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Preliminary findings report for the Mandal - Ustaoset fault zone precious metals exploration project

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CONFIDENTIAL REPORT

Preliminary Findings Report for the Mandal – Ustaoset Fault Zone Precious Metals Exploration Project

Portal to the Hamre Copper Mine, Bygland, Norway

Valley Metals Exploration AS

(Previously: Sola Produksjonsutvikling AS)

February 2001

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Executive Summary

The Mandal – Ustaoset zone is a large transcrustal fault that extends from near Mandal in Vest Agder county, through central Aust Agder county, through north-western Telemark county, and onto Hardangervidda in Buskerud county, where it becomes covered by the Caledonian thrust nappes. The Mandal – Ustaoset zone resembles other large-scale faults in Paleozoic crustal rocks in other parts of the world which are known to host economic gold deposits. The exploration model adopted is that a fault zone such as the Mandal – Ustaoset zone, acted as a path for transport of gold and other metals to be carried upwards in the earth's crust with fluids or magmas. Where conditions are favourable the gold is no longer transported, and is deposited in the surrounding rocks. In some cases if the amount of mineralized rocks is large and/or the grade of gold is high then an economic gold deposit may be formed.

Although no major gold occurrence has previously been known along the Mandal – Ustaoset zone, the area hosts numerous copper-silver and iron deposits, some of which were mined in the 1800's and early 1900's. In 1999 fieldwork was initiated to examine the gold potential along the Mandal – Ustaoset zone. As a preliminary method to examine the zone, abandoned mines and known metal occurrences were examined and sampled along the whole extension of the fault, with the exception of Hardangervidda. Of the rock samples collected to date 204 gold assays and 31 silver and copper have been conducted by the Mineral Division of SGS United Kingdom Ltd. in West Midlands UK. Gold was detected in many of the area examined giving a positive indication that the model is correct and that the fault zone carried gold. Significant gold discoveries in both Valle and Bygland municipalities have demonstrated the occurrence of high-grade gold necessary for creating an economic deposit. In addition, the gold is often found together with high-grade silver and copper giving the potential for the discovery of multi-metal deposits.

Gold was found in association with copper mineralized pegmatite swarms in many areas, including Hamre Mine, at Straumsfjordheia and Berevatn – Hovatn areas. Alteration assemblages in these areas include silicic, potassic, carbonatization and albitization. In addition, gold was discovered in shear zones, in particular at the Rotemo road cut alpong with copper and zinc and the abandoned Bø copper Mine near Valle. Alteration at these sites is dominated by quartz, biotite, sericite and possibly albite.

The most significant gold discoveries during the 1999 and 2000 field seasons are as follows:

Straumsfjordheia (Valle):	up to 52.4 g/t gold and 117.3 g/t silver.
Hamre Mine (Bygland):	up to 11.73 g/t gold and 243 g/t silver
Rotemo (Valle):	up to 1.76 g/t gold
Bø Mine (Valle)	up to 1.62 g/t gold
Berevatn – Hovatn (Valle):	up to 1.44 g/t gold
Fjelestad (Evje og Hornnes):	up to 0.62 g/t gold

In addition to the significant discoveries, minor discoveries along the zone are discovered in Audnedal, Åseral, Fyresdal, Tokke og Vinje municipalities. Mineral claims of interesting areas have been made at the Directorate of Mining, with a total of 311 claims (approximately 78 km^2).

The metallogeny of the area is similar to Proterozoic gold – copper deposits in Australia and northern Fennoscandia. The model in which oxidizing fluids transported by granitic melts upwards through the crust, then expelling gold- silver and copper bearing fluids is supported by alkaline granites, alkaline granite porphyries, and alkaline pegmatite swarms found along the Mandal Ustaoset zone. In many cases, the alkaline pegmatite intrusions are gold-bearing. Gold, silver and base metals may then be further transported through shear zones as chloride complexes in hot, highly saline oxidizing fluids. The most effective mechanisms for precipitation of the metals from chloride complexes are the reduction in temperature and oxygen fugacity. A sites for reduction can include interaction with graphite-bearing host rocks. The mixing of fluids at intersections of fault zones can also result in both the reduction of temperature and oxygen fugacity.

These discoveries represent a new region in Norway that may host economic Proterozoic gold deposits. Further fieldwork is needed to conduct detailed exploration of the significant gold discoveries, and to conduct regional exploration in order to find new sites of significant mineralization. It is recommended that the next phase of exploration at Straumsfjordheia, Hamre, Rotemo and Bø Mine include detailed geological mapping, detailed geochemical sampling, and ground geophysics. Geophysical methods should investigate the use of combined magnetic and gravity surveys, and radiometric surveys. During field mapping, attention should be particularly given to areas with intersecting of shear zones. The following phase should include regional exploration of the zone, particularly in Aust Agder with geochemical and airborne geophysical tools.

1.0 Introduction

1.1 Project background

In the early 1980's a major fault zone, the Mandal – Ustaoset zone, was first discovered to be crosscutting the Proterozoic shield rocks in southern Norway. Based on analogies with other large-scale fault zone structures in areas such as the Canadian Shield and Western Australia with host lode gold and mesothermal gold – silver deposits, geologist Ragnar Hagen realized the potential of the Mandal – Ustaoset fault zone. With the development of the model a project group to investigate the zone was founded in 1998. Grassroots field work in 1999 lead to the discovery of gold at several sites. In June 2000, a new company, Sola Produksjonsutvikling AS was founded by the project group and soon joined by new investors. Continued work through the 2000 field season has lead to further discoveries of gold and silver mineralization. The exploration model based on the Mandal – Ustaoset fault zone together with the results of the grassroots work is presented in this report.

1.2 Proterozoic geology of southern Norway.

The geology of southern Norway is dominated by the Sveconorwegian Middle Proterozoic rocks of the Baltic Shield (Pharaoh & Brewer, 1990) (Figure 1). To the west and north these rocks are covered by the Paleozoic Caledonian thrust nappes, and to the east the shield is crosscut by the Permian aged Oslo Graben. To the south, the Proterozoic rocks extend to the shores of the North Sea.

Previously, two smaller terrains separated by fault zones have been delineated within the Proterozoic rocks, the Bamble area along the southeast boundary (Padget & Brekke, 1996) and the Kongsberg area to the east (Dons & Jorde, 1978) (Figure 1).

The remaining area of the Proterozoic area of southern Norway is mostly composed of gneisses, supracrustal rocks of the Telemark Suite, and post-kinematic granites (Sigmond, 1985). The Telemark Suite is composed of:

1) The Bandak group, dominantly composed of quartzite and quartz-rich schist, metabasalt and metarhyolite. The Bandak is the youngest group in the Telemark Suite.
2) The Seljord group is composed of quartzite and quartz-rich schist, and carbonate-rich schist.
3) The Rjukan group is composed of metarhyolite, metabasalt, quartzite, and meta-tuffs and meta-conglomerates. The Rjukan Group is the oldest in the Telemark group.

With comparison to other Precambrian volcanic – clastic terrains, the Telemark Suite may be roughly considered a greenstone belt.

A major fault zone dividing the Proterozoic rocks, named the Mandal – Ustaoset zone, was first discovered by Sigmond (1985). This zone was shown to separate two geologic distinctive terrains within the shield rocks. Geological observations that support this conclusion are as follows:

- The Bandak group of the Telemark suite is found truncated along its western contact to the Mandal – Ustaoset zone (Sigmond 1985).
- A belt of late- and post-tectonic granites is found along the western edge of the zone (Sigmond 1985).
- Age dating of the post-tectonic granites shows that the granites on the western terrain are older (≥960 Ma) than those in the eastern terrain (920 – 940 Ma) (Andersen et al., 2000).
- The western terrain has a higher and more variable magnetic field than the eastern terrain that shows lower magnetic content (Sigmond, 1985).
- Rocks west of the zone contain higher contents of uranium and thorium (Sigmond 1985).
- The terrains have distinctive metallogenic signatures, with the majority of molybdenum occurrences found in the western terrain, and the majority of copper and nickel occurrences in the eastern terrain (Sigmond 1985).
- Recent isotopic studies of these terrains by De Haas et al. (2000) showed that the rocks on either side of the Mandal – Ustaoset zone have distinctively different mantle sources.

West of the Mandal – Ustaoset zone the terrain is called the Rogaland – Vest Agder block (Figure 1). The area east of the zone is now called the Telemark intrusives gneiss block which is partly covered by the supracrustal rocks of the Telemark Suite, as discussed above.

1.3 Geology and structure of the Mandal – Ustaoset Fault Zone

The Mandal – Ustaoset fault zone extends from the coastline near Mandal, and northward approximately 300 km to Ustaoset on Hardangervidda where the Caledonian thrust nappes thereby overlie it (Figure 2). Setesdalen lies parallel to the zone, and is crossed by the zone in the vicinity of the village of Austad.

The zone is interpreted represent a deep trans-crustal fault, with deep ductile deformation in the south, to more brittle deformation northward (Figure 3). In the southern 70 km of the zone the fault is represented as a linear zone of augen gneisses (Falkum, 1984) that are interpreted to be younger granitic rocks that were intruded into the fault zone (Sigmond, 1985). North of this zone (70 km to 120 km) the zone is represented by a series of low angle thrust faults (Falkum, 1984). Northward of this area, the fault zone is represented by high angle faults that generally divide gneisses and granites on the west from the Telemark suite rocks on the east (Sigmond, 1975). Sigmond recognizes at least three generations of movement along the zone, the youngest being a brittle normal fault with the eastern block down-dropped (personal communication).

A lineament study of the Mandal – Ustaoset zone has been conducted using a LAND SAT satellite image of southern Norway (1:250,000) (Figure 4). The faults and/or lineaments may be divided into 3 main groups.

> ***Lineation group 1***: North-south trending zones interpreted to be related to the Mandal – Ustaoset Zone
> ***Lineation group 2***: Northeast trending zones interpreted to be genetically related to the Mandal – Ustaoset zone
> ***Lineation group 3***: Late East-West trending faults and lineations.

The age of the tectonism along the zone is constrained by age dating to be between 1509 Ma and 540 Ma (Ragnhildsteit et al., 1994 & Sigmond, 1985). Deposition of the Bandak Group of the Telemark Suite post-dates the earliest movements on the fault.

Recent work has interpreted the Mandal – Ustaoset fault zone as a large-scale transverse shear zone which along which the western Rogaland – Agder block has been transported southward (Haas, et al., 1999). These authors liken the tectonic setting to accreted terrains in a Cordilleran-type orogenic belt.

Two alkali feldspar granites are mapped near the fault zone (Falkum, 1984), one east of Mandal and the other west of the village of Bygland. These intrusions are of special interest because such intrusions are linked to gold deposit formation (Peterson and Newton, 1991).

1.4 Geophysical, geochemical and other data of the Mandal – Ustaoset Fault Zone area

Detailed geophysical data of the Mandal – Ustaoset area is very limited. Aeromagnetic map at a scale of 1:250,000 (NGU 1978a & b; NGU, 1993a) help to delineate the fault zone, especially in the southern ductile region. Gravity anomaly maps (1:250,000) (NGU, 1993b & 1996) do not help to delineate the fault zone.

Maps of radioactivity emitted from bedrock in Vest – Agder and Aust – Agder counties shows that the area surrounding the southern and central portion of the Mandal – Ustaoset fault zone has anomalously high radiation (Lindahl, 1988; Lindahl and Sørdal, 1988). These maps are based on measurements made with a scintillometer along roads.

Very limit geochemical information of the rocks surrounding the Mandal – Ustaoset zone exists. National geochemical and soil and flood sediment surveys with a wide sampling distribution cover the area (Figure 5). The soil survey includes 29 elements differenced between the A- (humus), B- and C-horizons (Njåstad et al., 1994). Metallic elements of interest include silver, copper, zinc, molybdenum, and lead. Flood sediment data includes total concentration for 31 elements, and acid soluble concentrations for 30 elements (Øyen et al., 1990) Metals of interest included in these surveys include copper, zinc, molybdenum, lead, and arsenic. A detailed survey of 19 elements, including copper, zinc, lead and molybdenum, from stream sediment in Telemark County (does not extent to the western borders of the county (Ekremsæter, 1984). No previously collected gold geochemical data is known.

During the Quaternary period ice transport was in a southeasterly direction (Riiber and Bergstrøm, 1990). Where present in the mountainous regions, glacial till is thin and discontinuous. Setesdalen is a distinctive U-shaped valley formed during glaciation, and has thick till and fluvial deposits in addition to talus deposits (Riiber and Bergstrøm, 1990).

1.5 Known gold occurrences in southern Norway

Two gold-bearing districts, the Telemark and Mjøsa – Vänern District, have previously been discovered in the Proterozoic rocks of southern Norway (Gaál and Sundblad, 1990).

The Telemark district is composed of a few quartz vein-hosted gold deposits within the Telemark Suite and Bamble Block (Gaál and Sundblad, 1990), with the abandoned Bleka Mine being the largest. The Bleka mine produced an estimated 200 kg of gold between the

1870's and 1930's (Petersen and Jensen, 1995). Numerous small deposits with gold mineralization are known around the Telemark and Bamble area (Peter Ihlen and Terje Bjerkgård, personal communications).

Mjøsa – Vänern District is a zone that extends from the Eidsvoll area near Lake Mjøsa in Norway southeastward to Lake Vänern in Värmland County, Sweden. The gold deposits are found either along or between the Mylonite zone and the Dalsland Boundary Thrust (Figure 1). Gold deposits include the Eidsvoll, Ädelfors and Harnäs (Sundblad et al., 1995). The Harnäs Mine in Sweden operated during the 1990's, and 150 kg of gold from quartz veins was produced between 1993 and 1995 (Alm et al., 1995).

In the area around the Mandal – Ustaoset fault zone no previous exploration for gold is known. The presence of gold is limited to references to the observation of gold in one chalcocite sample at the "Gamle" Mine at Straumsfjordheie (Helland, 19??), electrum at Bø mine (Nodrum & Wel, 1981), 0.3 g/t in copper ore concentrate at Åmdals Verk Mine analyzed in 1937 (Lindahl, 1976), and 1.2 g/t in a copper vein west of Dalen (Foslie, 1918).

The well-known gold mineralization at Bømlo on the southwestern coast of Norway is hosted within rocks in the Caledonian nappes (Christensen and Stendal, 1995), and is therefore outside the scope of this discussion.

1.6 Exploration Model

Archean and Proterozoic gold deposits are typically spatially and genetically related to regional shear zones (Kerrich and Feng, 1992, Colvine, 1989), which have similar characters to the Mandal – Ustaoset zone.

Cameron (1989a, b & c) suggested that in active tectonic areas gold might be leached from the deeper crust and transported upwards along deep-seated shear zones (Figure 6). Transport of the gold could be accomplished by oxidizing H_2O- and CO_2-rich fluids or within magmas formed by partial melting of the crust. Sillitoe (1991) showed a close genetic relationship between granitic melts and gold mineralization. Interestingly, Cameron (1989b) used the Bamble region of southern Norway as an example, and showed that the crust was depleted with respect to gold.

Studies of large regional shear zones show that at depth the shear zones are wide zones of ductile deformation (Cameron, 1989c) (Figure 7). Near the amphibolite- greenschist boundary there is a ductile to brittle transition, and at shallower depths brittle deformation predominates (Colvine, 1989). Although most Archean and Proterozoic gold deposits are found within the ductile – brittle transitional zone (Kerrich and Feng, 1992), gold deposits may also be hosted within the deep ductile and shallow brittle zones (Colvine, 1989; Groves and Foster, 1991).

Proterozoic gold – copper deposits are well described in Australia and Fennoscandinavia (Davidson and Large, 1994; Ettner et al., 1994; Bjørlykke et al., 1993). Similar to Archean deposits they are located along major structures. However, Proterozoic gold deposits have a unique metallogenic nature, that being associated with base metals. In contrast to Archean and many Phanerozoic deposits, Proterozoic gold – copper deposits formed by very hot, oxidized, highly saline solutions which transported gold and other base metals (for example: Goellnicht et al., 1989; Ettner et al., 1993; Davidson and Large, 1994). These fluids fit

Cameron's model of transport of gold from deep crust within oxidized granitic melts. These saline fluids may also be related to alkaline alteration found associated with Proterozoic gold – base metal deposits (Peterson and Newton, 1991).

Trapping sites for gold and copper are dependent on mechanisms of metal precipitation. Mechanisms for gold and base metal deposition from chloride complexes in the Proterozoic hot saline fluids are different than mechanisms for Archean gold deposits where gold is supposed to be transported as sulfur complexes. The most effective mechanisms for deposition from chloride complexes include both decrease in temperature and oxygen fugacity (Davidson and Large, 1994). At the Bidjovaggi Au-Cu mine, gold mineralization is found at the oxidation front to graphitic schists, and a fluid inclusions study showed that fluids were reduced in the ore zone (Ettner et al., 1993). Mixing with cooler waters is suggested by Goellnicht et al. (1989) for the genesis of the Telfer Au – Cu deposit, and mixing with waters having lower oxygen fugacity are suggested for the formation of the Olympic Dam Au – Cu – U – Ag deposit (Oreskes and Einaudi, 1992). In addition, Zaw et al. (1994) suggest phase separation of N^2 from the highly saline solutions may have resulted in mineralization at Tennant Creek. Trapping sites for gold and copper mineralization therefore include:

1. sites where reducing conditions exist, such as graphite-bearing host rocks,
2. structural intersections where different fluids can mix, or
3. ductile to brittle transitions where phase separation can occur.

1.7 Analogies

Analogies for Archean gold deposits located along regional shear zones are found in several areas including the Superior Province of Canada and Yilgarn Block of Western Australia (Card et al., 1989; Groves and Foster, 1991). Although the gold districts are found distributed regionally along the large scale shear zones, on the smaller district scale gold mineralization is found associated to smaller faults intrinsically related to the large regional fault zones (Groves and Foster, 1991).

Within the Superior Province of Canada, the Abitibi Greenstone Belt hosts numerous gold deposits. These deposits are predominantly located along two fault zones, the Destor-Porcupine Fault and the Kirkland Lake – Cadillac Fault (Latulippe, 1982; Roberts, 1987; Colvine, 1989). Major gold-producing camps, including Porcupine, Kirkland Lake and Val d' Or districts are found associated along these faults (Figure 8). These structures are interpreted to be strike-slip movements at a convergent plate margin.

Within the Yilgarn Block of Western Australia several gold deposits each containing over 10 tons gold are found along major trans-cratonic fault zones (Groves, and Foster, 1991). The Norse – Wiluna Belt is the most productive area within the Yilgarn Block, where the gold deposits lie along strike- to oblique-slip shear zones (Figure 9). Groves and Foster (1991) suggest that the gold mineralization was related to oblique closure of a volcanic arc and marginal basin in a convergent margin setting.

Good Proterozoic analogies are known in Australia and on the Fennoscandian Shield. In Australia these deposits include, among many others (see Davidson and Large, 1994) Telfer (Goellnicht et al.,1989), Tennant Creek district (Zaw et al., 1994; Rattenbury, 1994), and gold – copper deposits in the Mt. Isa Block (Williams, 1994). On the Fennoscandic shield these deposits include Bidjovagge in Finnmark (Bjørlykke et al., 1987; Ettner et al., 1993), the

Pahtohavare in Sweden (Martinsson, 1992), and Saattopara Mine in Finland (Bjørlykke et al. 1993).

1.8 Methods Used

During 1998 and 1999 a collection of geological, geophysical, and geochemical data from the area surrounding the Mandal – Ustaoset zone was collected. In addition, historical references to mining and exploration activities in the area were collected.

Fieldwork to evaluate gold potential along the Mandal – Ustaoset zone has been conducted during the 1999 and 2000 field seasons. Initial sites for fieldwork were chosen based on mineralization reported in NGU database of ore deposits and occurrences (1987a, b, c & d). Secondary choices for site visits were based geological interpretations and on descriptions from the Directorate of Mining archives. Recognizance mapping was conducted at some of the sites where gold was discovered.

A total of 182 rock samples from sampling of mine waste, outcrops and float samples have been collected. Of these samples 155 samples are assayed for gold, and 31 samples assayed for silver and copper. In addition, 24 samples were analyzed for zinc, molybdenum, lead, and arsenic, and five samples were analyzed for uranium and thorium. Gold analyses were conducted by fire assay with atomic adsorption finish. Silver, arsenic, copper, lead, zinc and molybdenum were conducted by acid digestion with atomic absorption finish, and uranium and thorium were analyzed by pressed pellet with x-ray fluorescence measurement. The Mineral Division of SGS United Kingdom Ltd. in West Midlands UK conducted all analyses.

Some samples were collected for polished thin section microscopy and scanning electron microscope analyses.

1.9 Infrastructure of the area

The Mandal – Ustaoset fault zone cross four counties; from south to north being Vest - Agder, Aust – Agder, Telemark and Buskerud. Most of the zone is relatively accessible from highways and secondary roads, except in northern Telemark County and Buskerud County where the fault crosses Hardangervidda (Hardanger Plateau) (Figure 2).

Within Vest – Agder the zone is within a low wooded area and is sparsely populated by mostly small farming-based villages. In Aust – Agder the zone extends across a low mountainous plateau (500 to 1000 m over sea level). The relatively sparse population of this area is concentrated in Setesdalen. In Telemark County the zone continues through a low mountainous area, until it reaches Hardangervidda where it climbs to 1100 to 1400 m over sea level. Two larger villages of Dalen and Åmot are located near to the zone. Food and lodging is easily obtained along the zone.

A large airport with regular domestic flights is located in the port city of Kristiansand, approximately 30 km east of Mandal. Highway 9 follows Setesdalen northward from Kristiansand, providing good transportation possibilities to the area. The north-central extent of the zone is crossed by highway E134, a four hours drive west of Oslo.

Small airstrips are found in Fyresdalen and south of Straume in Setesdalen. Larges lakes in the area also give many potential sites for the landing of seaplanes.

Due to the extensive development of hydroelectric power plants in the region, numerous high power lines crosscut the zone. As an example, a high power line crosses Staumsfjordheie 1500 m south of the Berevatn prospect.

The southern and middle portion of the Mandal – Ustaoset zone crosses mostly privately owned forested or low mountain areas, so no major environmental conflicts can be expected. However, the northern-most extent of the fault 75 (km) on Hardangervidda crosses wilderness protected areas and the Hardanger National Park. This portion of the Mandal – Ustaoset zone has therefore been excluded from this exploration effort.

Norwegians populate the area. No other indigenous peoples with extraordinary land rights populate the area.

2.0 Grassroots Exploration Results

Grassroots sampling of mine sites and other mineralized areas has led to the discovery of numerous mineralized areas along the Mandal – Ustaoset zone. These results demonstrate that gold occurs in anomalous concentrations within the zone. In some of the areas, discoveries of higher-grade gold concentrations have identified a group of first priority target areas. These areas include Straumsfjordheie, Hamre Mine, Rotemo mineralization, Bø Mine, and other assorted areas. An overview of the areas, together with background information, recognizance mapping and assay results are presented below.

2.1 Straumsfjordheie Targets

2.1.1 Location

The Straumsfjordheie area is located in Valle Municipality, in Aust - Agder County (Figure 2 & 3). The area has includes the abandoned mines *Gamle* mine ("Old mine"), Amalie mine and Kong Oscars (or Kongens) mine ("The kings mine"). The area lies between 750 to 850 meters over sea level and has a forested low rugged to hilly terrain. Numerous bogs also cover the area.

The area may be accessed by a 5 km long private unpaved road from Straume in Setesdalen to Mjåvatnet Lake. Straumsfjord is then accessed by boat over Mjåvatnet, followed by a 100 m portage to Straumsfjord Lake. Access by trail may be made from a trailhead 10 to 13 km north at Tordalsbu, or a trailhead 10 km southeast at Kile. The size of Straumsfjord also allows for seaplane access.

2.1.2 History

The first report of mining activity in the Strømsheie area is from the late 1600's when Peder Linde mined silver ore east of the Strømme farm (Helland, 19??). The exact location of this mine is a matter of controversy, and the two main alternatives are either the "Gamle" mine or an undiscovered site along the shores of Mjålvatnet Lake. This also seems be the source to local oral folklore concerning a lost silver mine in the Setesdalen area.

In the 1823 Ole Sangesand built a small smelting oven at the site and produced a small amount of copper (Helland, 19??). In 1825 Professor Esmark claimed the mineral rights and described rich copper ore in a granite vein (Helland, 19??). In a chalcocite crystal he described a content of 0.69% silver and some gold. Interestingly, this is the only known printed reference to gold in the Setesdalen area.

In 1845 Setesdalen copper works received concession to exploit minerals at several sites at Strømsheie, including Kong Oscars mine, Amalie mine, Gamle mine, and Kævens mine. These mines were exploited for copper, with silver as a possible by-product. Ore was transported by sled during the winter to Åraksbø in Setesdalen, where for a short period until 1850 it was smelted. After this period the ore was transported to Kristiansand by steamship and rail. Neumann (1955) estimates that the copper production from the mines at Straumsheie was around 100 tonnes copper.

2.1.3 Geology and Structure

The geology of the area is dominated by interlayered quartzite and amphibolitic greenstone schist of the Telemark Suite (Sigmond, 1978) (Figure 10). In the Grøssæ area the Telemark greenstones are interpreted to include metabasalt, metasandstone, metaconglomerate, and minor metarhyolite or metarhyodacite.

The quartzite and greenstone schist strike north to south with a steep eastward dip (70° to 80°).

Granitic rocks and pegmatites commonly intrude the Telemark Suite rocks. In places, the granites are zoned with pegmatitic centers. Intrusions of these rocks are generally found along contacts between the quartzite and amphibolite schist.

The area has moderately good outcrops, however large areas are covered by thin glacial till and bogs (Riiber and Bergstrøm, 1990).

2.1.4 Gamle Mine

Gamle Mine is located on the top of a ridge 100 m west of the northern end of Stavvatn Lake, located north of Straumsfjord (map sheet Grøssæ 1513 III, 1:50:000). The site is mislabeled on the Grøssæ map sheet and the economical 1: 5,000 map Fossevatn (BH 026 – 5- 1), where the site of Gamle Mine is labeled "Kongens Gruver".

Mine workings at Gamle mine are apparently three relatively shallow shafts and shallow surface workings. The shafts at Gamle mine is presently flooded.

The mine is located within relatively large pegmatite intrusions within amphibolite schist, but immediately east of the contact with quartzite. There are apparently at least two different pegmatite intrusions at the mine.

Mineralization at Gamle mine is reported to be thin (>10 cm) horizontal veins of chalcocite and bornite mineralization in pegmatitic rocks and less commonly impregnations in the host rock (Falkenberg, 1910; Neumann, 1955). Secondary copper mineralization includes malachite and chrysocolla.

In 1844 copper ore grades of representative samples from two ore piles were reported to be 66.39% and 37.97% copper (Neumann, 1955).

Sodic plagioclase ($Ab_{90}An_{10}$), quartz and muscovite are common minerals in the pegmatite. Some muscovite is described by Neumann (1955) to be nearly complete altered to chlorite. Delessite, a ferroan variety of clinochlore, was also described by Neumann (1955). Epidote and garnet alteration of the amphibolite schist wall rocks was observed.

Accessory minerals described at the mine include yellow beryl, kasolite ($Pb(UO_2)SiO_4 \cdot H_20$), brookite (TiO_2) and uraninite (UO_2) (Neumann, 1955).

In 1999 and 2000 samples of the mine waste showed anomalous to high gold values (Table A). The highest gold values found to date along the Mandal – Ustaoset zone, 35.14 & 52.4 g/t gold were analyzed from the same composite mine waste sample. This sample was mainly composed of chalcocite-bearing pegmatite. Two other copper mineralized samples showed 0.72 and 2.26 g/t gold. Another mine waste composite sample of un-mineralized pegmatite feldspar and muscovite 0.93 g/t gold and 12.5 g/t silver. Rock chip samples of altered amphibolites found along the boundaries of the excavated ore body did not show anomalous gold (<0.01 g/t). Two samples analyzed for copper showed 1.0 and 14.5 % copper.

Table B shows that the contents of arsenic, lead, zinc and molybdenum in the mineralized samples is low.

2.1.5 Skakketjørn – Syvråbukte area

The area Skakketjørn – Syvråbukte stretches from the Gamle Mine 1800 m southward to the northern shores of Straumsfjord (map sheet Grøssæ 1513 III, 1:50:000) (Figure 10). Mortenson (1910) mentions numerous places in this area where copper mineralization is discovered. During the 1999 and 2000 field season two of these areas were found.

Malachite mineralization was found in a pegmatite vein northwest of Skakketjørn, and approximately 200 m southwest of Gamle mine. The pegmatite occurs with a zoned granitic intrusion on the contact between the quartzite and amphibolites. One sample collected here showed 0.20 g/t gold, 79.6 g/t silver, and 27.84 % copper (Table A)

Copper mineralization at Syvråbukte is mentioned by Falkenberg (1910) and shown on the 1:250,000 geologic map by Sigmond (1975). Malachite staining can be seen on a large pegmatite block 30 m north of the shore at Kobbervik ("*Copper Bay*"). Two samples of this pegmatite show 0.01 and 0.13 g/t gold (Table A). The silver content analyzed in one sample was relatively low (4.7 g/t).

Table B shows the concentrations of arsenic, lead, zinc and molybdenum in one sample from Skakketjørn and one sample from Syvråbukte. The concentrations of these metals are low.

2.1.6 Amalie & Kong Oscars Mines

The Amalie Mine is located on a narrow ridge top1800 m directly north of Gamle Mine, and approximately 350 m east of Ramvatn Lake (map sheet Grøssæ 1513 III, 1:50:000) (Figure 10). Kong Oskars Mine is located approximately 500 m north of Amalie Mine. Note that the location is correctly located on the Grøssæ map sheet, but incorrectly located on the economical 1: 5,000 map Fossevatn (BH 026 – 5- 1).

At Amalie Mine two parallel but discontinuous copper-rich veins were mine along a strike distance of 180 meters, and in places to a depth of 10 meters (Evje, 1910 & 1944). Shafts at the mine are presently flooded (Figure 11). One 8 meter deep decline along the veins system has a lower portal and therefore is not flooded.

The ore-bearing veins have a north-south strike with an 80°E dip at the surface, which abruptly changes to a 30°E dip 8 meters below the surface (Evje, 1910). Kong Oscars mine lies along strike and is apparently a continuation of the same vein system.

The veins are described as pegmatitic and quartz veins with chalcocite mineralization (Neumann, 1955). The host rocks for the veins are amphibolite schist. Neumann (1955) describes one of the copper-mineralized pegmatite veins to be 40 cm thick, striking 10°E and dipping 60°E. The pegmatite vein is described having a foliated internal structure with long flat sheaths of chalcocite. Secondary copper mineralization includes malachite and chrysocolla.

In 1844 copper ore grades of representative samples from four ore piles were reported to be 8.89%, 16.83%, 24.43% and 17.76% copper (Neumann, 1955). A representative sample from the waste from hand separating gave 6.5% copper.

The pegmatite vein is dominated by albite ($Ab_{90}An_{10}$) with minor quartz and muscovite (Photo of hand sample). The subordinate nature of quartz and muscovite clearly divide the mineralization style from that found at Gamle Mine. Secondary minerals of magnetite, fluorite, garnet, apatite, epidote, and carbonate are described in some areas of the ore (Neumann, 1955). Alteration of the rocks may therefore be generally characterized as carbonate, potassic (with calcium salt accessory minerals such as fluorite and apatite) and possibly skarn alteration (garnet and epidote). Albitization of the wall rocks may exist.

Seven mine waste and rock chip samples were collected during the 1999 and 2000 field seasons, and the copper-rich mine waste samples showed anomalous gold values. Three mine waste samples were collected from handpicked piles of low-grade ore at Amalie and Kong Oskars Mine (Table A). The low-grade copper ore contained 0.06 and 0.24 g/t gold at Amalie mine, and 0.06 g/t at Kong Oskars Mine. One sample analyzed from Amalie Mine showed 55.1 g/t silver and 8.99 % copper. The four other samples of altered amphibolites, and weakly mineralized pegmatites showed no anomalous gold.

Similar to Gamle Mine, one mineralized sample shows low concentrations of arsenic, copper, lead and molybdenum are low (Table B).

Numerous other exploration pits are described between Gamle Mine and Amalie Mine, but these have not yet been located. These include chalcocite mineralization in granite at Brattebrækfjell and Flatkjærn exploration pits, and ilmenite mineralization in quartz-rich granite at Kvævin and Fosvasosen exploration pits (Falkenberg, 1910).

2.1.7 Berevatn Prospect

A copper exploration pit is found 200 meters from the northwest shores of Berevatn Lake (map sheet Grøssæ 1513 III, 1:50:000). This prospect is 5.5 km north of Gamle Mine (Figure 10). The sight is located just below 900 m and is sparsely wooded.

Table A: Anomalous gold results from Straumsfjordheie area

Site	Sample number	Gold (g/t)	Silver (g/t)	Copper (%)	Description
Gamle Mine					
	168606	0.72	n.a.	n.a.	Mine waste grab sample with chalcocite in pegmatitic rocks
	168607	2.26	n.a.	n.a.	Block sample: chalcocite mineralization in plagioclase – qtz - epidote vein
	168608*	0.93	12.5	1.01	Selective grab sample: Pegmatitic feldspar without visible copper mineralization
	168651*	35.14 & 52.4	117.3	14.51	Mine waste grab sample with chalcocite in pegmatitic rocks
Skakketjørn					
	168612*	0.20	79.6	27.84	Rock chip sample: pegmatite vein chalcocite, malachite and muscovite.
Syvråbukte					
	168614*	0.01	4.7	0.22	Rock chip sample: pegmatite with minor malachite in quartz and feldspar
	168655	0.13	n.a.	n.a.	Composite sample: qtz-muscovite-feldspar pegmatite with minor chalcocite and malachite
Amalie Mine					
	168603	0.06	n.a.	n.a.	Low grade ore pile composite sample: chalcocite and malachite mineralization
	168652*	0.24	55.1	8.99	Low grade ore pile composite sample: chalcocite and malachite mineralization
Kongens Mine					
	168605	0.06	n.a.	n.a.	Low grade ore pile composite sample: chalcocite and malachite mineralization
Berevatn					
	168601	0.02	n.a.	n.a.	Chip sample: epidote altered biotite schist.
	168767	0.65 &1.44	50.5	2.69	Composite sample: pegmatite with chalcocite, malachite and molybdenum
Bergheie					
	168616*	0.96	24.3	0.99	Chip sample: Pegmatite with epidote alteration of quartzite and minor malachite and chalcocite
	168701	0.58	n.a.	n.a.	Chip sample: Epidote altered quartzite with minor malachite
	168707	0.01	n.a.	n.a.	Composite sample: coarse fluorite, epidote and quartz alteration with minor malachite alteration
	168709	0.05	n.a.	n.a.	Chip samples: altered quartzite with minor malachite and chalcocite
	168768	0.01	n.a.	n.a.	Composite sample with epidote, fluorite, tourmaline and qtz mineralized pegmatite with minor malachite.

n.a.: not analyzed
* Samples analyzed for selected metals (see Table B).

Table B: Additional metals analyzed for selected samples at Straumsfjord

Sample number	Location	Gold (g/t)	Arsenic (ppm)	Lead (ppm)	Zinc (ppm)	Molybdenum (ppm)
168608	Gamle Mine	0.93	<50	100	<100	<100
168651	Gamle Mine	35.14 & 52.4	20	60	70	50
168612	Skakketjørn	0.20	<50	200	100	<100
168614	Syvråbukte	0.01	<50	400	<100	<100
168652	Amalie Mine	0.24	30	230	90	60
168616	Bergheie	0.96	<50	100	200	100
168617	Bergheie	<0.01	<50	200	200	100

At Berevatn chalcocite mineralization is described as evenly distributed impregnations in a granitic intrusion (Falkenberg, 1910; Nordrum and Wel, 1981) (Figure 12). The intrusion is approximately 6 m thick, strikes north to south, and is found at the contact between quartzite and amphibolite schist. The length of the intrusion is not known. The contact and intrusion follows a low area in the terrain and is poorly exposed.

Two samples from this prospect were analyzed for gold. A sample of the pegmatite with weak copper mineralization was analyzed twice giving 0.65 g/t and 1.44 g/t gold (Table A). The same sample showed 50.5 g/t silver and 2.69 % copper. One sample of the amphibolite schist with epidote mineralization contained 0.02 g/t gold.

2.1.8 Bergheie Prospect

Bergheie is located in Valle Municipality, in Aust Agder County (map sheet Grøssæ 1513 III, 1:50:000). The site is approximately 9 km north of Gamle Mine and is the northernmost exploration pit known in the Straumsfjord area (Figure 10). The site is 2,5 km southwest of a trailhead at Tordalsbu. Tordalsbu is 25 road kilometers west of Fyresdalen on a partly paved road. The turnoff for this road is 6 km north on highway 355 from the village of Fyresdal. The trail at Tordalsbu is well maintained and passes within 800 m of the exploration pits.

The site is at an elevation of 1,020 meters over sea level. The area is rugged and above tree line which gives relatively good exposure of the geology.

An old copper exploration pit on the summit of Bergheie is described by Falkenberg (1910). He describes the mineralized zone as 5,5 meters wide. A clean copper ore sample from the site during this first investigation gave an analysis of 55% copper. Nordrum and Wel (1981) present a map of the zone, which is at least 230 m long and 10 to 30 meters wide. Pegmatite intrusions crosscut the zone. Mineralogy of the zone includes fluorite, chalcocite, digenite, bornite, wittichenite, chalcopyrite, hessite, epidote, quartz, feldspar and garnet (Nordrum and Wel, 1981).

Recognizance sampling of the area found that two adits existed along the southern slope of Bergheie Mountain. One exploration pit was found on the crest of the southern slope, and one exploration pit is located on the summit. The two adits were filled with water, so the extent of these workings is not known. Nordrum and Wel (1981) report an attempt to produce copper around 1900, and fluorite exploration in 1970 by A/S Sulfidmalm.

The geology of Bergheie includes quartz-rich metasandstone of the Telemark suite (Sigmond, 1978). The metasandstone are intensely sheared and intruded by pegmatite dikes parallel to bedding, all of which have a north-south strike with steep eastward dip. The mineralization zone described by Nordrum and Wel (1981) lies within a intensely sheared zone. The length of the shear zone has not yet been mapped, but is at least 600 m long and up to 40 meters wide. The shear zone is located about 50 meters west of the contact with a large granitic intrusion that trends in the same direction. Surrounding the pegmatites and in contact to the shear zone, the metasandstone show intense epidote mineralization.

Due to the discovery of a small gold anomaly (0.01 g/t) in the exploration pit on the summit during the first reconnaissance survey, the area was re-sampled in 2000 (Table A). One rock chip sample of altered quartzite and pegmatite with weak copper mineralization showed a high value of 0.96 g/t gold, 24.3 g/t silver, and 0.99 % copper. This sample also showed low contents of arsenic, lead, zinc and molybdenum (Table B).

Follow-up sampling along the zone confirmed with 4 of 13 rock chip or composite samples showing gold above detection levels. The highest of these was a highly altered quartzite with weak copper mineralization that gave 0.58 g/t.

2.2 Hamre Target

2.2.1 Location

The Hamre target is located in Bygland Municipality, in Aust Agder County (map sheet Bygland 1512 IV, 1:50:000) (Figure 2 & 3). The abandoned mine occupies a rather precipitous location on the upper edge of a 100 m high cliff along the western shore of Byglandsfjord (Figure 13 & 14). The mine is located approximately 500 m over sea level, and 300 meters over the lake level.

The base of the cliffs can be accessed by paved road along the western shores of Byglandsfjord. About 1 km south of the Hamre farm, a 4-wheel track leads to the top of the cliffs. From this point a 1,5 km walk northward along the cliff rim is required. The mine is located 100 m northeast of the Rysefossen waterfall.

2.2.2 History:

Mineralization at Hamre was first discovered sometime before 1826, and possibly worked by early German miners (Poulsen, 1826). A trace of the old mining technique "fire-setting" is seen near the mouth of the mine. In 1845 Setesdalen copper works investigated the deposit.

The first modern attempts to mine the copper ore at Hamre was 1907 to 1908 (Mortenson, 1911). During this period a rope ladder was constructed up to the mine and an adit was driven 25 meters along an ore vein. The ore was hand separated and exported. In 1908 it is reported that 50 tons of copper sulfide ore was exported to an English buyer. During this period silver was discovered in the deposit.

In 1913 Germans worked the mine and installed an elevated cable to transport the copper ore to the shore of the fjord (Winsnes, 1961). The road along the western edge of the lake was not yet constructed, so ore had to be transported further by ship. The remains of this cable can be found at the mine and on the talus slope below the cliff. A 30 m long adit along a lower pegmatite and two small drifts may have been made during this period (Figure 13). In addition, a small open pit was excavated in another pegmatite body, about 20 m above the adit opening. During this period 22 tons of higher-grade chalcocite ore (10 % Cu) and 70 tons of low-grade ore (2 to 3 % Cu) were produced (Poulsen, 1961). Exploration along the side drifts during 1913 did not result in the discovery of more high-grade ore, likely resulting in the closure of the mine.

2.2.3 Geology and structure

The geology of the Hamre mine is dominated by a dike swarm that intrudes Paleozoic amphibolite gneiss (Figure 14). In the mine, the pegmatite are dominated by quartz, albite and biotite. Some of the pegmatites are rich in magnetite. Contacts and xenoliths of gneiss show that the pegmatite intruded during or after brittle deformation of the rocks. The age of the pegmatite intrusions is not known.

The pegmatite veins generally strike east west, are dip up to 30° south. The foliation in the gneiss is approximately N40°W with a 45°S dip.

The area is faulted by three main sets of faults. The first is north-south trending high angle fault system. The cliff face at the Hamre mine is apparently along this fault system. The north-south trending faults are in places abutted by northeast trending and east-west high angle faults. Age, offset, or direction of movement along these three sets of faults is not yet known.

The geology of the area is well exposed, however, thick forest and bogs cover large areas of the plateau (Figure 16). On large alkali granite intrusion is mapped approximately 1.5 km to the northwest of the mine, but hasn't yet been sampled. Air photos showing lineations indicate that the intrusion is older than east-west structures.

2.2.4 Mineralization and alteration

The main copper mineralization occurs as disseminated to veined chalcocite in a swarm pegmatite veins. The mineralized veins range in thickness, and occur up to 4 m thick, and the exposed thickness of the mineralized swarm is approximately 50 m.

Previously collected chalcocite samples from the main adit showed copper values of 0.33 to 3.30 % (Winsnes, 1961). Other minor copper mineralization included bornite and malachite (Mortenson, 1911). One silver analysis of a simple copper concentrate showed 587 grams Ag per ton (Mortenson, 1911).

Potassic alteration in the wall rocks near the pegmatite contacts includes both biotite and sericite mineralization. In places the altered rocks are friable. The pegmatites have a high albite content and some albitization of the wall rocks may exist.

Recent analysis of the pegmatite veins, associated quartz veins and gneissic rocks in the Hamre underground and open pit workings showed excellent gold (0.01 to 11.73 g/t) and silver (12.5 to 243.3 g/t) results (Table C). In addition, 10 of 16 samples collected on the surface within a radius of 300 m of the mine revealed anomalous gold values (0.01 – 1.96 g/t) within quartz veins, pegmatites and granites. One additional granitic sample collected 1.5 km to the south also showed anomalous gold (0.01 g/t).

Within both the underground and open pit workings the best gold results were discovered in the copper mineralized pegmatites. Samples of pegmatites without visible copper mineralization contained between <0.01 and 0.07 g/t gold. Within a radius of 300 m pegmatites closest to the mine showed highest gold values. Quartz veins and biotite granites showed anomalous values between 0.01 and 0.03 g/t gold. Samples collected within the 300 m radius that contain < 0.01 g/t gold were all pegmatites.

Copper analyses show that mineralized pegmatite veins contain up to 24 % copper. Additional metal analyses for some samples are shown in table D. These results show that there is a low concentration of arsenic, lead, zinc and molybdenum in the samples.

Table C: Anomalous gold results from Hamre mine and surrounding areas

Site	Sample number	Gold (g/t)	Silver (g/t)	Copper (%)	Description
Underground Mine Samples					
	168632	0.03	n.a.	n.a.	Chip sample, tunnel wall: Peg w/ no observed Cu mineralization
	168633	0.07	n.a.	n.a.	Chip sample from tunnel wall: Magnetite-bearing pegmatite with no observed copper mineralization
	168634	0.07	n.a.	n.a.	Chip sample from tunnel wall: Granitic gneiss with no observed copper mineralization
	168635	0.45	n.a.	n.a.	Chip sample from tunnel opening: Pegmatite with chalcocite and malachite
	168636*	1.35	243.3	23.94	Chip sample from tunnel opening: Pegmatite with chalcocite and malachite
	168637*	8.78	211.6	20.30	Composite sample of mine waste with strong chalcocite mineralization
	168638	0.76	n.a.	n.a.	Chip sample from tunnel opening: Pegmatite with strong chalcocite and malachite mineralization
	168639*	11.73	51.1	6.15	Chip sample from tunnel opening: Pegmatite with strong chalcocite mineralization
	168640	0.26	n.a.	n.a.	Chip sample from tunnel opening: Pegmatite with weak chalcocite mineralization
	168641*	0.18	12.5	13.26	Chip sample from tunnel opening: Altered biotite gneiss with malachite staining
	168658	0.96 & 0.26	n.a.	n.a.	Mine waste from talus slope below cliffs: Pegmatite block w/ qtz vein and minor chalcocite
	168662	0.03	n.a.	n.a.	Chip sample: Pegmatite w/ chalcocite
	168816	0.01	n.a.	n.a.	Chip sample: coarse biotite granite
	168821	0.07	n.a.	n.a.	Chip sample: Pegmatite with disseminated chalcocite and malachite mineralization
	168822	0.73	n.a.	n.a.	Chip sample: Pegmatite with coarse disseminated and veined chalcocite
	168823	0.21	n.a.	n.a.	Chip sample: Pegmatite with coarse disseminated and veined chalcocite
	168840	0.71	n.a.	n.a.	Block sample: pegmatite w/ chalcocite, bornite & malachite
Open Pit Samples					
	168643*	0.86	46.6	4.75	Composite sample of pegmatite with chalcocite mineralization
	168644	0.14	n.a.	n.a.	Composite sample of qtz vein with minor chalcocite mineralization
	168836	0.44	n.a.	n.a.	Chip sample: Mega crystalline pegmatite w/ chalcocite & malachite
	168837	0.03	n.a.	n.a.	Composite sample: pegmatite w/ chalcocite
Surface Samples					
	168642*	1.96	64.9	5.05	Chip sample: outcrop between underground mine and open pit, pegmatite w/ chalcocite & malachite
	168660	0.47	12.4	2.37	Block sample: between underground mine and open pit pegmatite w/ chalcocite
	168661	0.01	n.a.	n.a.	Composite sample: between underground mine and open pit, pegmatite w/ chalcocite
	168825	0.03	n.a.	n.a.	Outcrop chip sample: Biotite granite
	168829	0.02	n.a.	n.a.	Outcrop chip sample: quartz vein w/ biotite and minor disseminated chalcocite
	168831	0.02	n.a.	n.a.	Outcrop chip sample: Pegmatite with no observed mineralization
	168833	0.01	n.a.	n.a.	Block sample: Biotite granite w/ weakly disseminated chalcocite, and minor epidote
	168835	0.01	n.a.	n.a.	Block sample: Pegmatite w/ chalcocite
	168838	0.02	n.a.	n.a.	Sub-outcrop chip sample: Pegmatite w/ ilmenite
	168839	0.16	n.a.	n.a.	Outcrop chip sample: pegmatite w/ chalcocite & malachite
	168841	0.01	n.a.	n.a.	Float sample of granitic rocks along dirt access road to cliff top.

n.a.: not analyzed
* Samples analyzed for selected metals (see table D).

Table D: Additional metals analyzed for selected samples at Hamre

Sample number	Location	Gold (g/t)	Arsenic (ppm)	Lead (ppm)	Zinc (ppm)	Molybdenum (ppm)
168636	Underground	1.35	<50	200	300	100
168637	Underground	8.78	<50	<100	200	100
168639	Underground	11.73	<50	<100	100	<100
168641	Underground	0.18	<50	<100	100	<100
168643	Open pit	0.83	<50	<100	<100	<100
168642	Surface	0.24	<50	<100	<100	<100

2.3 Rotemo Target

2.3.1 Location

Rotemo is located in Valle Municipality, in Aust Agder County (map sheet Valle 1413 II, 1:50:000) (Figures 2 & 3). The site is 6 road kilometers north of Valle along highway 9. The mineralized zone is exposed in two road-cuts at the turn-off of highway 45, which continues northeast to Dalen in Telemark.

The site is around 340 meters over sea level, and is just above the western banks of the Otra River. The road cut on highway 9 is approximately 50 meters long, and 30 meters long on highway 45. The area is forested, but there are relatively good rock outcrops on the steep slope northeast of the road cuts.

2.3.2 History

Old records refer to a copper exploration pit in the area, called Flateland (Henriksen, 1897). In 1845 Setesdalen Copper Company was granted mining rights of Flateland (Helland, 19??). An unsigned claim letter from the 7th of June, 1884 describes the exploration pit near the postal road. Based on this information, it is conceivable that traces of the exploration pit were removed during the construction of the two highways at the Rotemo intersection.

The geology map of Sigmond (1975) plots a copper occurrence on the ridge to the east of the highway intersection, however this occurrence has not yet been located. Nordrum and Wel (1981) report that a exploration pit is located to the northwest near Vollen.

2.3.3 Geology and structure

The rocks in the target area are quartz-biotite gneiss and amphibolite schist that have been sheared parallel to foliation. Mineralized quartz veins are found within the sheared schist and are also oriented parallel to the foliation.

The width of the shear zone is approximately 20 m. Along the rock face of the road-cut the oxidation of iron sulfides has resulted in red to brown stains on the surface of the rocks in the shear zone (Figure 17). A lineation in the topography corresponding to the position and trend of the shear zone can be traced at least 10 km to the northeast and 5 km to the southwest.

Approximately 700 m to the southeast of the Rotemo intersection, a thick mineralized quartz vein was also discovered. The vein is up to 1.5 meter thick and crosscuts granite.

NGU's geological map (1:250,000; Sigmond, E., 1975) shows that these rocks belong to an arm of migmatized granitic to granodioritic gneisses and biotitic gneisses, which generally trends northeast between massive granite bodies (Figure 18). The age of these rocks are Proterozoic in age, however, the exact age is unknown.

2.3.4 Mineralization and alteration

Disseminated chalcopyrite is observed in the gneiss, schist and the quartz veins. Sphalerite and minor bornite was observed in the quartz vein. Rock chip samples of the quartz-biotite gneiss gave gold results of 0.10 and 0.14 g/Mt, whereas 1.74 g/Mt was found in the quartz veins (Table E).

Potassic alteration is observed throughout the shear zone, exhibited by sericite mineralization. Immediately adjacent t, and within, the quartz veins large crystals of biotite are observed.

Table E: Anomalous gold results from the Rotemo area

Site	Sample number	Gold (g/t)	Silver (g/t)	Copper (%)	Description
Upper Road Cut					
	168774*	0.10	6.0	0.13	Composite chip sample. Rust zone in sheared quartz-biotite gneiss and amphibolite schist, w/ disseminated chalcopyrite
	168807	0.02	n.a.	n.a.	Chip sample: Biotite schist
	168808	0.02	n.a.	n.a.	Chip sample: Granitic intrusion w/ disseminated sulfides
	168809	1.62	24.5	0.97	Chip sample: Shear zone through schist with intense sericite alteration
	168810	0.09			Chip sample: biotite gneiss w/ disseminated sulfides
	168811	0.12	8.5	0.32	Chip sample: gray amphibolite schist with disseminated sulfides
	168812	0.06	n.a.	n.a.	Chip sample: Biotite - gneiss w/ sulfides
	168813	0.01	n.a.	n.a.	Chip sample: Biotite - gneiss w/ sulfides
	168814	0.02	n.a.	n.a.	Chip sample: Amphibolite schist
	168842	0.34	n.a.	n.a.	Chip sample: Quartz vein w/ finely disseminated sulfides within seritized and sheared schist zone
Lower Road Cut Samples					
	168798	0.14	n.a.	n.a.	Chip sample: quartz-biotite gneiss w/ sulfides
	168799	1.76	18.9	0.99	Chip sample: Brecciated quartz vein w/ feldspar, biotite, sericite, chalcopyrite and sphalerite
	168815	1.68	n.a.	n.a.	Chip sample: Brecciated quartz vein w/ feldspar, biotite, sericite, chalcopyrite and sphalerite
Southeastern Road-cut					
	168914	0.02	3.0	0.002	Chip sample: Quartz vein (1.5 m thick) with disseminated chalcopyrite and molybdenum
	168915	0.06	7.5	0.043	Chip sample: Sulfide-rich zone (pyrite > chalcopyrite) within the quartz vein.
	168921	0.03	n.a.	n.a.	Chip sample: Quartz vein by shores of the Otra River.

n.a.: not analyzed

* Samples analyzed for selected metals (see table F).

Table F: Additional metals analyzed for selected samples at Rotemo

Sample number	Arsenic ppm	Lead ppm	Zinc ppm	Molybdenum ppm
168774	30	80	1800	<100

2.4 Bø Mine Target

2.4.1 Location

Bø Mine is located in Valle Municipality, in Aust - Agder County (Figure 2 & 3). The site is 3.5 km southwest of the village of Valle, and 1.5 km south of the farming area of Åmli. The mine is approximately 500 meters over sea level on the crest of a small north-south trending ridge on the western slope of Setesdalen valley. The farm of Bø is located on the valley floor 500 m to the southeast.

The area may be easily accessed from a turn-off from highway 9 approximately 2 km south of Valle. From this intersection, a paved secondary road switchbacks through Åmli, and a well maintained gravel road at the third switchback leads southward 1.5 km to the mine.

2.1.2 History

Mining activity at the Bø Mine occurred during at least two periods. The first period of mining activity that is known is 1844 and 1845, where production of 1281 "Tdr" (barrels) of ore (ca. 500 tons ore) was produced with 10 to 12 % Cu (Henriksen, 1897). After this period the mine was between 30 to 50 m deep (Henriksen, 1897; Holmsen, 1885). Mining attempts were also made by Evje copper works in 1863 and 1888 (Nordrum and Wel, 1981).

From 1915 to 1918 the mine waste operated by G.A. Henriksen & Co (named Sørlandske Bergindusti in 1918). During this four year period it is reported that 337 tons of export ore (10 – 13 % Cu) and 1493 tons of "washing ore" (3 – 5% Cu) were produced (Bergmester, 1967; H/MS, 1920). The mine employed up to 15 men for mining, and children for hand picking of the ore. Mining was halted on the 1st of August 1918. In 1971 the mine was drained of water and investigated by A/S Sulfidmalm (Nordrum and Wel, 1981).

Today the mine is filled with water. The exposed workings are approximately 35 m long in a N30W trend and around 5 m wide (Figure 20). One column helps to support the hanging wall and workings continue below the water level at an angle of about 50°E, which is the dip of the ore body.

An exploration pit, "Bø skjerp", to the northwest of the mine is reported (Henriksen, 1897; Bergmester, 1967; Helland, 19??). Mining rights for this sight were granted to Setesdalen Copper Company in July of 1845 (Helland, 19??), however it is unlikely that the mineralization was ever exploited. Mining authorities investigated the area in August of 1885, but the exploration pits were not located (Holmsen, 1885). The terrain immediately northwest of the mine appears to have been trenched, however it is well overgrown and no outcrops are observed.

2.1.3 Geology and Structure

At the Bø mine, an arm of amphibolite schist trends N30W and dips 50°E into granitic rocks. The amphibolite schist is approximately 35 m thick (Horneman, 1944). Within the meter of the amphibolite schist, immediately below the granitic hanging wall (Figure 19 & 20), the rocks are highly sheared. The hanging wall granite appears to be an alkaline granite porphyry with abundant magnetite.

The arm of amphibolite schist is interpreted to be an extension of the schist and gneiss that are mapped along trend on the eastern side of Setesdalen (Sigmond, 1975) (Figure 18). Recognizance mapping of the Bø area indicates that quartzite of the Telemark Suite may also be present (Figure 18), although not mapped by Sigmond, 1975). This extension of schist is interpreted to be along a major northwest-trending shear zone extending from the Mandal – Ustaoset fault zone.

Mineralization is concentrated in the up 0.5 to 1 meter, immediately below the hanging wall granite, and could be followed 30 m in surface exposures (Winsnes, 1965). Thickness of the ore is reported to decrease at depth (Holmsen, 1881). Mineralization is dominated by chalcopyrite, bornite and pyrite in veins and impregnations (Horneman, 1944). Nordrum and Wel (1981) also describe molybdenum, wittichenite, digenite, hessite, tellurobismuthite, galena, electrum, magnetite and hematite. A photomicrograph in Nordrum and Wel's (1981) report shows a thin vein (0.10 mm) with hessite, tellurobismuthite and electrum, crosscutting bornite

A total of 12 of 13 samples analyzed from Bø mine showed anomalous gold values (Table G). The highest gold value of 1.62 g/t was found by collecting a large composite sample of mineralized mine waste. Detailed sampling of separate lithologies has shown gold values ranging from 0.05 to 0.44 g/t. The highest three values are found in low-grade copper ore (0.44 g/t Au), the mineralized hanging wall granite (0.30 g/t Au) and mineralized quartzite (0.16 g/t Au).

It is noted that the highest gold value (1.62 g/t) from the large composite sample could not be reproduced by more detailed lithological sampling. Therefore, it can be interpreted that at least one part of the large composite sample had a gold content at least an order of magnitude higher than the composite sample.

Table G: Anomalous gold results from Bø mine

Sample number	Gold (g/t)	Silver (g/t)	Copper (%)	Description
168624	0.10	n.a.	n.a.	Chip sample from pillar in mine: Quartz – chalcopyrite – pyrite veins in sheared amphibolite schist
168625	0.09	n.a.	n.a.	Chip sample from pillar in mine: Biotite schist w/ minor sulfides and malachite
168626	0.08	n.a.	n.a.	Chip sample from pillar in mine: Sheared biotite schist
168627	0.05	n.a.	n.a.	Chip sample from pillar in mine: Quartzite with minor malachite
168629*	0.30	14.5	5.10	Chip sample from hanging wall in mine: Granite w/sulfide veins
168630	0.44	n.a.	n.a.	Composite sample of low grade ore chip – cobble pile
168631	0.13	n.a.	n.a.	Composite sample of low grade ore chip – cobble pile
168659*	1.62, 1.60 & 1.44	34.0	7.09	Large composite sample (x kg) of mine waste
168770	0.08	n.a.	n.a.	Chip sample of outcrop: Quartzite near south end of mine, no observed mineralization
168771	0.07	n.a.	n.a.	Composite sample of mineralized quartz veins in mine wastes
168772	0.16	n.a.	n.a.	Block sample of mineralized quartzite from mine waste
168773	0.07	n.a.	n.a.	Composite sample of copper mineralized biotite schist in mine wastes

n.a.: not analyzed

* Samples analyzed for selected metals (see table H).

Two silver and copper analyses of samples showing higher gold values showed relatively low silver (14.5 & 34.0 g/t) and copper (5.10 and 7.09 %) concentrations. These same two samples show low concentrations of arsenic, lead, zinc and molybdenum (Table H).

Table H: Additional metals analyzed for selected samples at Bø Mine.

Sample number	Arsenic ppm	Lead ppm	Zinc ppm	Molybdenum ppm
168629	< 50	100	300	<100
168659	20	20	430	290

2.5 Other Areas

Several other areas with anomalous gold values have been discovered during the grass-roots exploration (Figure 21). Other areas in along the Mandal – Ustaoset zone are known for copper mineralization, however these sites have not yet been located. These sites (from south to north) are briefly discussed below.

2.5.1 Fjelestad

The NGU database of mineralization (NGU, 1987b) reports copper, arsenic and molybdenum mineralization near Fjelestad (Åseral, 1412 II; 1:50,000). The area is located within a wide zone of augen gneiss which trends north-northeast (Falkum, 1982). This augen gneiss may represent a side structure within the Mandal – Ustaoset zone.

At Fjelestad numerous bogs cover the terrain and the geology in the area is therefore poorly exposed. An exploration trench with massive arsenopyrite mineralization was located and sampled. One sample taken here showed an anomalous gold concentration of 0.62 g/t (Table I).

Table I: Metals analyzed for a sample collected at Fjelestad

Sample number	Gold (g/t)	Silver (g/t)	Copper (%)	Arsenic ppm	Lead ppm	Zinc ppm	Molybdenum ppm
168669	0.62	8.2	1.66	91800	170	2200	150

2.5.2 Bognevann iron mine

The abandoned Bognevann iron mine was one of several iron mineralized sites investigated within Vest-Agder. The mine is located approximately 13 km east of the village of Eiken, and 2 km south of highway 42. The mine is located 500 meters directly south of Bognevann Lake along a tractor road.

The mine occurs within granitic gneiss bordering the augen gneiss of the Mandal – Ustaoset fault zone (Falkum, 1982). Locally, the country rocks are amphibolitic.

The mine is a large open cut. The ore is dominated by massive specular hematite within a north-south vertical vein. Waste rock shows euhedral quartz crystals. Four of five samples collected from the mine showed gold values over the detection limit (Table J).

Table J: Anomalous gold results from Bognevann iron mine

Site	Sample number	Gold (g/t)	Silver (g/t)	Copper (%)	Description
	168781	0.02	n.a.	n.a.	Mine waste sample: specular hematite
	168783	0.08	2.5	<0.01	Mine waste sample: specular hematite with quartz
	168784	0.01	n.a.	n.a.	Mine waste sample: specular hematite with limonite oxidation
	168785	0.01	n.a.	n.a.	Mine waste sample: fine crystalline amphibolite country rocks.

n.a.: not analyzed

2.5.3 Gunnarsvatn

Mineralization is located on the western shore of Gunnarsvatn approximately 15 km southwest of the village of Evje (Åseral, 1412 II; 1:50,000). This site is reported in NGU database (NGU, 1987b) as a site with molybdenum mineralization.

Due to the fact that the site was found along a long angle thrust interpreted to be related to the Manus – Ustaoset zone, the site was visited. The thrust fault is mapped separating banded amphibolite to biotite gneisses on the west, from granitic to granodioritic gneiss on the east (Falkum, 1982).

Strongly oxidized pyrrhotite mineralization within an amphibolite was found and sampled for gold analysis. This sample showed 0.16 g/t gold.

2.5.4 Håverstøl Mine

Håverstøl Mine is located approximately 18 km northwest of Evje in Åseral Municipality of Vest Agder County. The mine is located at 700 m on a mountaintop on the eastern edge of Fiskårdalen valley (Åseral, 1412 II; 1:50,000).

The mine is located within a zone of amphibolite to biotite gneiss rocks sandwiched between two thrust faults (Falkum, 1982) interpreted to be related to the Mandal Ustaoset fault.

Mineralization at Håverstøl was found as chalcopyrite and pyrrhotite with quartz veins and as impregnations in gneiss (Carsten, 1917). The veins and impregnations in the gneiss are generally concordant to foliation and may be folded. In one place the zone is reported to be 0.7 meter thick with an average concentration of 8.6% copper (Carsten, 1917).

Only one sample of three samples collected at Håverstøl mine contained gold over detection limits. The sample was a chalcopyrite ore sample in quartz from the main ore zone, and contained 0.32 g/t gold.

2.5.5 Byglandsfjord - Åraksbø – Hovatn

Sulfide and copper mineralization is reported in several sites along the ridge of Setesdalen in the area of stretching from Bygland to Åraksbø (Bygland 1512; 1:50,000)(NGU, 1987b). A site with mineralization is also report near Hovatn, north of Åraksbø (Færden, 1962). These sites have not yet been localized in the field.

2.5.6 Rangastøyl

Copper mineralization is reported near Rangastøyl, 7.5 km north of Juvatn Lake (Austad 1412 I)(NGU, 1987b). A site survey of the area failed to find the mineralization. The site apparently lies within amphibolite to biotite gneiss rocks that are cut by thrust faults interpreted to be part of the Mandal – Ustaoset fault zone.

2.5.7 Stemsvatn

Several areas of copper mineralization are reported near Stemsvatn on Sördalsheia (map Valle 1413 II; 1: 50,000) by Henrisen (1911). Near Knapestöl bornite is described within pegmatite, with concentrations near the contact with the country rocks of mica schist. Northeast of Segberg several areas of malachite staining within pegmatite are mentioned. Near the north end of Stemsvatn, chalcopyrite is described in quartz veins within gneiss.

During field investigation of the Stemsvatn area, only the malachite mineralization northeast of Segberg was located. The area is generally composed of mica schist that is pervasively intruded by pegmatite dikes.

Of 15 samples collected around Stemsvatn, six samples showed detectable gold values (Table K).

Table K: Anomalous gold results from Stemsvatn area

Site	Sample number	Gold (g/t)	Silver (g/t)	Copper (%)	Description
	168717	0.06	n.a.	n.a.	Chip sample from Selberg cliff: Granitic vein in with cpy veinlets and malachite stains
	168722	0.11	n.a.	n.a.	Chip sample from Selberg cliff: Iron oxidized schist layer
	168802	0.02	n.a.	n.a.	Float sample: Qtz-feldspar-muscovite pegmatite with minor Fe-oxide staining
	168804	0.03	n.a.	n.a.	Float sample: Qtz-feldspar-muscovite vein in amphibolite
	168805	0.01	n.a.	n.a.	Outcrop chip sample: Qtz-feldspar-muscovite pegmatite with Fe-oxide staining
	168806	0.01	n.a.	n.a.	Outcrop chip sample: Qtz-feldspar-muscovite pegmatite

n.a.: not analyzed

2.5.8 Besteland – Straume

The presence of a "lost" silver mine in the Straume area of Setesdalen (map Valle 1413 II; 1: 50,000) has been the focus of many prospectors over the years (i.e. Myra, 1962). In 1961, a representative for the Mining Authority visited an exploration pit on the eastern side of Setesdalen near Straume where silver mineralization was reported (Holmsen, 1961). The exploration pit was located on a pegmatite intrusion oriented concordant with the foliation of the mica schist. During this investigation, no mineralization was observed (Holmsen, 1961).

The area was investigated during the summer of 2000. The area was well overgrown and the exploration pit was not located for certainty. However, three samples taken from outcrops and a possible excavation pit showed slightly anomalous gold values (Table L).

In addition, samples collected along a road cut near Besteland on the western side of Setesdalen also showed slightly anomalous gold values (Table P). These samples were biotite schist and pegmatite with iron oxide staining.

2.5.9 Rysstad

Copper mineralization at Rysstad has been reported since the 1800's (Henriksen, 1897). The coordinates given in the NGU database (NGU, 1987c) and the location of the marks on the geologic map by Sigmond (1975) are apparently erroneous. A good description of the location was found in an old claim letter to the Mining Authority (Evje Nikkelverk, 1884), places it at least 3 km west of Rysstad. However, the site has not yet been located in the field. A description of the Rysstad exploration pit reports the occurrence of chalcopyrite (Helland, 19??). The presence of bornite was also reported by Evje Nikkelverk (1884). In addition, Nordrum and Wel (1981) describe pyrhhotite, arsenopyrite, pyrite, together with quartz gangue and accessory graphite. The mineralization is described as a "fahlbånd" type hosted in graphite-bearing gneiss.

Table L: Anomalous gold results from Straume and Besteland areas

Site	Sample number	Gold (g/t)	Silver (g/t)	Copper (%)	Description
Straume					
	168646	0.03	2.5	0.009	Outcrop chip sample: Thin pegmatite vein with muscovite within seritized schist
	168647	0.01	n.a.	n.a.	Block sample near possible exploration pit: pegmatitic granite with abundant muscovite
	168648	0.01	n.a.	n.a.	Block sample near possible exploration pit: seritized schist with minor sulfides
	168649	0.01	n.a.	n.a.	Outcrop chip sample: Muscovite-rich pegmatite vein
Besteland					
	168911	0.02	n.a.	n.a.	Outcrop chip sample: biotite-qtz-schist w/ minor Fe-oxide stains on weathered surfaces
	168912	0.02	n.a.	n.a.	Outcrop chip sample: qtz-biotite pegmatite w/ moderate Fe-oxide stains on weathered surfaces
	168913	0.02	n.a.	n.a.	Outcrop chip sample: qtz-feld-biotite pegmatite & biotite-qtz-feld gneiss w/ minor Fe-oxide staining

n.a.: not analyzed

2.5.10 Kaldvassdalen

A small exploration pit is found in Kaldvassdalen, 3,2 km northeast from the eastern end of Store Björnavatn (Urdenosi, 1413 I; 1:50,000). Highway 45 (Dalen – Rotemo) runs along the northern shore of Store Björnavatn.

NGU's database (NGU, 1987c) reports the presence of nickel and copper at Kaldvassdalen. Nordrum and Wel (1981) report that asbestos was mined from ultramafic rocks at the site by an English company in the 1800's. The geology is dominated by an amphiolite lens-shaped body 1100 x 200 m, with smaller ultramafic intrusions and granitic pegmatites within. Within the altered ultramafic lenses the following minerals are found enstatite, olivine, cummingtonite, tremolite, serpentine, phlogopite, chlorite, chromite, magnetite, spinel, pyrrhotite, millerite, chalcopyrite and pentlandite (Nordrum and Wel, 1981). The granitic to pegmatitic to quartz veins that crosscut the amphibolite are weakly mineralized with sulfides.

The geologic map by Sigmond (1975) shows that Kaldvassdalen is located in a biotite schist zone that together with a narrow band of Bandak Suite rocks lies within a northwest trending structure. This structure is probably a splay of the Mandal – Ustaoset fault zone.

Three of the four samples collected at showed gold values over detection limits (Table M).

Table M: Anomalous gold results from Kaldvassdalen

Site	Sample number	Gold (g/t)	Silver (g/t)	Copper (%)	Description
	168916	0.04	n.a.	n.a.	Block sample: Granitic dikes in amphibolite
	168918	0.02	n.a.	n.a.	Block sample: Hydrothermal quartz vein
	168920	0.06	n.a.	n.a.	Outcrop chip sample: Black finely crystalline ultramafic rock

n.a.: not analyzed

2.5.11 Mosnap Mine

The abandoned Mosnap Mine is located 15 km directly south of Dalen in Fyresdal Municipality of Telemark County. The mine is found at 900 meters about sea level on the northwestern crest of Mosnap Mountain (Dalen 1513 IV; 1:50 000). Mining at Mosnap was conducted between 1866 and 1872. The NGU database (NGU, 1987c) reports the presence of copper, molybdenum, silver and bismuth at Mosnap.

The rocks of the area are composed of quartzite and metaconglomerate of the Bandak Group within the Telemark Suite. Mineralization at the mine occurs as bornite and chalcopyrite (Myhra, 1961). Other minerals include chalcocite, molybdenum, tellurobismuthite, hessite, wittichenite, galena, scheelite, magnetite, hematite (Nordrum and Wel, 1981). Gangue minerals include quartz, calcite, muscovite, chlorite and microcline (Nordrum and Wel, 1981). The ore was reported to occur in two parallel quartz veins, 10 m from each other, with a northerly strike and a dip of 60° to the east. Aplite dikes and thick pegmatite dikes are reported along both zones. Sericite alteration occurs in the pegmatite along the contacts to the quartz veins (Nordrum and Wel, 1981).

One of the adits is reported to be over 100 m long, with several sinks up to 80 m deep (Nordrum and Wel, 1981).

A sample of mine waste was collected and analyzed for gold (0.14 & 0.52 g/t), silver (60.0 g/t) and copper (1.60 %). Nordrum and Wel (1981) reports a silver analysis of clean copper ore with 0.5 % Ag.

2.5.12 Moberg

The Moberg mines are located approximately 5 km west of Mosnap Mine, in Fyresdal Municipality of Telemark County.

Moberg was mined by German miners from 1537 to 1549 (Nordrum and Larsen, 1995). Mineralization includes bornite, chalcopyrite, chalcocite, djurleite, digenite, molybdenum, tellurobismuthite, hessite, wittichenite, electrum, galena, native silver, hematite, quartz and calcite (Nordrum ad Wel, 1981).

Under the cultural preservation law, the remnants of human activity older than 1537 are protected. This sites has therefore not been investigated during this study. However, a quartz vein with hematite sampled in a road cut nearby at Slystøl, to the east, contained 0.02 g/t gold.

2.5.13 Åmdals Verk

Åmdals Verk copper mine is located 8 km south of Dalen in Tokke Municipality, of Telemark County. The deposit was discovered in 1690 and was mined discontinuously until 1945, with a total of 118 years of production (Nordrum, 1972). A mining museum is presently located at the mine.

The majority of the chalcopyrite and bornite occurred in four parallel quartz veins with the orientation N35E and a dip of 54 W (Lindahl, 1976). The veins are hosted in the Bandak Group just west of the large Skafså granite intrusion.

Gold was observed in samples of bornite by Nordrum (1972). Nearly no gold analyses are known, except for a report from the Mining Authority in 1937 which reported 0.3 g/t gold in the copper concentrate (Lindahl, 1976). Silver was reported to be 250 g/t in pure chalcopyrite, and around 100 g/t in the flotation concentrate (Lindahl, 1976).

Two samples of rocks from the mine wastes at Åmdals Verk confirm anomalous concentrations of gold in the rocks (Table N).

Table N: Anomalous gold results from Åmdals Verk copper mine

Site	Sample number	Gold (g/t)	Silver (g/t)	Copper (%)	Description
	168760	0.09	n.a.	n.a.	Composite mine waste (lower) sample: cpy & malachite mineralization in quartz veins in chloritized amphibolites. Lower waste
	16761	0.08	n.a.	n.a.	Composite mine waste (upper) sample: same as above

n.a.: not analyzed

2.5.14 Felland - Ukomdalen - Bratterud

Numerous areas with reported copper mineralization are report between the village of Dalen and west to Moi. Anomalous gold values have been discovered at three areas, Felland, Ukomdalen and Bratterud.

Felland is located approximately 7 km west of Dalen (Dalen 1513 IV; 1:50 000). The site is reported to contain copper and silver (NGU, 1987c). The area lies within a zone of meta-volcanite dominated Bandak group rocks immediately east of the Mandal - Ustaoset fault (Sigmond, 1975). A small overgrown exploration pit was located and both samples taken contained gold concentrations over the detection limit (Table O).

Ukomdalen is located 7 km northwest of Dalen. It is located on the south slope of Vøylås at around 400 meters over sea level, immediately above an abandoned farm Ukomdalen (Foslie, 1918) (Dalen 1513 IV; 1:50 000). Sulfides and copper are reported at the site (NGU, 1987c). There is an exploration adit at the site. Mineralization occurs as veins and impregnations of bornite, chalcopyrite and magnetite at the contact between epidote altered hornblende schist and a limestone body (Foslie, 1918). In addition, Nordrum and Wel (1981) describe wittichenite, hessite and galena. The hornblende schist and the limestone are both part of the Bandak Group (Sigmond, 1975). One sample of this ore showed anomalous gold (Table O)

Nearly 800 meters south of Ukomdalen, at an exploration pit called Tovhus, a sample of bornite and quartz was reported to contain 1.2 g/t Au and 18 g/t Ag (Foslie, 1918). This site has not yet been located.

Bratterud is located approximately 6 km north of Dalen, on the steep eastern slope of the Totak Valley (Vinje 1514 III; 1:50 000). The occurrence of chalcopyrite, pyrite, sphalerite, hessite, tellurobismuth, molybdenum, magnetite and hematite are reported (Nodrum and Wel, 1981). Gangue minerals include quartz, calcite and epidote. In one poorly exposed road cut, chalcopyrite mineralized quartz veins were found crosscutting chloritized amphibolite. One sample was collected at this site, which showed anomalous gold values.

Table O: Anomalous gold results from Felland, Ukomdalen and Bratterud.

Sample number	Gold (g/t)	Silver (g/t)	Copper (%)	Description
168904 (Felland)	0.02	n.a.	n.a.	Chip sample of wall rocks, seritized quartzite
167905 (Felland)	0.02	0.5	0.004	Chip sample of wall rocks, seritized quartzite
168763 (Ukomdalen)	0.16	n.a.	n.a.	Composite adit waste sample: Bornite, po & cpy in marble w/ epidote in hornblende schist
168759 (Bratterud)	0.06	n.a.	n.a.	Outcrop chip sample: Quartz veins with cpy in chloritized amphibolite

n.a. = not analyzed

2.5.15 Rottjørn

Rottjørn is located approximately 10 km north of the village of Åmot (Vinje 1514 III; 1:50 000): The occurrence of sulfides and copper is recorded at the site (NGU, 1987c). Nordrum and Wel (1981) describe chalcopyrite, pyrite within quartz veins in quartzite. Both quartzite and amphibolites of the Bandak Group occur at Rottjørn, and rhyolitic rocks outcrop immediately to the west Sigmond, 1975).

Gold was detected in one of two samples collected, sericite altered quartzite (<0.01 g/t Au) and amphibolite (0.03 g/t Au).

3.0 Conclusions

The grassroots exploration conducted to date show that there is anomalous gold along the Mandal – Ustaoset fault zone. These anomalous values support the model in which the Mandal – Ustaoset fault zone is a deep crustal structure which transported gold upward through the crust. The discovery of gold in both pegmatitic intrusions and shear zones agrees with Cameron's model where gold may be transported as both oxidizing magmas and fluids. The discoveries also agree with Sillitoe's models of gold mineralization related to granitic intrusions.

Large scale geologic similarities between the Mandal – Ustaoset zone to known shear zones hosting gold deposits include the presence of secondary fault structures, a Proterozoic greenstone belt (Bandak Group) and a syn-tectonic granitic intrusions. Geochemical similarities between the zone and known Australian and Fennoscandic Proterozoic gold districts include the gold – base metal association (± silver and uranium), and albitic, quartz, potassic, and carbonate alterations. The metal associations and alteration assemblages indicate that a hot, oxidizing, highly saline $H_2O + CO_2$ fluid was a transport media for the metals.

The presence of alkaline feldspar granite, alkaline granite porphyries, and numerous alkaline pegmatites along the zone are also similar to known Proterozoic gold – copper deposits. These intrusives may have a genetic role in gold transport through the crust, and the release of hot, oxidizing, highly saline $H_2O + CO_2$ fluids during final crystallization that transports gold and base metals. The abundance of iron oxide-bearing granites in the Mandal region, hemtate deposits, and magnetite-bearing pegmatites also support the model of an oxidizing environment.

Two favorable geologic environments are known to exist in the Manal – Ustaoset zone that could have potential for precipitating gold and base metals from chloride complexes. The first environment is intersections of shear zones that are found in several areas based on geologic mapping and lineation studies of satellite photos. The second favorable environment is reducing environments, such as the graphite-bearing gneisses described at Rysstad.

As shown, high grade gold concentrations have been discovered at Straumsfjordheia, Hamre Mine, Rotemo and Bø Mine. These discoveries have not only has lead to the development of exploration targets, it also demonstrates that the concentration of gold in economic grades is possible within the zone. Therefore, further exploration should not only focus on the known targets, but should also involve the exploration for "hidden" gold deposits.

Based on the initial "grassroots" exploration and evaluation project along the Mandal – Ustaoset fault zone, it is concluded that there is a potential for the discovery of economic Proterozoic gold - copper deposits in the area. The most promising areas discovered to date appear to be within Valle and Bygland Municipalities. It has therefore been decided that exploration should be continued in these areas. Other areas of secondary interest are Evje og Hornnes, Åseral, Fyresdal and Tokke municipalities.

Two objectives of the next phase of exploration are I) to conduct detailed exploration of the discoveries from previous field work, and II) to continue regional exploration along the Mandal – Ustaoset zone and related structures. In order to insure appropriate progress in the project these two objectives should be carried out simultaneously. For objective I, it is recommended that detailed exploration be conducted at Straumsfjordheia, Hamre, Rotemo and Bø Mine. This should include detailed geological mapping, detailed geochemical sampling, and geophysics. Several method of geochemical sampling should be considered and some sites tested to determine the best suited method for each area. Methods to be considered are shallow vs. deep soil or till sampling, stream sediment sampling and lake sediment sampling in the case of Straumsfjordheia. Rock chip sampling will continue to be the most direct geochemical exploration tool. Other than gold, silver and copper may be good "pathfinder" metals for identifying exploration targets. Geophysical investigations best suited for discovering gold deposits associated with sulfide deposits include induced polarization (IP), magnetic surveys, gravity surveys, and natural radioactivity surveys with portable scintillation counters.

Objective II is to conduct regional exploration along the Mandal – Ustaoset zone and related structures. Methods for the regional exploration must be suitable to be able to cover larger areas. In the first phase of regional exploration it is recommended that airborne geophysical measurements (gravity, magnetometry and radioactivity) be conducted in areas showing suitable structural settings for gold mineralization. Regional geochemical surveys can be conducted over larger areas. For example, a stream sediment sampling program of rivers and creeks draining in Setersdalen may give an overview of drainage areas with anomalous metals concentrations, quickly and economically.

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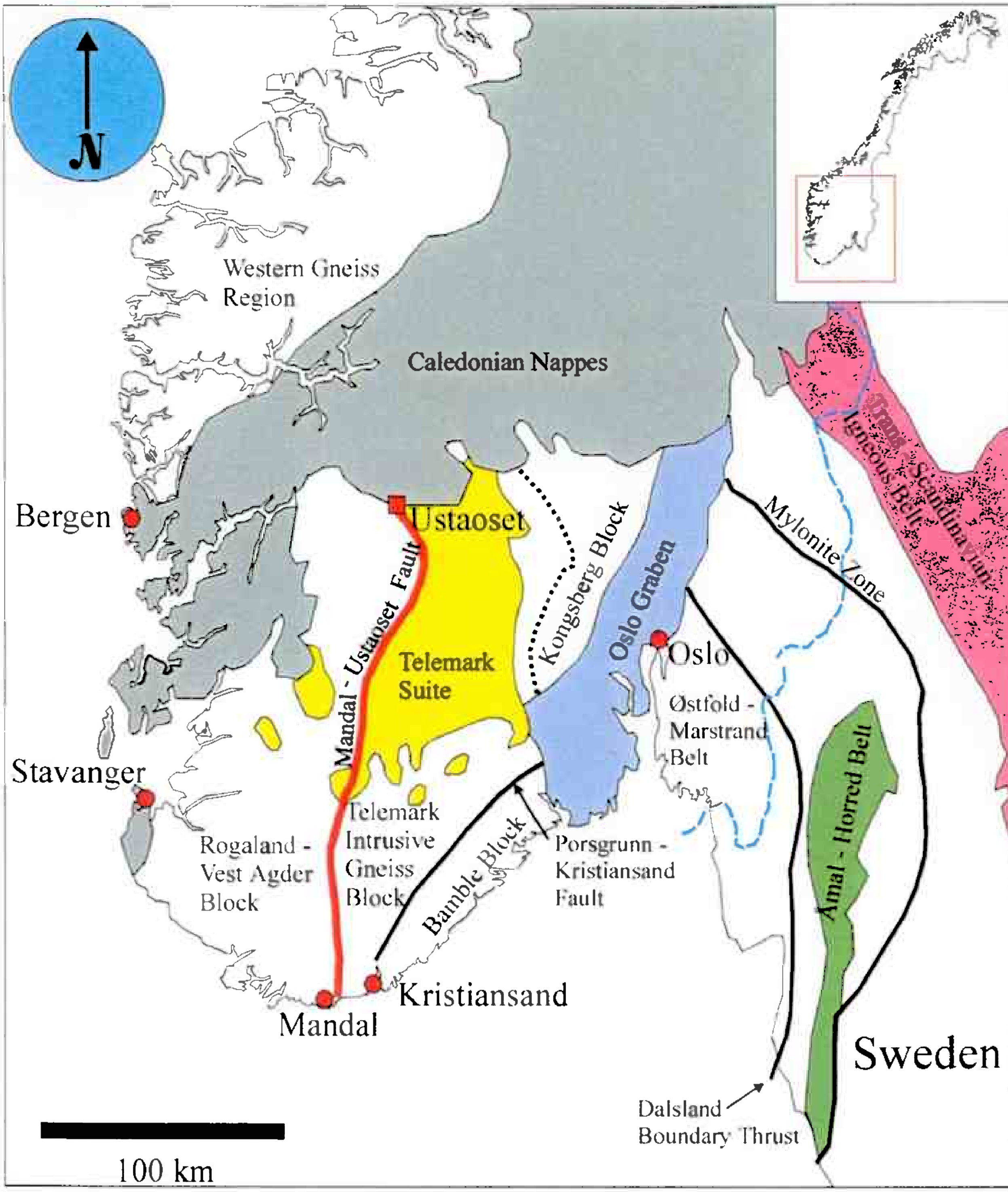


Figure 1: General geologic map of southern Norway and parts of Sweden with Proerozoic terrains and regional structures (Modified after Knutsen et al., 1997)

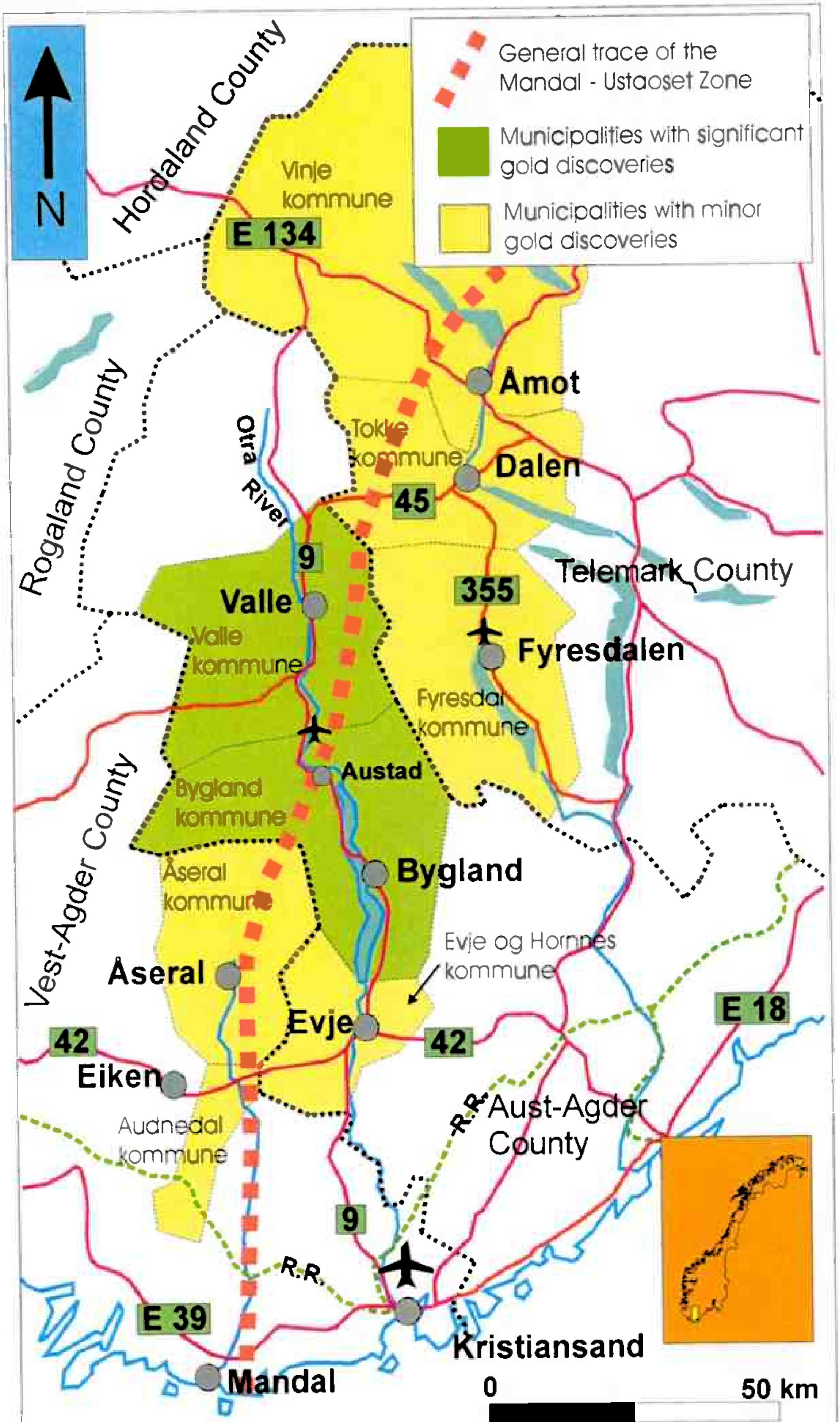
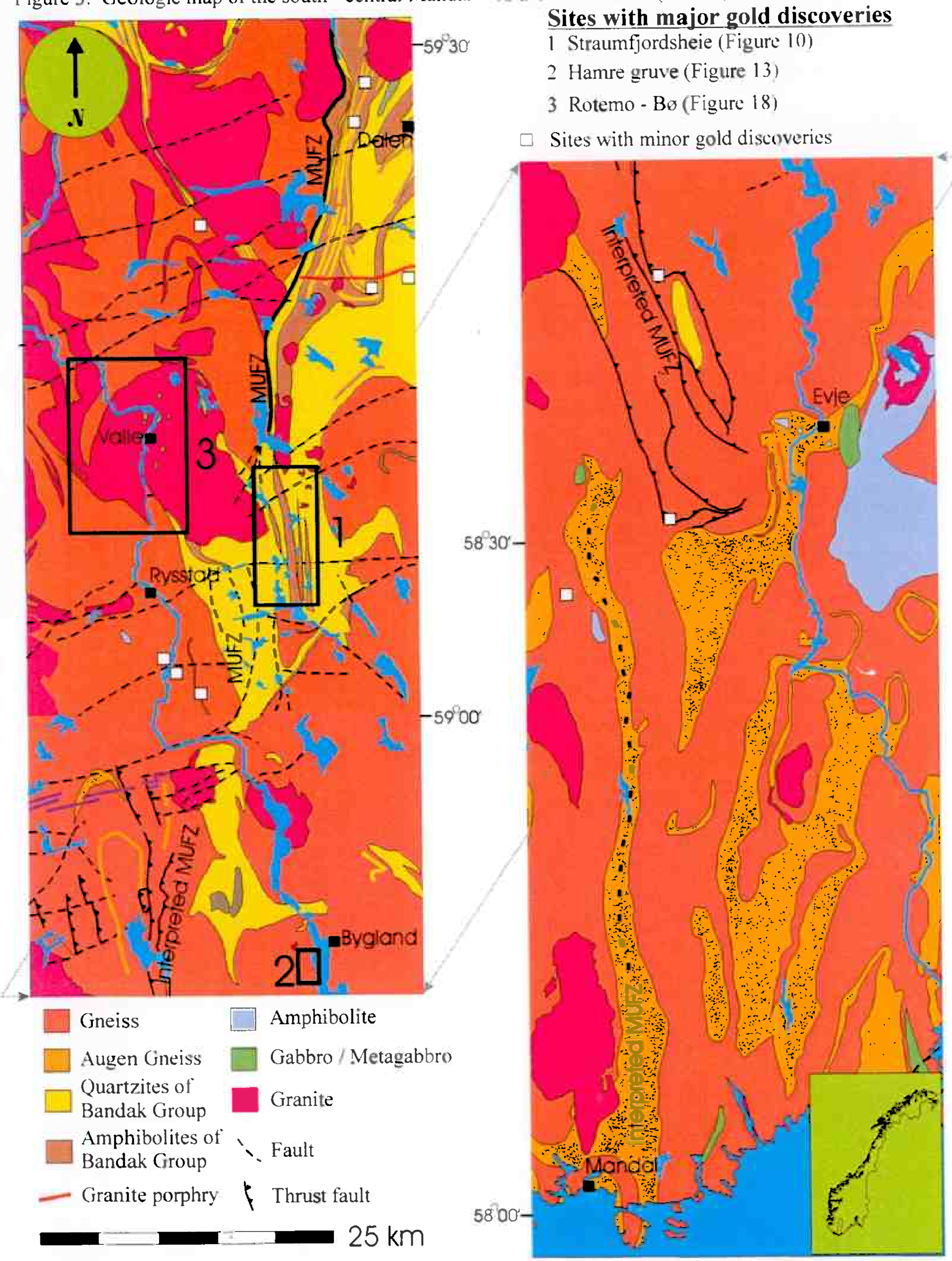


Figure 2: Location map of the south - central Mandal-Ustaoset Fault Zone

Figure 3: Geologic map of the south - central Mandal - Ustaoset fault zone (MUFZ)



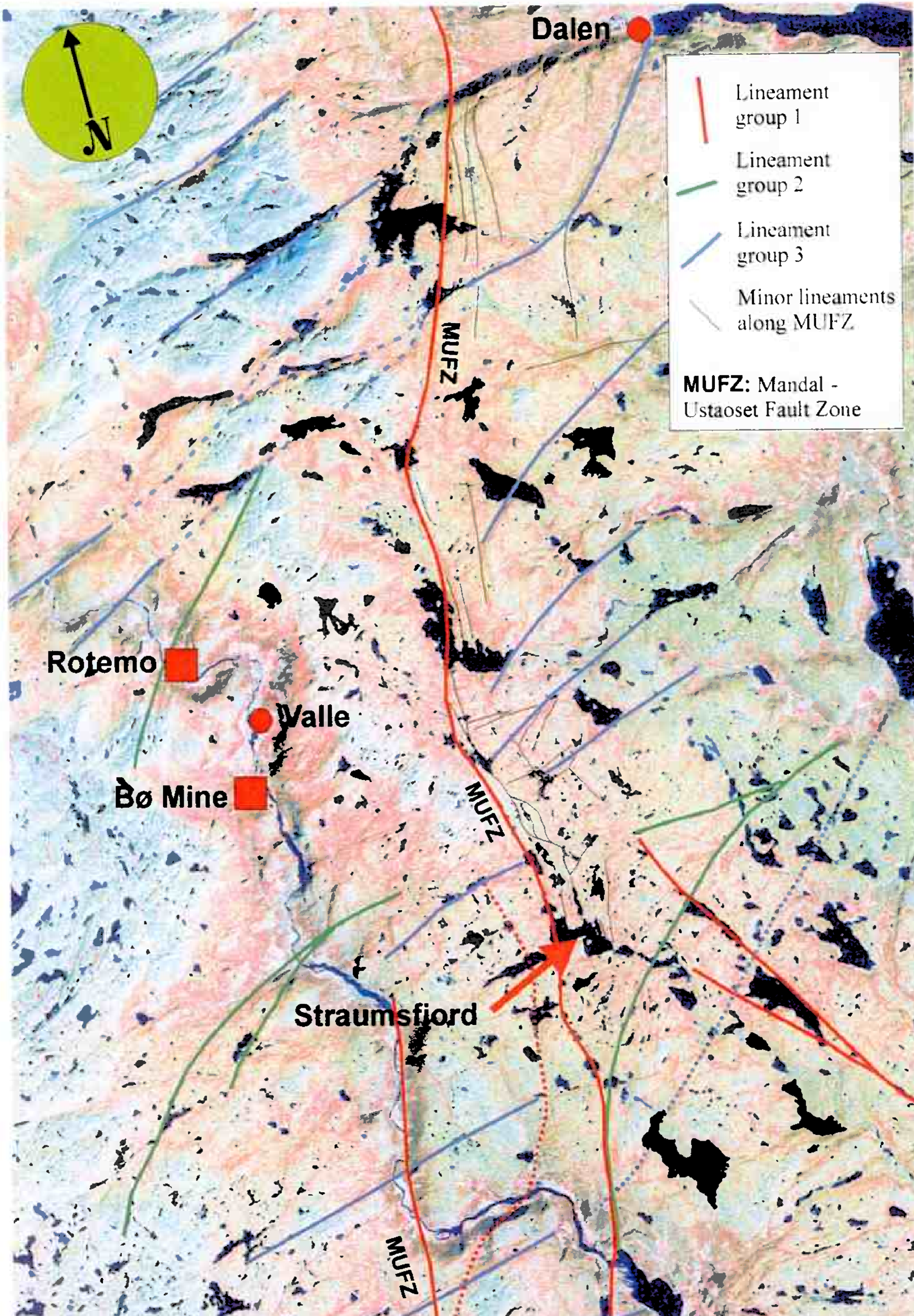


Figure 4: Major lineaments observed in central Mandal - Ustaoset zone from LAND SAT satellite image

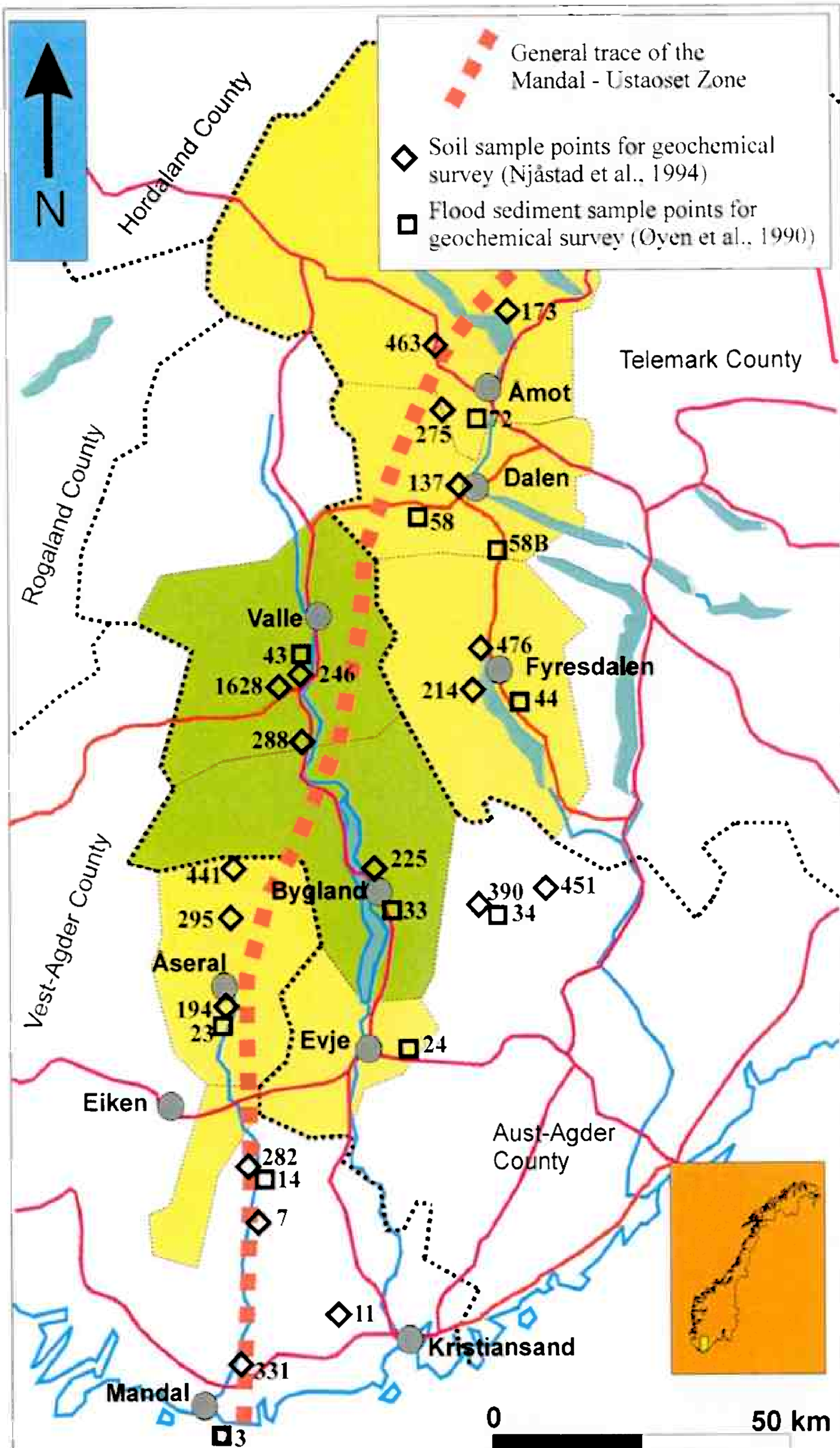


Figure 5: Location map of sample points of previous geochemical studies. Data is presented in Appendix. See Figure 2 for explanation of municipalities.

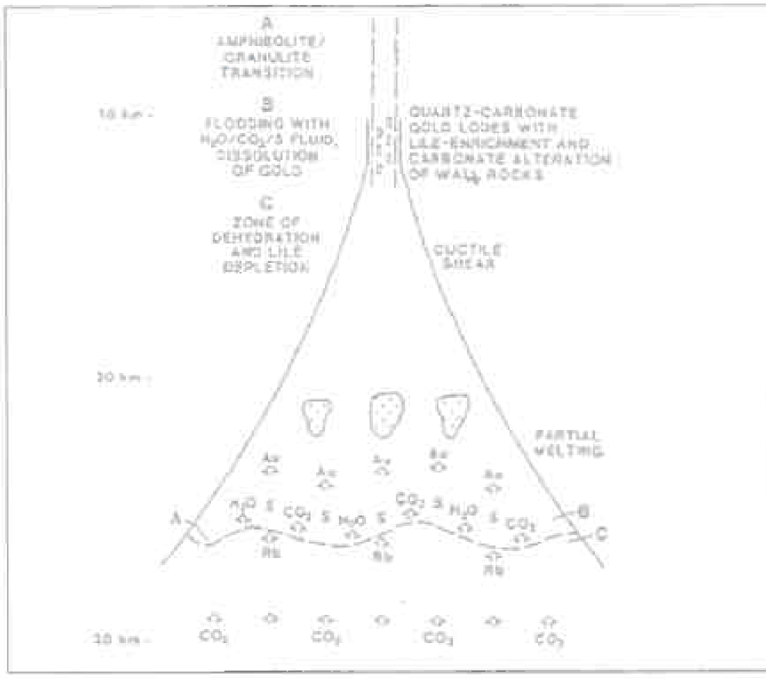


Figure 6: Cameron's (1989a) model of gold transport from deep crust through shear zones

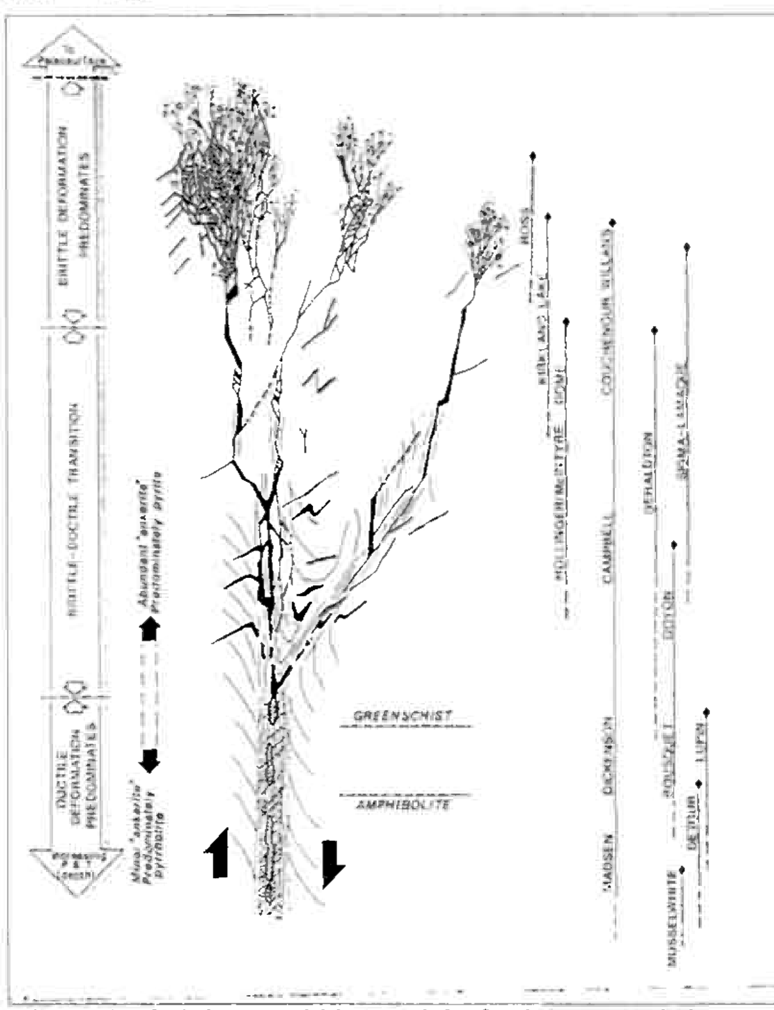


Figure 7: Colvine's (1989) model of a deep crustal shear zone showing transitions between deformational styles and interpretted location of known gold deposits

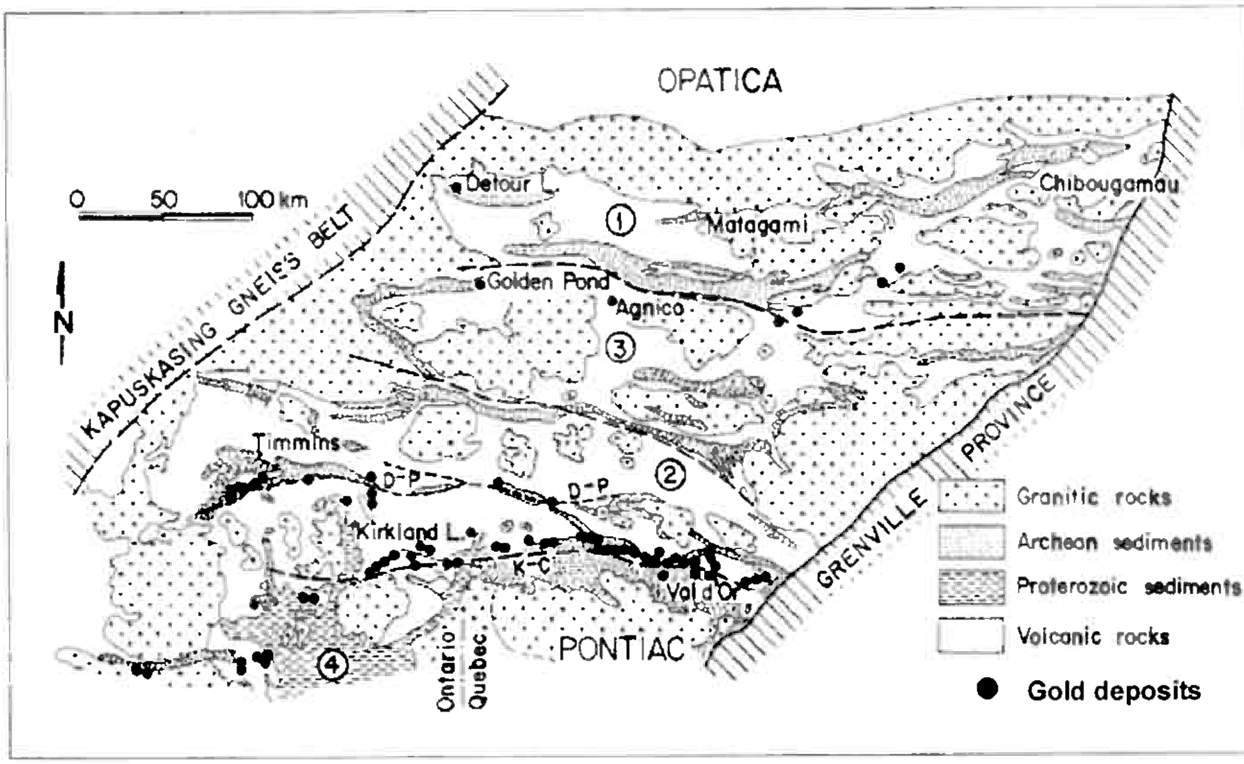


Figure 8: Example of fault systems with location of gold deposits from Abitibi belt in Canada (Kerrich and Feng, 1992)

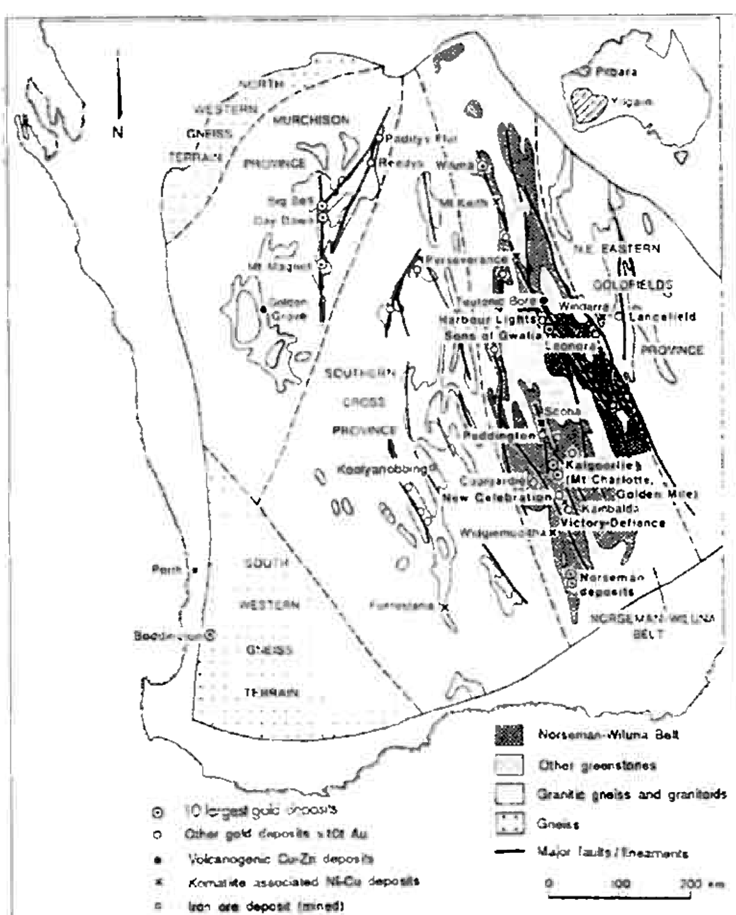


Figure 9: Example of fault systems with location of gold deposits from Yilgarn Block in Western Australia (Groves and Foster, 1991)

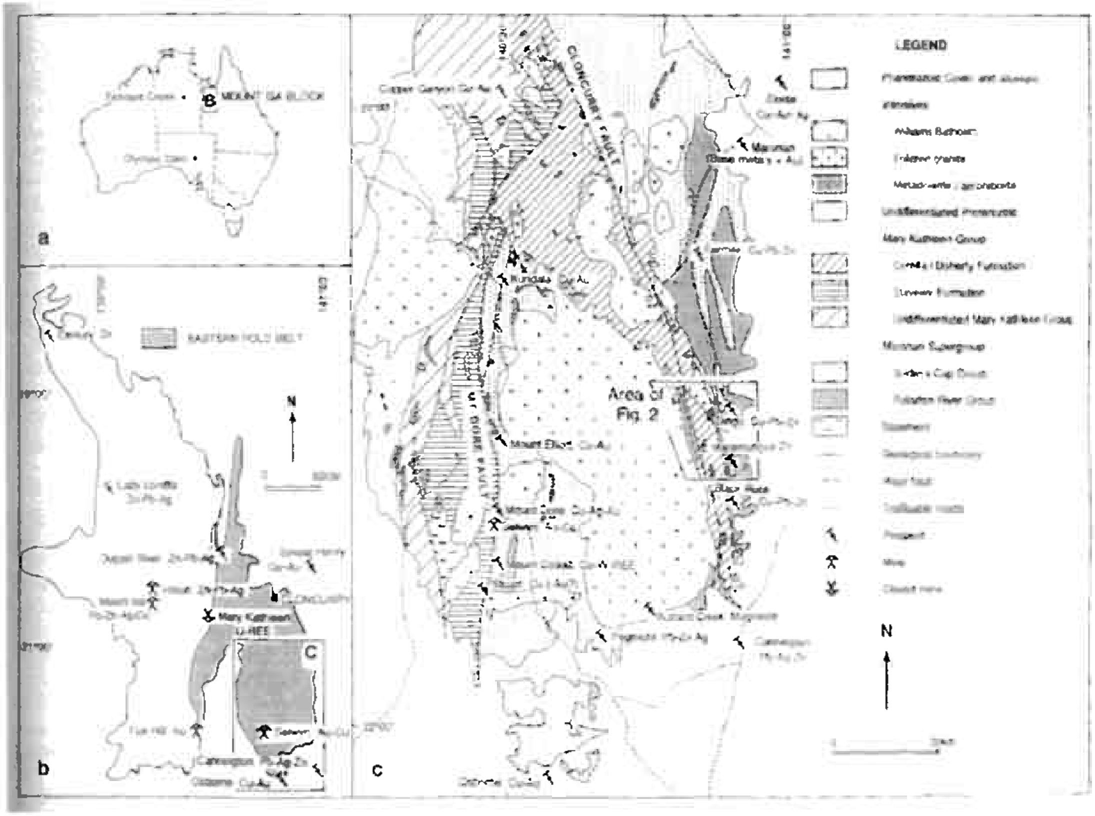


Figure 9b: Example of fault systems and Proterozoic gold-copper deposits in the Mount Isa Block (b) and details of the Selwyn Range (c), Australia (Williams, 1994)..

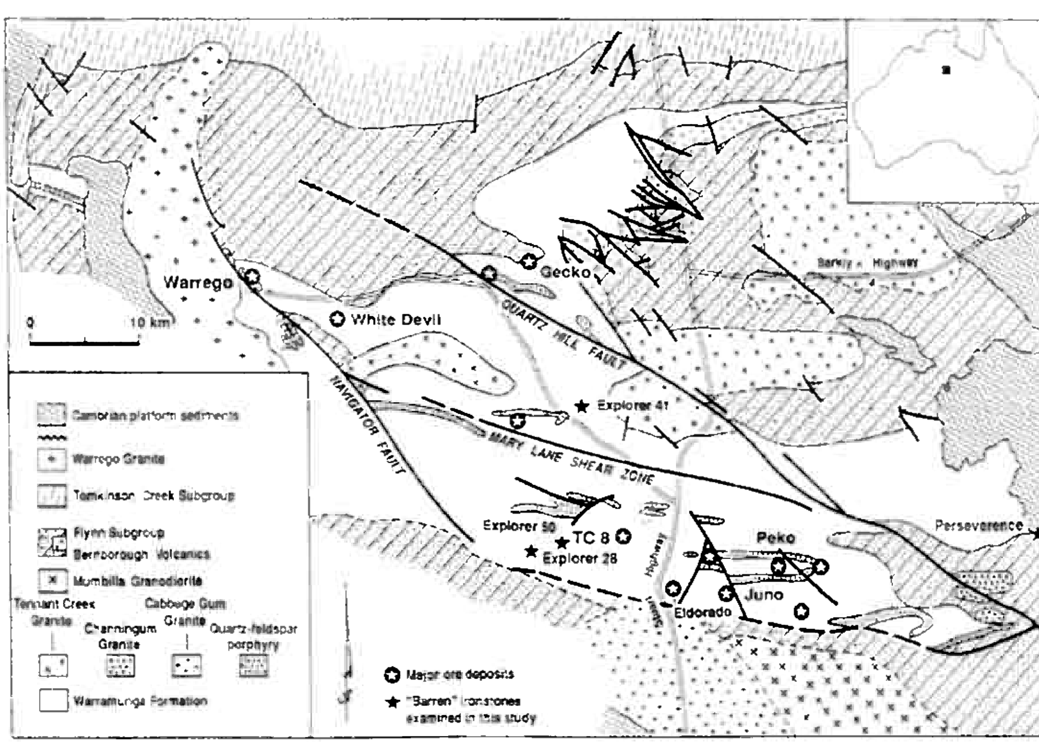


Figure 9c: Example of fault systems and Proterozoic gold-copper deposits in the Tennant Creek gold field, Australia (Zaw et al., 1994)..

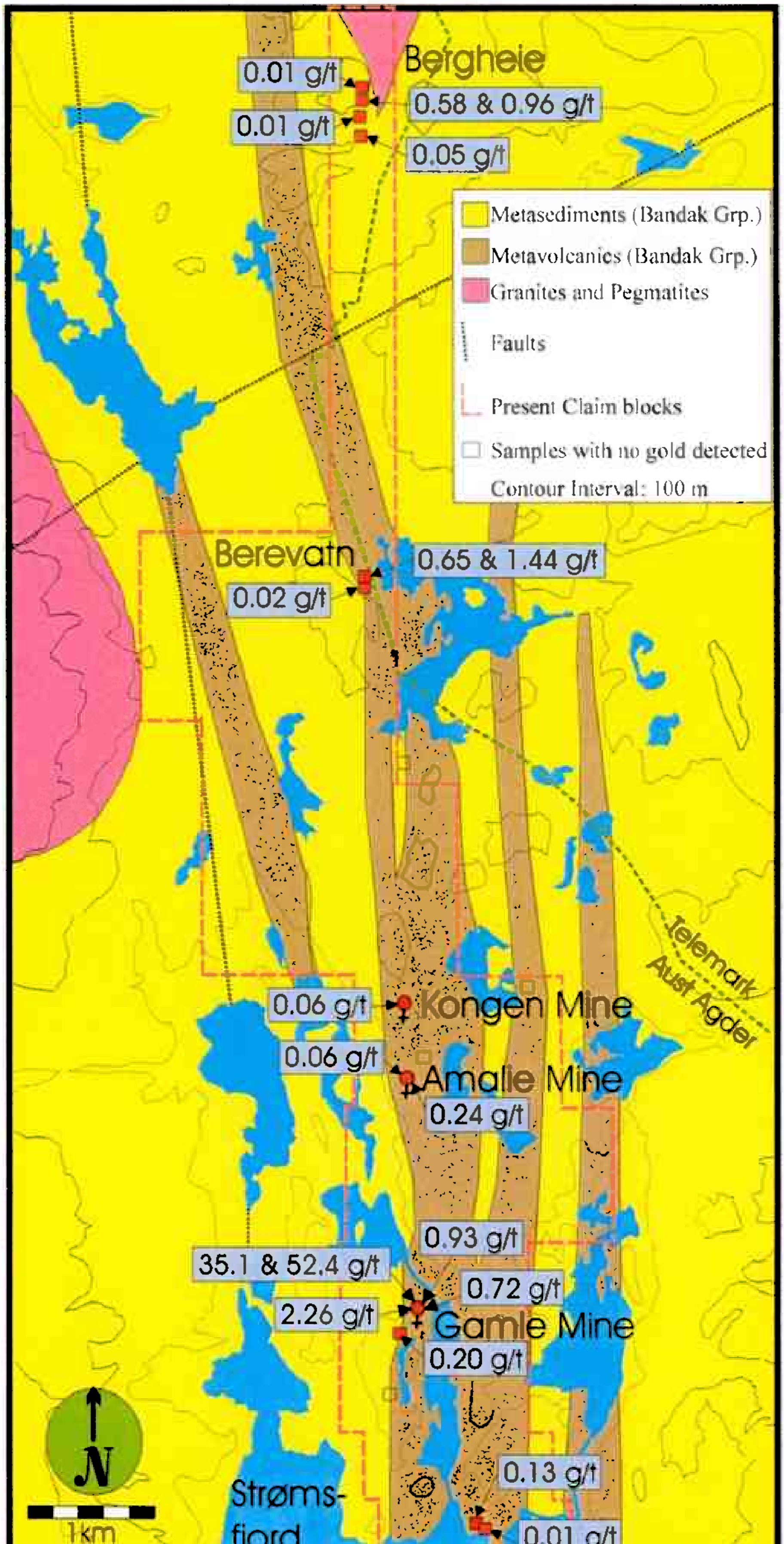


Figure 10: Geologic map of the Straumsfjordheia area. Geology modified after Sigmond (1975) and Neumann (1955).

Figure 11: Photo of Amalie Mine

Figure 12: Photo of the Berevatn exploration pit

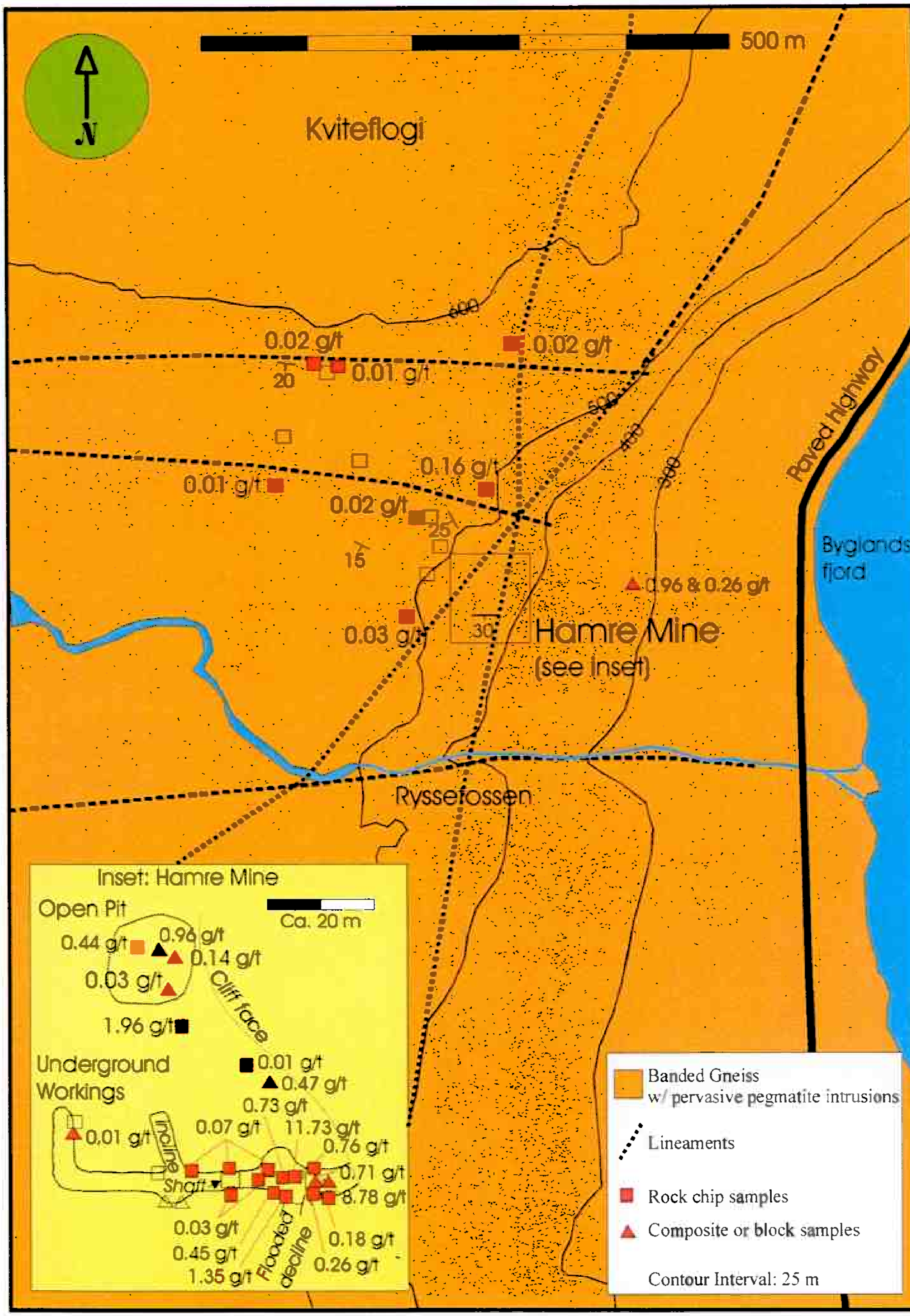


Figure 13: General geologic map of the Hamre area with sample locations


Figure 14: Photo from the portal to Hamre Mine, overlooking Byglandsfjord

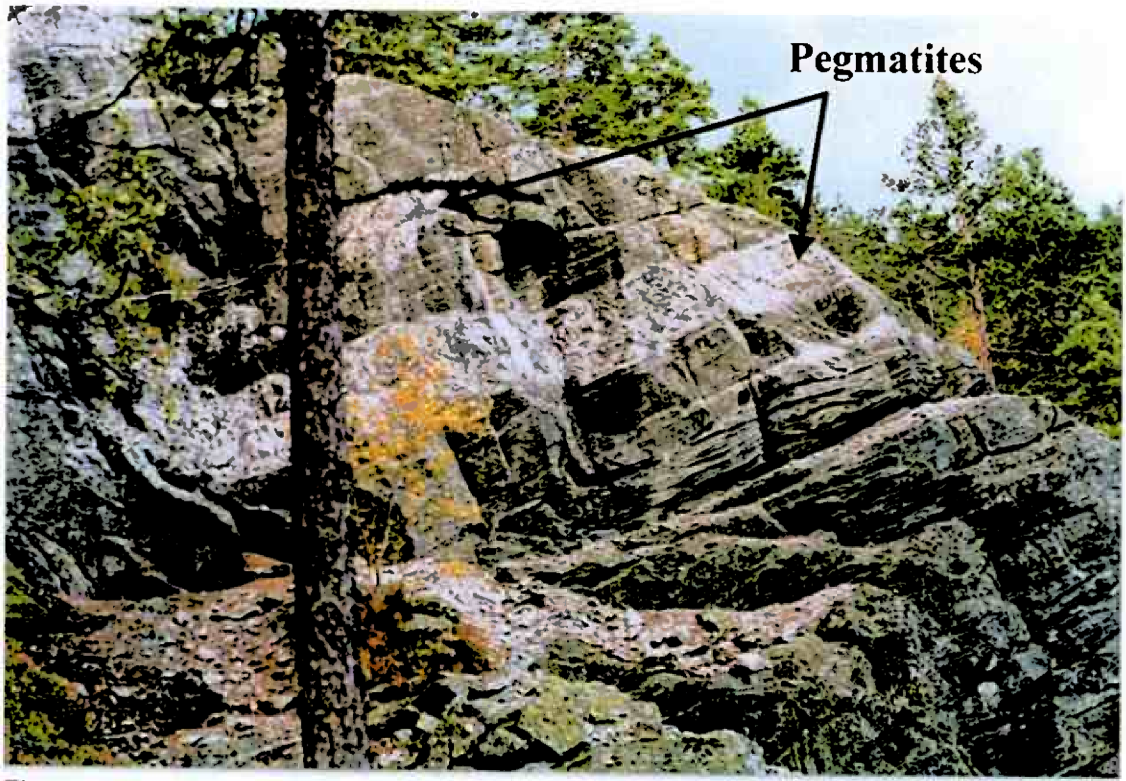


Figure 15: Photo of pegmatite intrusions at Hamre Mine

Figure 16: Photo of the area surrounding Hamre Mine

Figure 17: Photo of the road cut along highway 45 at Rotemo

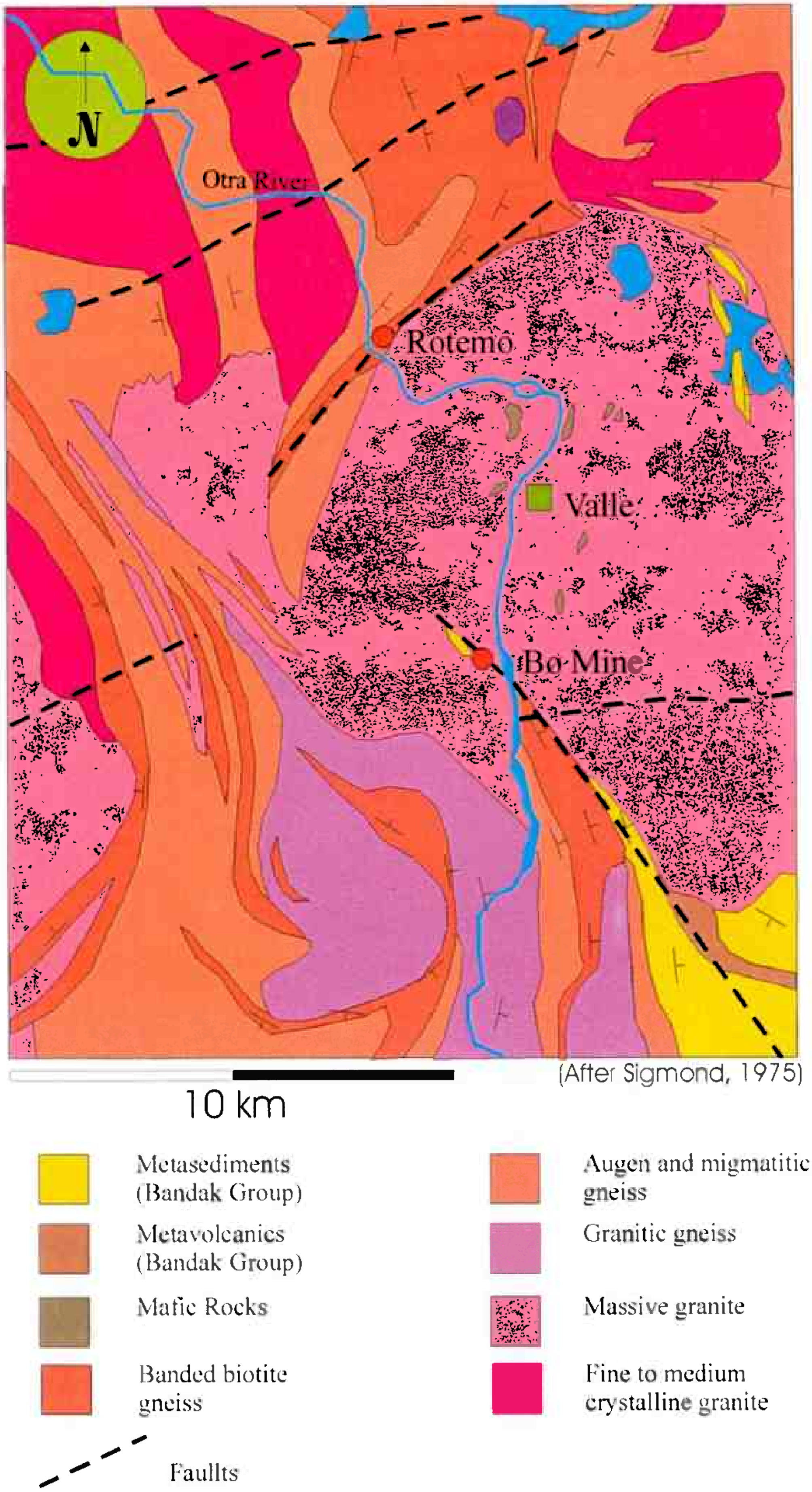


Figure 18: Geologic map o the Rotemo - Bø area

Figure 19: Photo of a pillar supporting the hanging wall at Bø Mine

Figure 20: Photo of the surface exposures of the Bø Mine

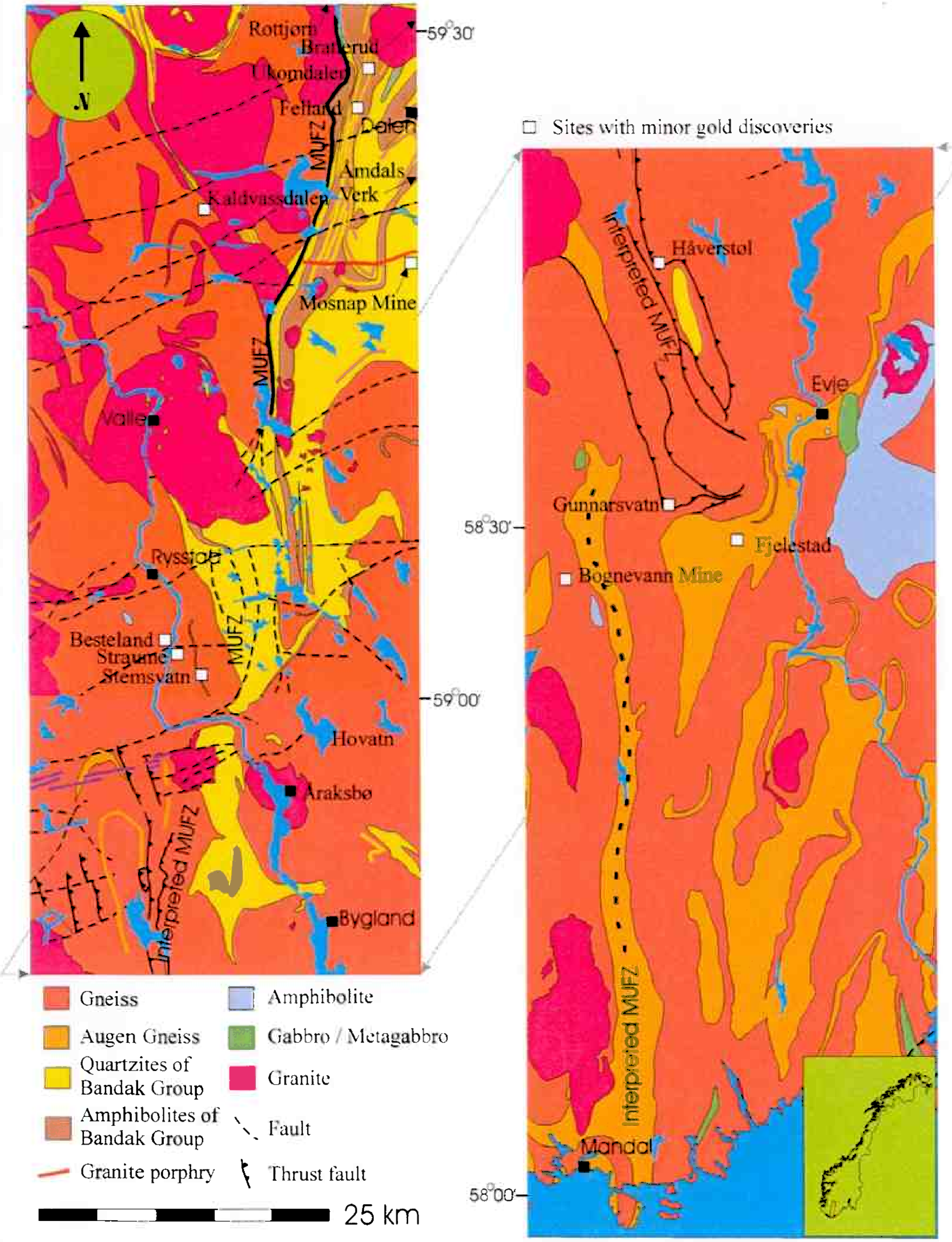


Figure 21: Geologic map of the south - central Mandal - Ustaoset fault zone with localities of minor gold deposits