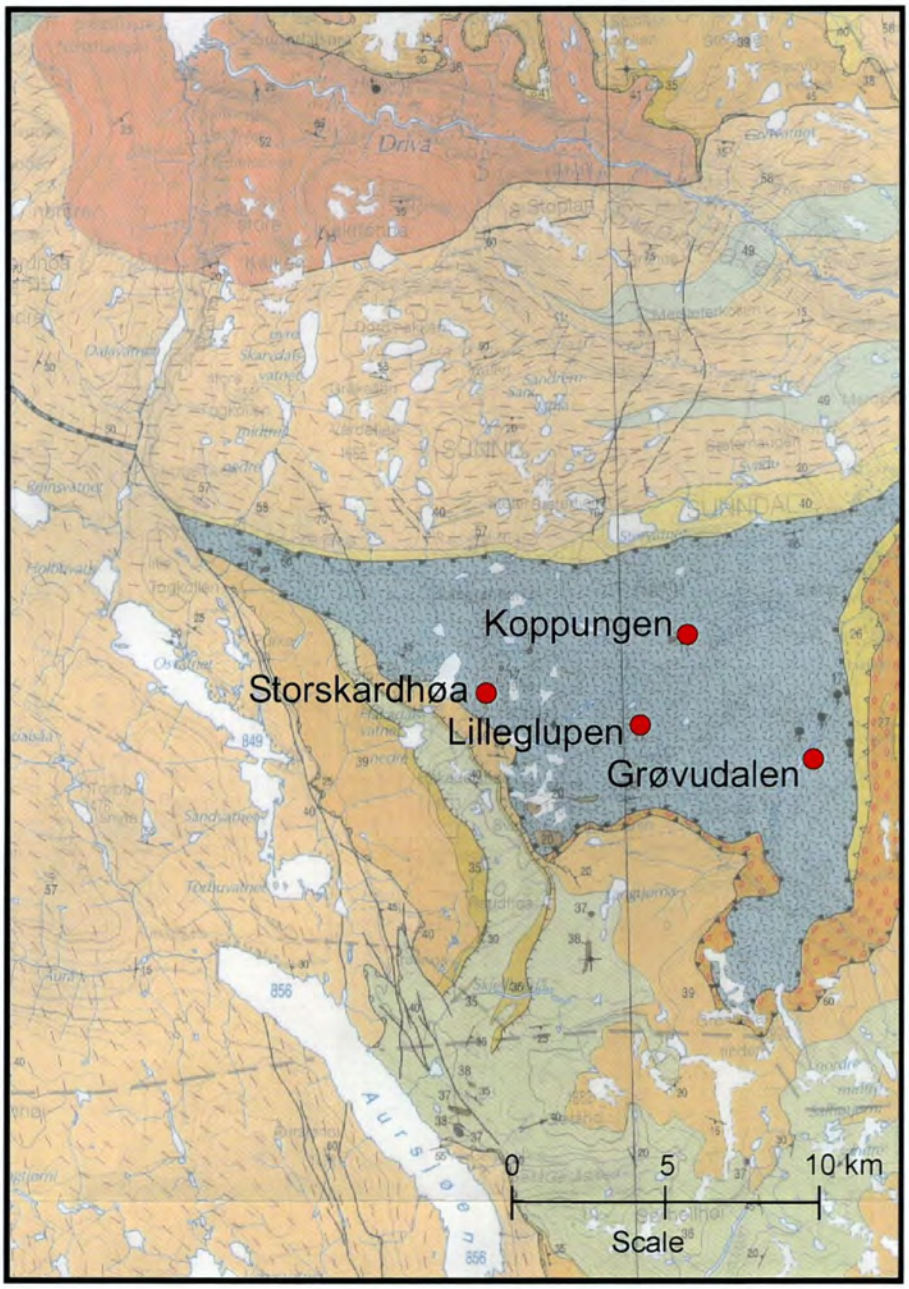

Figure 24: Talc / soapstone occurences in westernmost Dovrefjell mountain area, Møre & Romsdal county.
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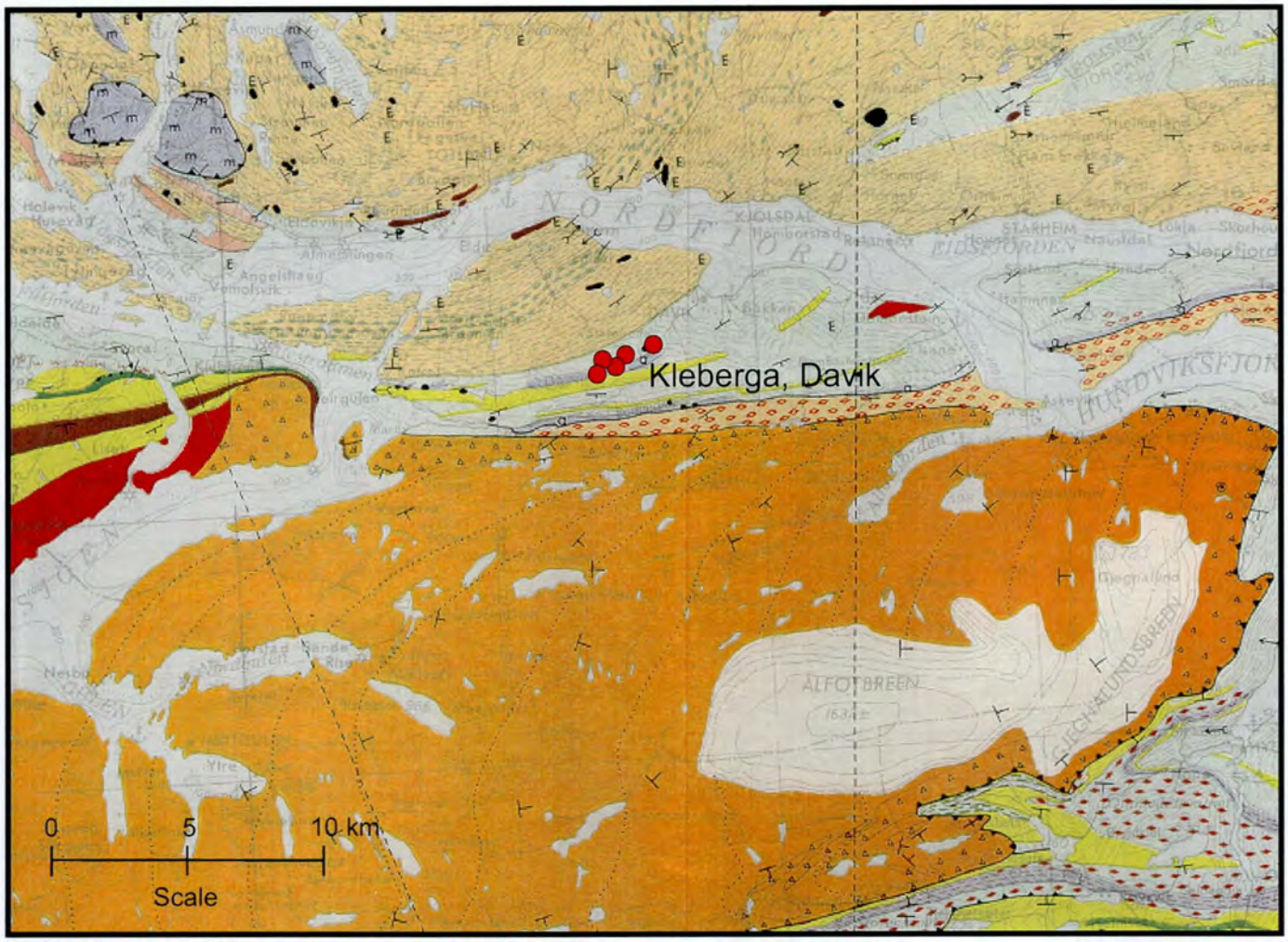

Figure 25: Talc / soapstone occurences in the western part of Sogn & Fjordane county.
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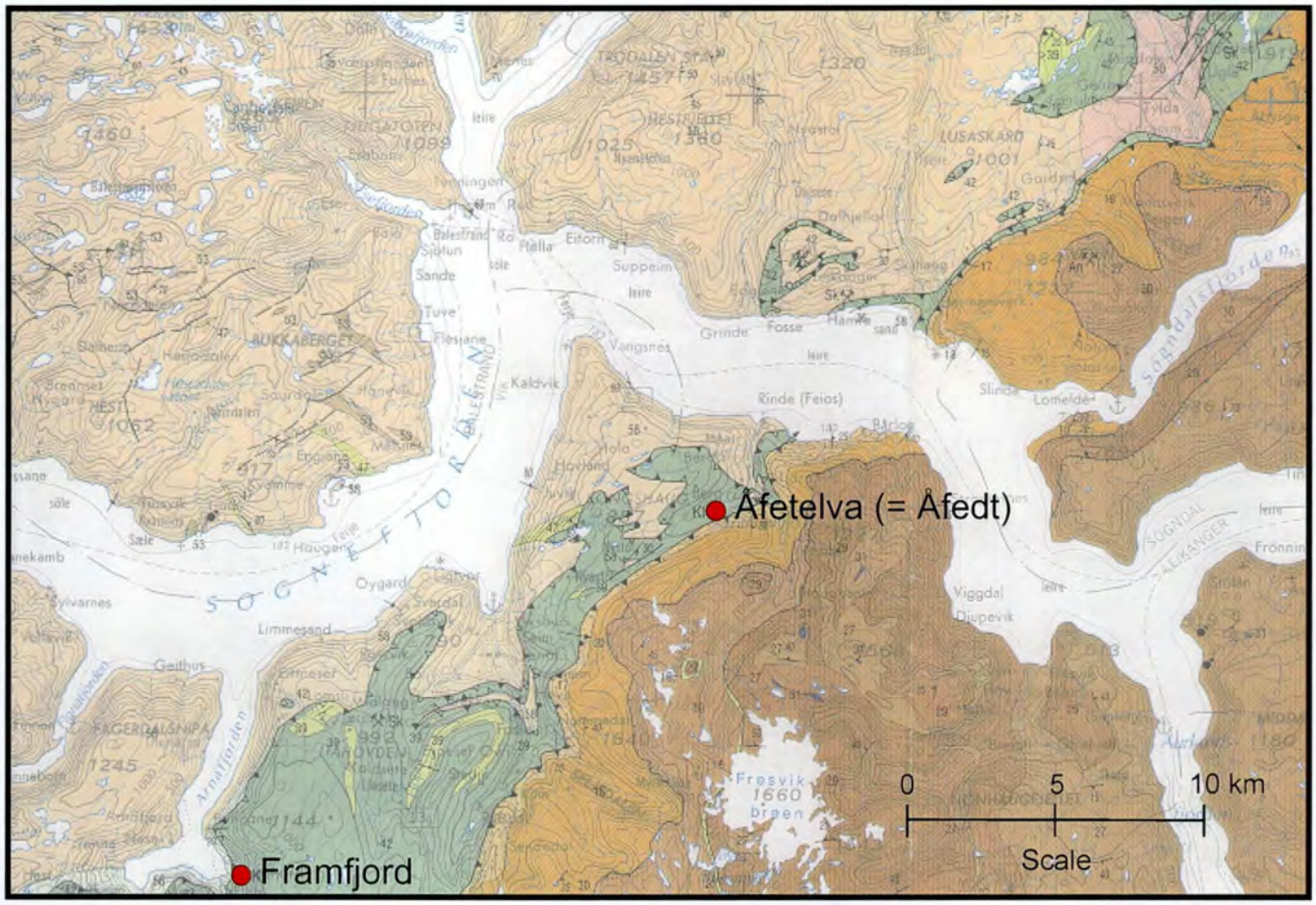

Figure 26: Talc / soapstone occurences in southern Sogn & Fjordane.
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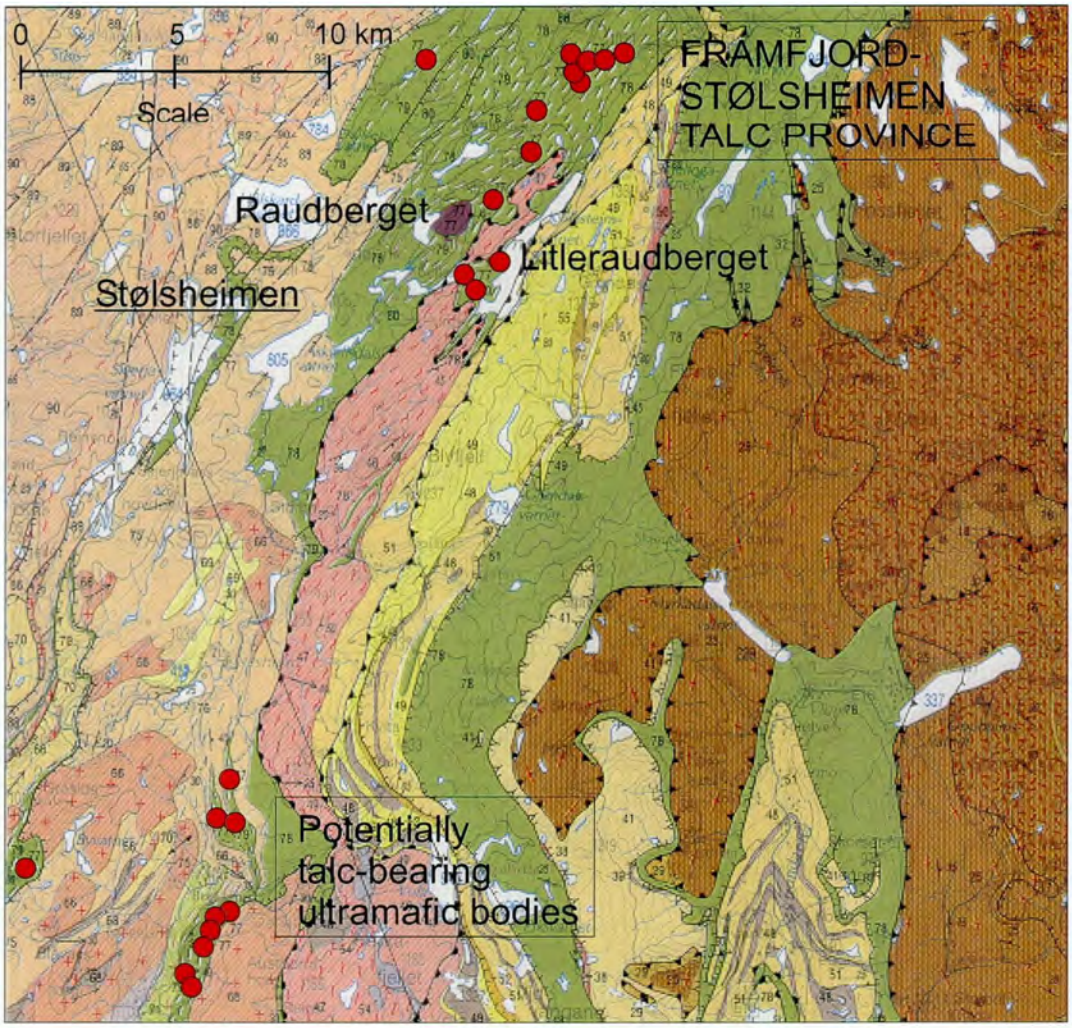

Figure 27: Talc / soapstone occurences in southern Sogn & Fjordane (Framfjord - Stølsheimen talc province). Map sheet ODDA, 1:250 000 (Sigmond 1998).

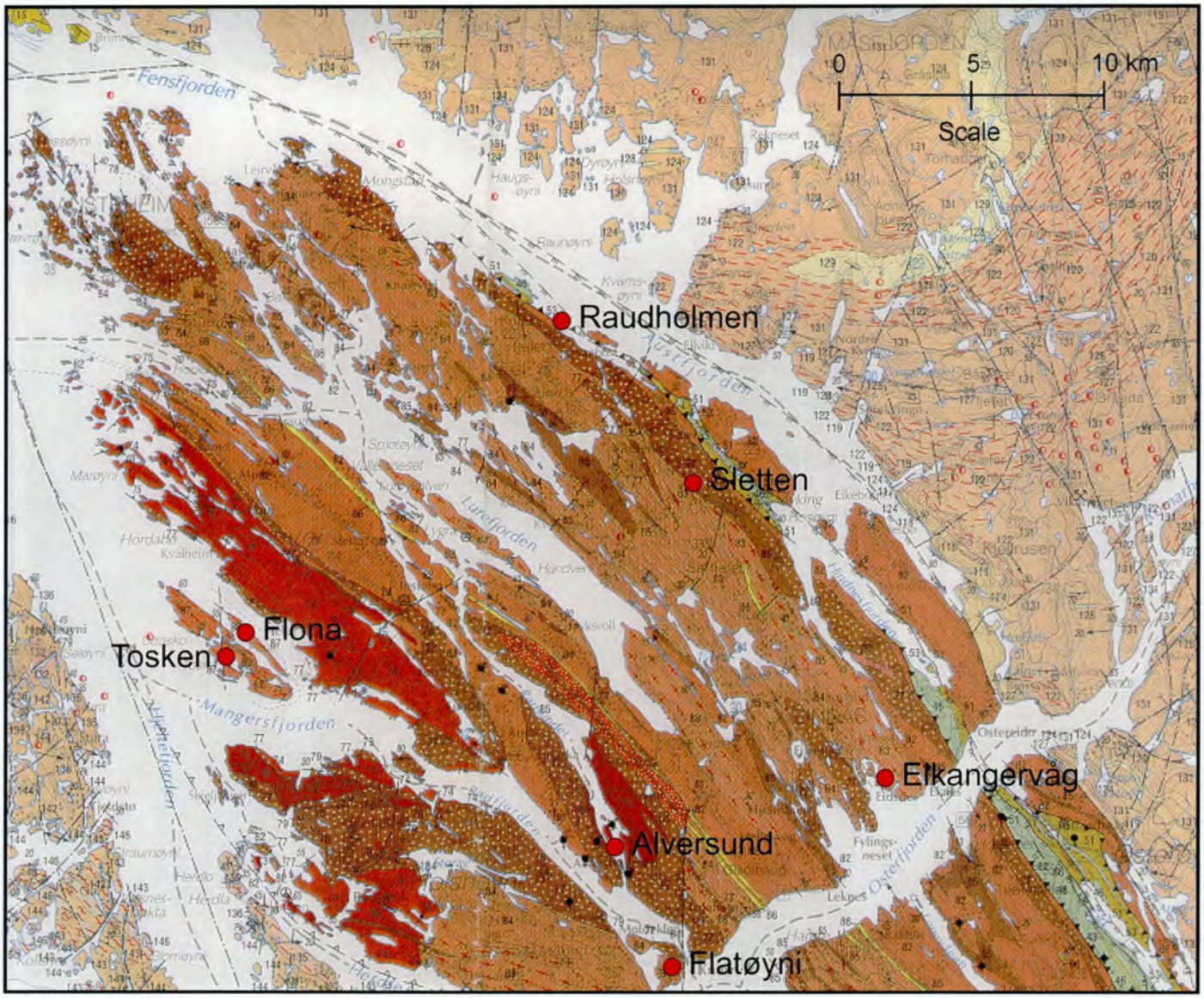

Figure 28: Talc / soapstone occurences in northern parts of Hordaland.
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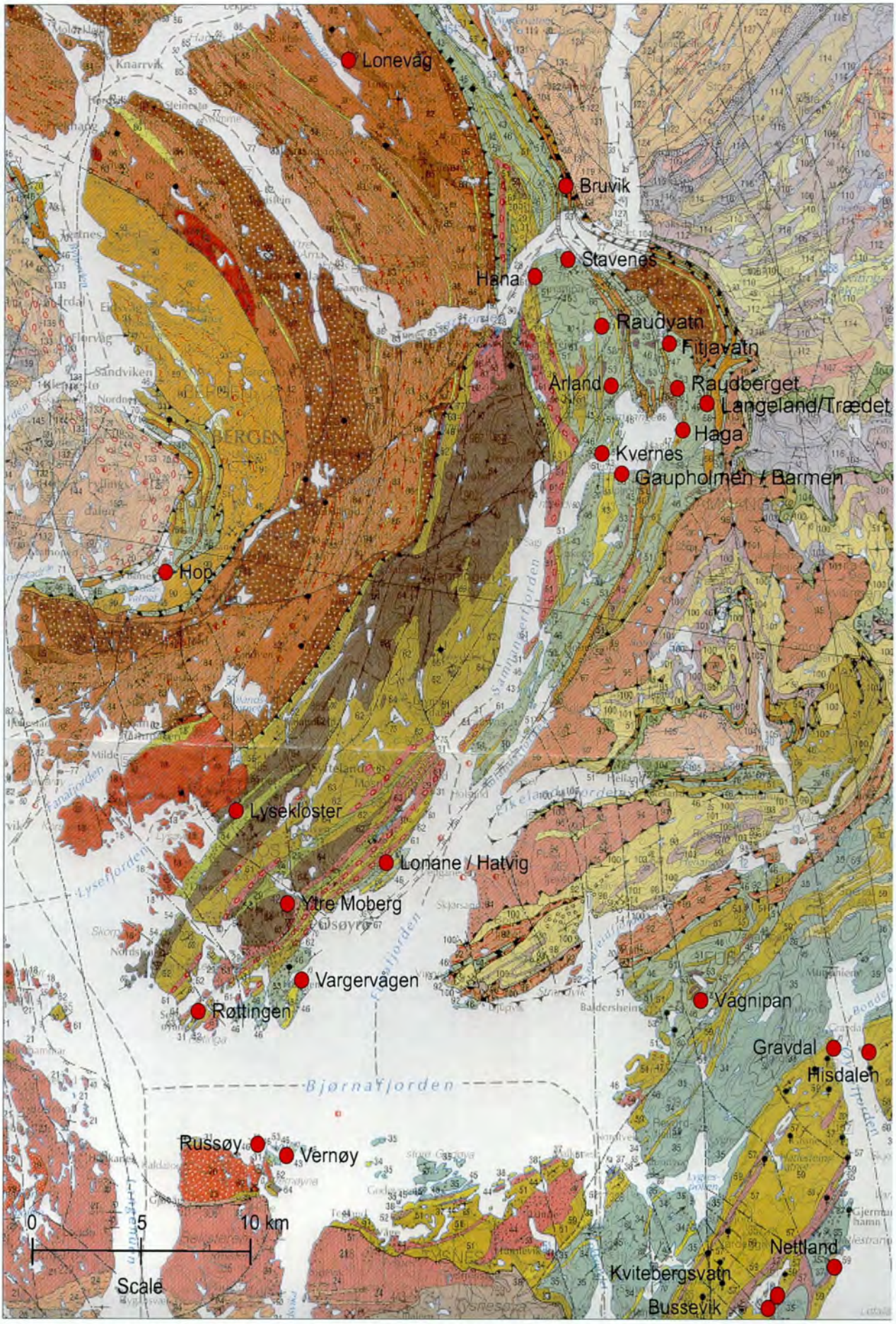

Figure 29: Talc / soapstone occurences in central Hordaland (outer Bergen Arc and adjoining areas). Map sheet BERGEN 1:250 000 (Ragnhildstveit & Helliksen 1997).

Figure 30: Talc / soapstone occurences in southern Hordaland (Hardanger district).
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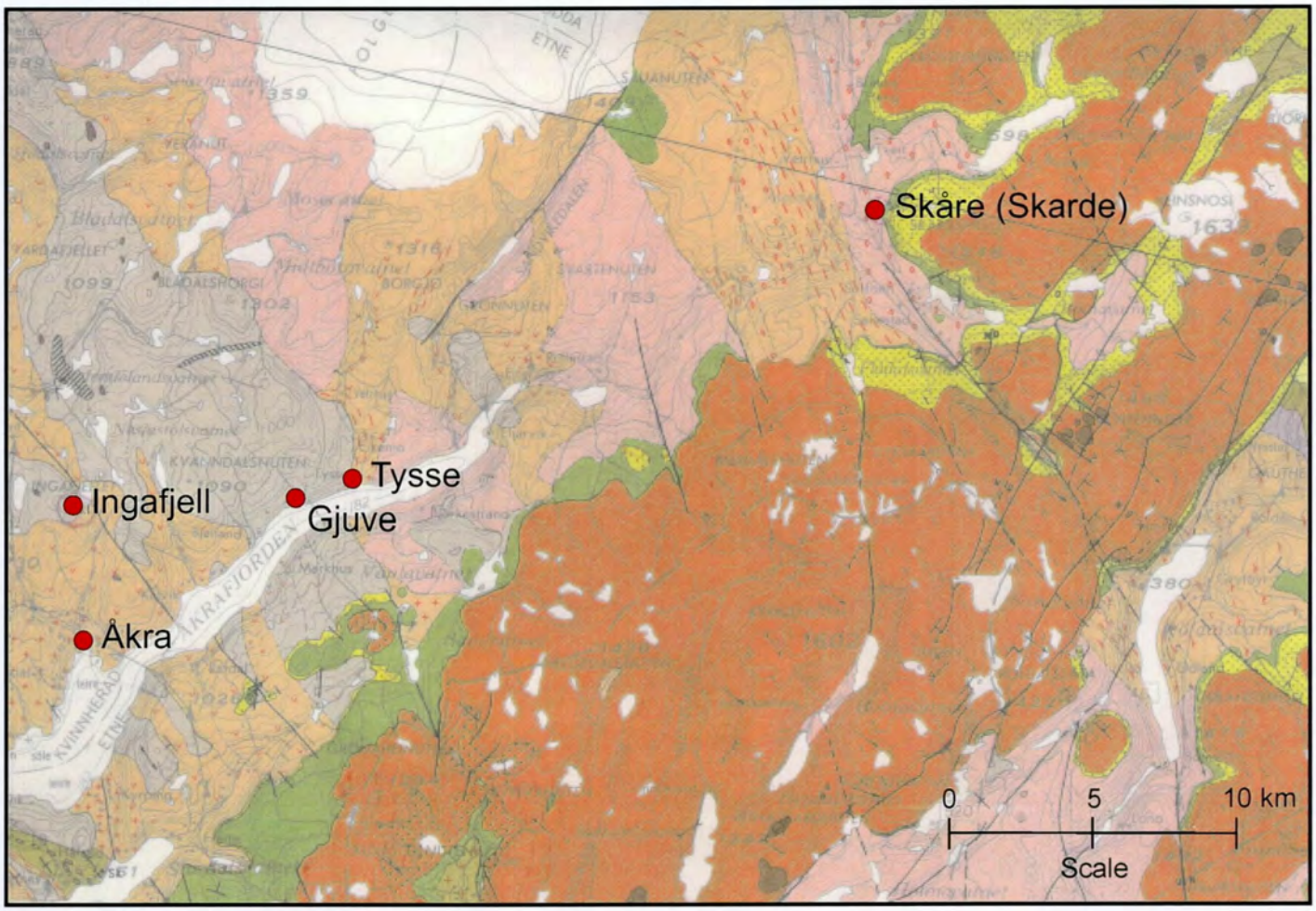

Figure 31: Talc / soapstone occurences in southeast Hordaland.
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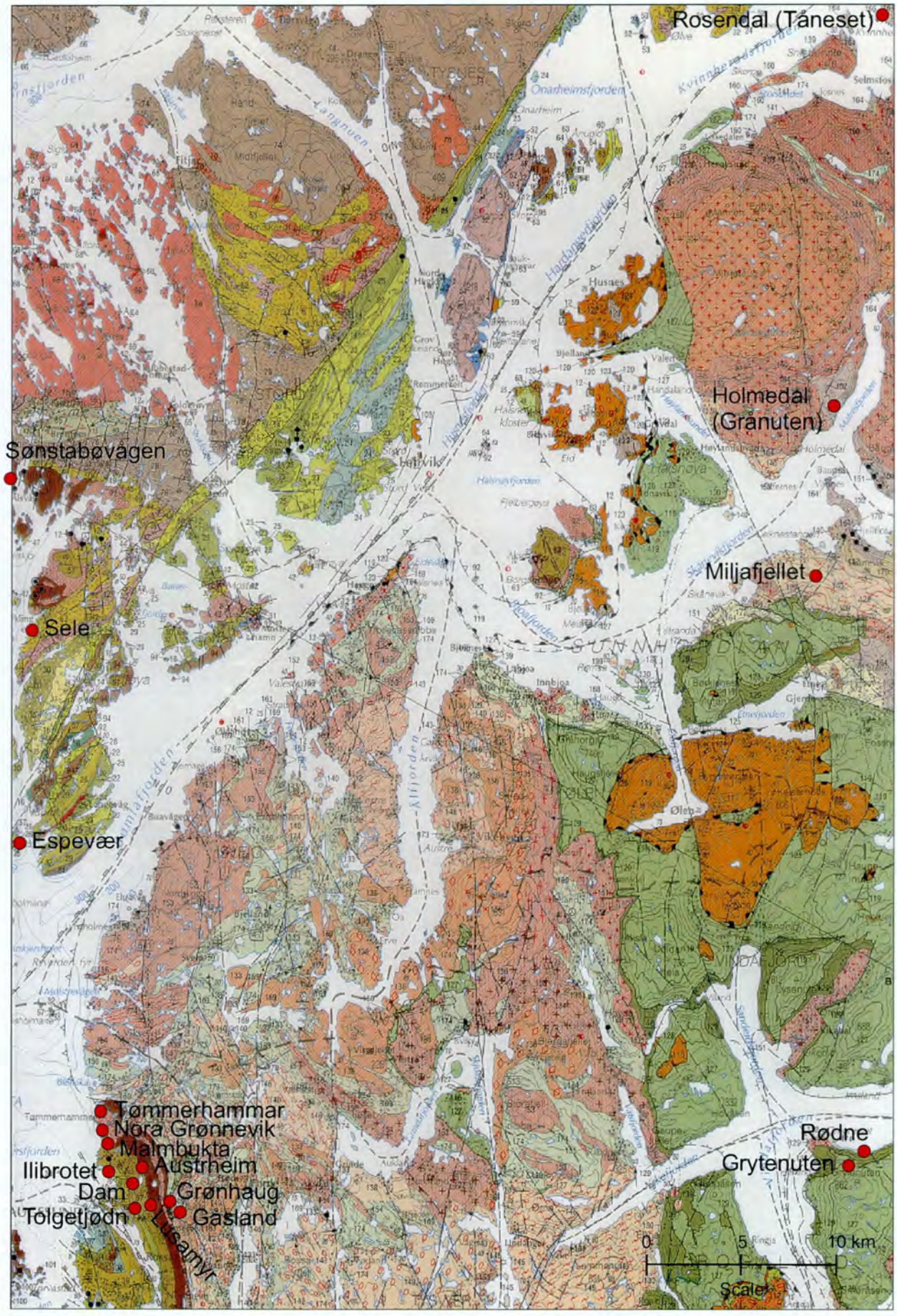

Figure 32: Talc / soapstone occurences in southern Hordaland / northern Rogaland.
Map sheet HAUGESUND, 1:250 000 (Ragnhildstveit et al. 1998).

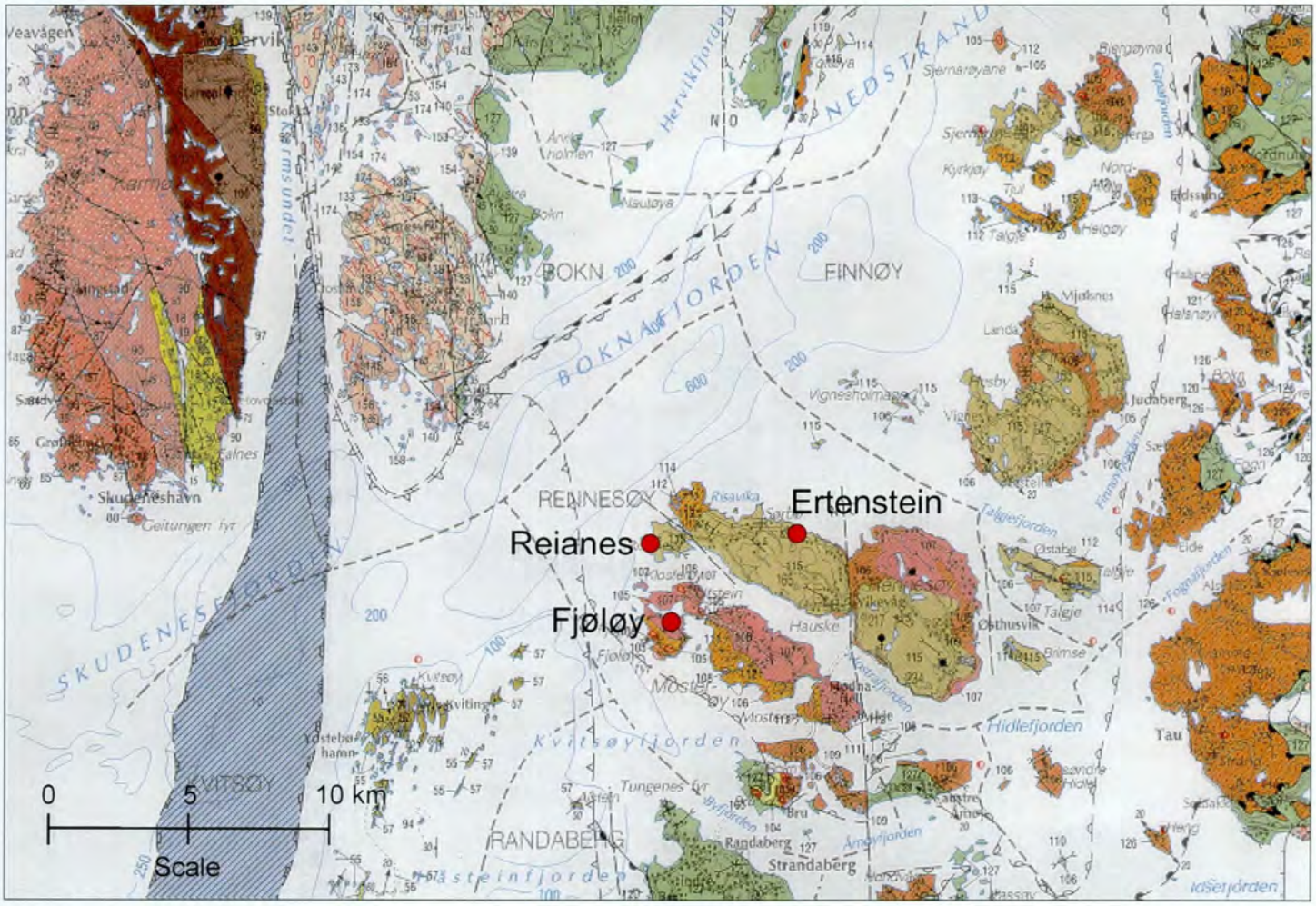

Figure 33: Talc / soapstone occurences in northern Rogaland.
Map sheet HAUGESUND, 1:250 000 (Ragnhildstveit et al.).

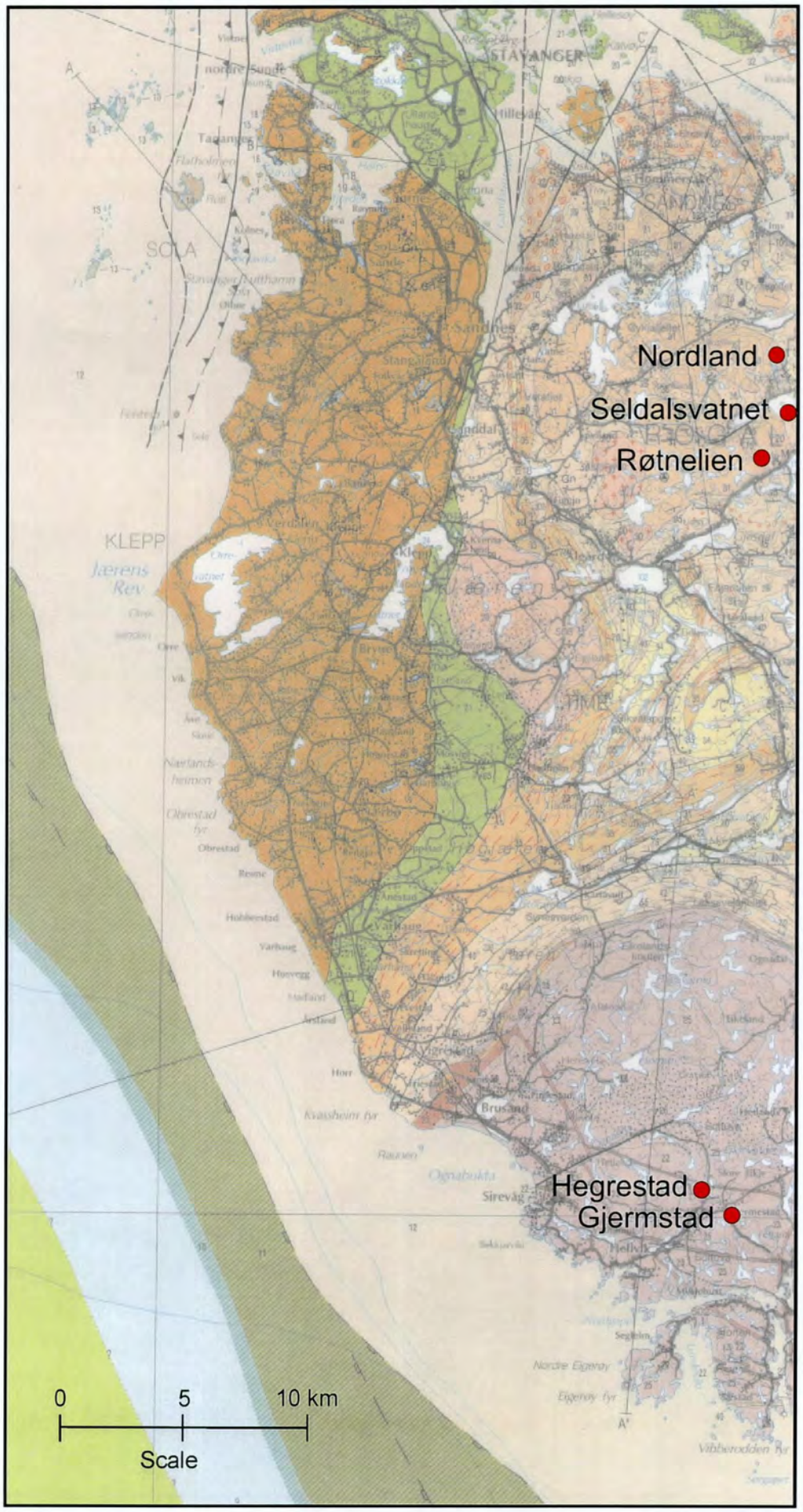

Figure 34: Talc / soapstone occurences in central and southern Rogaland.
Map sheet STAVANGER, 1:250 000 (Jorde, Sigmond & Thorsnes 1995).

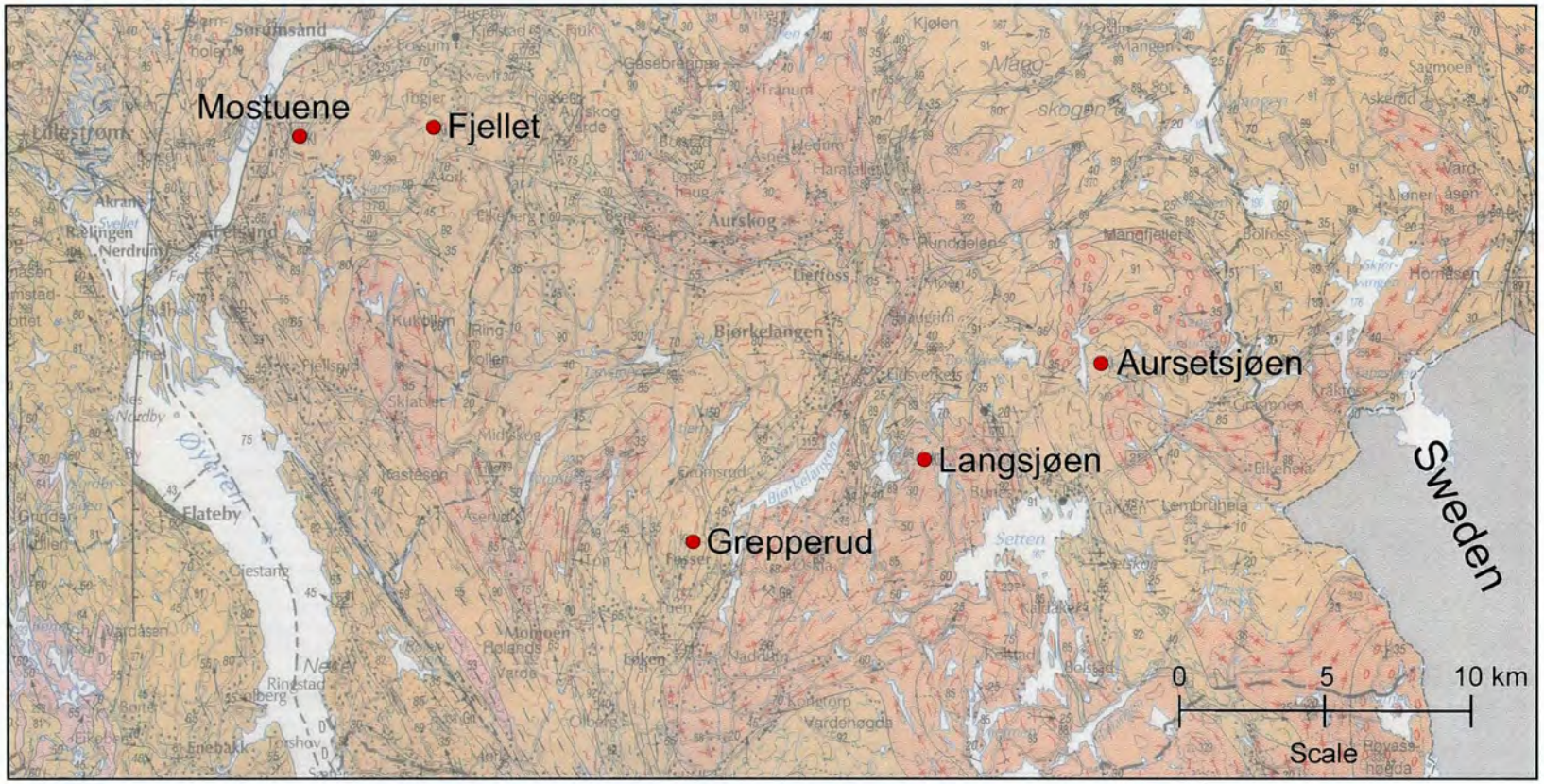

Figure 35: Talc / soapstone deposits in Akershus county.
Map sheet Oslo, 1:250 000 (Berthelsen, Olerud & Sigmond 1996)

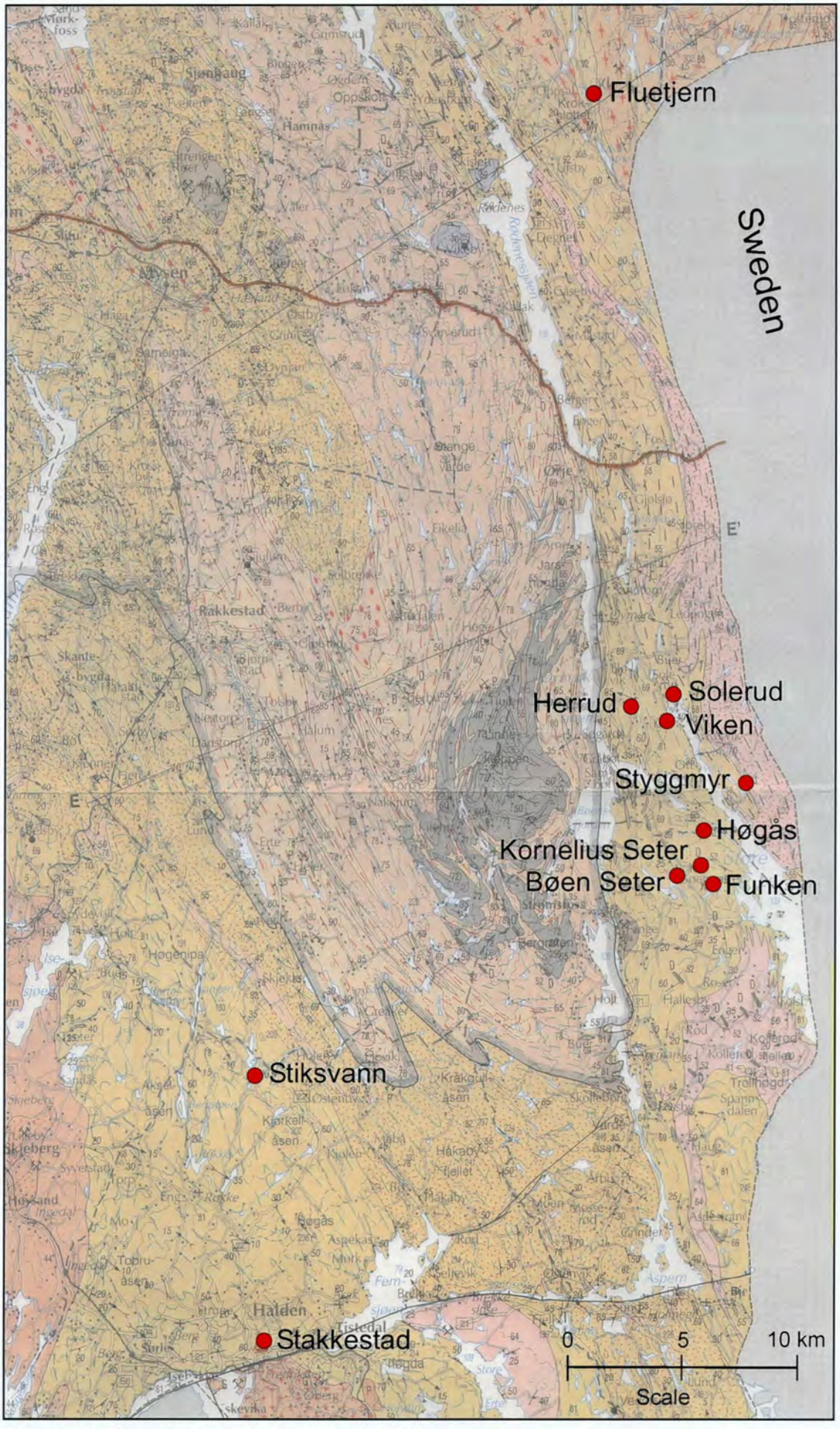

Figure 36: Talc / soapstone deposits in Østfold county.
Map sheet Oslo, 1:250 000 (Berthelsen, Olerud & Sigmond 1996)

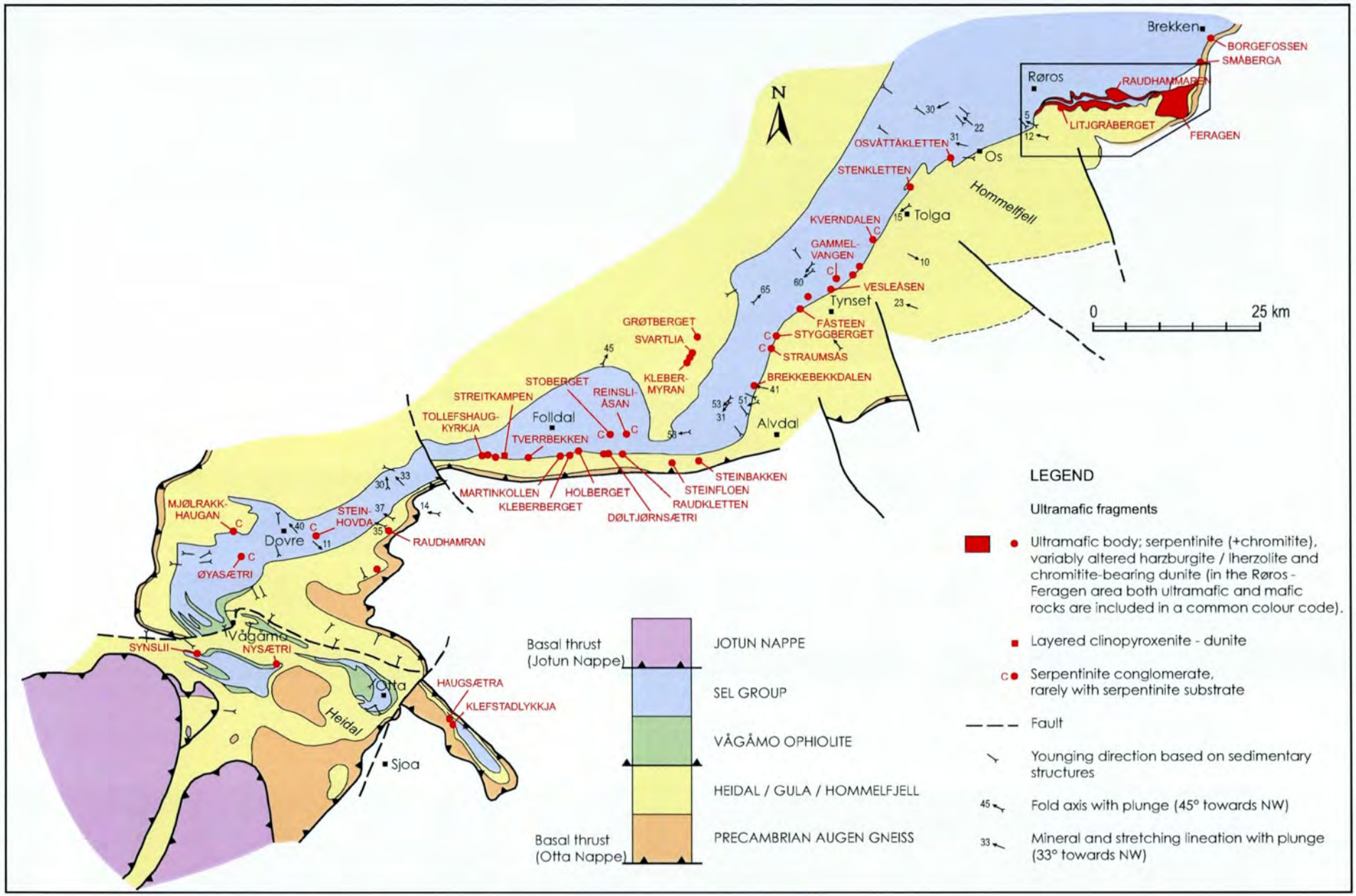

Fig. 37 Geological sketch map of the Vågå - Røros tract showing the locations of the ultramafite bodies.

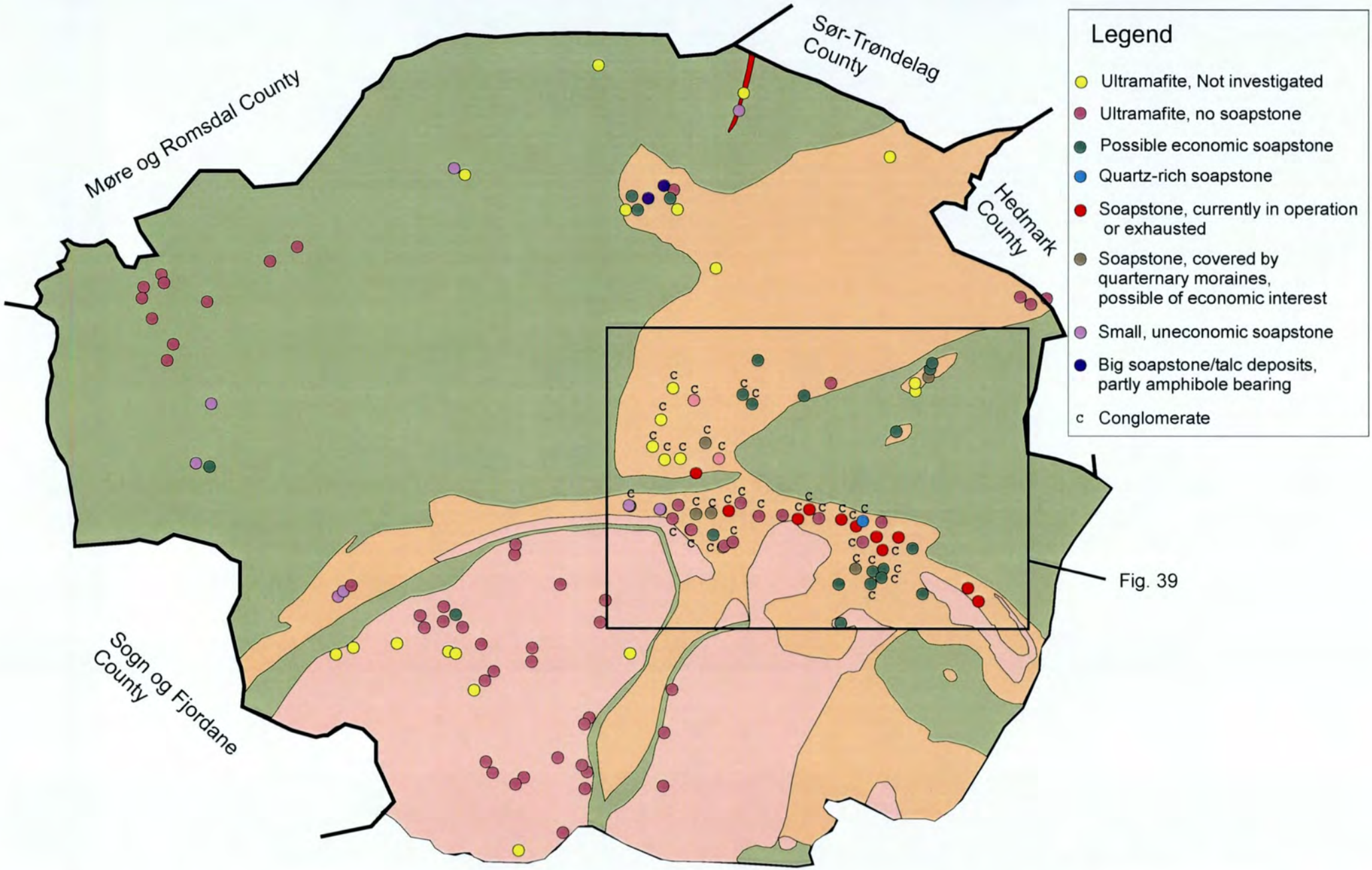

Fig. 38: Distribution of ultramafites in the North-Gudbrandsdalen Region (northern part of Oppland county). The geological background is based on Holtedahl & Dons (1960). Scale 1:1 mill. Boxed area is shown in further details in Fig. 39. Modified from Nilsson (1983).

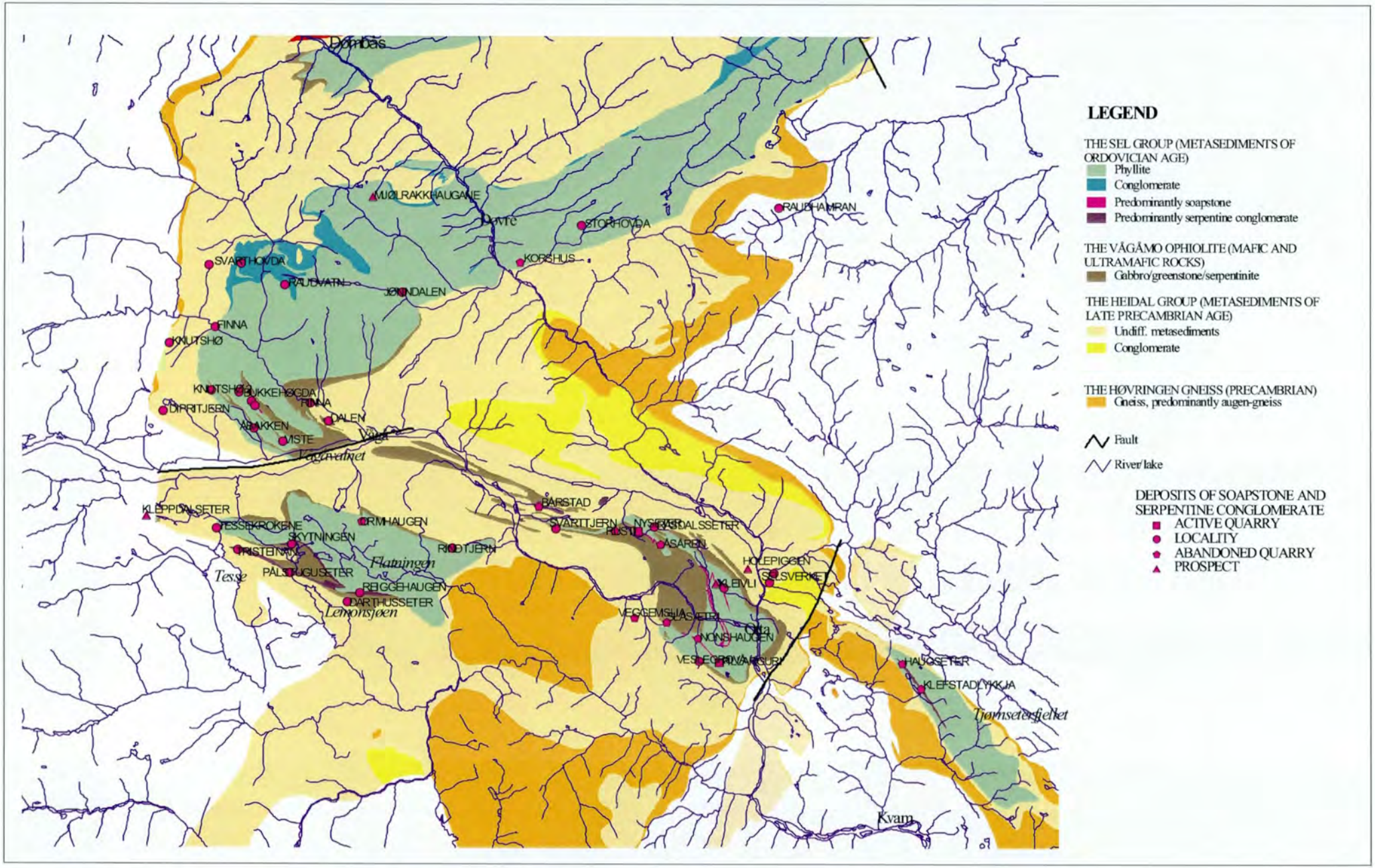

Figure 39: Distribution of ultramafites in the central part of the Nord-Gudbrandsdal region.

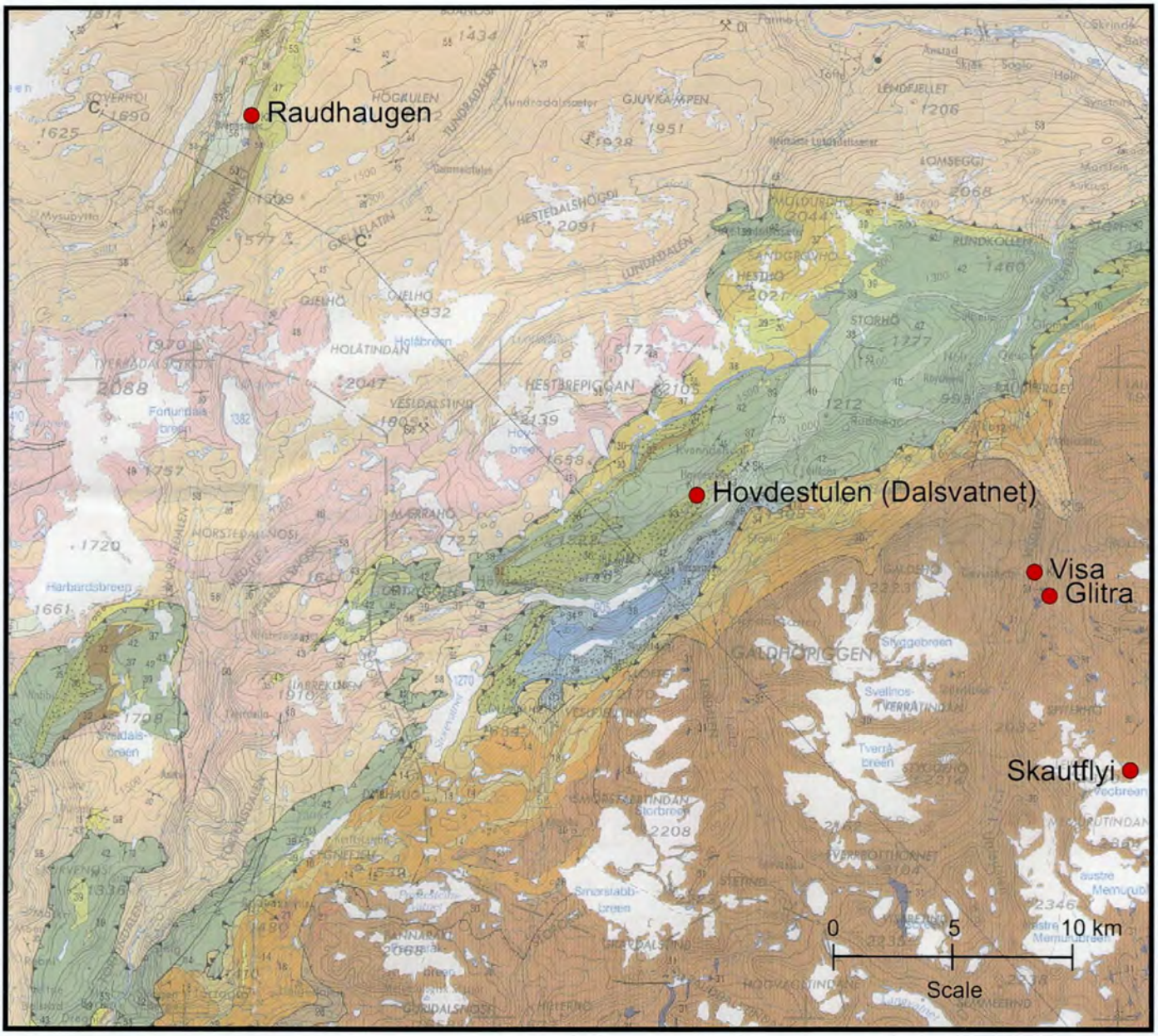

Figure 40: Talc / soapstone occurences in the NW part of the Jotun Nappe and adjoining areas, Oppland county. Map sheet ÅRDAL, 1:250 000 (Lutro & Tveten 1996).

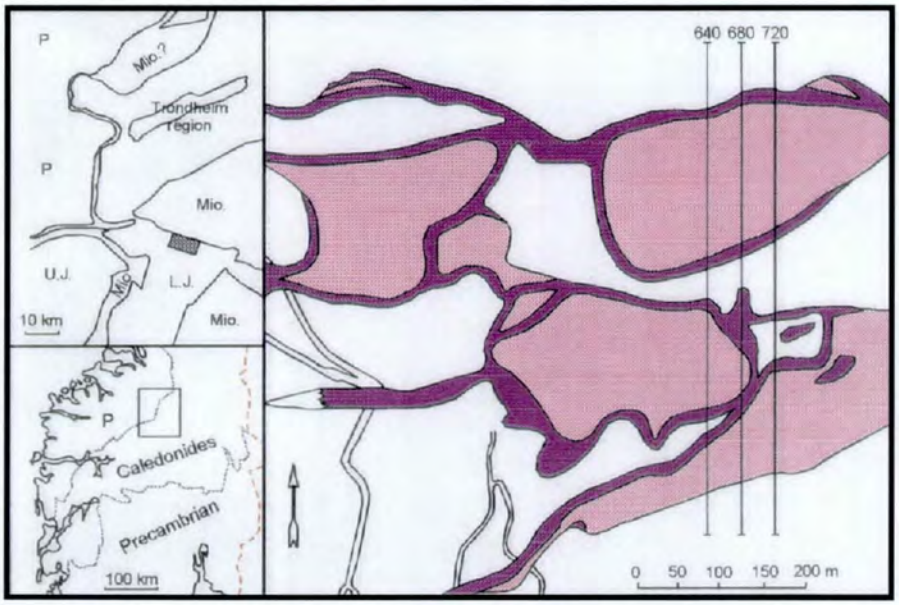

Fig. 41A: Geological map of the Lalm mining area with serpentinite (pink), soapstone (lilac) and greenschists, and so on (white).

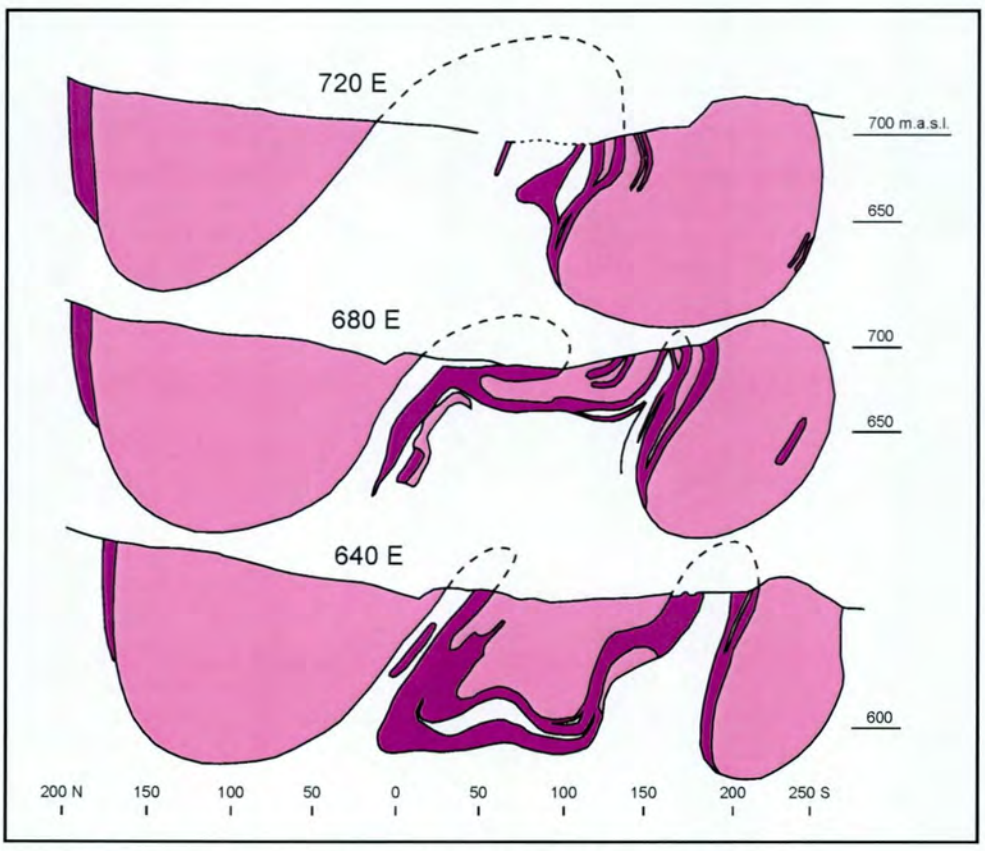

Fig. 41B: Sections along mining profiles 640 m, 680 m and 720 m E. Symbols as in figure 41A.