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Geology of the Mauken tectonic window, Målselv, Troms

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Geological Survey of Norway
P.O.Box 6315 Sluppen
NO-7491 TRONDHEIM
Tel.: 47 73 90 40 00

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Title:
Geology of the Mauken tectonic window, Målselv, Troms

Authors: Terje Bjerkgård, Iain Henderson, Jan Sverre Sandstad, Johannes Schönenberger, Trond Slagstad	**Client:** NGU
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Summary:

This report presents the results from bedrock mapping in the Mauken tectonic window, carried out in several periods in 2011-2013. During the NGU MINN program, the Mauken area has been subject to a high-resolution airborne geophysical survey (magnetometry, radiometry, EM), followed by bedrock mapping and structural geology investigations. The work in the Mauken area is part of a larger project in Southern Troms, with the goal to work out a structural-tectonic-metallogenic model and interpretation for the basement areas in the whole region.

The Mauken window is divided three main geological units: 1) The Andsfjell-Kampen felsic intrusive complex in the west, 2) a central supracrustal unit, the Målselva Group, comprised of the metavolcanic Myrefjell Formation (mainly greenstone and greenschist) and the metasedimentary Aurevatn Formation (mainly siltstone, sandstone and micaschist), 3) the Øverbygd intrusive complex in the east, which is a very diverse unit with ultramafic, mafic, intermediate to felsic rocks. There are two iron formations in the volcanic Myrefjell Formation of the Målselva Group. None of these are of economic interest. Rocks of the Andsfjell-Kampen complex intrude greenstone and greenschist of the Myrefjell Formation, while it is a tectonic contact between the Øverbygd complex and the Målselva Group.

The metamorphic grade of the basement rocks seems only locally to have exceeded middle greenschist facies conditions.

The contact to the overlying Caledonian nappes is tectonic, and generally flat lying Caledonian lithologies are in contact with steep, nearly vertical, dipping basement rocks.

On the basis of whole-rock geochemistry, greenstones of the Myrefjell Formation most likely were formed in an arc to back-arc setting. The Andsfjell-Kampen intrusive complex show geochemistry in accordance with a within-plate setting (WPG), while samples from the more diverse Øverbygd Complex have compositions more similar to volcanic arc granites (VAG). Dating of the intrusive complexes show a large age span, from 1878 Ma to 2836 Ma. The Målselva group must have formed prior to 2109 Ma, which is the age of the cross-cutting granodiorite of the Andsfjell-Kampen complex.

Based on regional geophysics and similar geology, the Målselva group may be correlated with the Astridal belt in the Senja shear belt to the west, and possibly the eastern part of the Rombak window in the south.

The only significant gold mineralization in the Mauken window is the so-called "Main Zone", however this may be too small and too low-grade to be of economic interest. The mineralization is, however, interesting as it may represent a new type of gold occurrence in Norway. A possible model of formation is that gold, arsenic and sulfur were released during metamorphism from diagenetic sulfides in carbonaceous siltstone and transported by fluids along structural pathways e.g. the siltstone-greenstone contact and deposited higher up in the sequence. A similar origin may be suggested for some of the Au-As deposits in the Rombak tectonic window; however those deposits are probably some 2-300 Ma younger.

Keywords: Bedrock geology	Ore geology	Geochronology
Geochemistry	Tectonic Window	Precambrian
Mineralization	Gold	Arsenic

CONTENTS

APPENDIX

Geological map of the Mauken Basement Window

1. INTRODUCTION

The area to the north of Målselva in the Målselv municipality is known as the Mauken basement window (e.g. Zwaan et al., 1998), named after the prominent mountain in the area.

During the NGU MINN program, the area has been subject to a high-resolution airborne geophysical survey (magnetometry, radiometry, EM), followed by bedrock mapping and structural geology investigations (in progress). The Danish company Scandinavian Highlands (SH) has explored in the area since 2007, looking mainly for gold (http://scandinavian-highlands.com/projects/mauken-greenstone-belt-gold-project.aspx).

The work in the Mauken area is part of a larger project in Southern Troms, including from west to east; the basement areas at Senja, Mauken and around Altevatn (Figure 1). The main goal of the project is to work out a structural-tectonic-metallogenic model and interpretation for the whole region.

This report presents the results from bedrock mapping in the Mauken area, carried out in several periods in 2011-2013. A geological map is attached in the back-cover of the report.

2. REGIONAL GEOLOGY OVERVIEW – EARLIER WORK

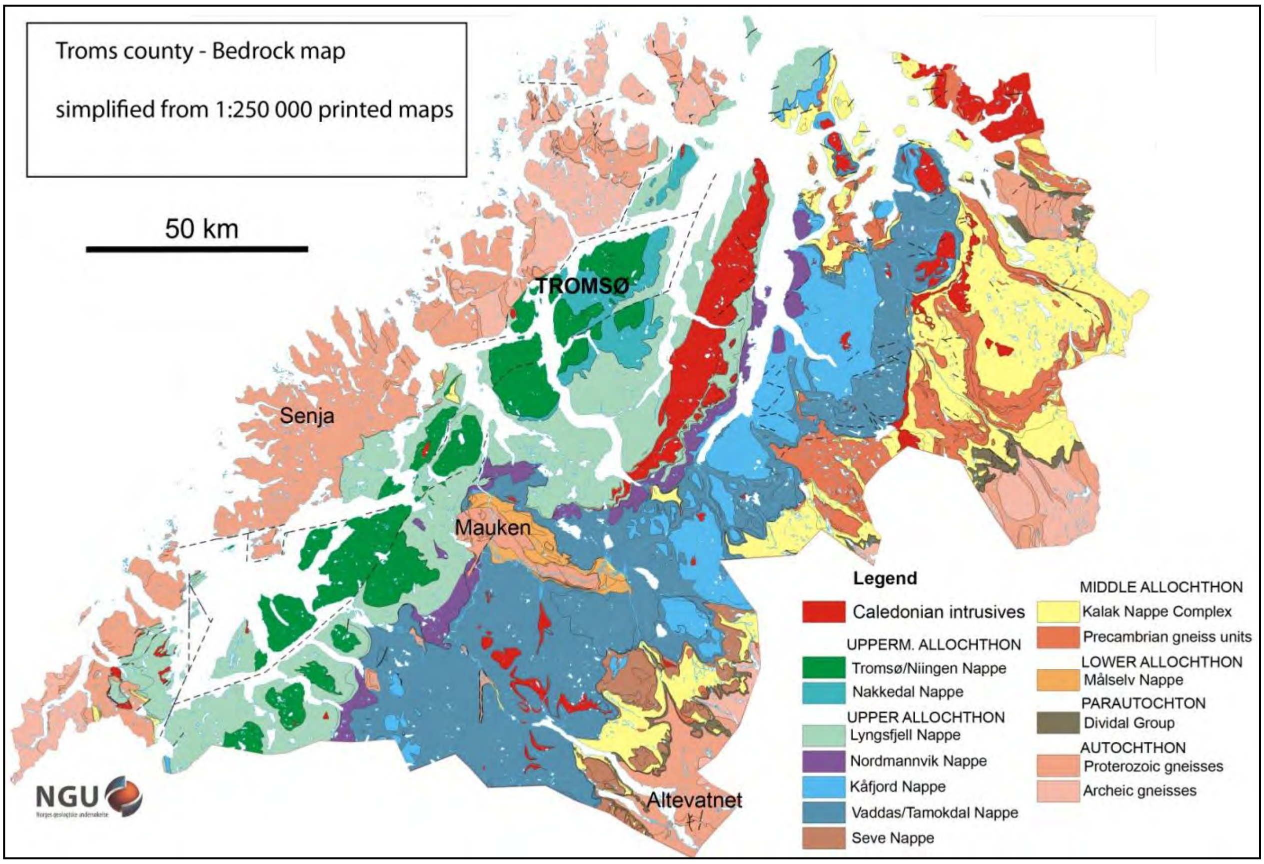

Figure 1: Simplified tectonostratigraphic map of the Troms county, based on 1:250 000 bedrock maps published by NGU.

The Mauken basement window is located in Southern Troms, approximately midway between the basement areas of Senja and Altevatnet (Figure 1).

The window is surrounded and partly covered by rocks of the Målselv Nappe (Figure 1), especially in the north and on the eastern side, comprising mainly sediments of late Precambrian age (Andresen et al., 1985, Zwaan et al., 1998). To the south and southwest it is overlain by sediments of the Vaddas/Tamokdal Nappe known as the Senja Nappe in this area (Fareth, 1981), comprising mica schist, quartzite and marble (Andresen et al., 1985). The Senja Nappe is structurally overlying the Målselv Nappe Complex. In the west it is also in tectonic contact with the Lyngsfjell Nappe.

Low grade sediments, including conglomerate, sandstone and shale separate the Pre-cambrian basement from the overlying nappe units in the eastern part of the area. These rocks lie unconformably on top of the basement rocks and interpreted to be equivalent to the Neo-Proterozoic to Early Cambrian Dividal Group (Gustavson, 1963, 1966).

2.1 Earlier work in Mauken

The first descriptions of the bedrock in the Mauken area are by the geologist K. Pettersen in 1887 (referenced in Landmark, 1967). He describes the "granite" of Mauken and Andsfjell, and notes that it is a discordance between the granite and the overlying schists. On this basis Pettersen concluded that the granite had to be Precambrian in age.

Gustavson (1963, 1966) mapped the basement windows and overlying Caledonian units to the south and east of the Mauken window, and thereby defined and established the extent of the autochthonous cover of metasediments in the Dividal Group.

Three publications in the NGU yearbook 1966, describe the geology in the Mauken area, namely from K. Landmark, A. Berthelsen and F.Kalsbeek & N.Ø. Olesen. The paper of the latter two authors (Kalsbeek & Olesen, 1967) deals mainly with the small basement window to the east of Mauken, where the Dividal Group is well exposed. Berthelsen (1967) divides the Precambrian rocks of the Mauken window into four units, namely 1) the Myrefjell formation – metavolcanics with intermixed and intercalated metasediments, 2) the Aurevatn formation – various metasediments in contact to the metavolcanics on the N-side, 3) the Øverbygd crystalline complex – granodiorite, migmatites, gabbroic to metabasaltic rocks and 4) the Kampen granodiorite – massive to foliated granodiorite with relics of gneiss. The Myrefjell and Aurevatn formations were included into the Målselva group. But unfortunately, Berthelsen included part of the Caledonian sediments into his Aurevatn formation. Landmark (1967) gives a thorough description of the geology of the window for his 1:100 000 scale bedrock map Målselv (Landmark (1959). The paper deals with mineralogy and chemistry of both the granodioritic intrusive and the amphibolites. It also describes the contact-relationships with the Caledonian metasediments. Landmark seems to have missed the unit of Precambrian metasediments (i.e. the Aurevatn formation by Berthelsen), and included it into the Caledonian units.

On the preliminary 1:50 000 map Takvatnet (Fareth, 1982) and the 1:250 000 map Tromsø (Zwaan et al., 1998) the interpretation by Landmark described above is retained, and the Aurevatn formation has disappeared and is replaced by a far too extensive unit of amphibolite!

3. AIRBORNE GEOPHYSICS

Helicopter-borne geophysical surveys were carried out in the Mauken area in 2011; including magnetics (Figure 2, Figure 3), electromagnetics (Figure 4, Figure 5) and radiometry (Rodionov et al., 2012). Because the area was partially snow-covered when measured, the radiometric data sets unfortunately are difficult to interpret.

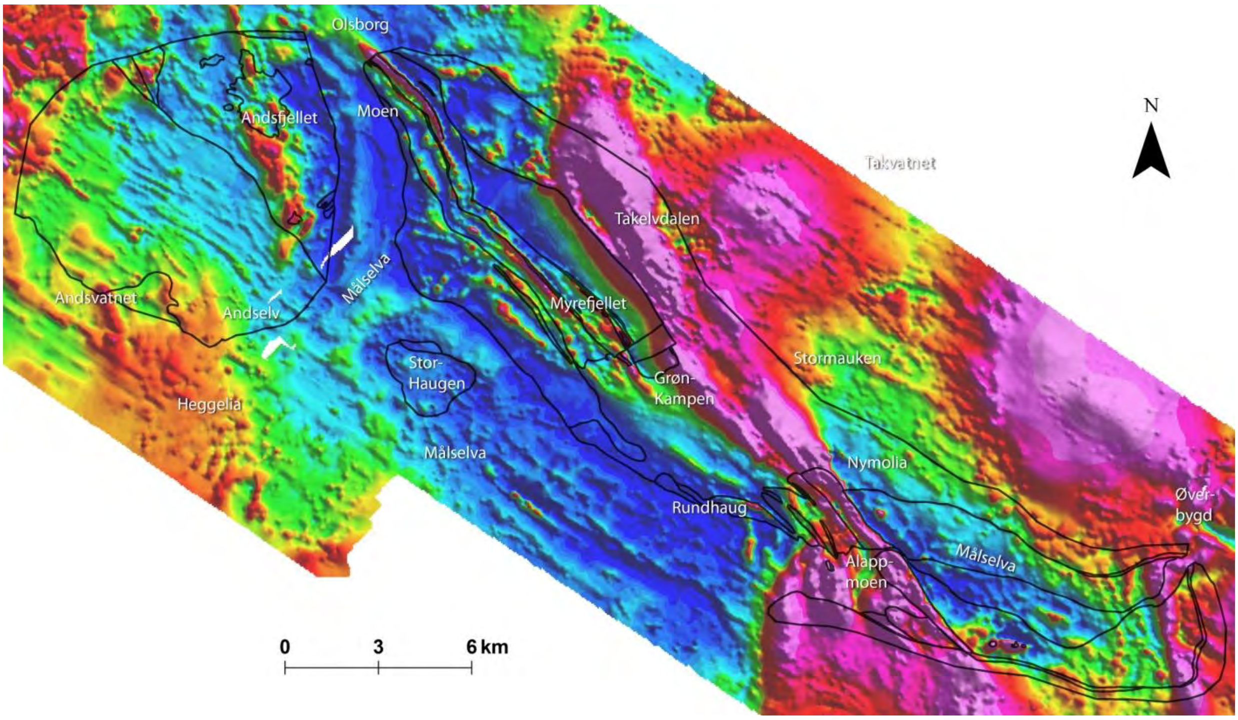

Figure 2: Airborne geophysics – magnetic data of the Mauken area. In black are shown the geological boundaries. For legend of the data, see Rodionov et al., 2012.

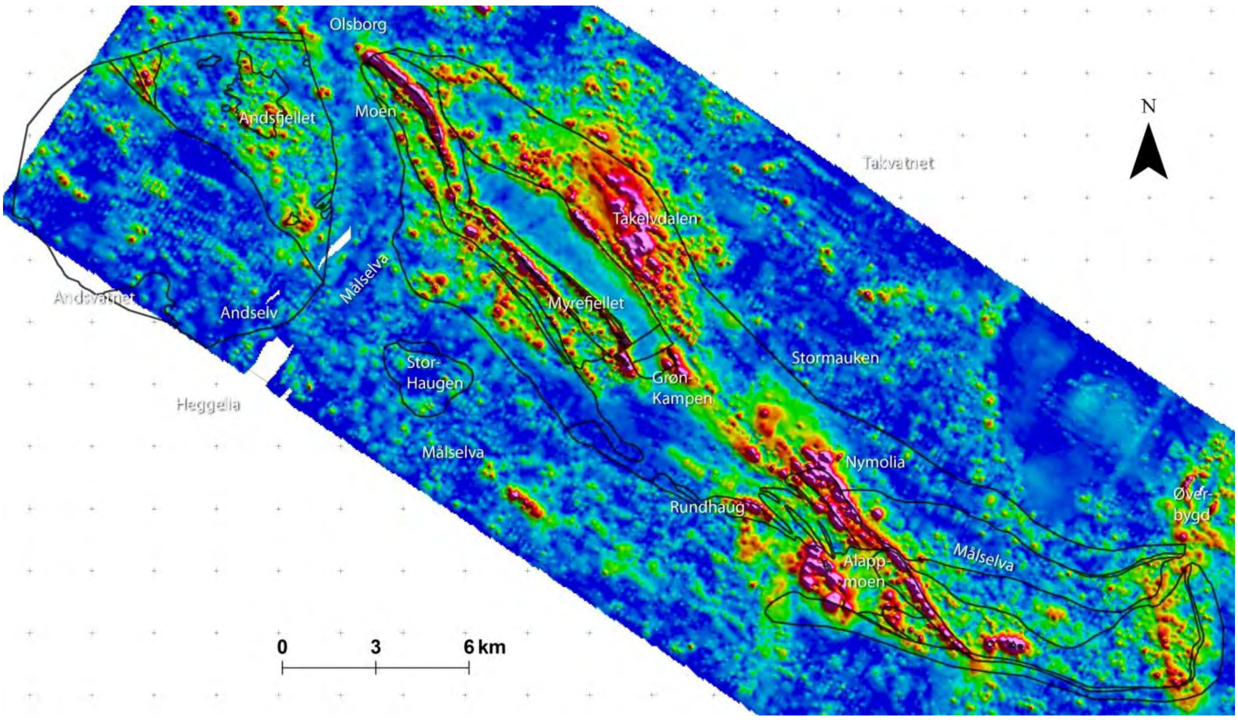

Figure 3: Airborne geophysics – magnetic signal of the Mauken area. In black are shown the geological boundaries. For legend of the data, see Rodionov et al., 2012.

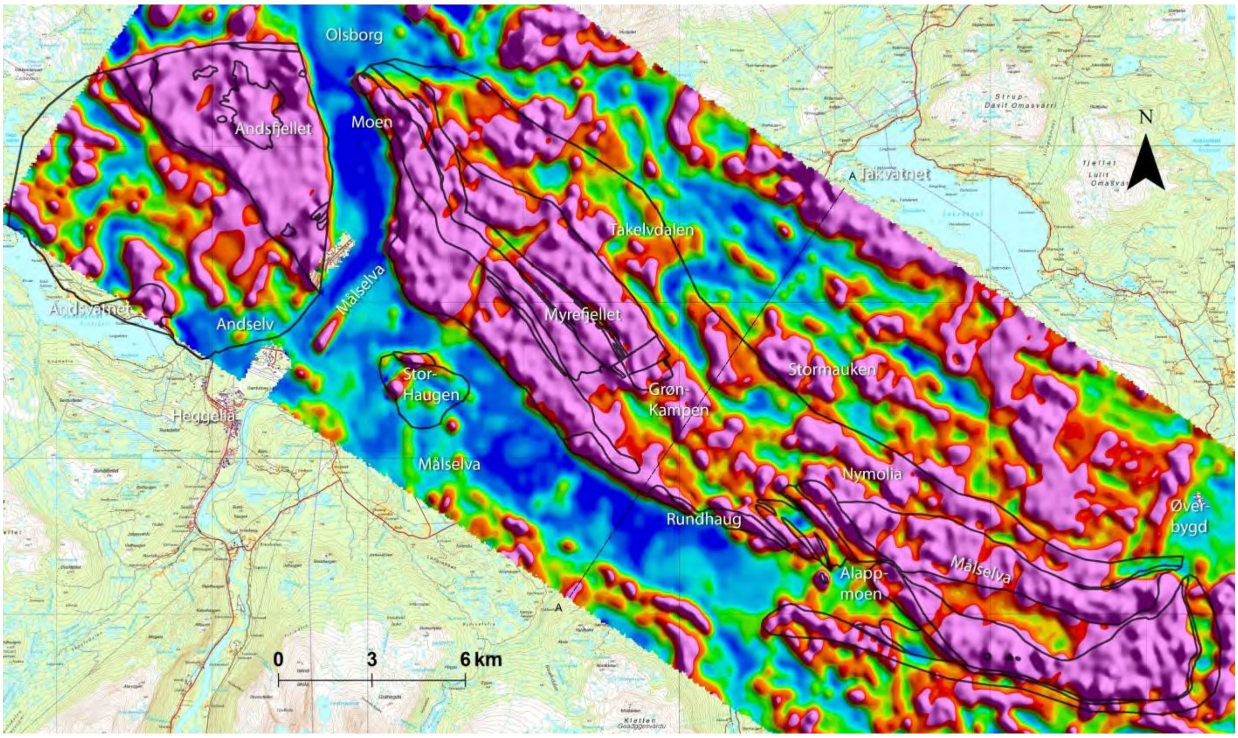

Figure 4: Airborne geophysics – apparent resistivity (7K) of the Mauken area. In black are shown the geological boundaries. For legend of the data, see Rodionov et al., 2012.

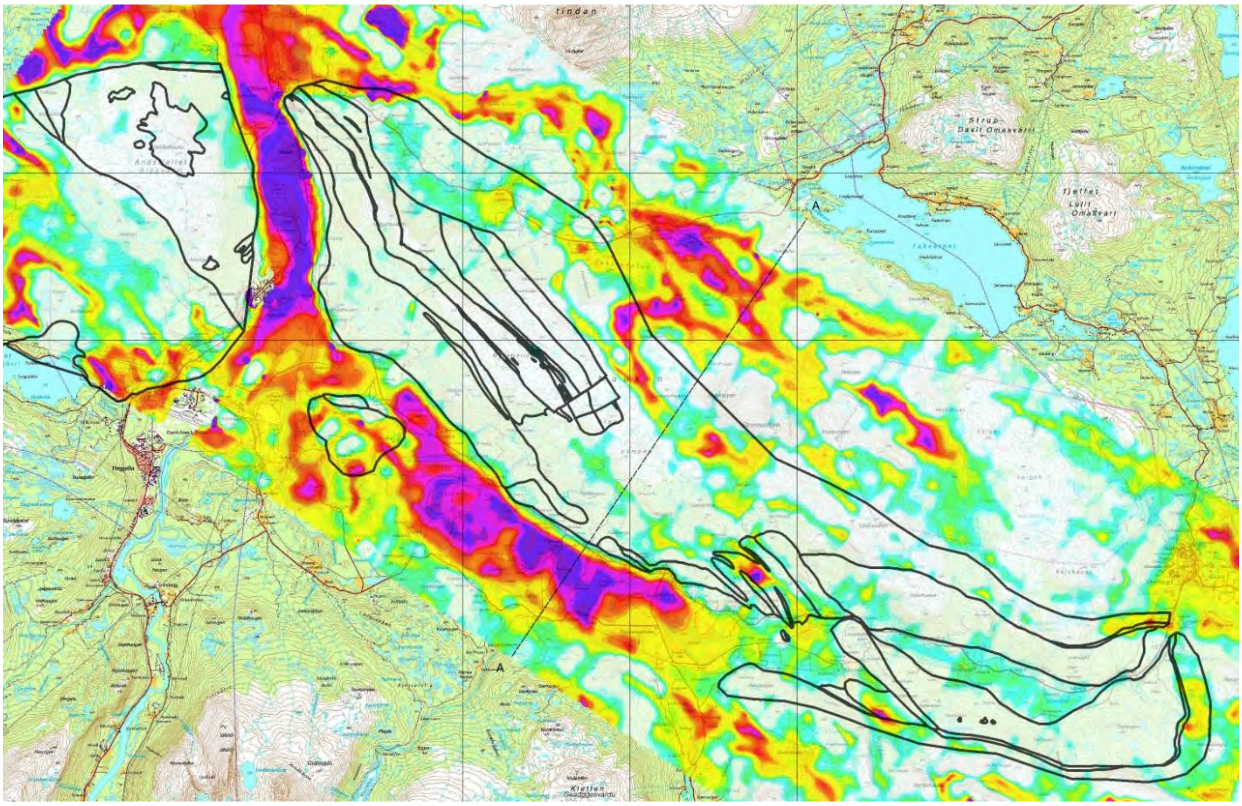

Figure 5: Airborne geophysics – conductivity (880 hz) of the Mauken area. In black are shown the geological boundaries. For legend of the data, see Rodionov et al., 2012.

4. GEOLOGY OF THE MAUKEN WINDOW

The Mauken window may be divided in three main geological units (Figure 6): 1) A mainly felsic intrusive complex in the west, covering Andsfjellet and the western side of the slopes of Mauken from Moen to Rundhaug, 2) a central unit of volcanic and sedimentary rocks, extending from Olsborg in the NW to Alappmoen in the SE, 3) a very diverse intrusive suite, including ultramafic, mafic, intermediate to felsic rocks, present in the eastern part of the window. In the area between Grønkampen, Nymolia and Rundhaug, the basement rocks are overlain by Caledonian units, dividing the basement window in two parts.

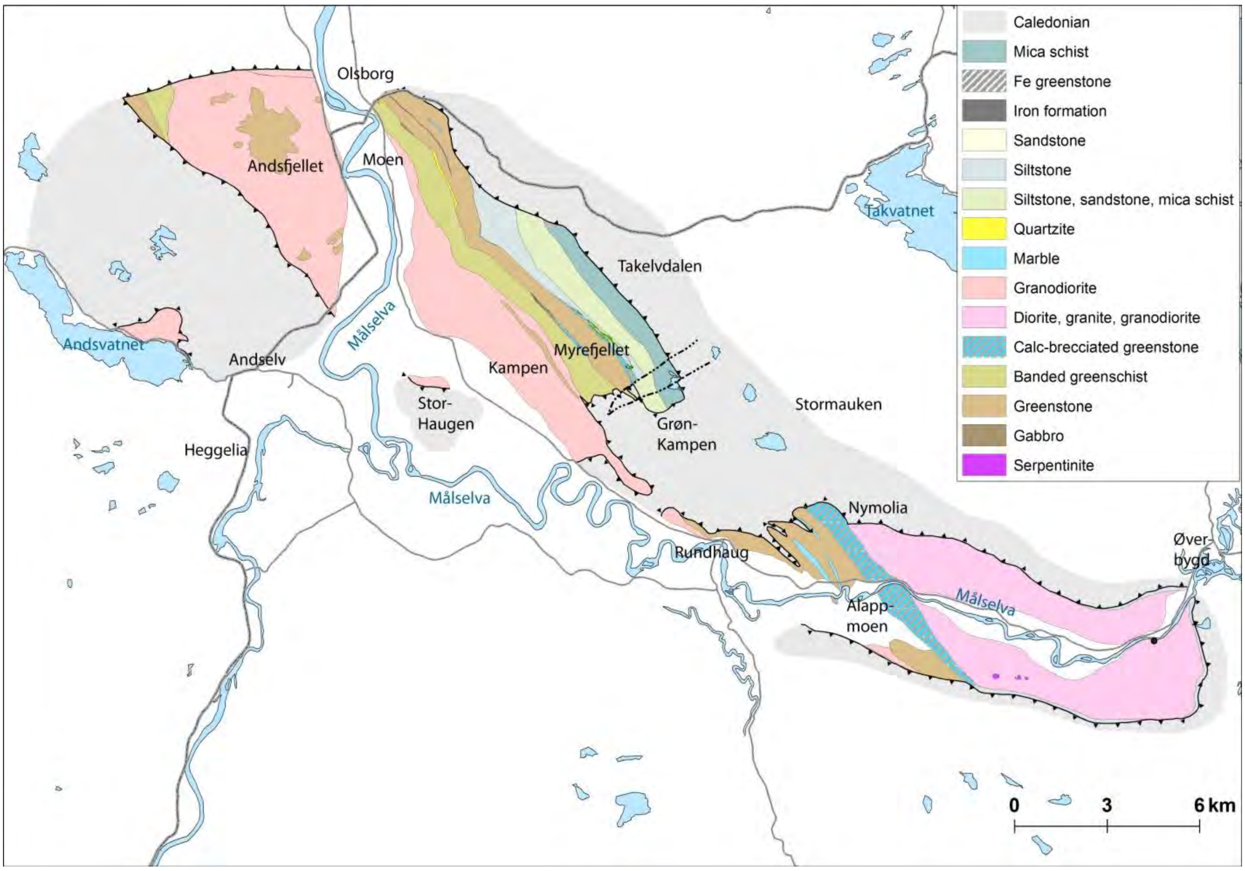

Figure 6: Geological overview of the Mauken basement window. For a more detailed map, see back cover.

4.1 The Andsfjell-Kampen intrusive complex

This intrusive, polymagmatic rock complex dominates at Andsfjellet and continues along the southwestern, steep slopes of the valley of Målselvdalen from Moen and 7-8 km south-eastwards to Rundhaug (Figure 6). It is also present in outcrop and road section to the west of Andselv, along the northern shores of Andsvatnet (Figure 13).

The intrusive unit comprises several intrusive phases with compositions varying from tonalite/trondhjemite to granodiorite and minor granite (Figure 7 to Figure 10). At Andsfjellet, a fairly large proportion of the complex is of granitic composition.

Figure 7: Granitic phase (left - pinkish coarser) intruding trondhjemite/tonalite (right – grayish finer grained). Locality: Målselv Fjellandsby (ski resort) UTM 408537 7664255.

Figure 8: Relatively dark granodiorite intruded by veins of granitic pegmatite. Locality: Målselv Fjellandsby (ski resort) UTM 408500 7664376.

Figure 9: Light, leucocratic trondhjemite intruded by quartz-plagioclase veins. Locality: Målselv Fjellandsby (ski resort) UTM 408498 7664400.

Figure 10: Typical granodiorite with leucocratic, granitic pods. Locality: Målselv Fjellandsby (ski resort) UTM 408498, 7664400.

Figure 11: Felsic dykes intruding the large central mafic raft at the top of Andsfjellet. UTM 401609, 7670280.

Figure 12: Veins of trondhjemite crosscutting greenstone. Locality: The road to Målselv Fjellandsby (ski resort), UTM 408988, 7663980.

The intrusive character of the complex is evident at several places: At Andsfjellet, a number of mafic bodies are found as rafts within the intrusive, locally intruded by a number of dykes rooted in the main felsic intrusion (Figure 11). To the west of Myrefjellet, smaller and larger lenses and layers of greenstone is incorporated in the intrusive granodiorite. Veins of the felsic rocks intrude the greenschist and greenstone (Figure 12). Thin sills of more fine-- grained felsic rock are also found up to several hundred meters inside the greenschist unit. These observations show that the felsic intrusive complex is younger than the mafic rocks.

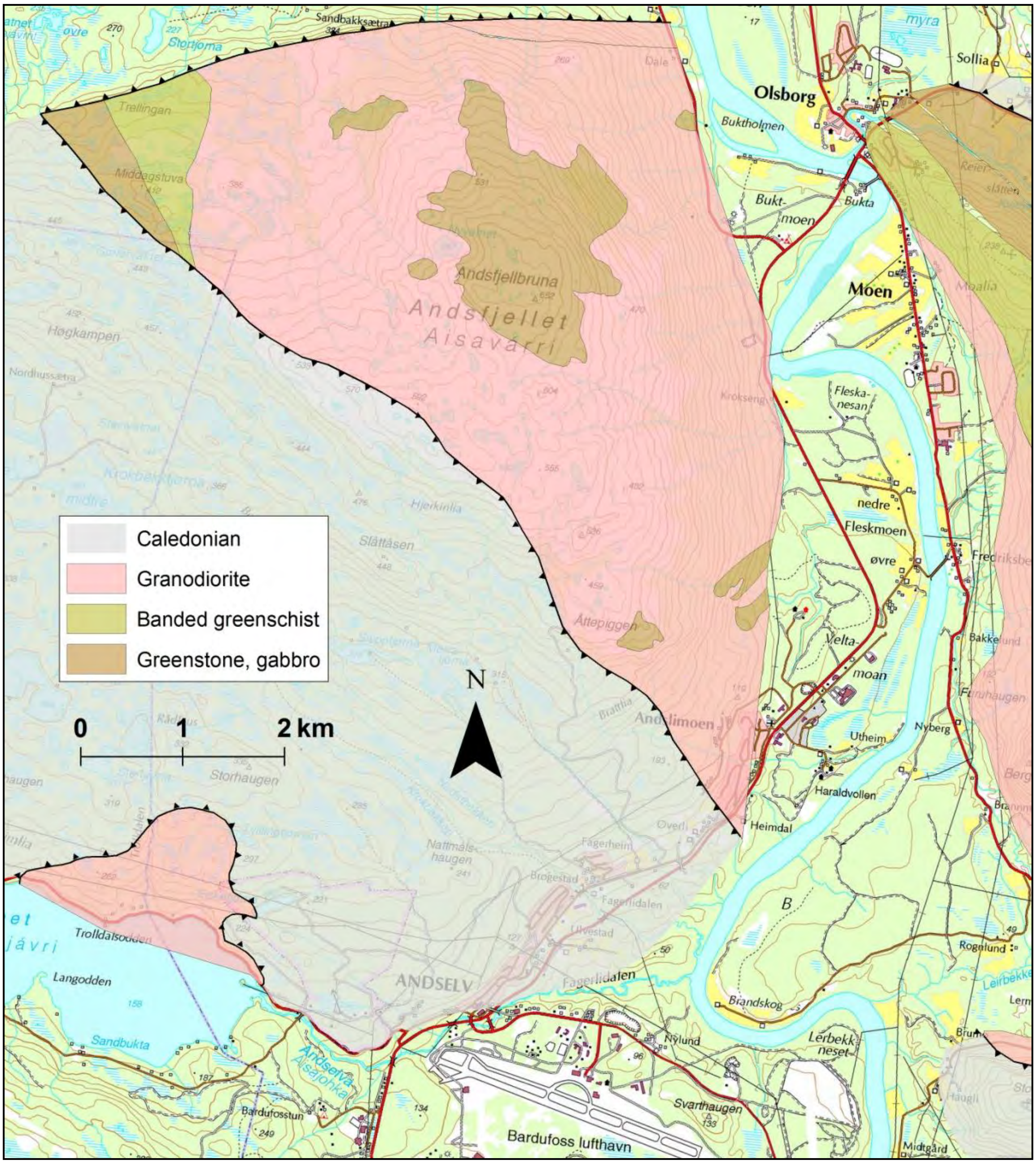

Figure 13: Geology of the Andsfjellet area (to the west of Målselva).

The felsic rocks to the east of Målselva, contain quartz, plagioclase and K-feldspar as main phases, while biotite is a common subordinate mineral. The content of K-feldspar varies, accordingly the rock classifies as trondhjemite, tonalite, granodiorite or granite. Muscovite, clinoamphibole and epidote are the most common accessory phases.

At Andsfjellet the felsic rock is mainly leucocratic with abundant quartz, alkali feldspar and usually low, but varying amounts of plagioclase (granite to granodiorite). The content of biotite is very low. In one place reddish up to 3 mm large garnets were observed and in one instance, small (secondary?) fluorite grains (1-2 mm) occurred. General grain size ranges from 0.3 to 1.5 cm. On fresh surfaces, it ranges from white, grey to light pinkish and orange. Thin sections reveal varying amounts of small grains of titanite, and accessory muscovite, Fe-Ti oxides, greenish amphibole and late calcite in the felsic rocks. A few of the samples contain some sulphide grains (pyrite, pyrrhotite).

Quartz veins/pegmatites varying in width from a few centimeters up to ca. 20 cm are common within the Andsfjellet part of the complex. A few coarser-grained pegmatites of granitic composition are also present with thickness of max. 30 to 50 cm. There are also few up to 10 cm wide, greenish epidote-rich, very fine grained veins, as well as mafic (amphibolitic) dikes of varying width up to 1 m. In most cases the following sequence of events can be interpreted from field relationships: emplacement of the granite body – followed by intrusion of mafic dikes – followed by intrusion of quartz veins/dikes/pegmatites. This interpretation is based on cross-cutting relationships and confirmed in several localities all over the felsic body of the Andsfjell area.

4.1.1 Gabbroic rocks/amphibolite (greenstone) at Andsfjellet

Fine grained mafic rocks with a microgabbroic texture were found at several places within the felsic complex at Andsfjellet. Their grain size varies from very fine to slightly coarser (1 mm up to ca. 1 cm). The feldspar grains reach sizes of 1 cm by 2 mm. About 1 km south of Sandbakksætra this gabbroic rock covers a larger area (Figure 13). The contact to the surrounding granitoid seems to be rather sharp. There are no granitic veins/pegmatites intruding this gabbroic rock (or vice versa). This larger gabbroic body appears fairly homogeneous regarding composition apart from some grain size variation. The homogeneity suggests that it is an intrusive body rather than an altered metavolcanic xenolith.

Other gabbroic rocks are interpreted to be dikes, intruding the felsic rocks, but also other gabbroic bodies. These rocks contain mainly greenish amphibole, feldspar and some contain quartz. Amphibole grains are often aligned in one direction. In one sample, there seems to be no feldspar, but only quartz. In addition to feldspar and amphibole, some Fe-Ti oxides occur as small grains.

In the field as well as in the thin sections, it is no major visible difference between the gabbroic rocks which occur as dikes and and those which occur as more massive bodies.

4.1.2 Xenolith/raft at top of Andsfjellet

The top of Andsfjellet (Andsfjellbruna) comprises a body of fine grained metavolcanic and possibly also metasedimentary rocks (Figure 13). This body is considered to be a large raft/xenoliths in the intrusive complex. Within the raft, there are also mafic dikes cross cutting it, probably similar to the ones described in the previous section.

The body is very heterogeneous with respect to rock type, grain size and alteration features. Dominating is a very fine grained (no individual minerals distinguishable) mafic (amphibolitic) rock. In addition there are coarser grained mafic rocks with a gabbroic texture, and felsic, grayish, quartzitic rocks (metasediments?). It is not possible to map out different units as they often vary on meter-scale.

The surrounding granite shows some interfingering/intruding structures (Figure 11) and there are also some veins/pegmatites within the metavolcanic and possibly metasedimentary rocks.

On the SW side of the metavolcanic unit (c. 1 km west of the top of the mountain) is a “bleaching” of the intrusive granitoid. There, most of the granitoid is fine-grained and leucocratic, nearly without mafic minerals. This fine grained rock seems only to occur close to the boundary between the granite and the mafic rocks. Furthermore, the transition from granite to the fine grained leucocratic rock seems to be gradual, while the contact between the mafic and the leucocratic rocks is sharp. It is possible that the leucocratic rock was formed because of heavy infiltration of fluids released from the granite. The fluids could also have caused the alteration to the quartzitic looking rocks within the metavolcanic/ metasedimentary succession in the western part of the window.

4.2 The Målselva Group

The Målselva Group comprises mainly mafic metavolcanics and fine grained metasediments, and is is situated central in the window, bounded by intrusive complexes in the west and east (Figure 6). The unit strikes mainly NW-SE and is mainly steeply dipping to the SW or vertical (dips 70-90^{O}).

The name *Målselva Group* was suggested by Berthelsen (1967) to include all the supracrustal rocks in the Mauken window, and is retained in this report. The western boundary is intrusive, as described above, while the eastern boundary is tectonic (see below). Between Grønkampen and Rundhaug, the unit is covered by Caledonian meta-sediments.

The supracrustals comprise mainly (from southwest to northeast, Figure 14) banded/ laminated (probably tuffitic) greenschist, greenstone, siltstone, sandstone and mica schist. Units of calc-brecciated greenstone, small gabbroic bodies and iron formation are also present. The metavolcanic units were collectively called the Myrefjell Formation and the metasediments the Aurevatn Formation by Berthelsen (1967). The names are retained in this report. However, Berthelsen (op.cit.) also included parts of the Caledonian cover into the Aurevatn Formation.

4.2.1 <u>Banded greenschist</u>

This rock type occupies a c. 12 km long and 6-700 m wide belt from Moen and south-eastwards to Myrefjellet (Figure 14), between the felsic intrusive complex and the unit of massive greenstone. A similar banded unit is found on the W side of Andsfjellet (see below, Section 4.2.3).

The greenschist is generally strongly laminated and banded on mm- to cm-scale, with alternating lighter grayish and darker greenish bands. The lighter bands are enriched in quartz and plagioclase, while the darker bands are rich in chlorite, amphibole or/and epidote. Some banded layers are also overall more felsic. Within the unit are also several more massive layers of greenstone.

Close to the northern boundary of the unit is a 5-20 m thick layer of banded to laminated schist (Fe greenstone on the maps), which is quite strongly enriched in magnetite. The unit contains bands with 2-4 % magnetite (measurements by handheld susceptibility meter, Figure 15). This unit may be related to a thicker unit of iron formation, which is situated between the greenschist and greenstone units (described in chapter 4.2.6).

On the basis of the banded to laminated character, as well as the mineralogy, the greenschist unit is interpreted to be of a tuffitic origin.

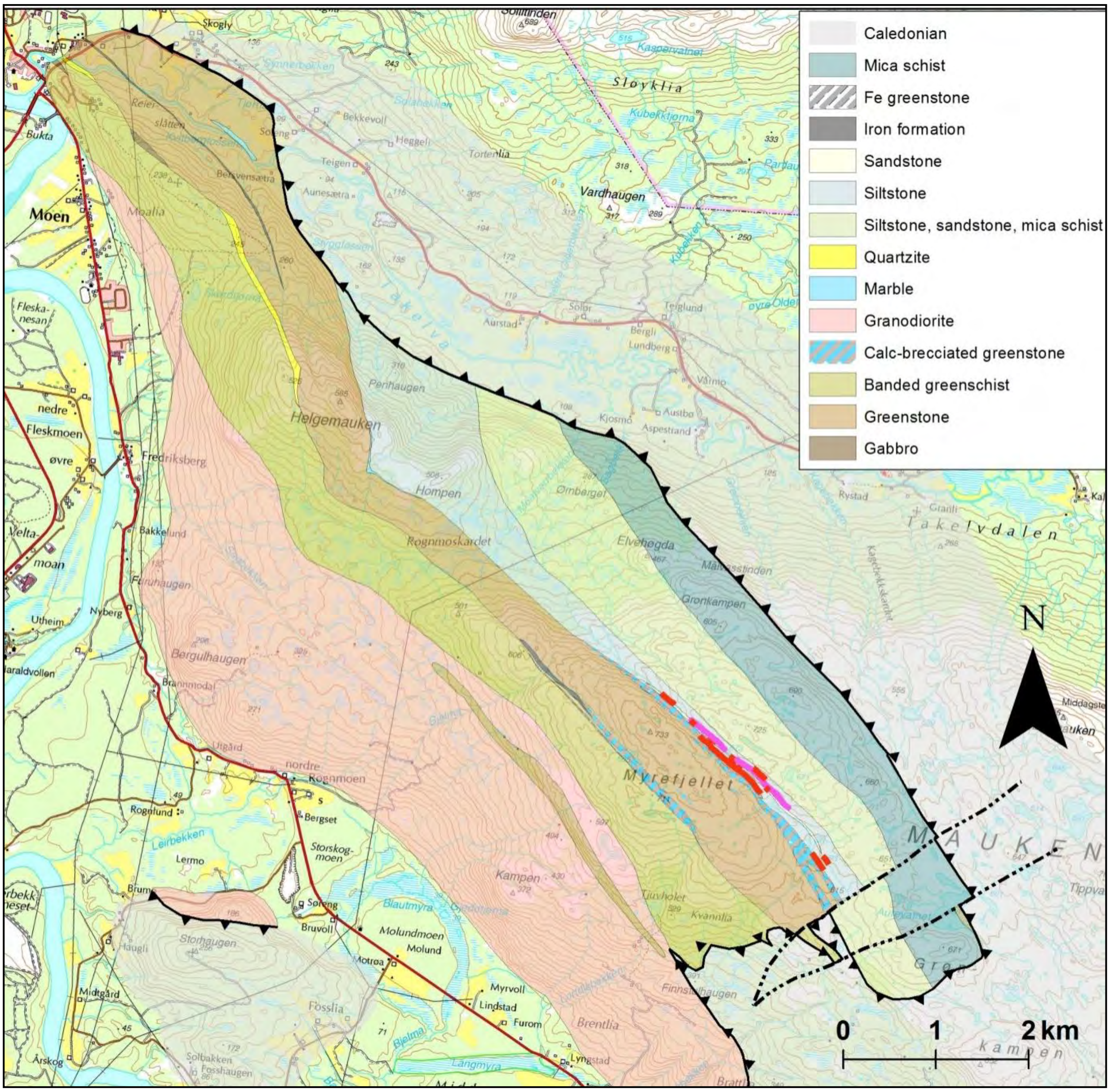

Figure 14: Geology of the central part of the Mauken window. Red and purple lines mark the gold mineralization of the so-called "Main Zone" (see chapter 8). See Figure 6 and the map in the appendix for the eastern part.

Figure 15: Strongly banded magnetite-rich schist, with alternating quartz-rich and magnetite-rich bands. The susceptibility meter shows a value of 103 x10^{-3} SI units, corresponding to c. 3 % magnetite in the rock.

4.2.2 Greenstone

This rock unit is situated to the north of the unit of banded greenschist, in a 500 – 1000 m wide belt extending from Olsborg to Myrefjellet (Figure 6). It is covered by the Caledonian units between Grønkampen and Rundhaug. It continues on the other side of the Målselva river close to Alappmoen, before being covered again by the Caledonian units to the south. A similar unit of greenstone is also found on the W side of Andsfjellet (see below).

In the Olsborg-Myrefjellet segment (Figure 14), the northern contact of the greenstone is against fine-grained metasediments (originally siltstone). The greenstone close to this contact is calc-brecciated in the eastern part of the segment, and a few thin lenses of calcite marble are intercalated. In the Rundhaug-Alappmoen segment, the northern contact is marked by a thick unit (up to 2-300 m) of calc-brecciated greenstone. In this part of the greenstone also thicker lenses of calcite marble are intercalated.

In the Myrefjellet area, the greenstone consists mainly of 1-3 m massive layers, separated by more schistose or brecciated thin bands and layers. These layers are interpreted to represent basaltic flows. In several localities these layers consist of well preserved pillowed metabasalts (Figure 16, Figure 17). Some of these indicate that right-way up is towards the north.

In many places the greenstone is porphyric with mm-sized white grains of plagioclase, or has a micro-gabbroic texture.

Clinoamphibole and plagioclase are the main phases of the greenstone. Epidote is occasionally a major phase, but more often present as a subordinate mineral together with quartz and chlorite. Titanite and biotite are subordinate to accessory minerals, while carbonate, sericite and iron oxides/sulfides are common accessory phases.

Figure 16: Pillowed metabasalts at Myrefjellet (UTM 411740 7664760). Shape of the pillows indicates that right-way-up is up on the photo, which is northwards.

Figure 17: Pillowed metabasalts at Myrefjellet, showing chilled margins (UTM 411570 7664785).

4.2.3 Greenstone and greenschist at Andsfjellet

There are mafic metavolcanic rocks, comprising greenstone and greenschist in the northwest part of the Andsfjellet area (around Trellingan, Middagstuva, Figure 13). The westernmost 300-400 m comprises fairly homogeneous, but somewhat banded greenstone. Further towards the east, and approaching the contact to the granitic intrusion, the rocks get more heterogeneous and turn into more schistose rocks – greenschist.

Very close to the contact to the granite, there are light grayish, almost quartzitic looking, very hard rocks in close association with fine-grained, mafic rocks with a microgabbroic texture (grain-size up to a few mm) where feldspars and mafic minerals are easily distinguishable. The boundary to the granite is defined in this area where the first, clearly identifiable granitic rocks occur.

4.2.4 Calc-brecciated greenstone

An extensive layer of calc-brecciated greenstone is situated to the north of the greenstone unit in the Alappmoen - Nymolia area (Figure 6). It is more than 7 km long and 300-900 m thick. Similar, but much less extensive layers occur on both sides of the massive greenstone unit in the Myrefjellet area (Figure 14).

This rocktype consists of fragments of greenstone in an irregular network of white calcite (Figure 18). It is found associated with the lenses of calcite marble in the greenstone to the east of Rundhaug (Figure 19). Occasionally small lenses of calcite are found within the greenstone. Thus, one possibility (most likely?) is that this rock formed during deformation and subsequent infiltration of calcite from the surrounding carbonate layers.

The greenstone is strongly altered and consists mainly of chlorite, quartz and calcite, while plagioclase is subordinate. The rock is enriched in magnetite, which occurs in subordinate to accessory amount.

Because of relatively high content of magnetite (up to 3-4 %), the rock gives a strong magnetic anomaly that can even be traced through the Caledonian thrust sheets (chapter 3 and Figure 2).

Figure 18: Typical calc-brecciated greenstone. Locality: Road section east of Rundhaug, UTM 421360, 7656750.

Figure 19: Calc-brecciated greenstone overlying marble. Locality: Nymolia, UTM 419080, 7658225.

4.2.5 Metasediments

A unit of metasediments, the Aurevatn Formation (Berthelsen 1967) comprising mainly metasiltstone, metasandstone and mica schist, comprises the northern part of the window in the area between Grønkampen and Olsborg (Figure 14). This unit is important, as it hosts the main gold mineralization in the Mauken area (see chapter 8).

The formation has a maximum thickness of more than 1.5 km to the north of Myrefjellet, before wedging out westwards against the Caledonian thrust.

Close to the contact to the greenstone unit, the first 100-150 meters westwards of the sediments are dominated by laminated metasiltstone. It is in this siltstone unit the main gold mineralization is situated (Figure 20). Within the siltstone are also several thin layers (1 to 4 meter thick) of fine- to more coarse-grained metasandstone, but also thicker sandstone layers are present, as shown in Figure 20.

The metasiltstone is typically finely laminated on mm to cm-scale, with alternating darker and lighter bands (Figure 21). The dark bands are enriched in biotite and/or graphite, while the lighter contain more quartz and sericite/muscovite. Banding is also due to variations in grainsize. Other minerals in the metasiltstone are chlorite, tourmaline and apatite. The content of graphite in the siltstone appears to increase to the southwest towards the greenstone contact.

The sandstone beds vary from very fine-grained to relatively coarse-grained, often displaying graded bedding (Figure 22, Figure 23, Figure 24). In some cases what could be crossbeds are recognized, indicating that right-way-up is northwards (Figure 25). The subrounded clasts consist mainly of quartz and sericitized feldspar, but the sandstone also contains a few clasts of very fine-grained quartz-feldspar rock.

Further northeast, the siltstone grades into metasandstone, which shows a rhythmic banding on meter-scale between finer silty to coarser, sandy layers (Figure 20). This part of the unit could possibly represent turbidites. The thickness of this part is 500-700 meters.

Furthest to the northeast and in contact with the Caledonian thrust sheets, is a 500-600 meter thick unit of more homogeneous fine-grained, dark mica schist, dominated by quartz and biotite, but also contains subordinate amounts of carbonate, especially close to the metasandstone unit. The contact between the sandstone and schist is marked by a valley-like depression.

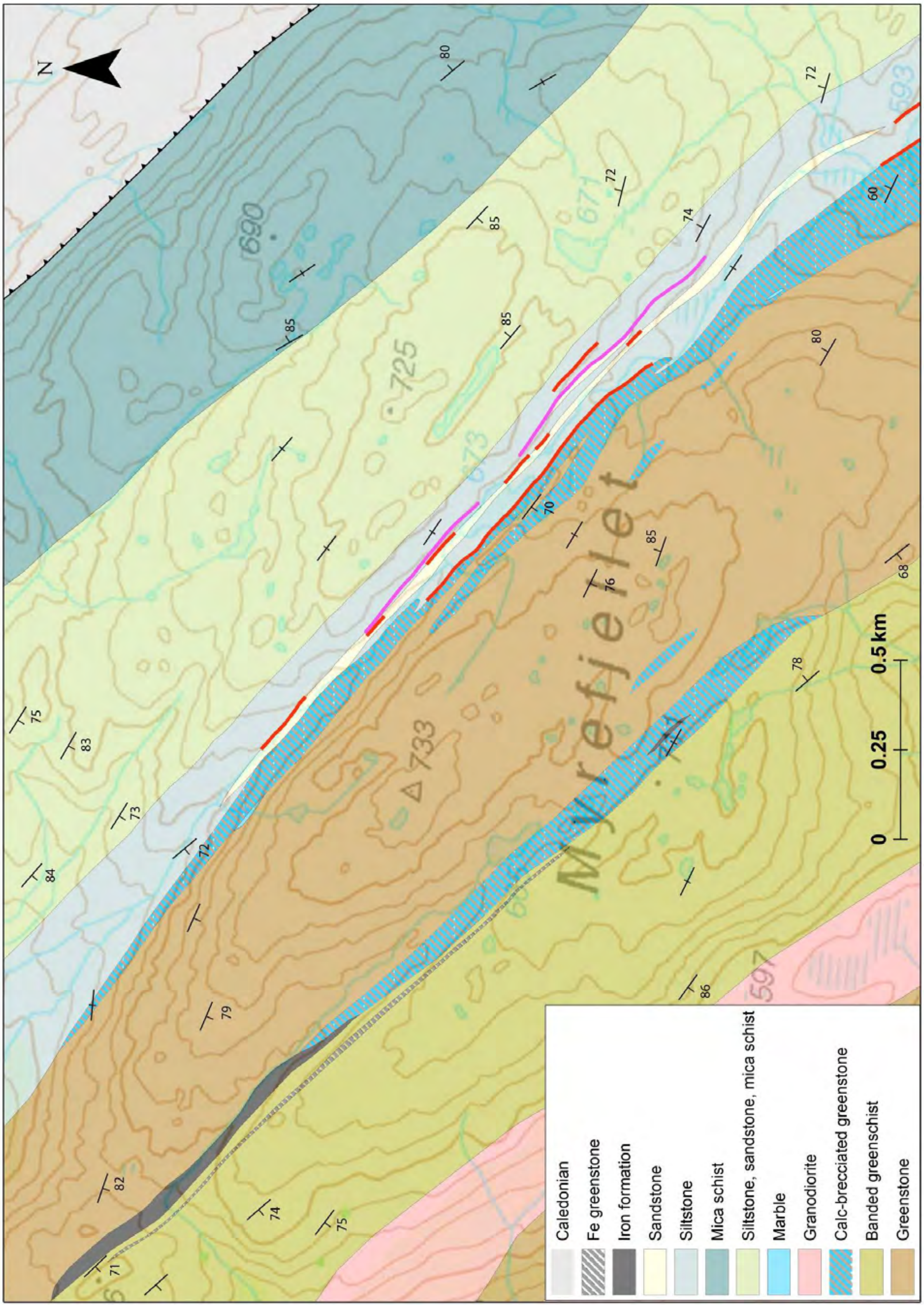

Figure 20: Geology in the Myrefjellet area of the Mauken window. Red lines mark iron-sulfide mineralizations, while purple is the gold mineralized main zone.

Figure 21: Typical laminated siltstone. Locality: To the north of Myrefjellet, UTM 411930, 7664960.

Figure 22: Alternating fine- and coarse-grained sandstone. Locality: To the north of Myrefjellet, UTM 412370, 7664585.

Figure 23: Alternating fine- and coarse-grained sandstone, showing graded bedding. Close-up of Figure 22. Locality: To the north of Myrefjellet, UTM 412370, 7664585.

Figure 24: Close-up photo of rather coarse-grained layer of sandstone. Same locality as Figure 22.

Figure 25: Laminated to banded sandstone, with trough-like structure, indicating that right-way-up is to the north. UTM 409135, 7667545, close to Rognmoskardet.

The contacts between the various lithologies within the Målselva Group in the Myrefjellet area seem to be mainly of primary origin. However, the calc-brecciated greenstone present close to and at the contact between some of the main lithological units (Figure 6, section 4.2.4), show that strong deformation took place at some time, possibly during the Caledonian nappe emplacement.

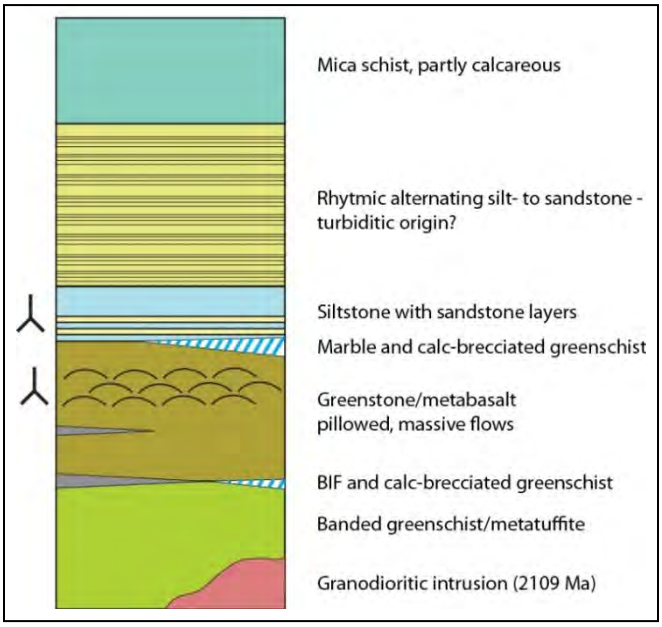

Figure 26: Schematic stratigraphic profile through the Målselva Group.

As shown above, at several localities in the sedimentary sections of the Målselva Group, primary structures like cross-bedding, graded beds, etc., show a consistent picture, i.e. right-way is towards north. Also shapes of pillows in the greenstone unit indicate that right-way-up is towards the north (Figure 16). From this, a stratigraphic profile of the Målselva Group has been constructed (Figure 26).

4.2.6 Iron formations

There are two iron formations in the Mauken window, both situated in the Målselva group. One is situated within the major greenstone unit to the north of Myrefjellet (Figure 27) and one is situated at the boundary between the banded greenschist and greenstone to the west of Myrefjellet (Figure 30).

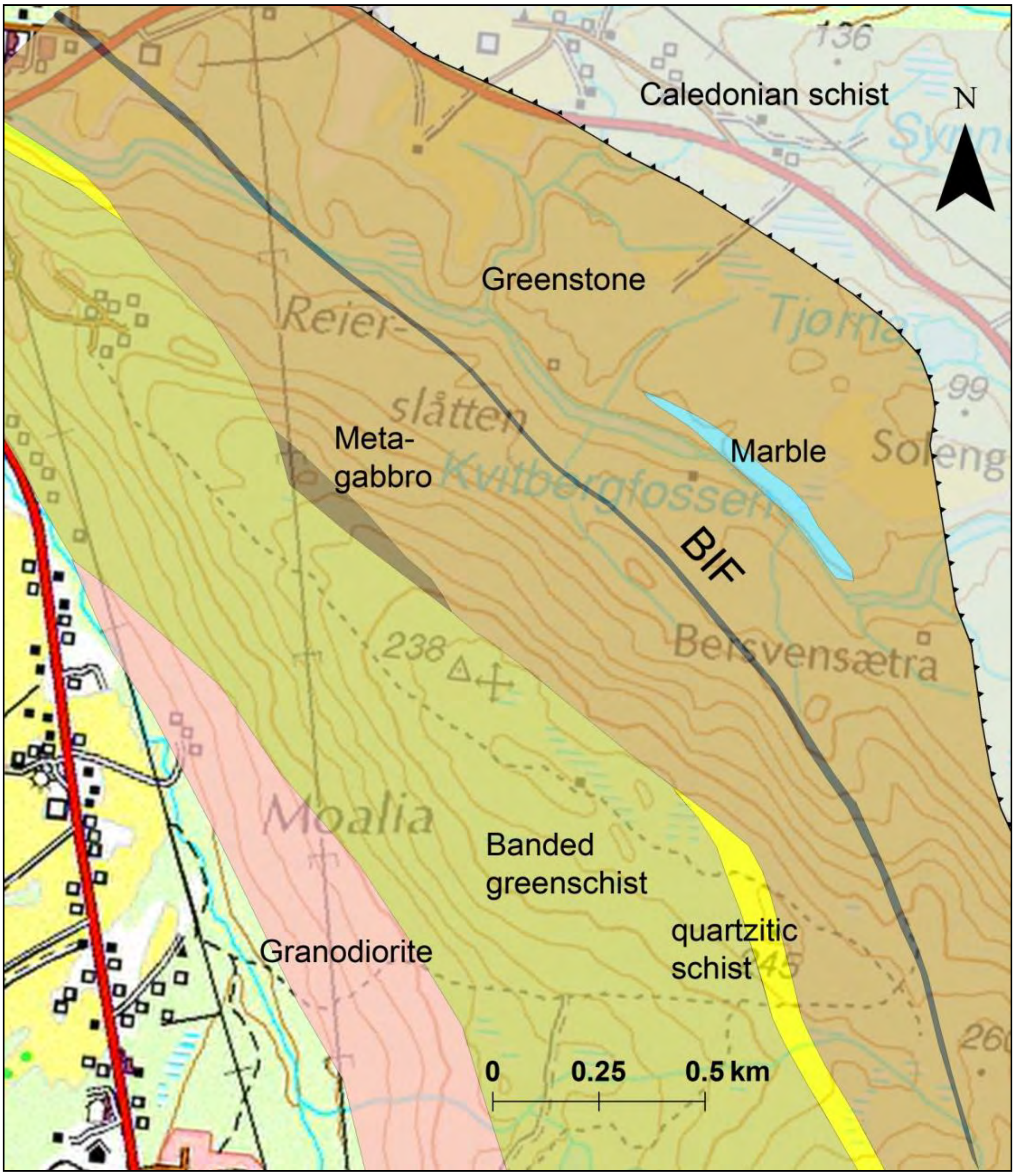

Figure 27: Geology in the northern part of the Mauken area, showing the banded iron formation (BIF) located in the greenstone unit.

The northernmost iron formation forms an extensive layer within the major greenstone unit, stretching from the main road (E6) in the northwest and southeastwards up the steep slopes towards Helgemauken (Figure 27). It gives a strong magnetic anomaly (Figure 2, Figure 3). The total length of the zone is more than 3.5 km, while the thickness is 6-7 m. The northernmost outcrop of the zone is in the river Takelva, where it is a strongly foliated, laminated on some cm-scale, quartz- and carbonate-rich, iron formation, some 6-7 m thick (Figure 28). The iron mineral is magnetite. The outcrop shows isoclinal folding with development of transposed foliation. In the south, it shows more of an irregular banding, partly with lenses of fine-grained magnetite and quartz (Figure 29). The northern outcrop contains quartz, carbonate and magnetite as major phases, while pyrite, chlorite and biotite are accessories. The southern outcrop is dominated by quartz and magnetite, while carbonate is absent. Chlorite and grunerite are subordinate phases.

Geochemistry (two samples) shows contents of 28.0 and 21.6 % Fe_2O_3, while the content of TiO_2 is very low (0.05 and 0.01 %) for the northern and southern outcrops, respectively. The same samples contain 0.87 and 0.17% P_2O_5.

Figure 28: Outcrop of banded iron formation in Takelva. The photo is taken eastwards. On the north side of the river is chloritic greenschist.

Figure 29: Outcrops of banded iron formation at the slopes of Helgemauken, showing alternating quartz and magnetite layers and lenses.

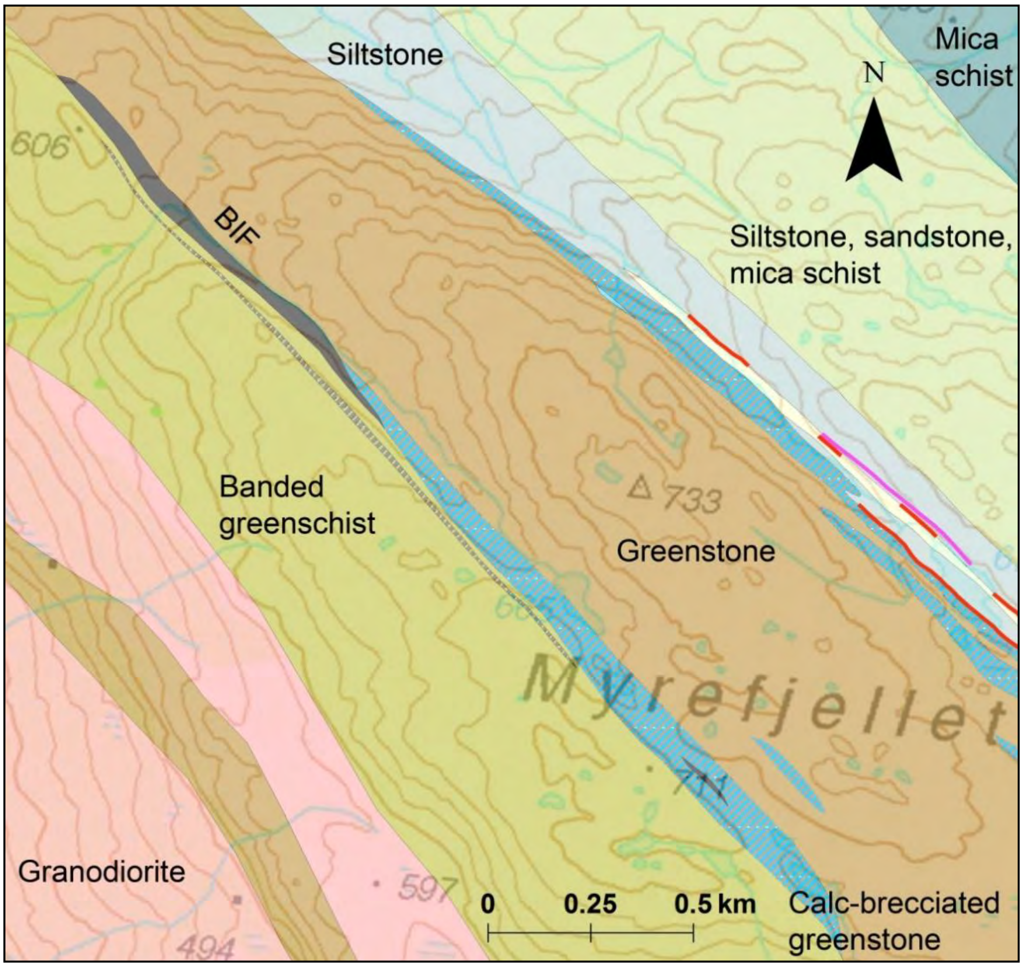

Figure 30: Geology in the area around Myrefjellet, showing the banded iron formation (BIF) at the boundary between greenschist and greenstone. Grey hatched line marks magnetite-rich greenschist, while red lines mark iron-sulfide mineralizations, and purple is the gold mineralized main zone.

The other iron formation is exposed in the pronounced Bjelma valley to the west of Myre-fjellet (Figure 30). This valley (with the Bjelma stream), marks the boundary between the banded, tuffitic greenschist and the generally massive greenstone/ metabasalt. It gives a well-defined magnetic anomaly (Figure 2, Figure 3).

The iron formation is located in the northwestern part of this valley, in the extension of a layer of calc-brecciated greenstone. It has a length of at least 700 m and a thickness of up to 30 m close to the major bend of the Bjelma stream.

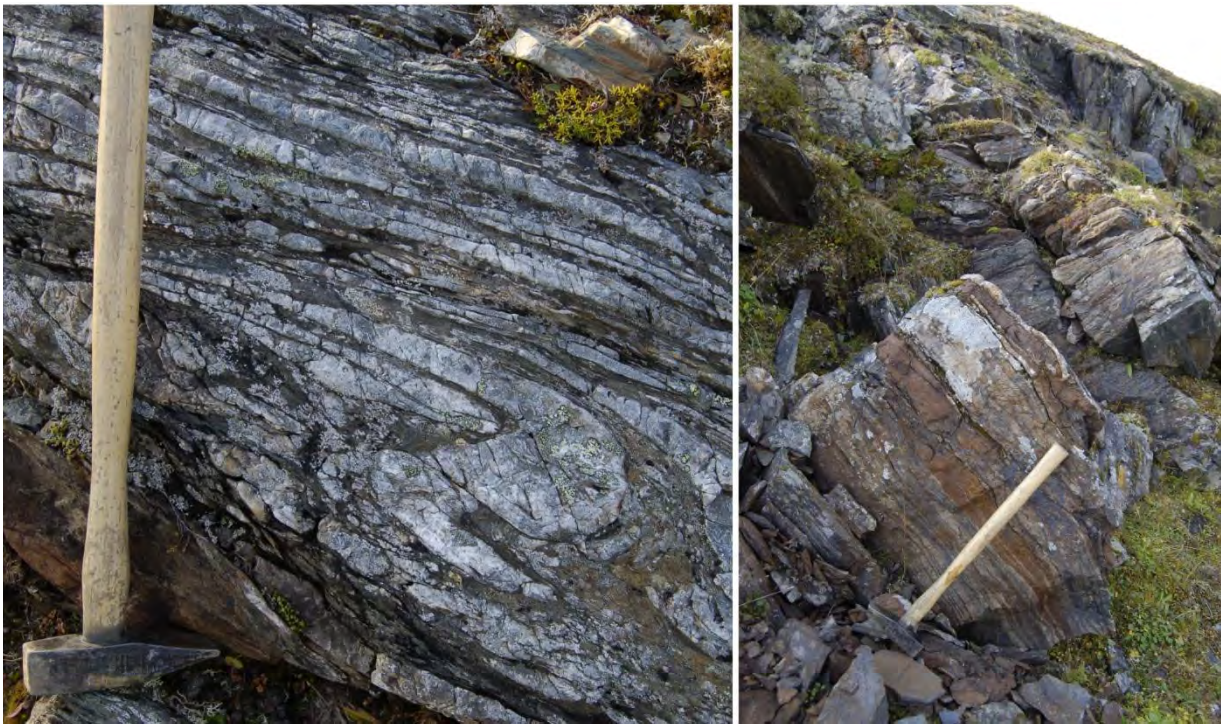

Figure 31: Outcrops from the iron formation in the Bjelma valley. The left photo shows a banded quartz-rich unit, while the right photo shows a banded carbonate-rich unit, where the carbonate is brown and iron-rich.

The iron formation varies in composition across strike, from quartz- to carbonate-rich (Figure 31). The carbonate is generally a brown, Fe-rich calcite or ankerite. Fine-grained magnetite is present in thin bands throughout the formation, generally the thin bands are found in zones less than one meter in thickness. Some zones in the formation are enriched in sulfides, mainly pyrite. One sample analyzed of the carbonate-rich part contains 25.5 % Fe_2O_3, 0.07 % TiO_2 and 0.18 % P_2O_5, and one quartz-rich sample contains 33.0 % Fe_2O_3, 0.03 % TiO_2 and 0.14 % P_2O_5.

As mentioned in section 4.2.1, a 5-20 m thick layer of banded to laminated schist quite strongly enriched in magnetite is present in the banded greenschist some meters from the boundary to the greenstone (Figure 30). The unit contains bands with 2-4 % magnetite (measurements by handheld susceptibility meter, Figure 15). The unit can be followed for more than 1 km along strike. It is possible that this unit somehow is related to the iron formation.

4.3 The Øverbygd Intrusive Complex

The Øverbygd intrusive complex stretches from Alappmoen in the west to Øverbygd in the east (Figure 6). In the west, it has a tectonic contact to the Målselva Group, with gradually increasing shear deformation of granodiorite westwards towards the contact. This contact is well exposed along the main road between Rundhaug and Øverbygd (UTM 421715, 7656755)

In the east and south, the intrusives are unconformably overlain by sediments (mainly siltstone), correlated with the late Precambrian/Cambrian Dividal Group (Gustavson, 1963, 1966).

The intrusive complex comprises a very diverse suite of magmatic, mainly intrusive rocks. The main rock types are granite, granodiorite and gabbro, while monzonite, diorite and ultramafic rocks are less common (Figure 32 to Figure 35).

The area has not been mapped in detail, and the different rocks have not been separated on the map. Generally granodiorite is dominating to the north of the river, while granite is most common in the south. Monzonitic to dioritic rocks are present in the easternmost part of the complex.

On the southern side of the river, to the east of Alappmoen are some small bodies of soapstone (Figure 35). These bodies are situated in a mainly granitic part of the intrusive complex together with lenses of greenstone (Lindahl & Nilsson, 2002, Nilsson & Lindahl, 2005). The soapstone appears to be of partly good quality and has been evaluated for dimension stone (op.cit.). The soapstone bodies give a strong magnetic signal, and another body was found during this project at Storhaugen some 750 m further to the west (Figure 2 and Figure 35).

There are complex relationships between the different intrusion phases of the complex, but from the field observations the granitic rocks seems to be the latest phase (Figure 32 to Figure 34).

Figure 32: Fine-grained gabbroic rock, intruded by coarse-grained granitic veins. Locality UTM 421920, 7657280.

Figure 33: Granitic veins intruding more fine-grained granodiorite. Locality UTM 424680, 7656200.

Figure 34: Porphyric dioritic to monzonitic rock, intruded by a granitic vein. Locality UTM 424440, 7654170.

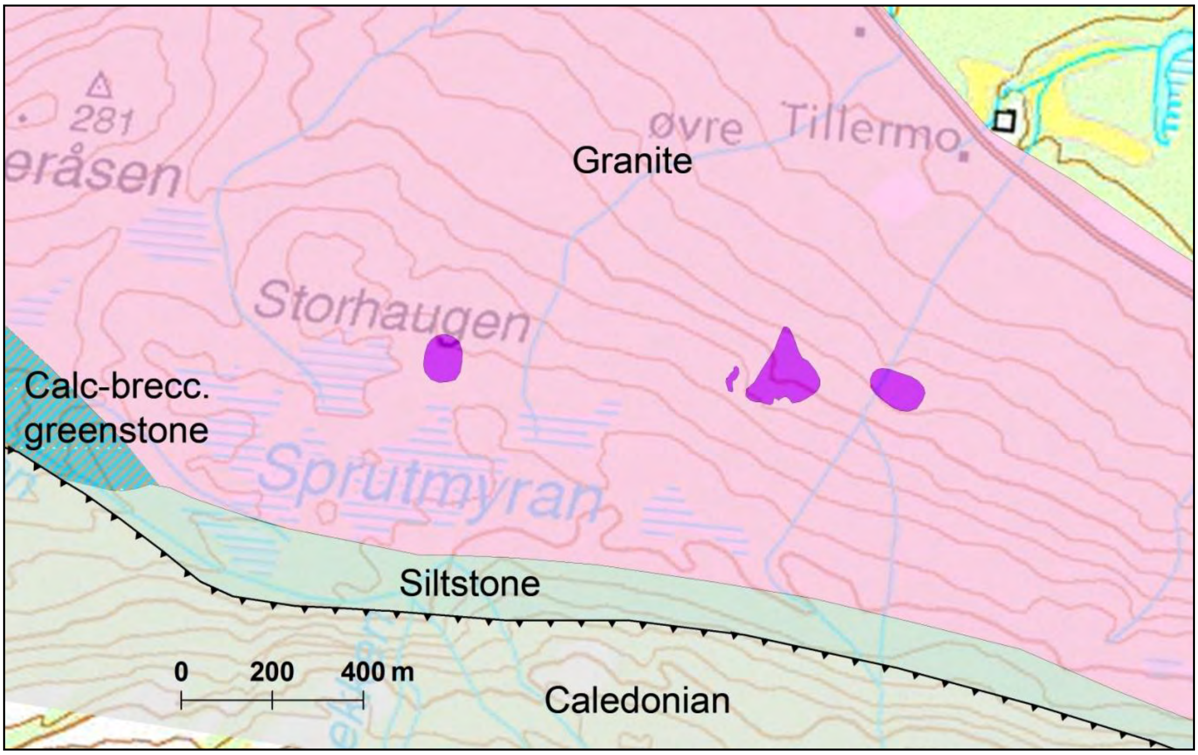

Figure 35: Section of the geological map (in the appendix), showing the soapstone bodies to the south of Målselva.

4.4 Metamorphic grade

Based on the mineralogy of especially the supracrustal rocks of the Målselva group, the metamorphism is generally low. Typical mineral assemblage in the greenstone/greenschist is albite, chlorite, epidote, biotite and actinolite, and the siltstone (pelitic schist) is dominated by quartz, sericite/muscovite, chlorite and biotite. Garnet has only been found in a few localities, and only as tiny grains in thin-sections. On this basis the metamorphic grade seems only locally to have exceeded middle greenschist facies conditions.

5. STRUCTURAL GEOLOGY

5.1 Boundary of basement window to the Caledonian Nappes

At Andsfjellet the boundaries of the tectonic window to the surrounding Caledonian rocks are evident, as there is a marked contrast in rock type (Caledonian schist vs. Precambrian intrusive rocks) as well as dip of foliation (Caledonian rather flat up to 20-40 °, Precambrian usually much steeper i.e. 60-90 °, Figure 36).

The contact in the Andsfjellet area between the mainly granitic basement and the Caledonian rocks is often characterized by a considerable enrichment of quartz veins.

Some quartz veins are folded into the Caledonian rocks, while others crosscut the granitic rocks. In the contact area, the granite is often heavily sheared parallel to the overlying Caledonian rocks, but this zone is only ca. 1 m wide, suggesting that the Caledonian reworking of the underlying basement in this area is limited. It occurs e.g. along the boundary SE of Sætervatnet (Figure 13). The northern boundary, e.g. at trigonometry point 324 m close to Sandbakksætra, is characterized by a ca. 20 m wide zone of quartz-pegmatite, quartzitic and heavily altered granitic gneissic rocks. The quartz commonly shows cavities with secondary quartz growth.

Figure 36: The contact (stippled line) between inclined granitic rocks of the Mauken window in the foreground and flatlying Caledonian schists. Locality at Andsfjellet, UTM 398430, 7670760, photo towards south.

Similar structural contrasts are also found in the central part of the area, as shown in Figure 37: Flat-lying Caledonian lithologies are present in contact with steep, nearly vertical dipping basement rocks. The Caledonian schists are generally strongly foliated and sheared and often display an S-C fabric, indicating top-to east kinematics (Figure 38).

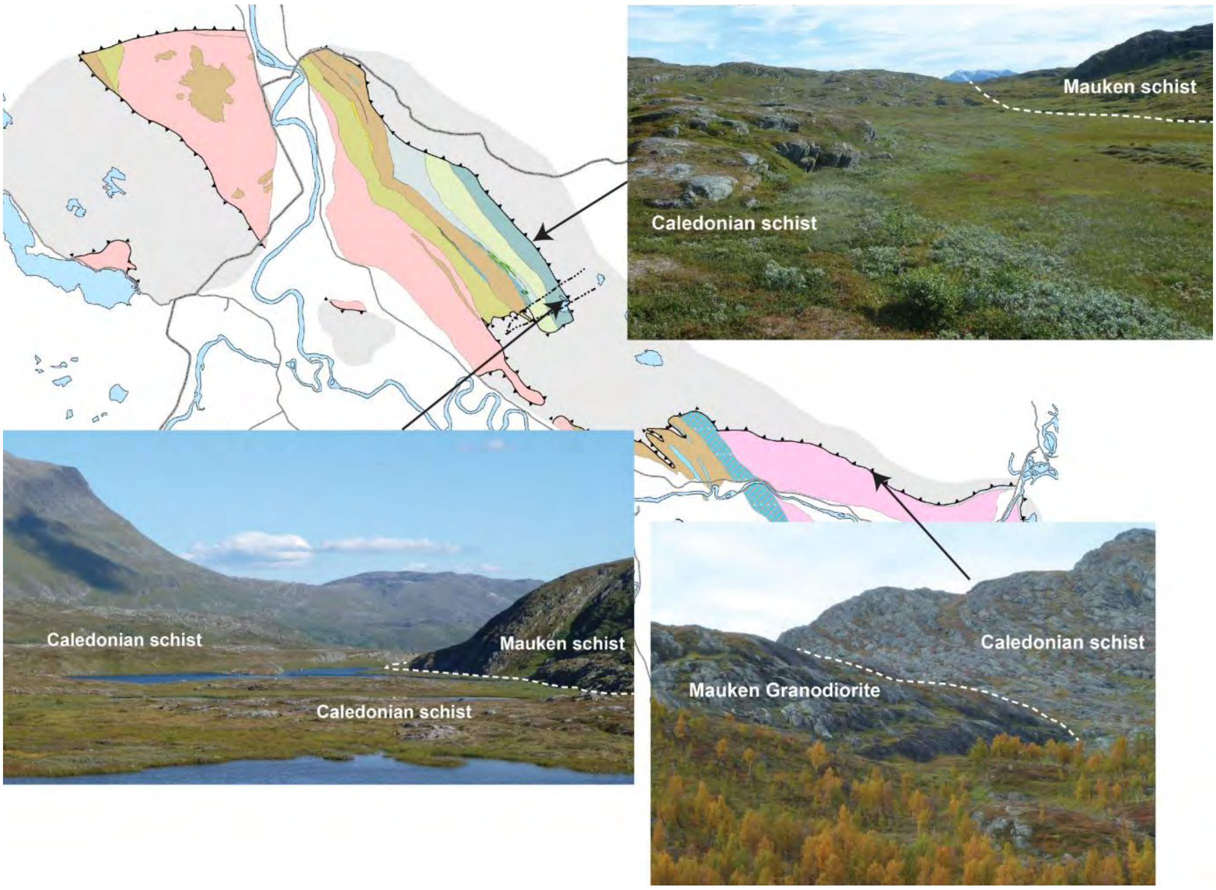

Figure 37: The northern contact between the Caledonian Nappes and Mauken window at 3 localities.

Figure 38: Typical flatlying, strongly foliated (S-C fabric) Caledonian mica schist. Locality UTM 418975, 7658990, Nymolia. The hammer-head points in the direction of movement, which is eastward.

Figure 39: Strongly folded quartzite (isoclinal folds) in the Caledonian Nappe unit above the contact to the Mauken window. Locality: Øvermoen UTM 417694, 7654685.

In the south, rocks of the Øverbygd intrusive complex is overlain by mainly very fine-grained metasiltstone, which is interpreted to be equivalent to the Dividal Formation (Figure 6, Gustavson, 1966). This unit is only a few tens of meters thick, and is followed upward of quartzitic rocks of Caledonian age. The quartzite is strongly deformed, with large scale development of isoclinal folding (Figure 39).

The northern contact of the Precambrian window with the overlying Caledonian nappes close to Takelva (see Figure 6), is more difficult to define. This is due to the fact that similar mica schist lithologies (i.e. similar mineralogy and metamorphic grade) are present in both the Precambrian rocks and the overlying Caledonian. However, small-scale structural and kinematic differences in strike-slip crenulation cleavage in the underlying Precambrian rocks and clear top-to-the east thrust kinematics in the overlying Caledonian, allow the precise mapping of the boundary.

6. LITHOGEOCHEMISTRY

131 samples were collected for geochemistry, comprising all the major lithologies in the area.

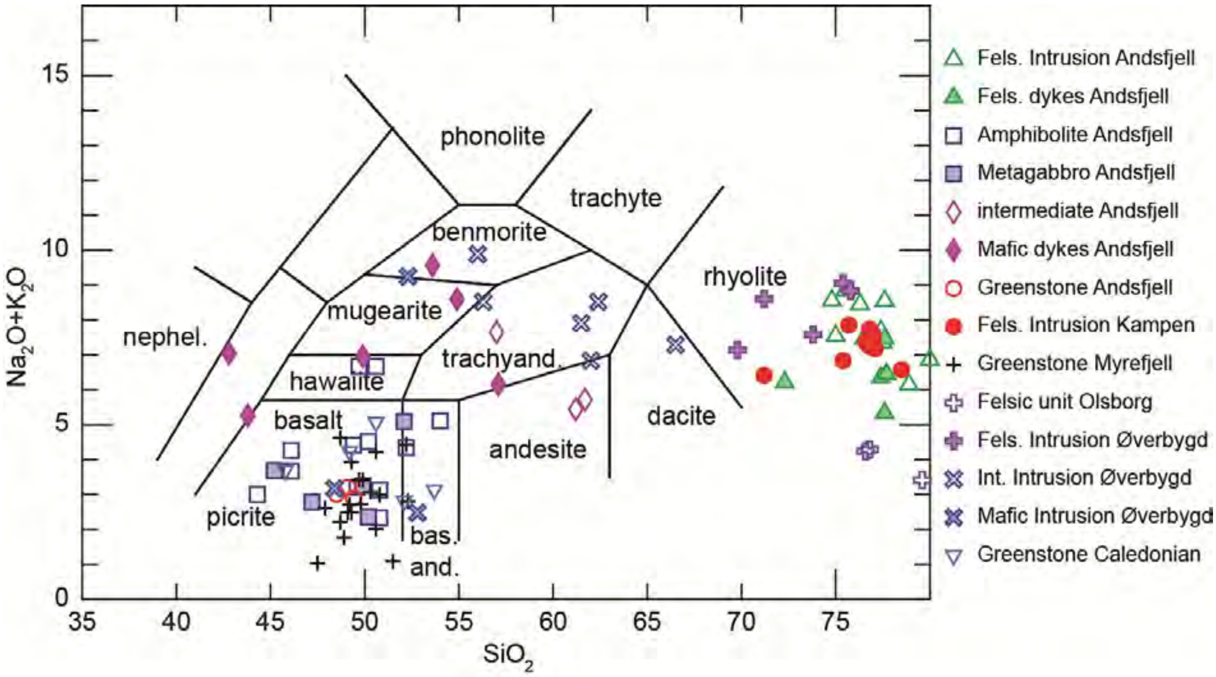

Figure 40: Samples of the magmatic rocks in the Mauken area plotted in the SiO_2 vs. Na_2O+K_2O diagram by Cox et al. (1979).

In Figure 40 is shown the data for the magmatic rocks in the area in the SiO_2 vs. Na_2O+K_2O diagram (diagram from Cox et al., 1979). Most of the rocks are mafic of basaltic/gabbroic compositions or felsic of rhyolitic/granitic compositions. Samples of more intermediate and alkaline compositions mainly come from the eastern part of the window (the Øverbygd area), but are also represented by mafic dykes and intermediate rocks from the Andsfjell area.

6.1.1 Mafic volcanic rocks

The greenstone units at Myrefjell (not including the tuffitic greenschist), Andsfjellet (NW) and the overlying Caledonian units are compared in various diagrams in Figure 41 and Figure 42. The averages of the mafic metavolcanics are shown in Table 1.

The diagrams show that the greenstone units are quite similar, but that the Caledonian greenstone samples plot more scattered than the samples from the window. The units all plot mainly as MORB type basalts in the diagrams in Figure 41, but close to the boundary to Island Arc tholeiites. In Figure 42 the average data show some enrichments in LILE compared to MORB, but generally flat patterns in HFSE. On this basis, an arc to back-arc setting seems likely for these rocks.

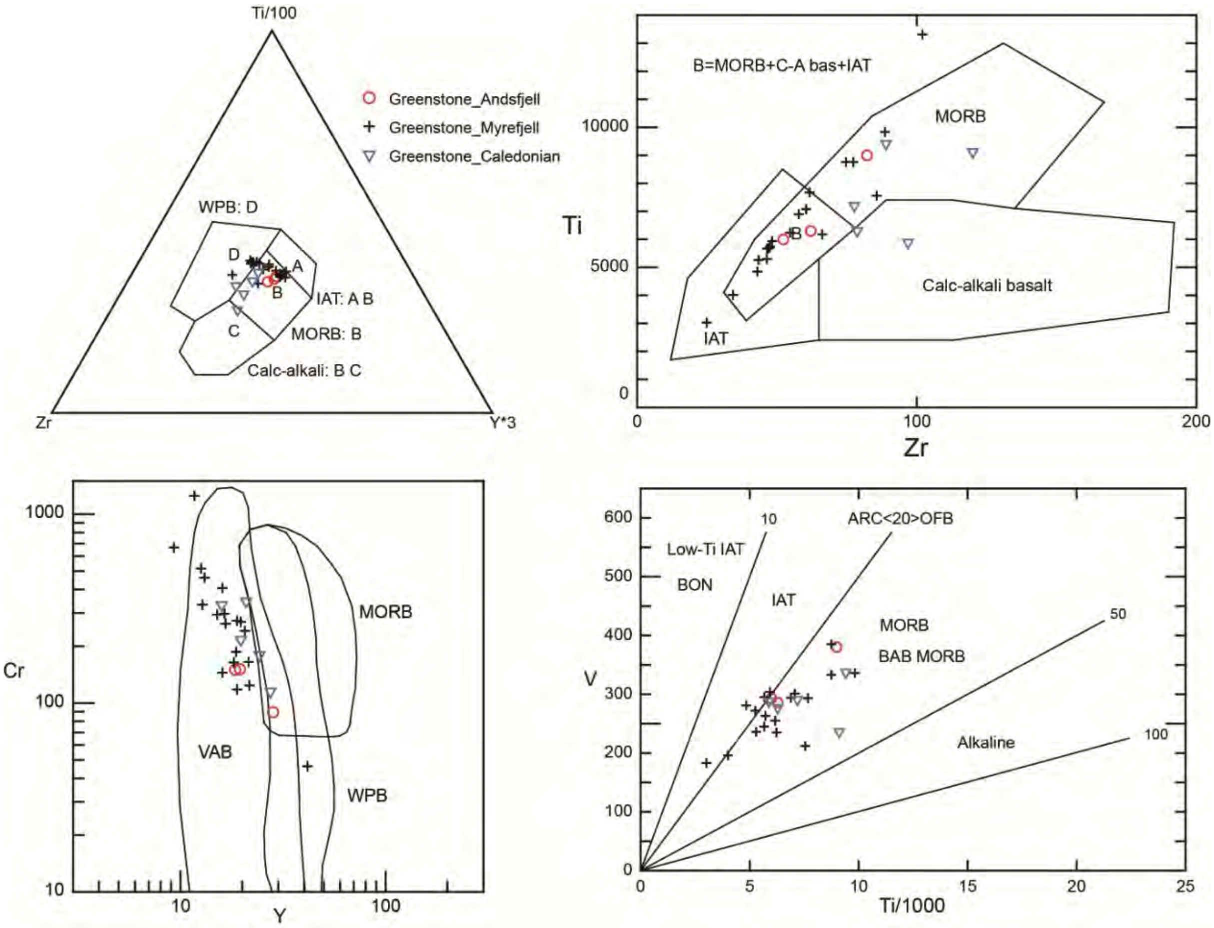

Figure 41: Greenstone from Andsfjellet, Myrefjell and the overlying Caledonian units plotted in various discrimination diagrams.

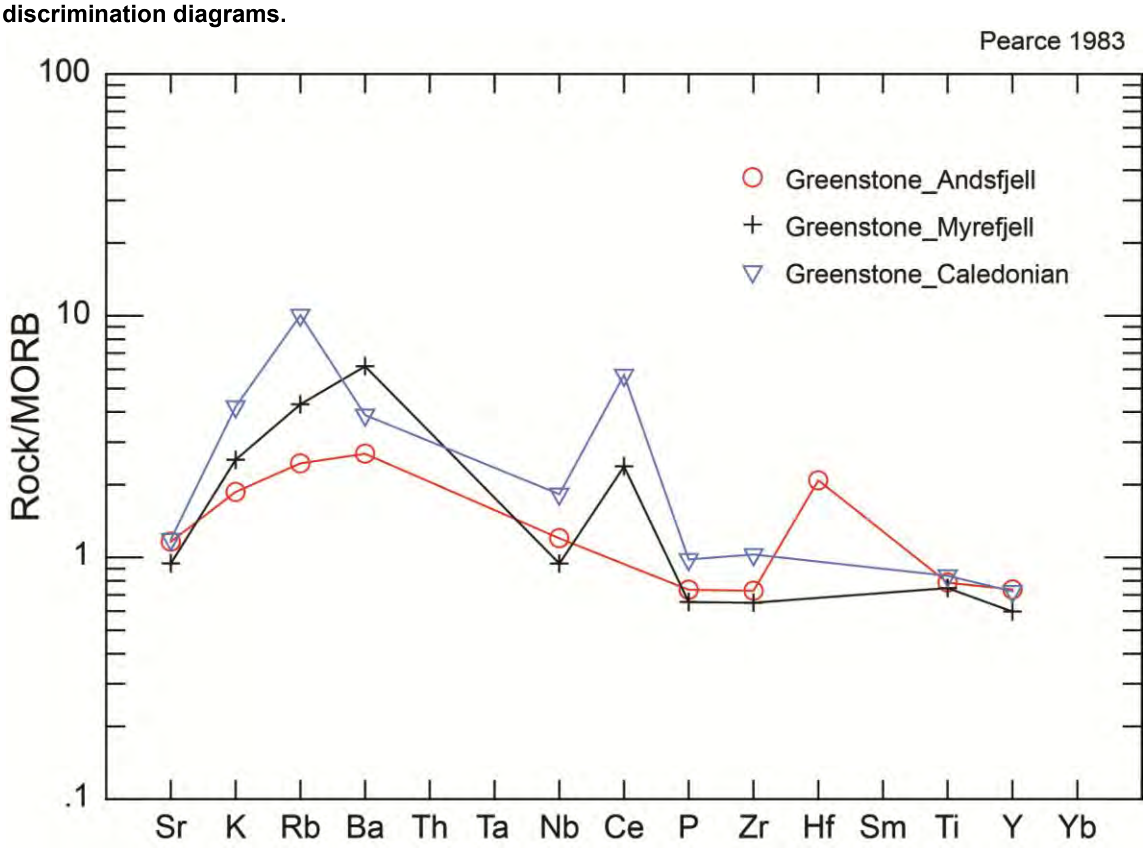

Figure 42: Averages of greenstone from Andsfjellet, Myrefjell and the overlying Caledonian units normalized to MORB composition (normalizing data from Pearce 1983).

Table 1: Average composition of the mafic metavolcanics in the Mauken window and the adjoining Caledonian units.

	Greenstone Myrefjell (N=19)	Greenschist Myrefjell (N=8)	Greenstone Andsfjell (N=3)	Greenschist Caledonian (N=5)
SiO2	49.81	50.16	49.00	50.28
Al2O3	13.08	15.04	13.87	13.06
Fe2O3	13.30	12.90	15.23	12.46
TiO2	1.12	1.38	1.18	1.26
MgO	8.40	6.60	7.21	6.49
CaO	8.63	7.71	9.55	7.60
Na2O	2.46	3.25	2.76	3.16
K2O	0.38	0.92	0.28	0.63
MnO	0.19	0.20	0.23	0.17
P2O5	0.08	0.44	0.09	0.12
LOI	2.81	1.55	0.45	4.49
Sum	100.27	100.15	99.80	99.72
Ba	124	263	54	78
Ce	24	32	n.d.	61
Co	50	43	55	44
Cr	326	170	130	208
Cu	70	59	33	125
Ga	15	16	17	16
Nb	3.3	8.9	4.2	6.4
Nd	9.9	16.9	n.d.	n.d.
Ni	147	79	77	115
Pb	7	7	4	8
Rb	9	28	5	20
Sc	39	30	42	33
Sr	113	156	139	142
V	294	172	320	286
Y	18	22	22	22
Zr	58	102	66	92
Zn	110	120	107	114

6.1.2 Other mafic rocks at Andsfjellet

The mafic rocks forming inclusions in the felsic intrusion at Andsfjellet have different geochemistry than the greenstone units. The data are plotted up in various diagrams in Figure 43, and show that these rocks mainly have more of a calc-alkaline to within-plate affinity.

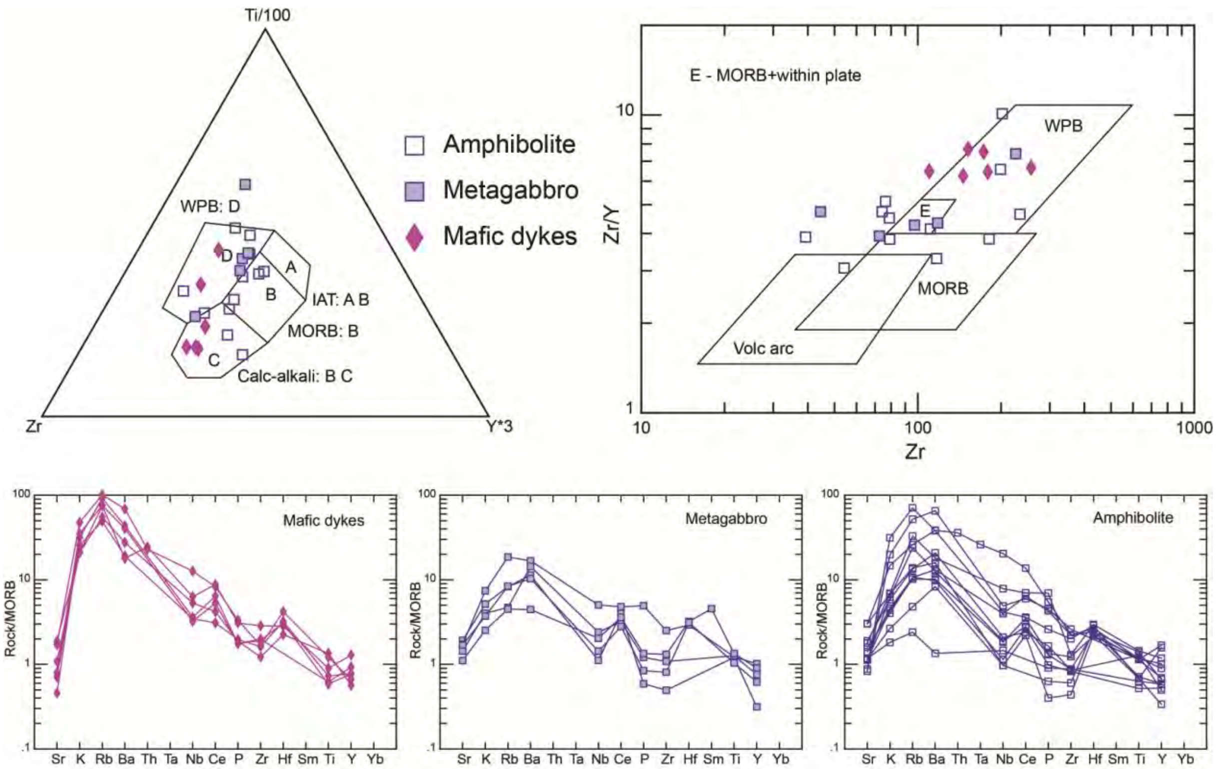

Figure 43: Dykes, metagabbro and fine-grained amphibolite at Andsfjellet plotted in various discrimination and spider diagrams (normalizing data from Pearce 1983).

6.1.3 Felsic intrusions

Chemistry of the large felsic intrusive units as well as the smaller dykes and bodies are plotted up in Figure 44 to Figure 46. The average data of the units are displayed in Table 2. Samples of the Andsfjell and Kampen part of the Andsfjell-Kampen intrusion have been separated in order to find if there are any differences between these.

In the various element plots (Figure 44) the Kampen and Andsfjell samples of the main intrusive overlap to a large degree, but the Andsfjell samples show a larger spread, indicating that it is less homogeneous in composition. This is also the impression from the field observations. The felsic rocks from the Øverbygd complex are clearly different in composition, having lower Fe/Mg-ratio, lower Nb content, and higher TiO_2. The Olsborg unit has a low Fe/Mg-ratio, is low in especially Na2O and high in Zr compared to the nearby Kampen unit. The felsic dykes at Andsfjellet are quite similar to the main intrusion.

In the Rb vs. Y+Nb and Nb vs. Y diagrams (Figure 44) by Pearce et al. (1984), the majority of the samples from Andsfjellet and Kampen plot in the field of WPG compositions, while the samples from the eastern complex mainly plot in the VAG field. Again the felsic dykes at Andsfjellet and the Olsborg units overlap with the Kampen and Andsfjell main intrusion samples.

The similarity between the Andsfjell and Kampen part of the Andsfjell-Kampen Complex is also displayed in the spider diagrams in Figure 45. The same pattern is shown for the Olsborg unit and Andsfjell felsic dykes in Figure 46. The composition as shown in the diagrams is in accordance with a WPG setting. A few samples from both main intrusion and dykes at Andsfjellet show low values of K, Rb and Ba, perhaps due to differentiation. The Øverbygd intrusive complex show low values of Nb, Y, Zr and high values of Ce compared to the other rocks (Figure 45). The pattern for this complex is quite similar to typical VAG setting, as shown by Pearce et al. (1984).

Table 2: Average compositions of the main felsic intrusive rocks in the Mauken window.

	Fels.intr.Andsfj	Fels.dyke Andsfj	Fels.intr.Kampen	Fels.unit Olsborg	Fels.intr.Øverbygd
	N=11	N=5	N=11	N=3	N=5
SiO2	77.31	76.52	76.27	77.67	73.20
Al2O3	12.64	12.72	13.03	10.88	14.54
Fe2O3	1.46	2.26	1.79	2.58	1.58
TiO2	0.11	0.16	0.14	0.13	0.22
MgO	0.14	0.60	0.19	1.87	0.56
CaO	0.67	1.25	1.08	1.30	1.15
Na2O	5.02	5.39	5.02	1.56	4.67
K2O	2.55	0.97	2.22	2.42	3.57
MnO	0.02	0.03	0.03	0.05	0.02
P2O5	0.01	0.02	0.02	0.01	0.06
LOI	0.28	0.35	0.43	1.56	0.70
Sum	100.35	100.34	100.20	100.13	100.36
Ba	549	425	670	903	735
Ce	104	71	88	84	77
Co	nd	3.6	nd	nd	4.1
Cr	22	20	38	6	19
Cu	12	20	17	6	18
Ga	17	14	17	16	17
La	49	27	39	45	39
Mo	nd	1.4	1.2	nd	nd
Nb	38	25	27	31	9
Nd	41	27	34	40	29
Ni	5	5	5	5	6
Pb	7	23	9	5	10
Rb	54	20	43	52	83
Sr	49	73	94	47	234
Th	16	11	11	12	11
U	2.5	1.5	1.6	2.8	nd
V	4	6	6	nd	16
W	nd	nd	nd	nd	nd
Y	52	40	44	58	10
Zn	19	52	32	74	20
Zr	197	250	190	319	126
Hf	7.9	6.0	5.7	8.6	nd

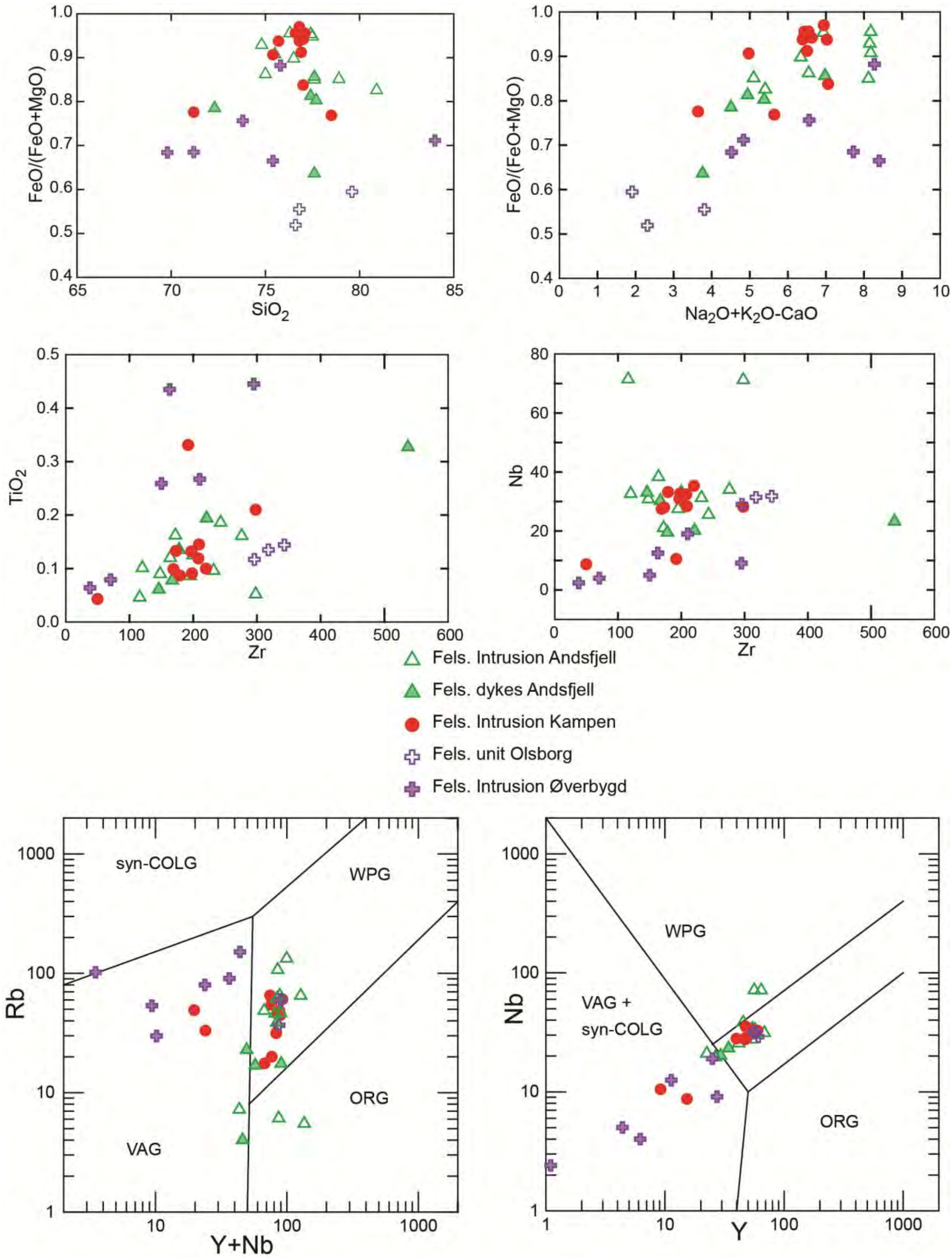

Figure 44: Felsic intrusive rocks from the main complexes plotted in element and discrimination diagrams. The discriminant diagrams are from Pearce et al. (1984).

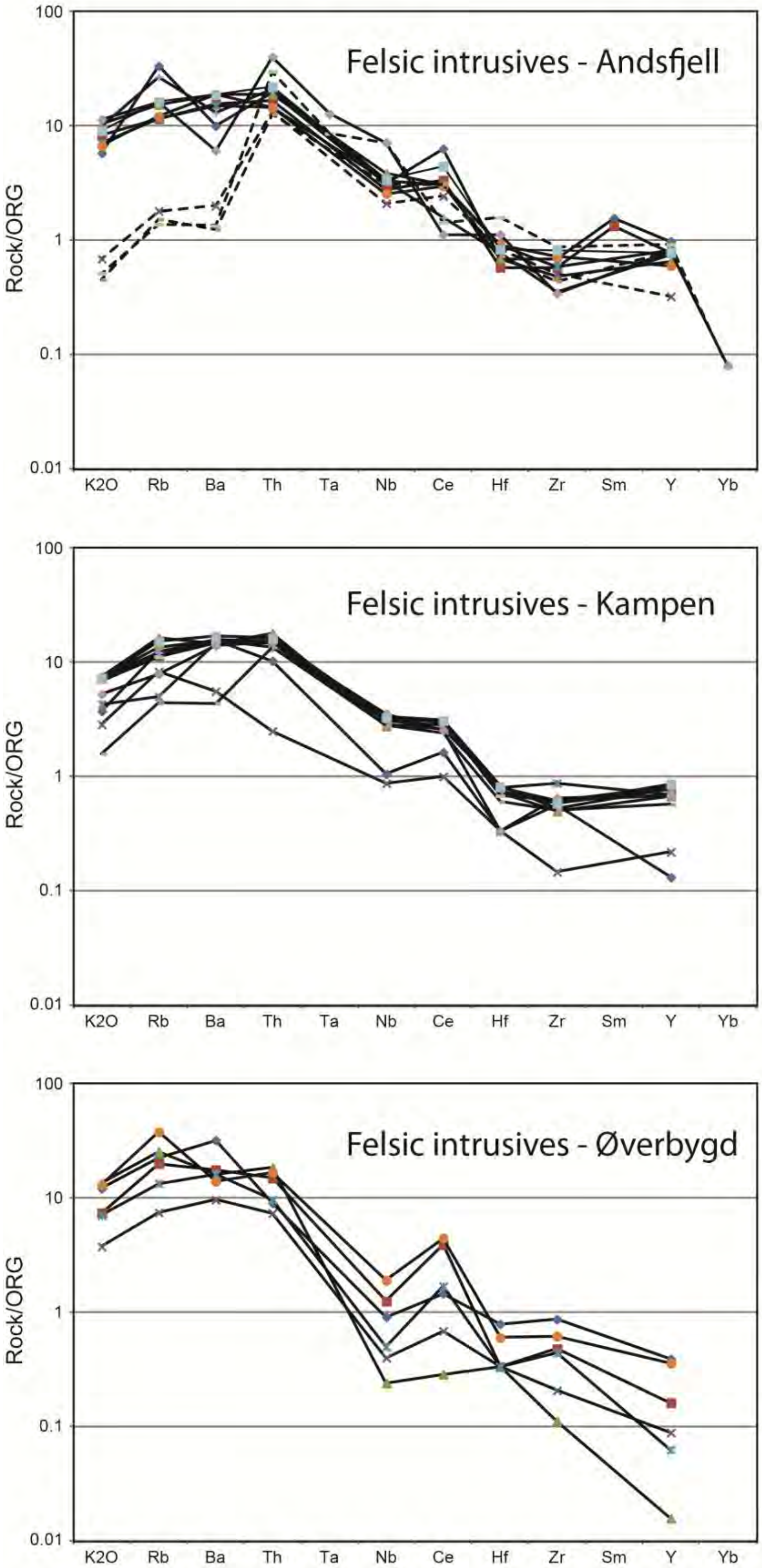

Figure 45: Felsic intrusive rocks from the main complexes normalized to Ocean Ridge Granite (ORG). Normalizing data from Pearce et al. (1984).

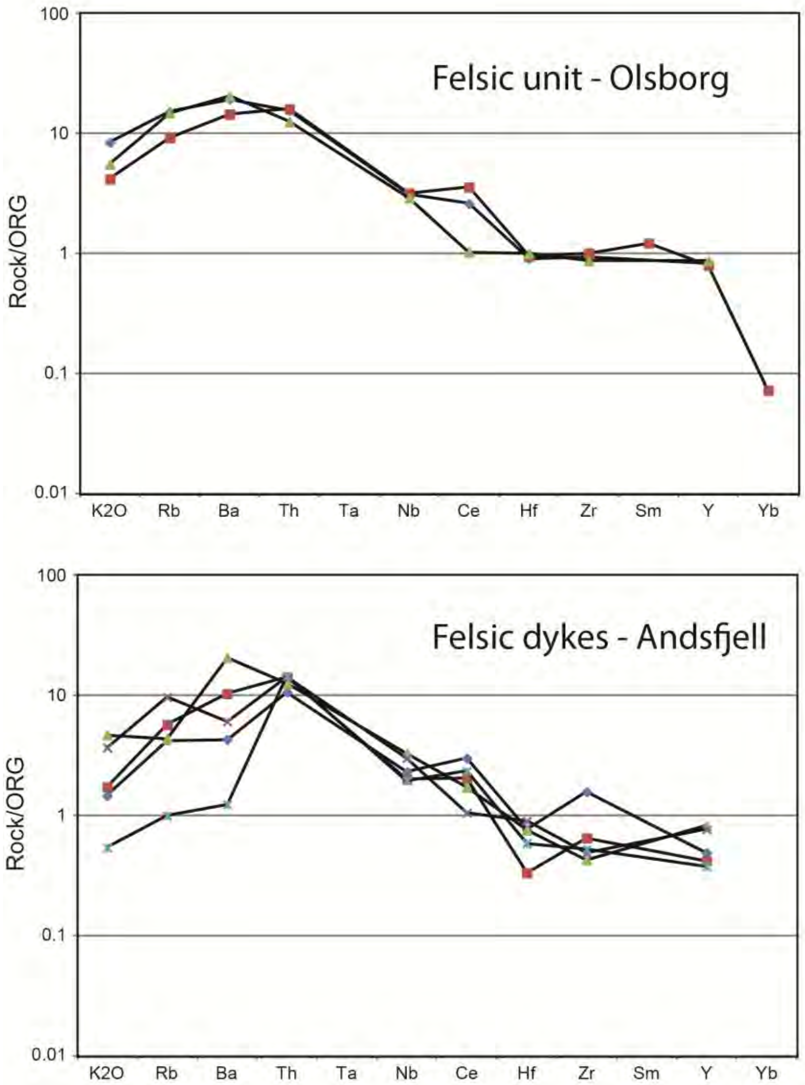

Figure 46: The felsic unit at Olsborg and dykes at Andsfjell normalized to Ocean Ridge Granite (ORG). Normalizing data from Pearce et al. (1984).

6.1.4 Metasediments

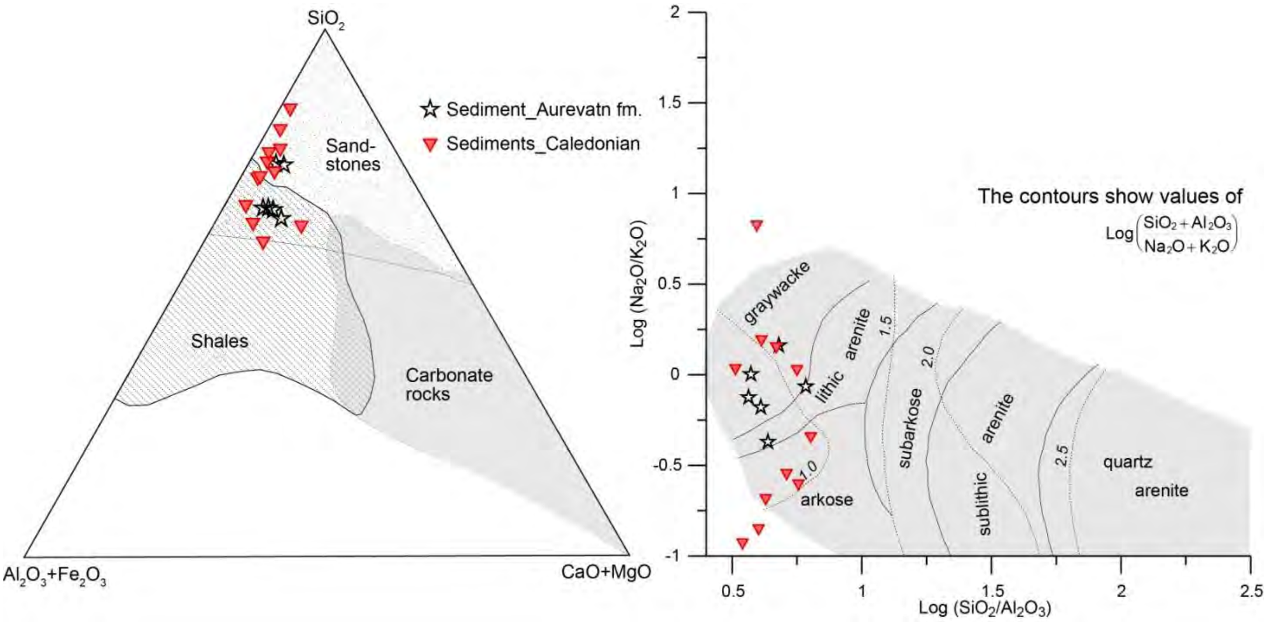

Figure 47: Sediments from the Aurevatn formation and surrounding Caledonian nappes plotted in classification diagrams. Caledonian sediments in red triangles and from the Aurevatn formation as stars.

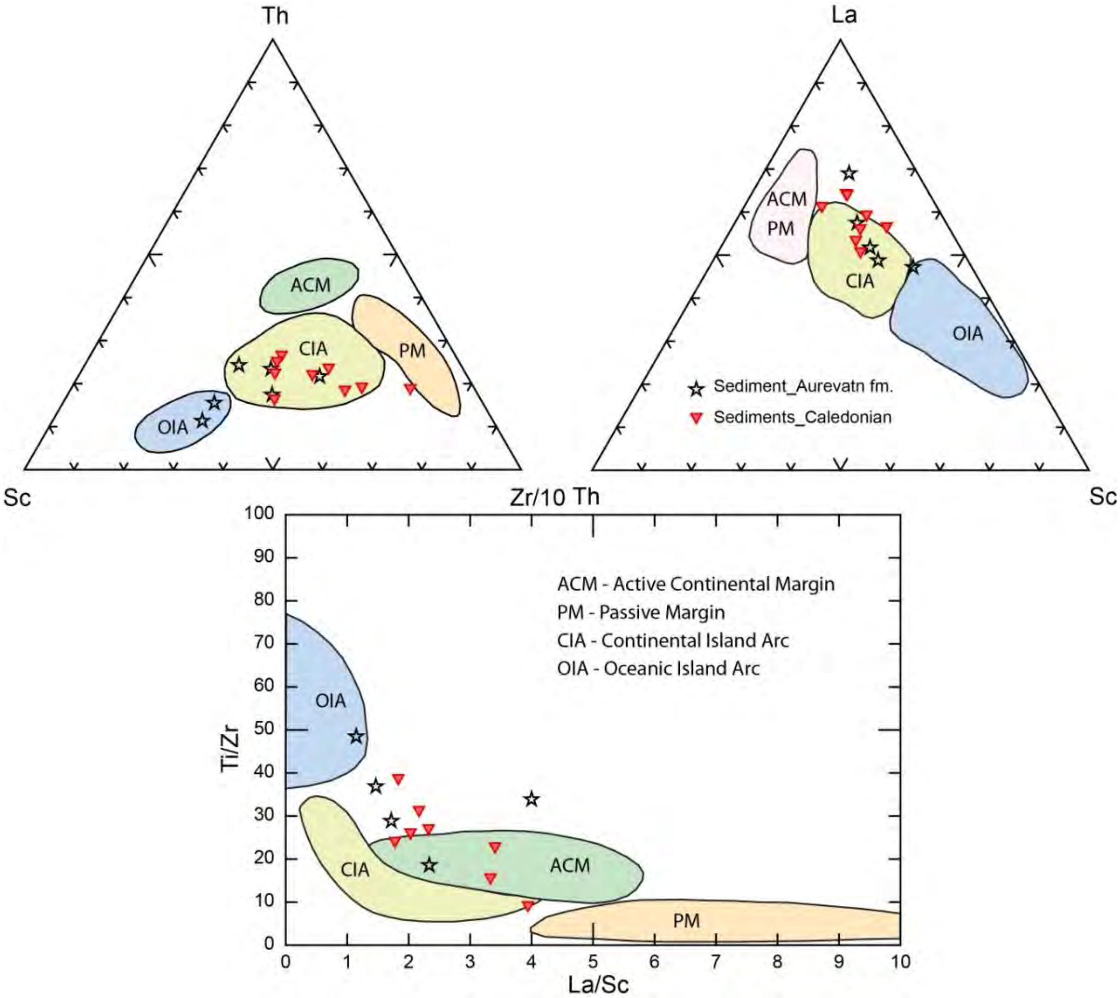

Figure 48: Sediments in the Mauken window and surrounding Caledonian nappes plotted in various discrimination diagrams (diagrams from Bhatia & Crook, 1986). Caledonian sediments in red triangles and from the Aurevatn formation as stars.

Metasedimentary rocks from the Aurevatn formation in the Mauken window and surrounding Caledonian Nappes have been analyzed by XRF, and the data are displayed in Figure 47 and Figure 48.

In the ternary Al+Fe-Si-Ca+Mg diagram (Figure 47) the rocks from the two tectonic environments overlap and partly plot in the field for sandstones and in the overlapping field for shales. Similarly, the units overlap in the binary log(Na/K) vs. log(Si/Al) diagram, and classify as arkose to greywacke type sediments (Figure 47).

In the discrimination diagrams in Figure 48 the rocks from the Aurevatn formation and the Caledonian also overlap in all diagrams. The units seem to have an affinity for continental island arc setting.

7. GEOCHRONOLOGY

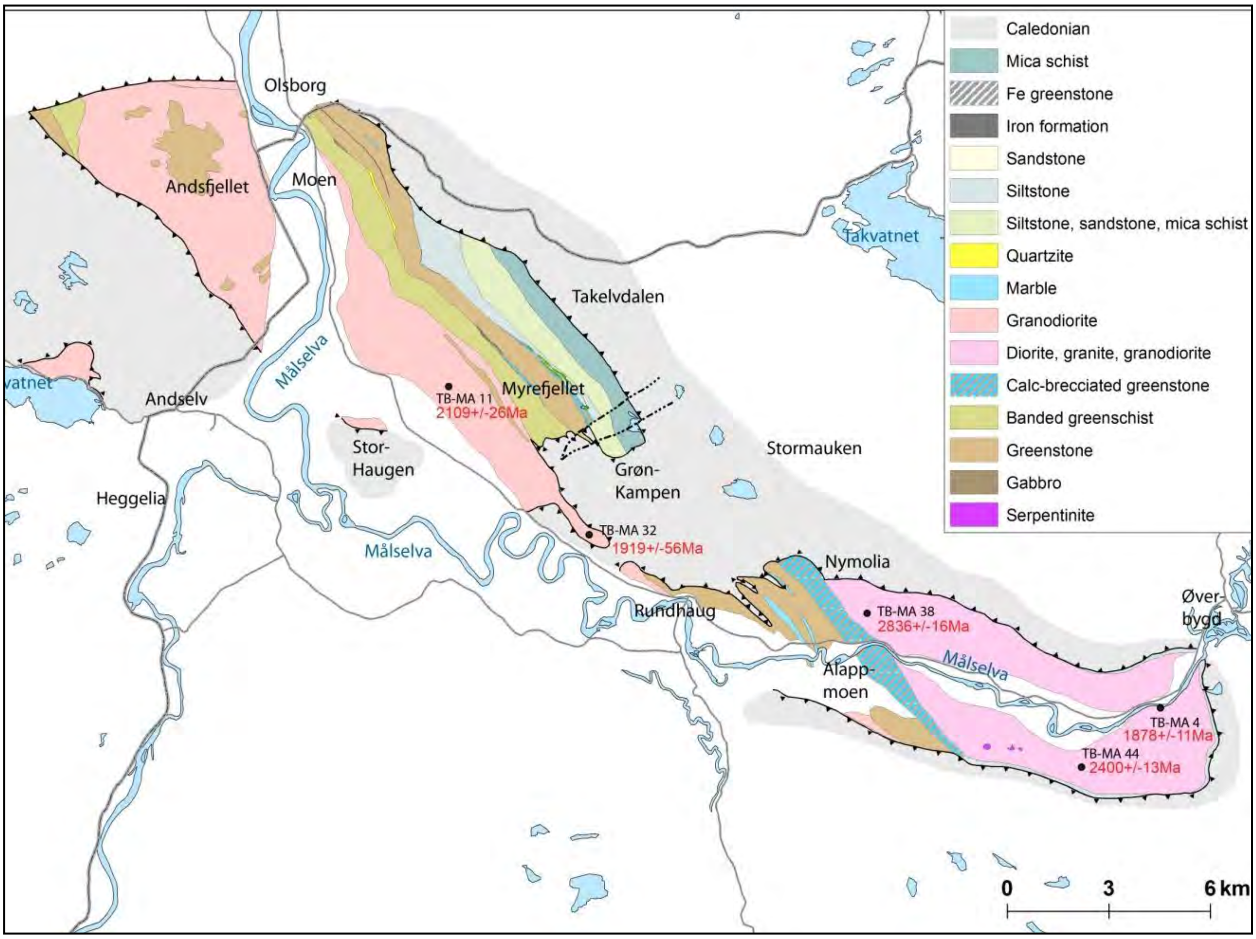

Figure 49: Geological overview map showing the locations and ages of the analyzed samples of felsic intrusive rocks.

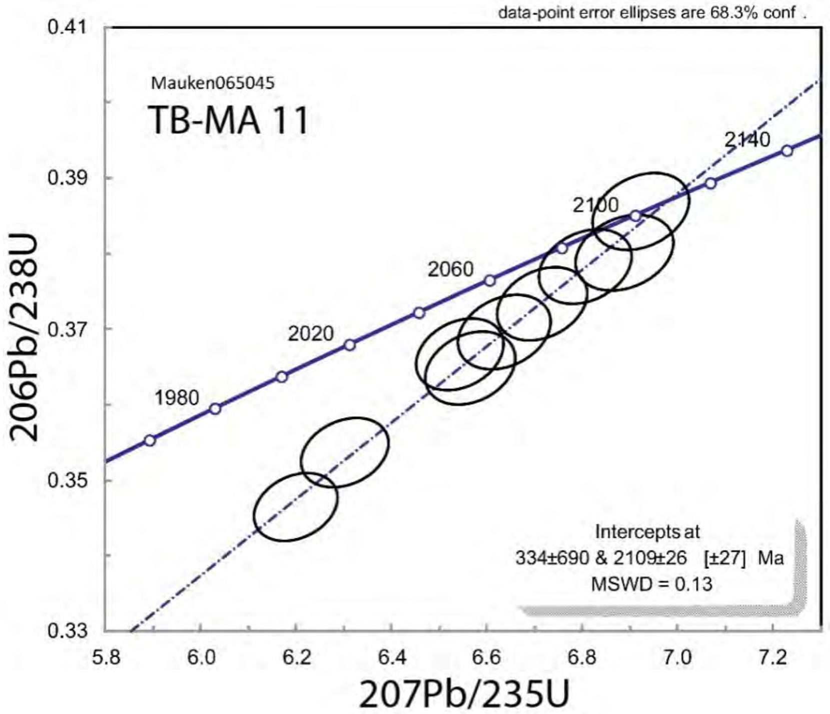

Figure 50: Geochronology data from the central Kampen granitic to granodioritic intrusion.

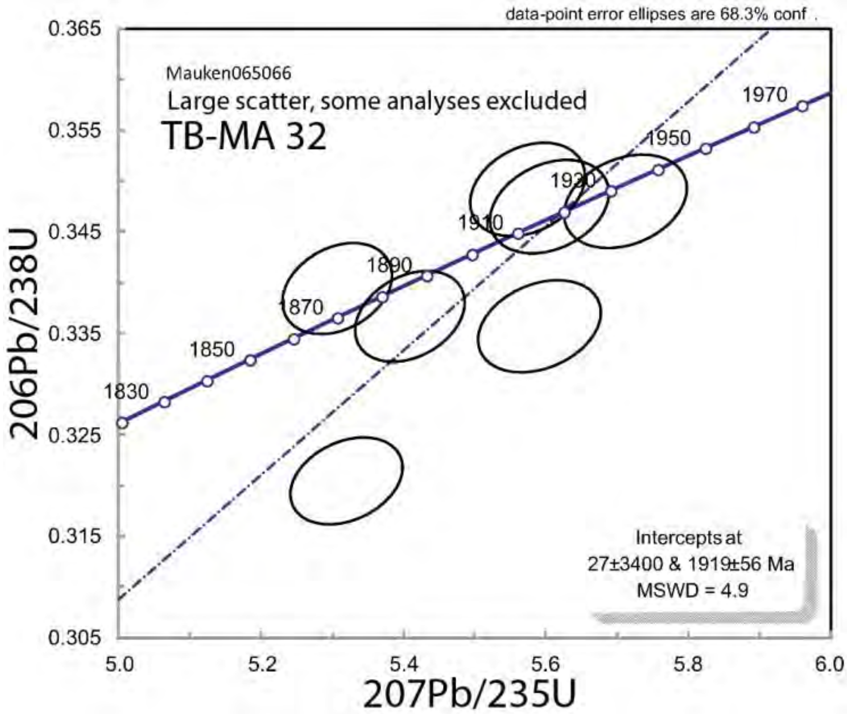

Figure 51: Geochronology data from the eastern part of central Kampen granitic to granodioritic intrusion.

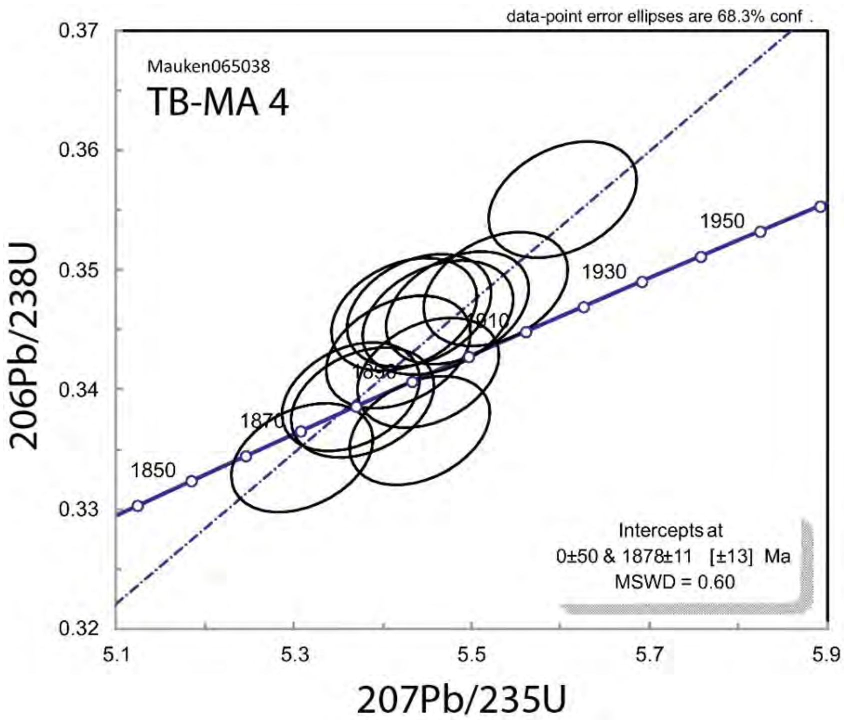

Figure 52: Geochronology data from a trachytic rock in the Øverbygd Intrusive Complex.

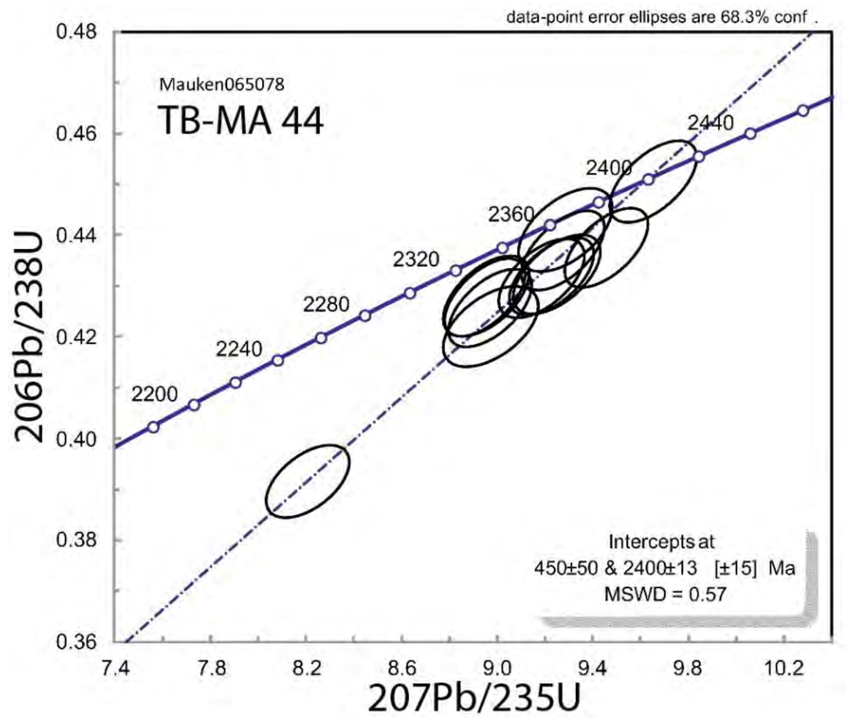

Figure 53: Geochronology data from a granite in the Øverbygd intrusive complex.

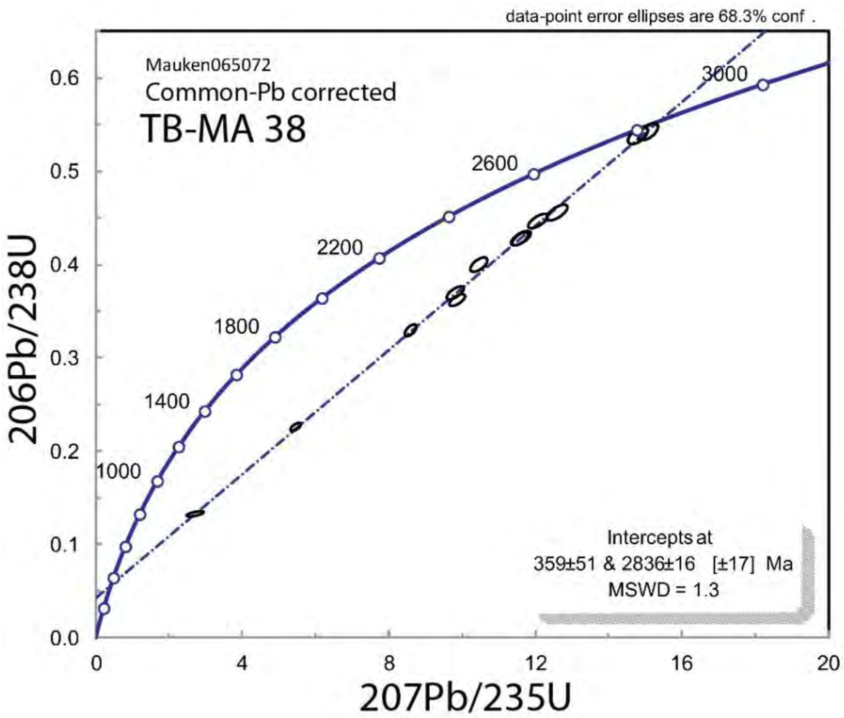

Figure 54: Geochronology data from a trondhjemitic rock in the Øverbygd intrusive complex.

Five samples from the felsic intrusive rocks have been dated, including two from the central Kampen granodiorite and three from the Øverbygd intrusive complex (Figure 49).

The two samples from the Kampen part of the Andsfjell-Kampen complex give ages of 1919 ± 56 Ma and 2109 ± 26 Ma (Figure 50 and Figure 51).

The three samples from the Øverbygd intrusive complex show a very large age span: 1878 ± 11 Ma (trachyte, Figure 52), 2400 ± 13 Ma (granite, Figure 53) and 2836 ± 16 Ma (trondhjemite, Figure 54).

8. GOLD MINERALIZATIONS

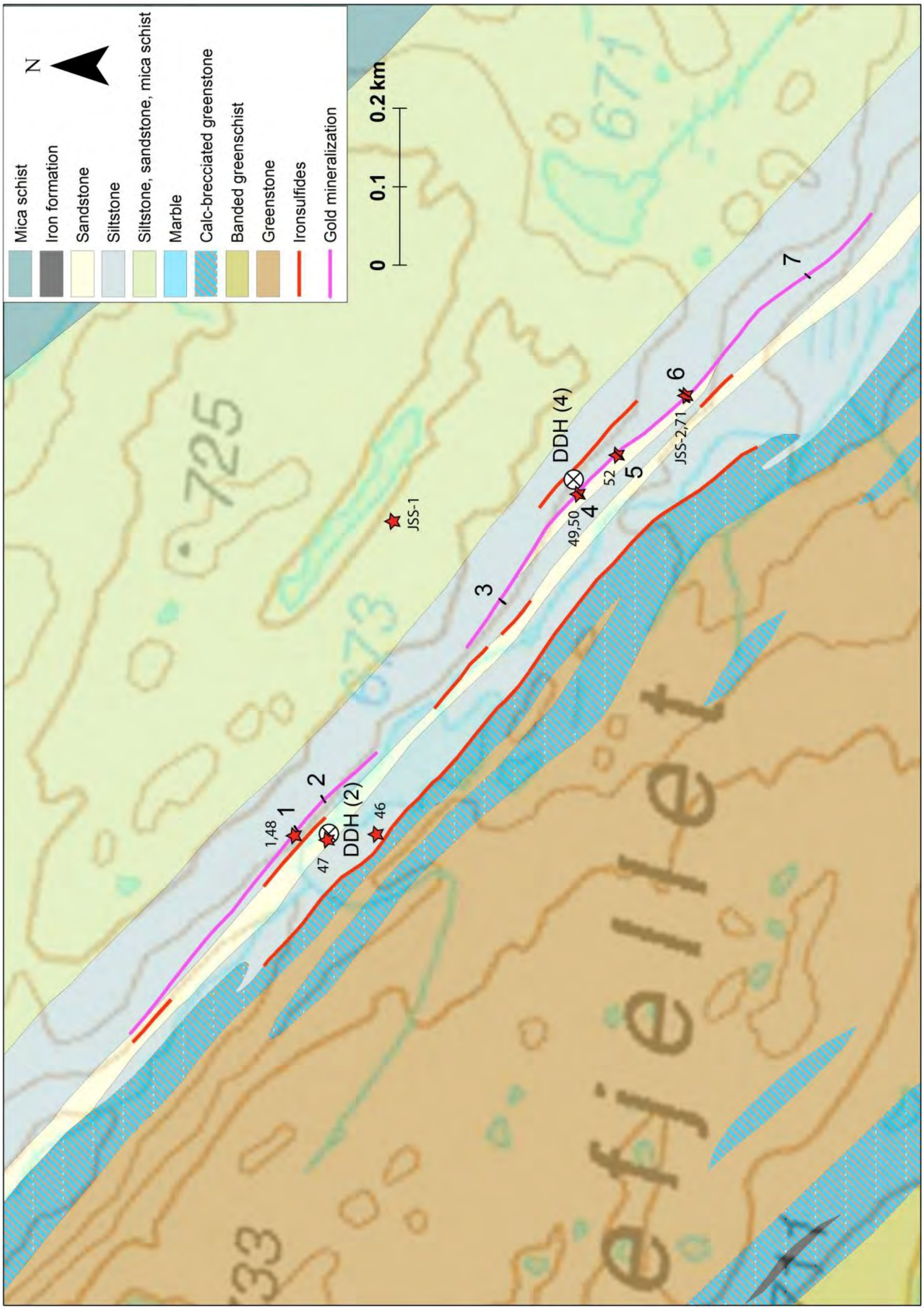

Figure 55: Geology of the "Main Zone" gold mineralization. The numbers 1-7 refer to trenches/sections with chip sampling done by Scandinavian Highlands. DDH (2) and DDH (4) refer to numbers of drillholes on two sites. Numbered stars refer to samples in Table 3**.**

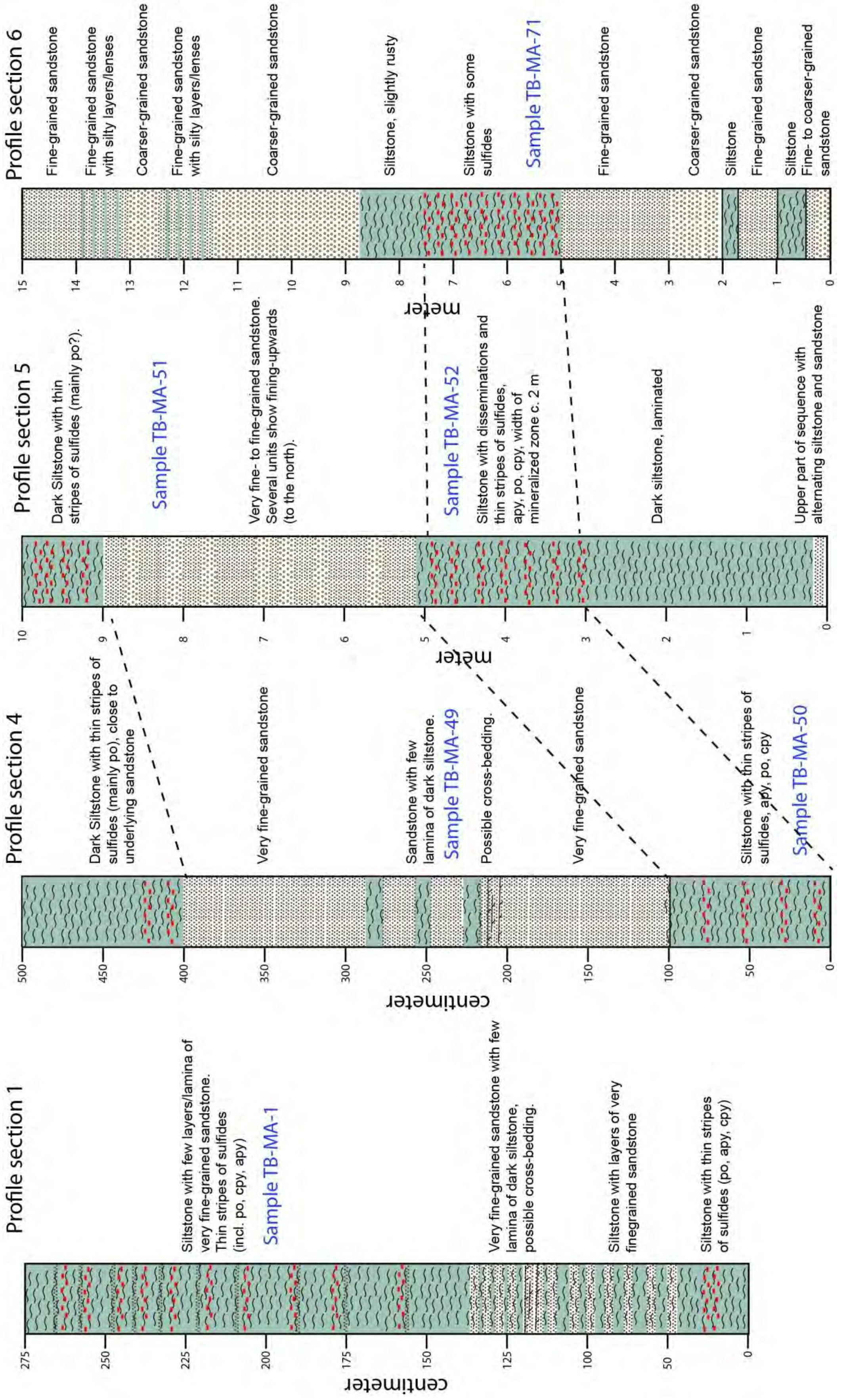

Figure 56: Logs of four of the trenches/sections made by Scandinavian Highlands. See Figure 55 for location. Note that the scale is in centimeters in sections 1 and 4 and meters in sections 5 and 6.

Scandinavian Highlands (SH) started their prospecting campaign in the Mauken area in 2007 and soon discovered gold anomalies in their stream sediment samples. Further work, including reconnaissance airborne TEM and magnetic surveys, soil sampling, mapping and rock sampling led to the discovery of the so-called "Main Zone", located in sediments close to the contact to the massive greenstone (see section 4.2.5 and Figure 55).

The company did trenching and chip sampling at several localities along the zone, resulting in that gold values up to 6 g/t were found in a zone 4-6 m wide and over a length of 1800 m (SH press release, 2011). The zone was drilled at two localities in 2010 (total of 6 holes, see Figure 55), but the results of the drilling were not promising. No more exploration work has been done by the company on this target since 2010. In 2013 a master thesis was completed on the mineralization (Alnes, 2013).

Detailed mapping of the area around the Main Zone has been carried out as part of this project (Figure 55). The trenches made by SH were also logged to find out more about the nature of the gold mineralization (Figure 56). A number of samples were also taken from the mineralization, as well as the host rock. The geochemical data from these samples is displayed in Table 3.

The mineralization is situated c. 100 m structurally and stratigraphically above the contact to the massive greenstone, in a steep to vertically dipping sequence of interbedded siltstone and sandstone (Figure 55). This sedimentary sequence is 150-200 m thick, and grades upwards into a > 600 m thick layer of rhythmically alternating, silty to more coarse sandstone, possibly a turbiditic sequence. The contact to the structurally underlying greenstone is marked by a 50-100 m layer of calc-brecciated greenstone, which includes thin lenses of calcite marble.

Logging of the trenches/sections made by SH (Figure 56) shows that the main mineralization is hosted by the more fine-grained siltstone and sandstone, and that the maximum thickness is 2.5 m (in section 6) to 2.7 m (in section 1). In sections 1 and 4, sedimentary structures which could be cross-bedding are present, while graded bedding are common in section 5 (Figure 23). These sedimentary structures indicate that the mineralized sequence has right-way-up towards the northeast.

The metasediments consist of irregular clastic grains of feldspar and quartz in a very fine-grained matrix of biotite and muscovite (Figure 57, Figure 58). Tourmaline is a common accessory, the boron indicating a seawater environment. The matrix minerals are commonly overgrown by late-stage clinozoisite/epidote and muscovite.

Arsenopyrite and pyrrhotite are the main sulfide minerals and occur mainly disseminated, but locally concentrated in thin bands. Chalcopyrite is a common accessory phase, associated with pyrrhotite. Arsenopyrite occurs as hypidioblastic to idioblastic elongated grains, up to several mm in length (Figure 57, Figure 59). It contains inclusions of the other sulfides, and appears to be a later phase than these.

The arsenopyrite grains are quite frequently associated with elongate quartz aggregates or lenses, while the hosting sediments commonly show varying degree of sericitization in bands close to the sulfides.

As shown in Figure 60, gold occur as small (10-20 μm) inclusions in arsenopyrite. A few small inclusions of gold are found in pyrrhotite and are also present in the silicate matrix.

Table 3: Geochemical data from the "main zone" at Mauken. For location of samples, see Figure 55.
(oxides in %, otherwise ppm).

	TB-MA 46	TB-MA 47	TB-MA_1	TB-MA 48	TB-MA 49	TB-MA 50	TB-MA 52	JSS_2	TB-MA71	JSS_1
S	0.16	0.13	0.39	0.05	0.10	1.09	0.74	1.26	0.89	0.94
Au	0.006	0.004	0.343	0.002	0.008	3.98	1.065	0.013	0.055	0.884
As	17.1	9.3	1820	52.1	26.5	9760	5620	54.4	110.5	9500
Cu	146	141	57	32	25	80	63	147	159	75
Zn	84	115	119	86	104	74	67	564	107	81
Pb	15	15	17	16	29	38	24	27	35	19
Ag	0.24	0.17	0.15	0.05	0.06	0.45	0.15	0.4	0.44	0.26
Sb	0.47	0.41	9.05	1.85	4.34	25.3	26.7	9.61	14.4	38.3
Bi	0.19	0.12	0.58	0.11	0.04	0.68	0.45	2.12	0.86	1.27
Te	0.08	0.06	0.14	<0.05	<0.05	0.51	0.22	0.59	0.6	0.52
Co	34.6	32.9	11	17.7	7.3	19.7	44.8	24.5	21	20.2
Ni	157	167.5	31.3	48.9	38.9	45.6	34.4	91.7	60.5	36.9
Mo	0.74	0.52	1.91	0.35	0.23	0.21	0.2	4.42	10.1	1.78
Ba	390	460	530	720	1020	600	1630	550	990	450
Ga	21.2	21.2	26.2	19.35	19.5	19	22	23.4	23.4	19.45
Ge	0.12	0.16	0.13	0.16	0.16	0.18	0.24	0.15	0.16	0.13
In	0.03	0.07	0.05	0.06	0.05	0.06	0.06	0.07	0.05	0.07
Se	1	1	2	1	1	2	1	3	3	2
Sn	1.7	1.5	1.9	2.2	0.8	1.2	1.6	2.1	2.6	2.5
Cd	0.20	0.15	0.20	0.11	0.15	0.18	0.14	4.36	0.11	0.11
Pt	<0.005	0.008	<0.005	<0.005	<0.005	<0.005	<0.005	0.007	0.007	<0.005
Pd	0.008	0.007	0.003	<0.001	0.002	0.001	0.002	0.009	0.009	0.001
Re	<0.002	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.005	0.004	<0.002
W	0.5	0.7	4.9	4.1	1.7	6.9	7.6	1.7	3.5	4
Cr	225	249	139	106	96	105	127	157	154	91
V	193	195	140	89	103	106	113	164	168	89
MnO	0.10	0.10	0.06	0.04	0.06	0.04	0.04	0.04	0.04	0.05
Fe2O3	8.19	9.31	5.72	5.20	5.42	5.55	5.02	9.45	7.93	6.69
TiO2	0.86	0.88	0.76	0.70	0.80	0.78	1.02	0.68	0.71	0.63
Al2O3	13.94	13.89	15.89	14.45	14.27	14.62	17.01	14.98	14.98	13.21
CaO	3.71	3.71	3.64	1.46	2.99	3.18	1.93	0.69	0.67	2.25
Na2O	2.93	2.17	2.22	0.96	1.83	2.43	1.70	1.47	2.62	2.70
K2O	1.58	2.20	3.40	4.37	3.42	3.02	5.12	4.38	3.41	2.39
MgO	4.96	6.12	2.55	1.97	2.47	1.99	2.17	4.10	2.92	2.24
P2O5	0.17	0.16	0.12	0.16	0.30	0.33	0.41	0.14	0.12	0.37
La	18.4	25.5	22	39.4	32.7	38.5	49.5	21.3	31.2	34.4
Ce	42.1	54.6	49.2	86.5	67.4	85.8	106.5	45.9	58.2	72.5
Y	17	19	17	27	16	16	26	19	20	24
Zr	77	76	116	115	28	40	42	98	111	121
Be	1.3	1.4	2.8	1.7	1.3	1.5	2.5	1.9	2.1	1.9
Hf	2.3	2.3	3.5	3.2	0.8	1.1	1.2	2.9	3.3	3.7
Ta	0.6	0.6	1.2	1.0	0.4	0.3	0.6	0.8	0.8	0.9
Nb	8.6	8.0	14.2	11.7	6.5	4.7	9.1	9.3	9.9	10.4
Rb	55	95	84	182	127	110	158	157	135	106
Sr	182	201	366	88	218	308	213	101	128	233
U	2.0	2.1	3.0	3.2	0.7	0.8	1.7	5.1	5.5	2.5
Th	5.7	7.2	8.9	12.3	6.8	8.2	10	9.3	11.4	12.4
Sc	27	30	18	14	13	14	16	25	24	14
Tl	0.5	0.5	0.9	0.9	0.9	0.7	0.9	1.3	0.8	0.8
Cs	3.5	4.3	9.0	10.8	11.5	6.7	7.7	12.3	7.3	6.3
Li	61	79	57	48	46	34	50	61	43	48

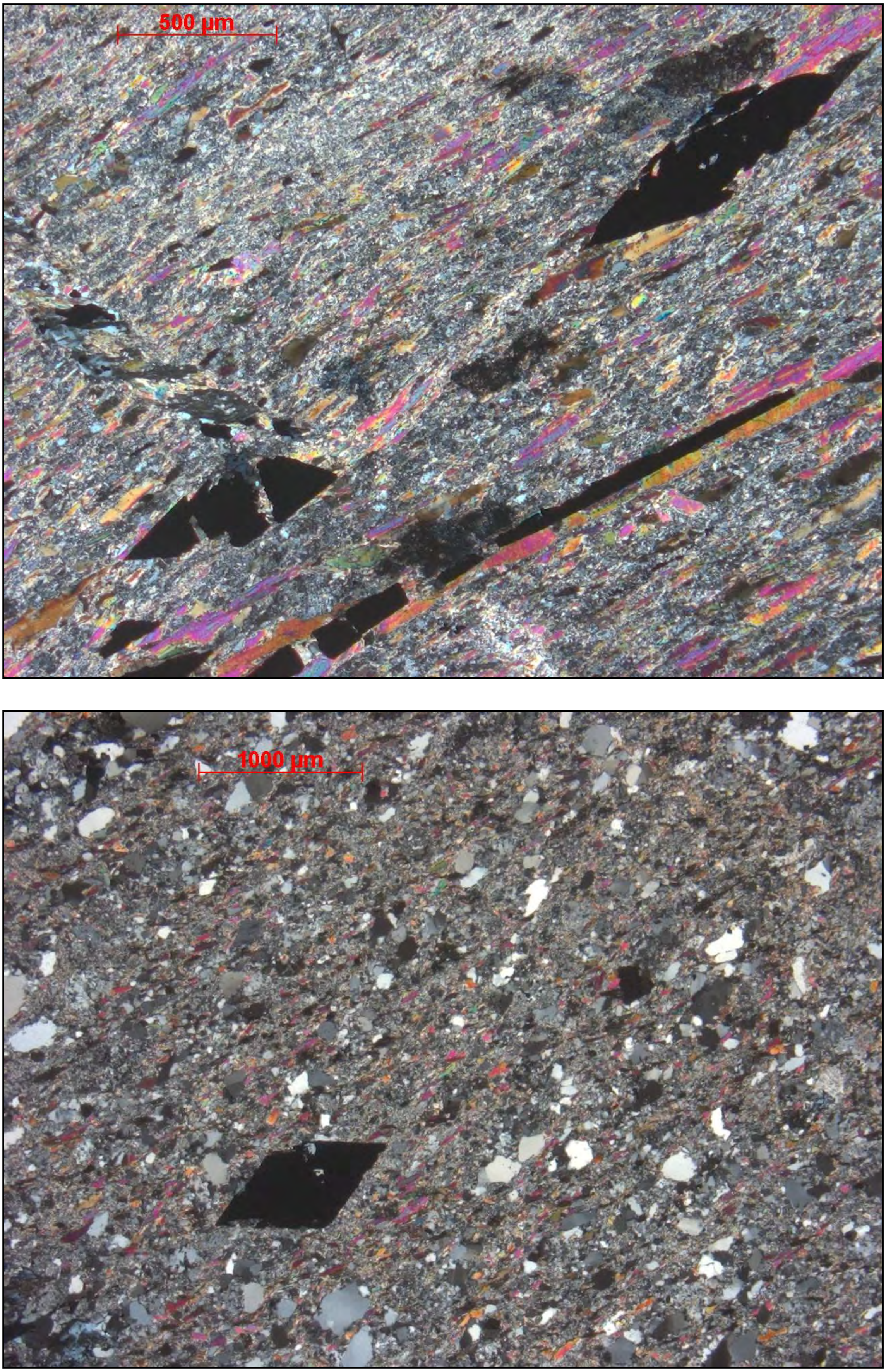

Figure 57: Photomicrographs of siltstone (upper – Sample TB-MA 1) and very fine-grained sandstone (lower – sample TB-MA 50) in the mineralized zone. Black idioblastic grains are arsenopyrite.

Figure 58: Photomicrograph of fine-grained sandstone (sample TB-MA 51).

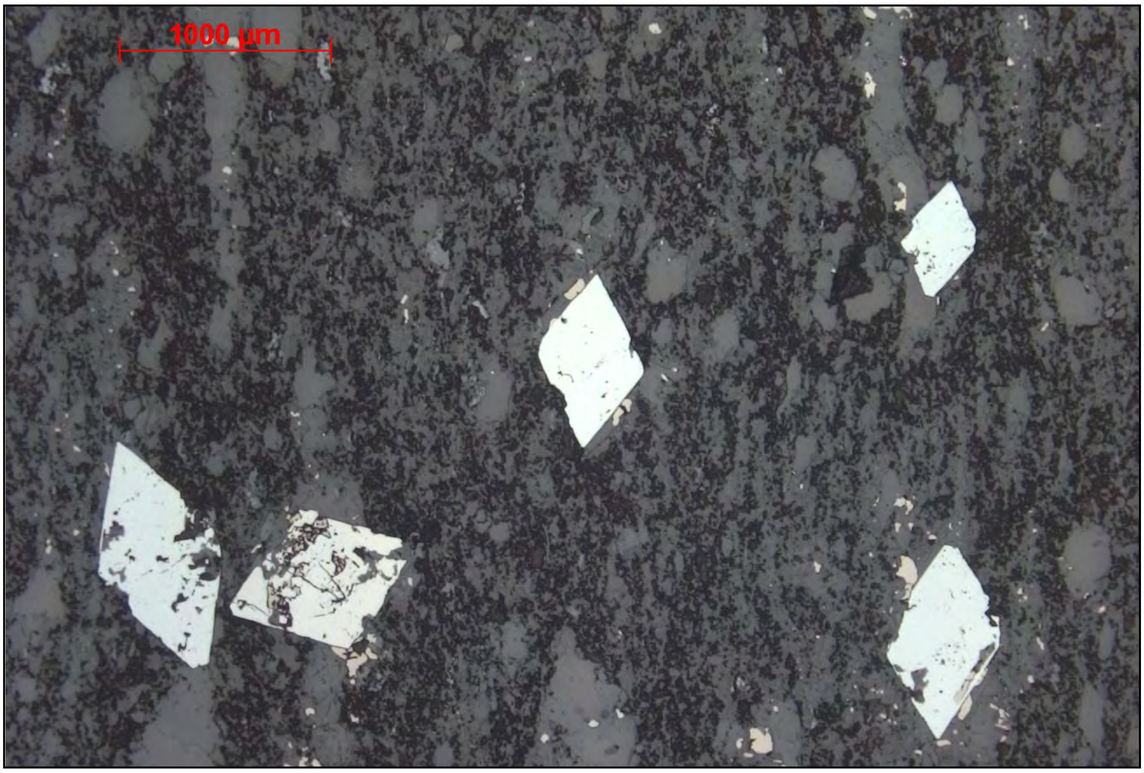

Figure 59: Photomicrograph (reflected light) of idioblastic arsenopyrite grains. Irregular smaller grains are mainly pyrrhotite (Sample TB-MA 52).

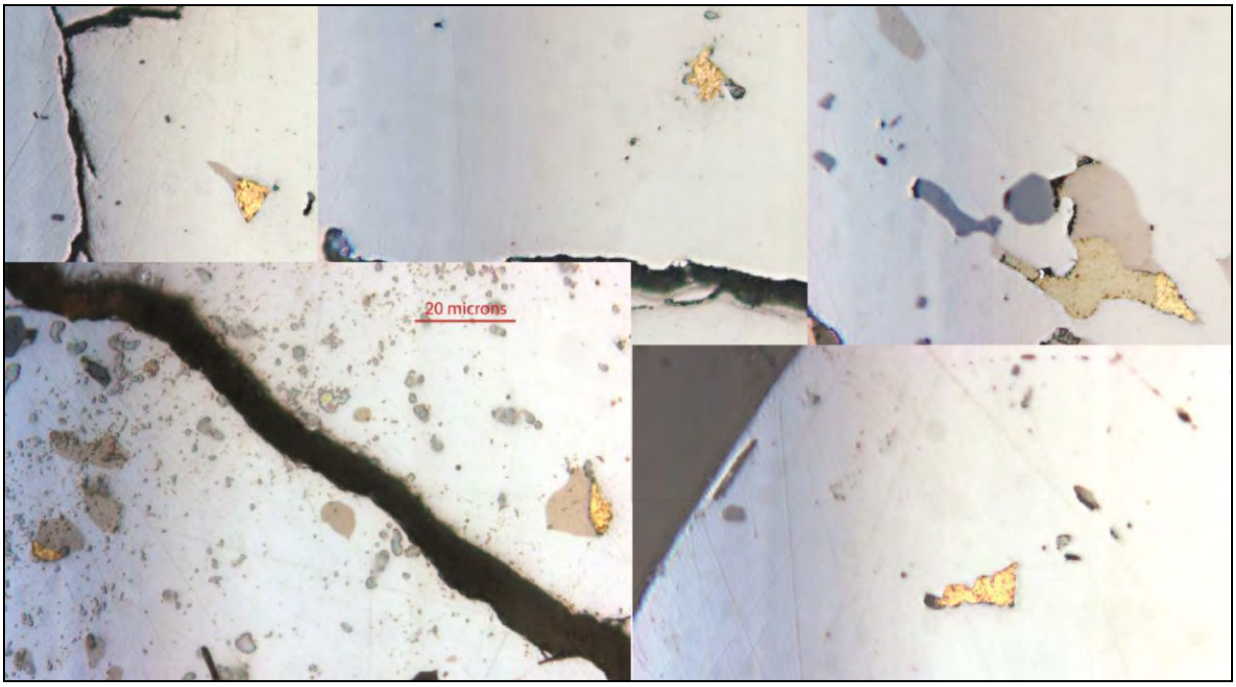

Figure 60: Collage of photos showing 10-20 μm gold grains as inclusions in arsenopyrite.

Four samples from the mineralization have been analyzed for a number of elements (TB-MA 1, 50, 52 and 71, see Figure 56 and Table 3). The data shows that the mineralization contains only gold (up to 4 ppm Au in sample TB-MA 50) and arsenic (up to 0.98 % As in sample TB-MA 50), while contents of base metals such as Cu, Zn and Pb are less than a few hundreds of ppm.

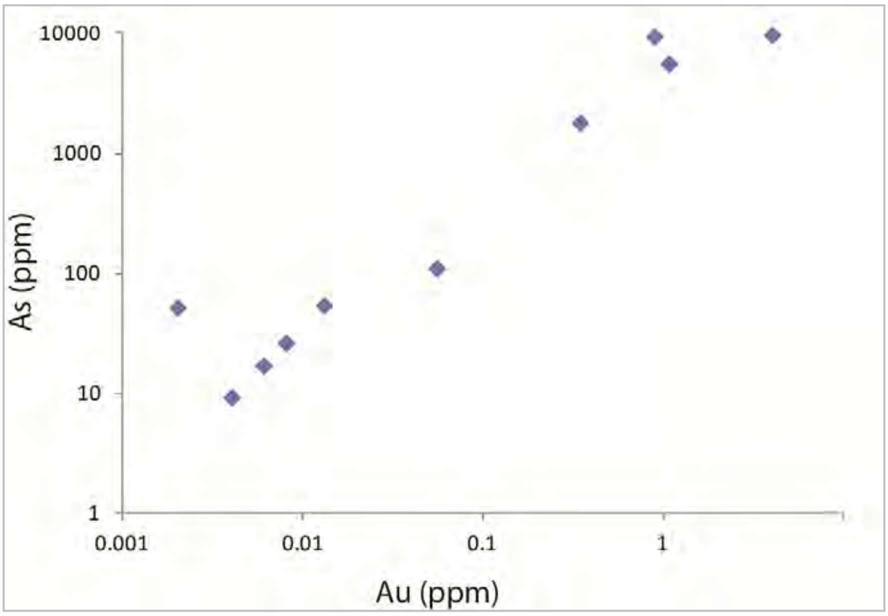

Figure 61: Plot of Au vs. As in samples from the "Main Zone" and associated metasediments.

Gold is strongly correlated with arsenic (Figure 61), and confirms the close relationship between the two elements.

Gold has also been found c. 200 m further to the north. This mineralization (marked by sample JSS-1 in Figure 55) consists of a weak dissemination of arsenopyrite and pyrite in thin quartz veins in fine-grained sandstone. Very fine-grained gold (10 μm) is present as inclusions in arsenopyrite. In addition to quartz, the veins contain chlorite and lesser amounts of biotite and muscovite. One analysis yields 0.9 ppm Au and 0.95 % As (Table 3).

High gold values have also been found at other localities, but these gold mineralizations are sporadic and have so far not been connected to a specific setting or lithology.

9. DISCUSSION

9.1 Geology and regional implications

Geochemistry of the greenstone in the Myrefjell formation show an arc-backarc affinity (Figure 42), while the sediments of the Aurevatn formation above the greenstone seems to have an affinity to continental arc setting (Figure 48). On this basis, it seems that the tectonic setting of the Målselva group must have been close to a continent.

With respect to age relationships, the felsic Andsfjell-Kampen intrusive complex is younger than the supracrustals of the Målselva group. This is based on crosscutting relationships (section 4.1 and Figure 12). The age of the intrusive complex is at least 2109 Ma (section 7), meaning that the greenstone unit is at least Paleoproterozoic in age.

The contact between the Øverbygd intrusive complex and the Målselva group is a major shear structure (section 4.3), which implies that the age relationship between these two units is not known.

The age of the Øverbygd intrusive complex ranges from 1878 Ma to 2836 Ma (section 7). Thus this complex has ages both younger and older than the Andsfjell-Kampen complex. However, based on geochemistry (section 6.1.3, Figure 44 and Figure 45), these two units have a different origin, the different intrusive in the Øverbygd complex being arc-related and the Andsfjell-Kampen complex being of within-plate origin.

Since the Mauken basement window is situated between the basement in the Altevann area in the east and the West Troms Basement Complex (WTBC) in the west (Figure 1), it is natural to look for the continuation of the Mauken lithologies in these areas.

Since the package of Caledonian nappes partly is fairly thin in the central Troms area, the regional magnetometry may at least indicate the most likely continuation of the Mauken basement window. The magnetic data is shown in Figure 62, and it includes both old low-resolution and new high-resolution data. The Målselva group mainly gives a very low magnetic response, and this low response seems to continue towards NW, under the Caledonian nappes, to the Malangen area between Senja and Kvaløya.

In the Malangen area there are two belts of supracrustal rocks, namely the Torsnes and Astridal belts (Ab and Tb in Figure 63). *The Astridal belt* on Senja comprises greenschist to amphibolite facies metavolcanic and metasedimentary rocks, including relic pillow-lava, tuffite, marble, calcareous mica schist and a thick pile of well-preserved, partly cross-bedded psammite (Bergh et al.2010). This rock assemblage is quite similar to the Målselva group. *The Torsnes belt* on the southern tip of Kvaløya comprises metaconglomerates, psammites, mica schist and amphibolite, which are partly mylonitized (Bergh et al., 2010). Furthermore, a maximum depositional age of 1970 Ma was obtained from detrital zircons (Myhre et al., 2009). On this basis The Torsnes belt is probably not a candidate for correlation with the Målselva group.

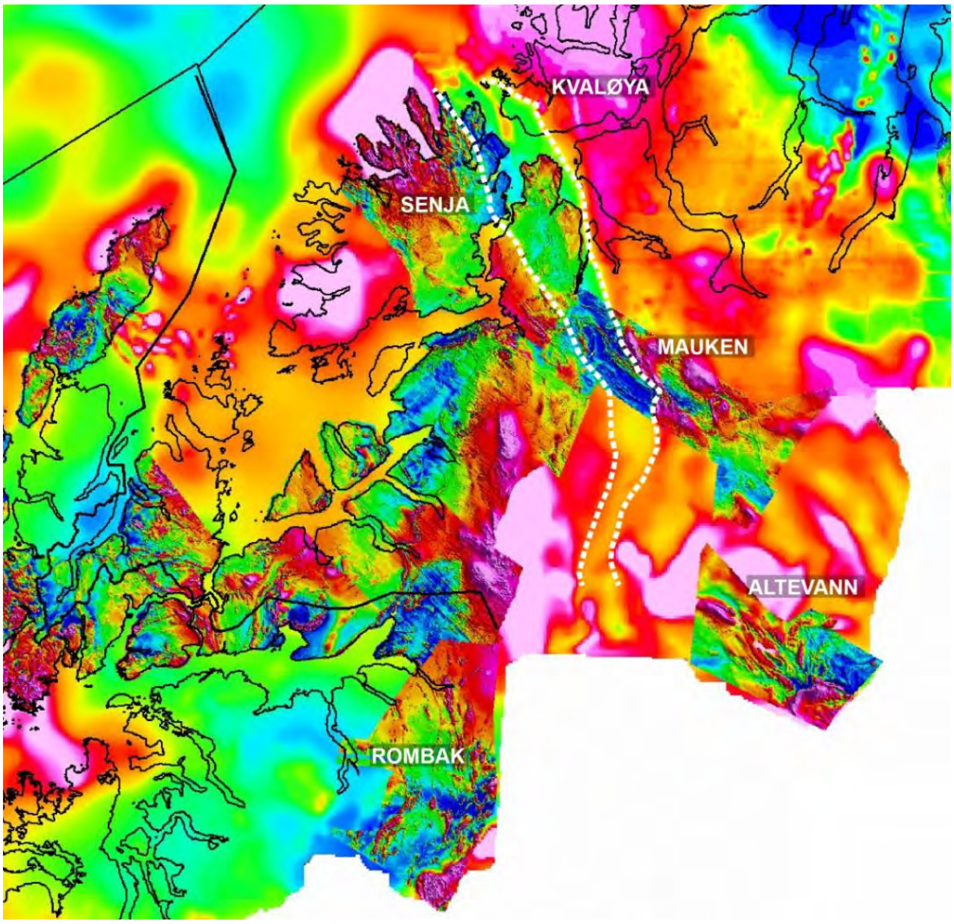

Figure 62: Regional magnetic data in southern Troms (both high-resolution new data and older low-resolution data). The stippled white lines show the most likely continuation of the Mauken basement window.

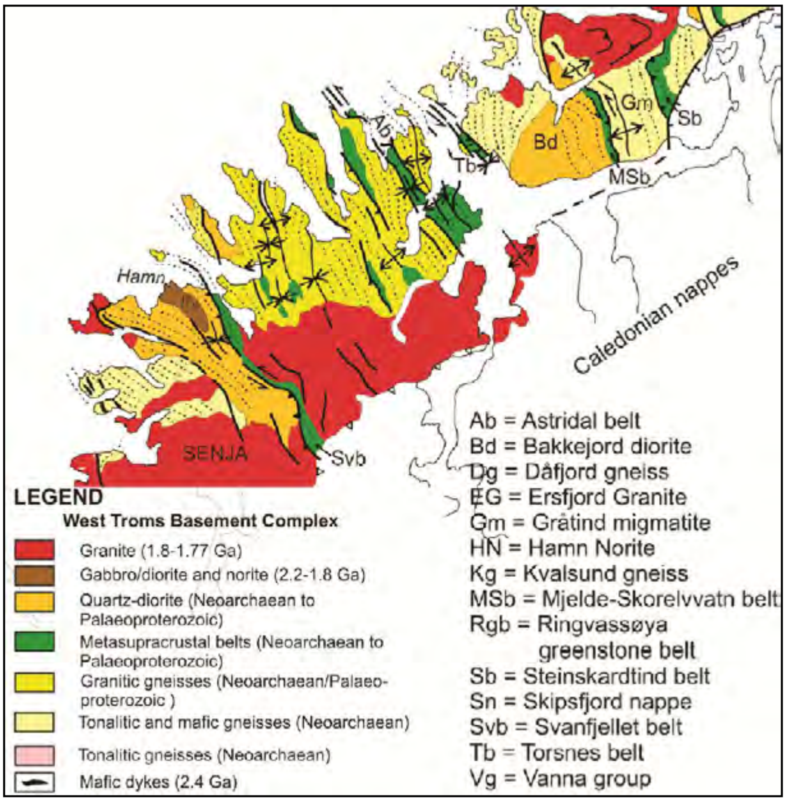

Figure 63: Overview of the geology in the Malangen area (from Bergh et al., 2010)

East and southwards from Mauken, the low magnetic signature of the supracrustals is diffuse, but seems to extend towards the south (Figure 62), and not eastwards into the Altevann area. Furthermore, supracrustal units with low metamorphic grade are not known from the Altevann area. The diffuse magnetic signals are partly due to the lower quality of the data, but probably also due to thicker Caledonian units.

It is possible that the Målselva group extends and can be correlated with the eastern part of the Rombak tectonic window. In the Sjangeli area, 2150-2175 Ma transitional island arc volcanics (partly pillow lava), greywackes and fine-grained biotite schist are known (Romer, 1989, Korneliussen & Sawyer, 1989). The 2150-2175 Ma age is however quite uncertain (based on Sr isotopes. Other data give ages younger than 1950 Ma for supracrustal rocks in the southern part of the Rombak window. The latter is based on dating of a tonalitic gneiss which is interpreted to be the basement for the supracrustal package (see Angvik, 2014 and references therein). More age data and new high-resolution geophysics in the area between Mauken and Rombak would perhaps solve the question of correlation.

The large age span of the intrusive complexes at Mauken (1878 to 2836 Ma, Figure 49) makes it difficult to correlate these units with other specific intrusions. Ages obtained on felsic complexes in the WTBC are mainly within the range 2560 to 2885 Ma (e.g. Bergh et al. 2010, Myhre et al. 2013 and references therein). This fits with the older age of 2836 Ma from the Øverbygd Complex, but the younger ages of 2100-2400 have not been found in any of the felsic units in the surrounding basement areas.

9.2 Gold mineralizations

The only significant gold mineralization found in the Mauken window is the so-called "Main Zone" (section 8). Other occurrences are more sporadic without any obvious connection to specific setting/lithology.

The "Main Zone" is localized in sand-/siltstone close to the contact to underlying greenstone, and this contact zone may have been important with respect to the formation of the mineralization.

The restricted thickness (up to 2.7 m) and extent of the mineralized zone (some 600 m), as well as low grade (only sporadic > 1 ppm gold), is clearly not economic. However, the zone disappears into a swampy area to the southeast and is covered by vegetation to the northwest.

One possible source of gold and arsenic in this setting is carbonaceous sediments, which are known to concentrate a number of metals in early formed, diagenetic iron sulfides (Large et al., 2011, Thomas et al., 2011). At Mauken, close to the contact to the underlying greenstone, the siltstone is quite rich in graphite, and also contains minor amounts of iron sulfides.

Greenstone could also be a source for gold, but the strong correlation and association of gold and arsenic (Figure 61), strongly suggest that arsenic was transported and deposited together with gold. Since the content of arsenic usually is low in greenstone, this lithology is probably not the source of arsenic or gold.

According to a model for orogenic gold deposits presented by Large et al. (2011), gold, arsenic and sulfur are preferentially released from the diagenetic sulfides because of recrystallization during later metamorphism (Figure 64). The resulting fluids may follow structural pathways and deposit the metals higher up in the sequence. In the case of Mauken, the fluids may have been concentrated along or close to the greenstone-sediment contact.

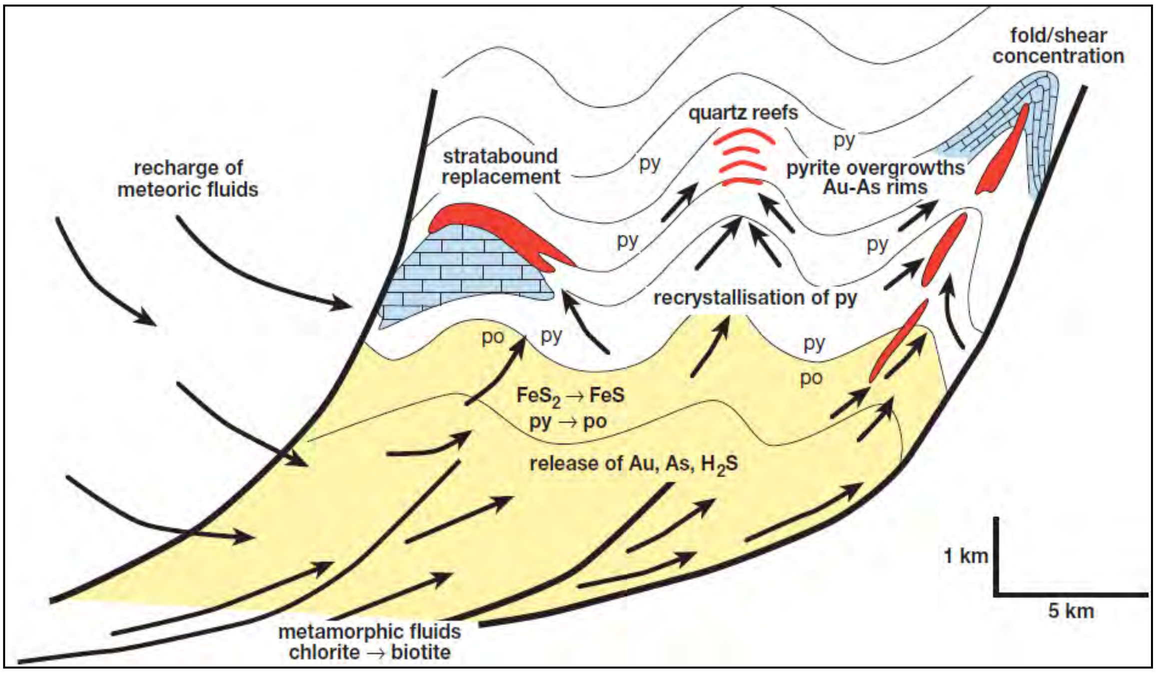

Figure 64: Model showing potential meteoric and metamorphic fluid pathways; gold, arsenic and sulfur is released from the carbonaceous sediments by conversion of sedimentary pyrite to pyrrhotite deeper in the basin (mid- to upper greenschist facies). Gold and arsenic are deposited in the upper stratigraphy, associated with focusing of fluids along faults and into anticlinal zones or shears, and along favorable rock contacts (from Large et al., 2011).

The gold mineralization at Mauken is very different from the mineralizations at Ringvassøya in the WTBC. In the latter gold is related to sulfide-bearing quartz veins, where the quartz in the most gold-rich veins is sugary in character (e.g. Sandstad & Nilsson, 1998). The veins are hosted by greenschist and greenstone (partly pillowed), crosscut by granite and dolerite dikes, all assigned to the Ringvassøya greenstone belt (e.g. see Bergh et al., 2010).

In the Rombak tectonic window there are several Au-As mineralizations, of which some are associated with fine- to medium-grained clastic sediments, i.e. metagraywacke and metasiltstone (Angvik, 2014). Those mineralizations have been suggested to be of orogenic type, related to shear zones and structures formed during the Paleoproterozoic (op.cit.).

10. SUMMARY AND CONCLUSIONS

High-resolution geophysics followed up by geological field work has led to creation of a new geological map of the Mauken basement window. Based on geochemistry this work has shown that the supracrustal rocks of the Målselva Group were formed in an arc-backarc environment, probably close to a continent. The Målselva group must have formed prior to 2109 Ma, which is the age of the cross-cutting granodiorite of the Andsfjell-Kampen complex.

Based on regional geophysics and similar geology, the Målselva group may be correlated with the Astridal belt in the Senja shear belt to the west, and possibly the eastern part of the Rombak window in the south.

The only significant gold mineralization in the Mauken window is the so-called "Main Zone", however this seems to be too small and low-grade to be of economic interest. The mineralization is, however, interesting as it may represent a new type of gold occurrence (related to and situated in metasediments) in Norway. A similar origin may be suggested for some of the Au-As deposits in the Rombak tectonic window, however those deposits are probably some 2-300 Ma younger.

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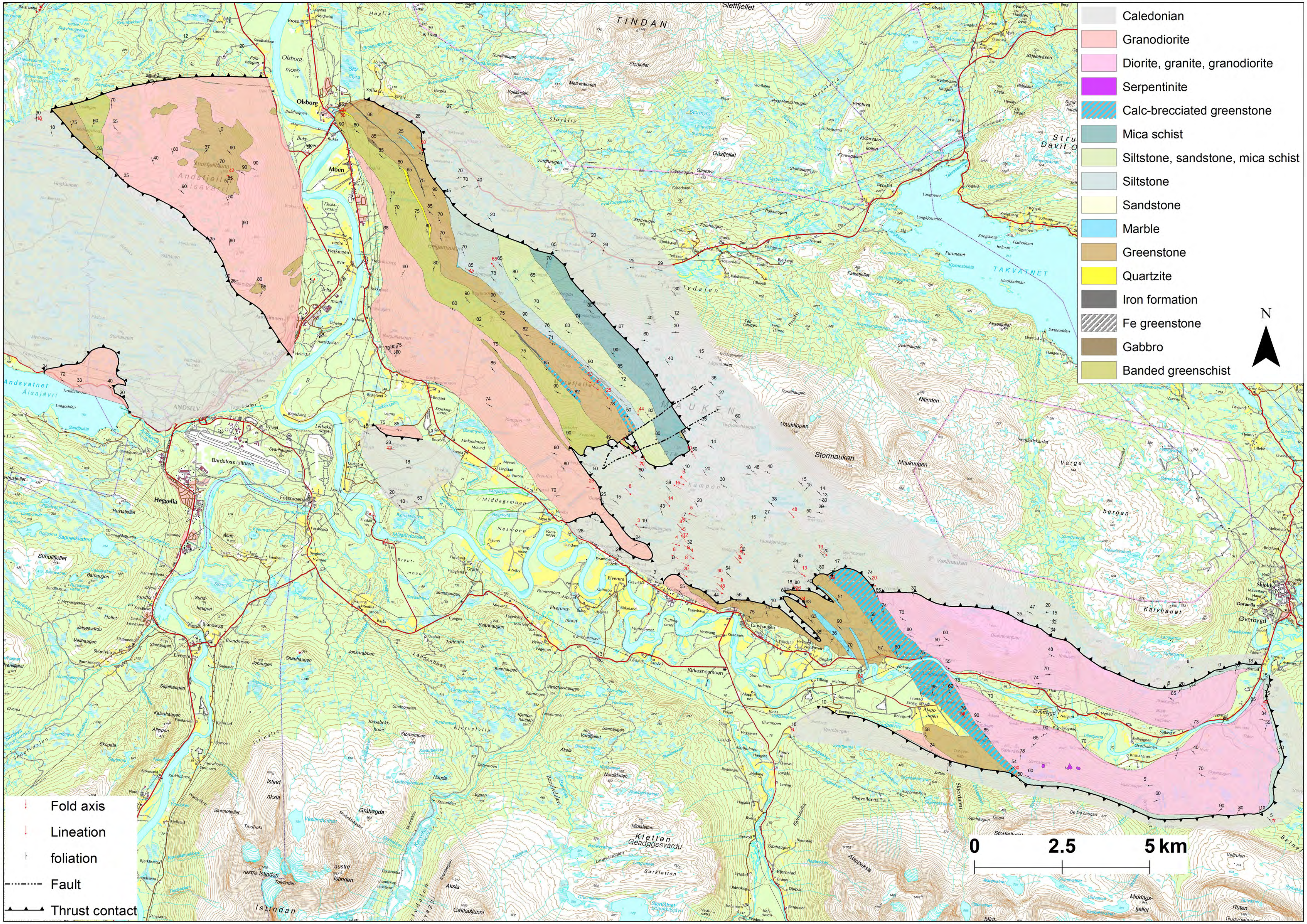
Caledonian
Granodiorite
Diorite, granite, granodiorite
Serpentinite
Calc-brecciated greenstone
Mica schist
Siltstone, sandstone, mica schist
Siltstone
Sandstone
Marble
Greenstone
Quartzite
Iron formation
Fe greenstone
Gabbro
Banded greenschist
N
0
2.5
5 km
Fold axis
Lineation
foliation
Fault
Thrust contact
TINDAN
Olsborg
Moen
Heggelia
Bardufoss lufthavn
Stormauken
TAKVATNET
Kletten
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GEOLOGICAL
SURVEY OF
NORWAY
- NGU -

Geological Survey of Norway
PO Box 6315, Sluppen
N-7491 Trondheim, Norway

Visitor address
Leiv Eirikssons vei 39
7040 Trondheim

Tel (+ 47) 73 90 40 00
E-mail ngu@ngu.no
Web www.ngu.no/en-gb/