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52

CONTENTS

	<u>Page</u>
1. Introduction	1
2. The Telemark Supergroup	3
2.1 The initiation of volcanism: The Rjukan Group	5
2.2 Clastic sedimentation: The Seljord Group	10
2.3 Continued sedimentation and renewed volcanism: The Bandak Group, the Leptites and the Vedalen Complex	14
2.4 Basic sills of the Rjukan- and Seljord Groups	18
2.5 A change in volcanism: The Heddevatn Group	19
2.6 Postkinematic granitic magmatism	20
2.7 Tectonics and metamorphism	20
2.8 The regional setting: Conceptual models	27
3. Mineralization of the Telemark district	33
3.1 Introduction	33
3.2 Stratabound mineralization	34
3.2.1 The Rjukan Group	36
3.2.2 The Bandak Group	54
3.3. Vein-type mineralization	70
3.3.1 Pegmatitic-pneumatolytic veins	72
3.3.1.1 Li - Sn - Mo - REE	72
3.3.1.2 Mo - Bi - Cu	74
3.3.1.3 Cu - Ag - Mo	75
3.3.2 Pneumatolytic-hydrothermal veins	78
3.3.2.1 Mo - Cu	78
3.3.2.2 Au - Bi - Fe - Ag - Cu - Pb - Se - W	80
3.3.3 Hydrothermal veins	87
3.3.3.1 Cu - Ag - (Au)	87
3.3.3.2 Fluorite	89
3.3.4 The epigenetic veins in time and space	89

	<u>Page</u>
4. Stream sediment survey	93
4.1 The Svartdal- Rjukan area	94
4.2 The Aslestad area	95
5. Summary and conclusions	97
6. Recommendations	101

APPENDICES

1. Estimate of the total 1983 budget for the Telemark project (20913).
2. Oversight over NH mutinger i Telemark i 1983.
3. Geophysical measurements at Guldnes.
By H. Elstad.
4. Geological report by H.K. Schønwandt on the Heddalsvatnet showings.

PLATES

1. Geological map SKIEN, 1:250.000
2. Geological map SAUDA, 1:250.000
3. Geological map KVITSEID, 1:100.000
4. Geological map RJUKAN, 1:100.000
5. Gothic scenario of southern Scandinavia.
- 6-21 Stream sediment sampling results.

1. INTRODUCTION

This report describes the results of geological reconnaissance work carried out in 1983 in the middle- to upper Proterozoic Telemark supracrustals.

Mining has taken place in the Telemark district for at least three centuries on numerous small but rich occurrences of Cu, Ag, Au, Bi, Mo, Pb and Zn. Most of the deposits mined were epigenetic veins as for instance the Bleka gold vein, but stratabound ore types have been known in the area for some time. With the recent renewed interest in precious metals and the large number of "new" predominantly volcanogenic bulk tonnage gold and silver ore types that have been defined especially in the western U.S.A., it was felt that a reassessment of the precious metal potential of Telemark was worthwhile.

The main aim of this summers work was accordingly to gather enough geological data to be able to motivate an exploration campaign in 1984. This aim was achieved by several methods. Regional geological reconnaissance work was carried out in the Telemark supracrustals and a literature study undertaken in order to define conceptual depositional models of the supracrustals and hence at a later stage delineate possible types of precious metal mineralization which may be expected to occur. As an aid to this work, and with a view to test the precious metal distribution in known mineralization, a number of old mines were superficially investigated and sampled. From limited previous work in the area and from the literature, the abandoned mines Guldnes, Hovin and Listøl were selected for closer investigation and sampling as they could represent examples of stratabound mineralization; two of these mines

were investigated by consultants P.M. Ihlen and H.K. Schönwandt. Sampling of low grade sulphide mineralization of various types was carried out during the regional reconnaissance and led to the discovery of hitherto unknown low grade Au-Ag-bearing horizons.

Two areas of which one contains the abandoned Bleka gold mine were selected to test the effectiveness of exploration by stream sediment sampling in this high-altitude, glaciated terrain, and one of the mines with stratabound ore (Guldnes) was covered by an IP/resistivity and ground mag. survey in order to define the geophysical response of this type of ore.

A total of 214 lithogeochemical samples and 236 stream sediment samples were collected and shipped to Mercury in Ireland for analysis for Au, Cu, Pb, Zn, Ni, Co, Bi, Ag and W.

A total of 48 man-weeks were spent in the area, including the work of three geologists (FDP, PMI, HKS), one engineer (Elstad) and four assistants (Elstad, Veisal, Norup, Thomsen); details are given in Appendix 1.

An estimate of the final budget for 1983 totals kr. 700.320.- inclusive of reporting; details are given in Appendix 1.

This report contains four major sections. The first part describes the lithologies and structures of the supracrustals, a scheme of development is established and conceptual depositional models for the supracrustals are proposed. The second part describes known and newly discovered mineralization of the district; it is divided into two chapters on stratabound and vein-type mineralization respectively. The third part gives a brief summary of the stream sediment survey and the fourth part consists of a summary and recommendations for further work in the area. A summary of the current Norsk Hydro claims in this district is given in Appendix 2.

2. THE TELEMAR SUPERGROUP

The supracrustals of the Telemark Supergroup comprise a sequence of acid and basic volcanics, quartzites, conglomerates, schists and subordinate marbles. In the central part of Telemark these supracrustals are up to 7000 m thick and occupy an area of approximately 9000 km² (Plates 1 and 2). Smaller areas occur in western Telemark, the Egersund area (Versteve, 1975; Falkum, 1982), and the widespread Fjordane supracrustal complex to the north of Telemark may similarly correlate with the Telemark Supergroup (Bryhni and Grimstad, 1970). In eastern Norway and in Sweden an area of approximately 19 000 km² consists of the sub-Jotnian Dala acid porphyries and overlying Jotnian quartzites. On the basis of similarity of lithologies and radiometric age determinations these rocks have been considered an equivalent to the Telemark Supergroup (Priem et.al., 1969).

The Telemark and Dalane supracrustals discordantly overlie older, in most cases Svecokarelian basement gneisses and granites. However, this relationship is by no means clear in Telemark due to remobilization of the basement during the postdepositional Sveconorwegian orogeny. Recent mapping in western Telemark nevertheless indicates a true basement-cover relationship (Sigmond, 1978) and a depositional contact has been reported by Naterstad et.al. (1973) from northwest Telemark. In Sweden the deposition of the Dalane complex postdates deformation and migmatization of the older basement gneisses (Lundqvist, 1979).

Radiometric datings of the Telemark Supergroup show the influence of postdepositional metamorphism and deformation to various degree. Versteve (1975) reports a Rb-Sr whole-rock "isochron" on acid metavolcanics from the lowermost Rjukan group indicating an age of formation of approximately 1665 Ma. Priem et.al. (1973) presents a number of Rb-Sr age determinations on acid metavolcanics from various formations of the Telemark Supergroup and concludes that the age of the

oldest supracrustals equals that of the Dala-porphyries in eastern Norway as previously determined by Priem et.al. (1969), i.e. 1570 ± 40 Ma. However, that part of the Dalane complex which is exposed in eastern Norway has been subjected to weak Sveconorwegian metamorphism and deformation (Dons, 1960) which may have caused some disturbance of the radiometric systems. In accordance with this Welin and Lundqvist (1970) reports Rb-Sr datings of undeformed Dala porphyries of 1635 Ma, equivalent to Versteeg's (1975) dating of the oldest Telemark supracrustals.

The youngest formations of the Telemark Supergroup belong to the Bandak and Heddevatn Groups, which may have formed as late as 1200-1000 Ma ago, i.e. during the initial stages of the Sveconorwegian orogeny (Sigmond, 1978; Oftedahl, 1980).

Basaltic dykes cross cutting the Dala porphyries and the overlying Jotnian quartzite have been dated at 1220 Ma and thus provide an upper possible age for the formation of a major part of this quartzite (Lundqvist, 1979).

The upper age limit of the Telemark supracrustals are determined by a number of granite intrusions which show radiometric ages of approximately 1100-800 Ma. (Killeen and Heier, 1975).

The available age determinations thus indicate that volcanic activity in the Telemark and Dalane regions began at approximately 1650 Ma ago and that deposition of supracrustals may have continued for more than 500 million years.

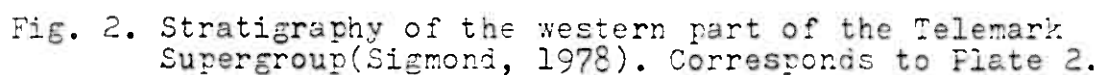
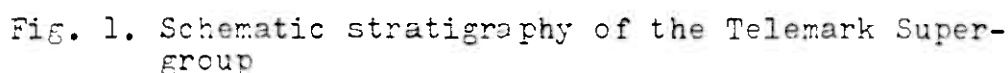
The Telemark supracrustals may be divided into four major units comprising one or more formally defined stratigraphic groups. From oldest to youngest these are (Dons, 1960; Sigmond, 1978; Annis, 1980): the Rjukan Group; the Seljord Group; the Bandak Group (equivalent to the so-called leptites and their northern continuation, the Numedal Group); and the Heddevatn Group.

The Rjukan- and Seljord Groups attain their largest thicknesses of more than 1000 m and 4000 m respectively in the central part of Telemark (Fig. 1), and have been folded and eroded before the deposition of the overlying strata: The leptites and the equivalent Numedal Group towards the east (minimum thickness of 3000 m), the central Bandak Group which attains a thickness of at least 2200 m, and the ca. 800 m thick western continuation of the Bandak Group, named the Blåbergås Group (Sigmond, 1978). The westernmost Heddevatn Group conformably overlies the Blåbergås Group and attains a maximum thickness of at least 3200 m (Fig. 2).

2.1 THE INITIATION OF VOLCANISM: THE RJUKAN GROUP

As originally defined in the Rjukan-Gausta area the Rjukan group comprises two formations: the lower predominantly acid volcanic Tuddal formation and the predominantly basic volcanic Vemork formation (Dons 1960). Dons' (op.cit.) work and later investigations have shown that a number of other rock units correlate with the Rjukan group, occurring in the following regions: Numedal; Brunkeberg-Seljord; Nissevatn-Fyresvatn-Amlí; Sæsvatn-Valldal.

The acid volcanics of the Tuddal formation comprise a large number of rock units related to the formation of explosive centers including welded tuffs, tuffs, lapilli tuffs, agglomerates, ? lahars, intrusive breccia pipes and probably small, dome-like intrusions. A few units, especially tuffs and welded tuffs which may have been deposited as ignimbrites, show a large thickness and a wide lateral extent, but in general the Tuddal formation is characterized by rapid lithological changes.



The lavafloWS are of green, grey, reddish, brown, yellowish and white colour and vary in texture between glassy or flint-like, aphanitic, quartz- and/or feldspar porphyritic and flowbanded (Fig. 3). Detailed mapping by Wyckoff (1934) in the Tuddal area indicate that typical acid flows are a few km long and some hundred meters thick in accordance with their original high-viscosity (rhyolitic) properties. Devitrification features such as lithophysae are widespread, in places completely replacing the original volcanite (Fig. 4).

Tuffs and lapilli tuffs exhibiting varying degree of welding form the major part of the Tuddal formation. They are generally of grey to reddish colour and vary in texture between aphanitic, dense to granular, quartz-feldspar porphyritic, and finely layered (Figs 5; 6). The tuffs form units of great lateral extent and with thicknesses of more than 600 m as seen for instance along the southern slope of the Rjukan Valley. Post-depositional deformation and metamorphism which increases in intensity north and east from Rjukan have transformed the tuffs into schistose and foliated quartz-feldspar - mica schists.

Agglomerate beds are frequently interbedded with the tuff-units and show gradations to the lapilli tuffs. The agglomerates consist of rounded to angular pebbles and blocks of acid and locally basic volcanics in a tuffaceous groundmass of quartz, alkali feldspar and sericite. A flow breccia, described by Dons (1960) is characterized by an extreme lack of sorting and may represent a mudflow (lahar).

Isotropic and homogenous rock units which may represent intrusive rhyolite porphyries have been noted in the Follsja area. They consist of an aphanitic, grey matrix with ca. 15 vol% yellowish feldspar phenocrysts (Fig. 7).

In the Tuddal area Wyckoff (1934) has described five small oval breccia pipes which occur along a 2 km long, north-south trending zone. They show sharp, subvertical contacts to the

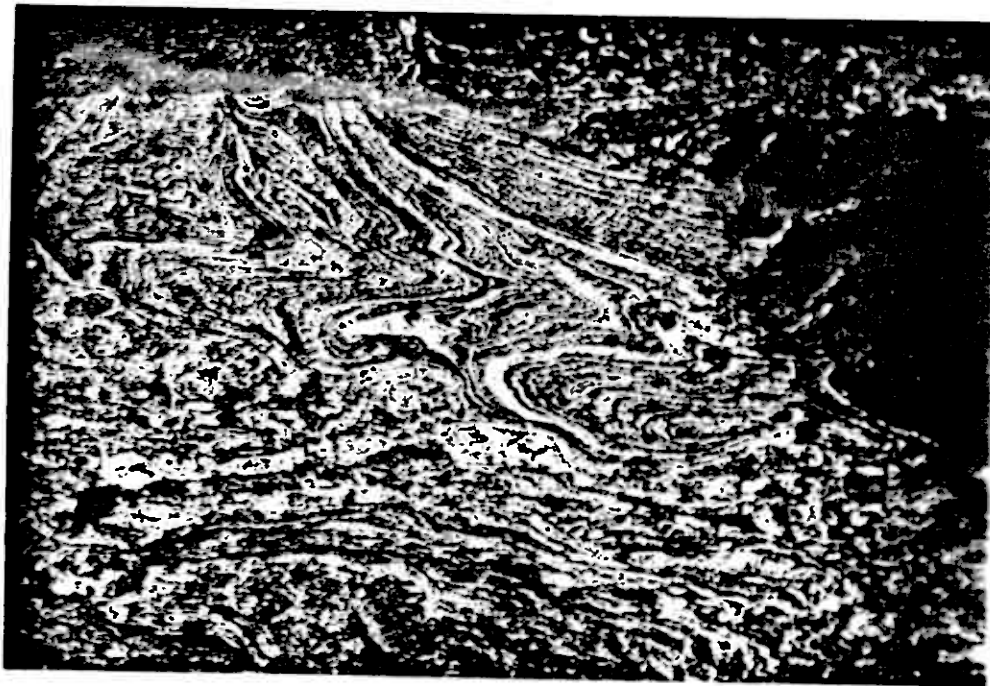


Fig.3. Flowbanded rhyolite north of Bjukan. Width of field ca. 30 cm.



Fig. 4. Lithoclastic in rhyolite flow, NW of Tuddal

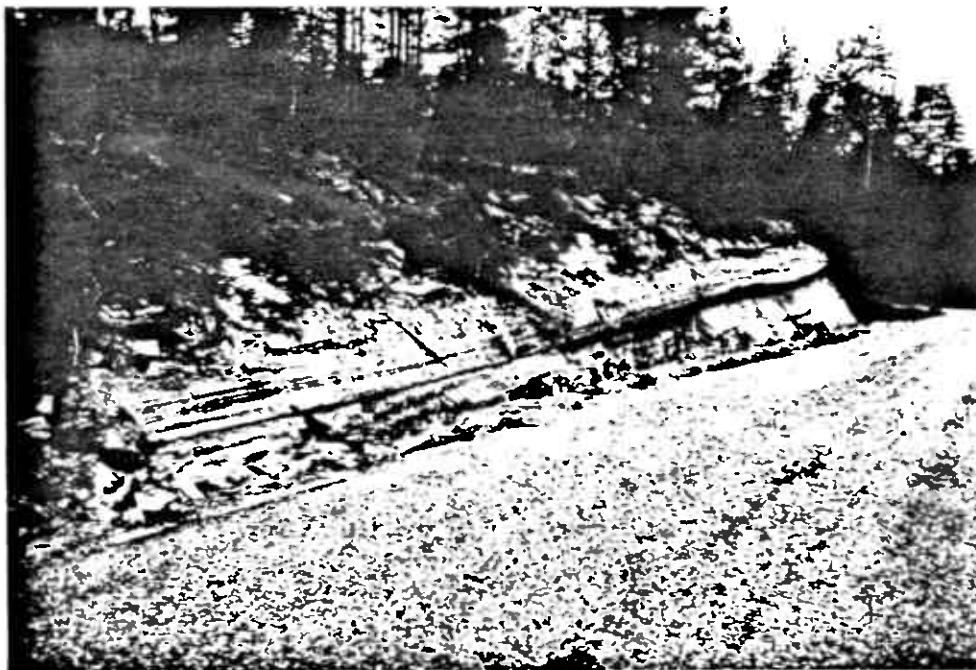


Fig. 5. Finely layered sequence of acid (crystal) tuffs along main road north of Follsjå.



Fig. 6. Welded tuff along main road to Veggli.



Fig. 7. Rhyolite porphyry with quartz- and feldspar phenocrysts. Along road from Föllsjå to Gransherad.

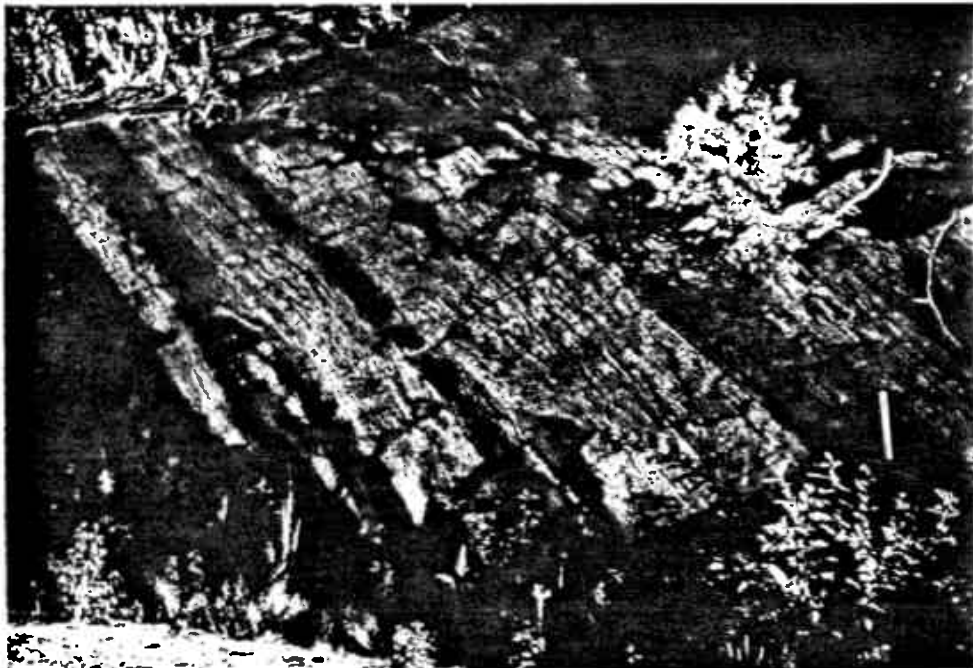


Fig. 8. Interlayered acid and basic (dark) tuffs. East shore of Tinnaja near Gjuvsjå.

surrounding acid tuffs and flows and consist of rounded, 0.5 to 2 cm sized quartz "pebbles" and up to 2 cm sized feldspar grains in a finegrained, biotite-rich quartz-feldspar matrix.

A number of basic volcanite beds are interlayered with the acid volcanics of the Tuddal formation, reflecting the bimodal character of the Rjukan group. These basic intercalations have previously been described as sills, of which some actually do occur in the Tuddal formation. However, this summer's work has shown that the majority of the basic rocks represent tuffs, agglomerate layers and basic flows, in places exhibiting pillow structures (Fig. 8; 9). These volcanites are in every respect similar to the overlying Vemork formation and clearly reflect the initial stages of basaltic volcanism.

The Vemork formation rests conformably on the Tuddal formation (Fig. 2, Plate 1). Its lower part consists of a more than 100 m thick basaltic agglomerate/conglomerate and tuff unit which is well exposed in the western part of the Rjukan Valley. This is followed upwards by a monotonous sequence of basic tuffs, massive and porphyritic flows and occasional agglomerate beds. In general these rocks are confined to the least deformed parts of the Telemark Supergroup and accordingly appear as greenschists consisting of chlorite, biotite, epidote, albite and calcite (ankerite). Minor intercalations include pebbly arkoses, greywackes and shales (biotite schists).

The Haglebu Metatuff described by Annis (1980) from the Numedal region situated to the north from Tinnsjø (Plate 1), occupies a stratigraphic position which is equivalent to the Rjukan Group and is accordingly correlated with this. The Hagleby Metatuff is more than 2000 m thick and occupy a vast area. It is characterized by its grey to pink colour and a massive to mottled appearance due to the presence of lithic siliceous fragments. The metatuff has been metamorphosed to a clinozoisite-biotite-quartz-albite schist, with ferrohast-ingite porphyroblasts making up about 10% of the rock.



Fig. 9. Pillow structure in basic tuff- and agglomerate sequence interlayered in an acid volcanic sequence; near Håkånes (Tinnsjø).



Fig. 10. The bottom of a small erosion channel in impure quartzites near Hovin at lake Tinnsjø. Note the pebbles (white).

In the Brunkeberg-Seljord district the Rjukan Group is developed more or less as in the northern areas, i.e. it is dominated by acid tuffs and flows. However, it contains minor intercalations of orthoquartzites, conglomerates, and basic flows and tuffs (Plate 3. Recent investigations in the region to the northeast of the Bandak granite (see Plate 3) have shown that the area Brunkeberg - Tveitgrendi - Årnotra is a part of the Rjukan Group and not, as hitherto assumed, the Bandak Group (Nielsen, pers. comm.). This area hosts a number of important mineral deposits including the Listøl As-mine, and consists of interlayered acid quartz-feldspar porphyritic tuffs, and basic chlorite-amphibole schists probably representing basic tuffs.

The Nissedal supracrustals are situated to the east of lake Nisser (Plate 1) and are known as the most host for the Søftestad iron ore deposit. The supracrustals occur in amphibolite-facies grade metamorphic terrain and comprise a sequence of basic and acid lavas, tuffs and agglomerates, the latter frequently carrying quartzite fragments (Mitchell, 1967). Characteristically the volcanics show evidence of alternating acid and basic extrusions with a predominance of basic rocks. The volcanics have been intruded by gabbros which have been altered to hyperites during the subsequent metamorphism. Although no direct correlation is possible it is assumed by several authors (e.g. Ploquin, 1980) that the Nissedal supracrustals are equivalent to the Rjukan Group.

Two small areas with supracrustals occurring between lakes Fyresvatn and Nisser have tentatively been correlated with the Rjukan Group (Stout, 1972; Plate 1). At Momrak on the eastern shore of lake Fyresvatn Stout (op. cit) defined the Lintjörn formation which predominantly consists of biotite schists with minor intercalations of amphibolite, quartzite and cordierite - gedrite gneiss. This is overlain unconformably by basic volcanic rocks which correlate with the Bandak Group and

therefore (in conjunction with the lithology) suggest the above mentioned correlation between the Lintjörn formation and the Rjukan group.

To the south of lake Fyresvatn and Nisser small areas with highly deformed and metamorphosed acid and basic volcanics occur. No direct correlation with central Telemark is possible, but on the basis of similarities in lithologies, petrochemistry and in part structure, Ploquin (1980) has suggested that these rocks may correlate with the Rjukan group.

Metasupracrustal rocks belonging to the Breive group (Sigmond, 1978) occur near lake Store Foresvatnet in the central part of map sheet Sauda (Plate 2). They consist of amphibolites and leptytes representing basic volcanics, metaquartzites, metaarkoses and/or acid metavolcanics, and they show more intense folding than the overlying strata. A discordant relationship to the latter is not possible to demonstrate directly, but a discordance is clearly seen in the geological map (Sigmond, op.cit.). These features suggest the correlation with the Rjukan group which is shown in Fig. 2.

Relatively few chemical analysis have been carried out on rocks of the Rjukan group. The felsic Hagleby Tuff of the Numedal region is described as being of dacitic composition (Annis, 1980), and Moine and Ploquin (1972) and Ploquin (1980) describe the rocks of the Tuddal formation in general terms as alkaline, siliceous and leucocratic with sodic rhyodacitic and potassic rhyolitic compositions. The SiO_2 content is in general above 71-73% with some analysis showing more than 77% SiO_2 ; rocks with less than 71% SiO_2 are rare. The acid volcanics are depleted in MgO and total Fe and the typical $\text{K}_2\text{O}/\text{Na}_2\text{O}$ ratio is ca. 2.25. A sodic trend is apparent towards the southern region (Brunkeberg-Nisser). Ploquin (op.cit) further characterizes the basic lavas of the Vemork group as basalts with a potassic trend, some exhibiting trends towards andesitic compositions.

In summary, the bimodal character of the Rjukan Group volcanics; the wedge-shape of the deposits; and the evidence of an underlying continental crust strongly suggest that these rocks were deposited in fault-controlled basins on the Baltic shield formed in response to extensional tectonism. The bulk of the acid volcanics have characteristics reminiscent of ignimbrites and may therefore have been related to the formation of calderas. The subsequent basaltic volcanism may have taken place as fissure eruptions in response to continued rifting or may have been related to shield volcanoes.

2.2 CLASTIC SEDIMENTATION: THE SELJORD GROUP

The rocks of the Seljord group consist predominantly of very pure quartzites with intercalations of conglomerate and various types of schists. They occupy large areas in central and eastern Telemark and may be traced continuously to the northerly Numedal region where quartzites form widespread deposits (Plates 1, 3 and 4). The group attains its greatest present thickness in the slightly deformed Rjukan-Gausta area where a minimum thickness of 4 km has been estimated (Ofstedahl, 1981). Towards the west the thickness of the quartzites rapidly diminishes (Fig. 2). Thinning may similarly take place towards the east although the postdepositional deformation obscures the relations in this region. Towards the north a thickness of ca. 3000 m has been estimated in the Numedal region.

In the Rjukan area the base of the Seljord group is developed as a thick conglomerate containing pebbles of quartzite, of the underlying basic and acid volcanics of the Rjukan group and of granitic gneisses which may represent basement rocks. This basal conglomerate is, however, not a universal feature of the Seljord Group. In the Seljord-Brunkeberg area very thick and extensive conglomerate horizons occur which previously have been interpreted as a basal conglomerate of the Seljord Group (Plate 1). The pebbles of these conglomerates consist almost entirely of quartzite and could thus not have been derived from other units than the

Seljord Group itself. These conglomerates are therefore not basal conglomerates but they indicate periods with erosion of already lithified sandstones. In the Numedal region Annis (1980) described the lower boundary of the quartzites as a zone of interfingering between the acid tuffs of the Haglebu Member and the sandstones.

Above the basal zone follows the thick, relatively homogenous quartzites that make up the major part of the Seljord Group and which typically consist of nearly pure quartz (up to 99%) with subordinate amounts of sericite, feldspar, epidote and magnetite, the latter forming rare heavy mineral seams. The grain size and sorting of the quartzites varies widely. In general medium to fine grained, relatively well-sorted quartzites predominate, although the range of lithofacies includes the following, characteristic types: massive medium grained quartzite; planar-bedded fine to medium grained quartzite with clay beds; planar- and trough cross-stratified fine-, medium- and coarse grained quartzites with clay beds grading into, and containing lenticular beds of poorly sorted, in part cross-stratified or poorly horizontally stratified conglomerates (pebble beds); and ripple bedded, very fine grained quartzite with clay laminae. Erosion channels on all scales are widespread (Fig. 10) and ripple marks of oscillation - and current type are ubiquitous. A large number of other types of sedimentary structures have been summarized by Singh (1969): herringbone cross-stratification; cross-stratification with overturned foreset lamination; mega-ripple bedding; ripple-lamination of various types; lenticular - and possibly flaser bedding; wavy bedding; raindrop imprints; bioturbate structures; slump structures; mudcracks (Fig. 11); and ball- and pillow structures. The colour of the quartzites is white to greyish. However, the white quartzite grades in the highest part of the stratigraphy into a hematite-stained, red quartzite. In many areas a blue tinge is apparent in especially greyish quartzites. This is caused by a high content of blue quartz grains which have been derived from porphyritic rhyolites of the Rjukan Group.

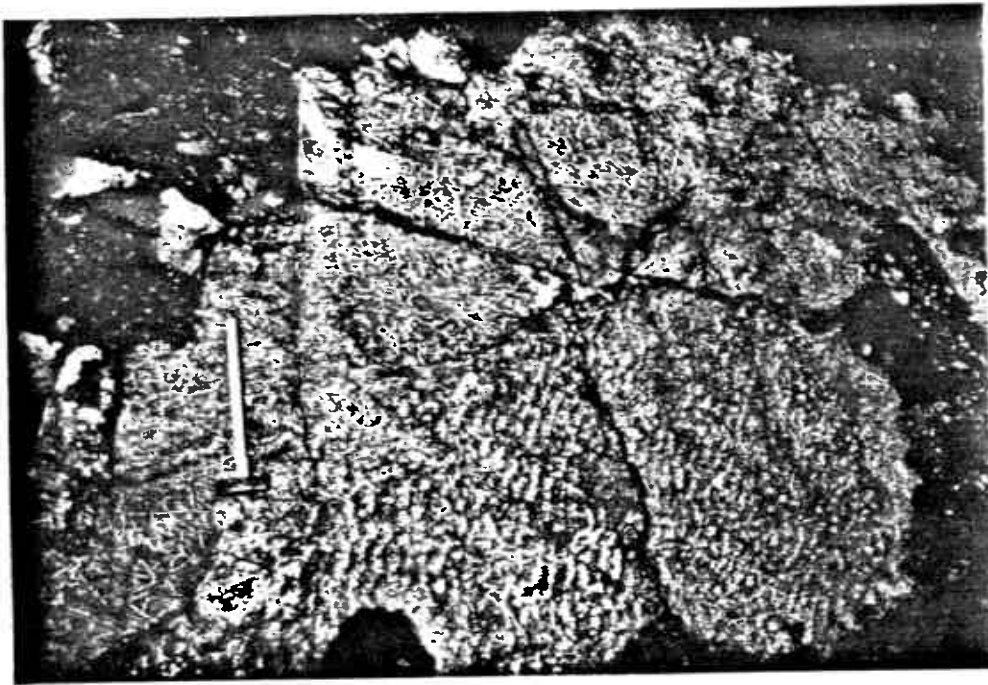


Fig. 11. Mudcracks and oscillation type ripples in clayey bed intercalated in quartzites. Near lake Sundsbarmvatnet.



Fig. 12. Multicoloured calcareous phyllite near lake Sundsbarmvatnet (same unit as in Fig. 11).

The quartzites show in central Telemark a gradation to various types of schists and silica-rich rocks which have been used as marker beds and been named the Svafjell-, Vindsjå-, Krakkset-, Lauvhovd- and Bondal schists by Dons (Plates 3 and 4). These schists form up to 1 km thick beds and some of them may be traced laterally over more than 25 km. In the field they appear as distinctive, multicoloured layers in general consisting of two lithofacies. The most widespread is a brown, yellow and green calcareous phyllite (Fig. 12) showing a gradation via calcareous quartz-bearing phyllite to pelitic, calcareous quartzite and to quartzite. Interlayered with the phyllites, and frequently occurring at the base of these, are up to 20 m thick layers of laminated, red, green, grey and brown chert (Fig. 13). These massive, flint-like rocks exhibit in places mudcracks and soft-sediment slump - or liquefaction structures (Fig. 14). Petrochemically the two lithofacies types are characterized by a very high potassium content (Ploquin 1980) probably caused by a large volcanic detritus component (Ofstedahl, 1981).

The mineralogical composition and the textures of the thick quartzites of the Seljord group show that they represent very mature sediments. The content of acid and basic volcanic pebbles in conglomerate beds and the in part large content of blue quartz grains in the quartzites indicate that they to a large extent were derived from the underlying volcanics of the Rjukan Group. To date no convincing evidence has been found which proves a postulated major unconformity at the base of the Seljord group (Dons, 1960). In fact, the derivation of a major part of the quartzites from the underlying volcanics would automatically result in unconformable contacts in places, and the evidence presented by Annis (1980) of a lateral interfingering and a gradation between the quartzites and the acid volcanics suggest that the deposition of the Seljord Group in other places was contemporaneous with the Rjukan Group. This is partly substantiated by the occurrence



Fig. 13. Finely layered
chert sequence (basal
layer of the Bortel schist)
near Gjuv).

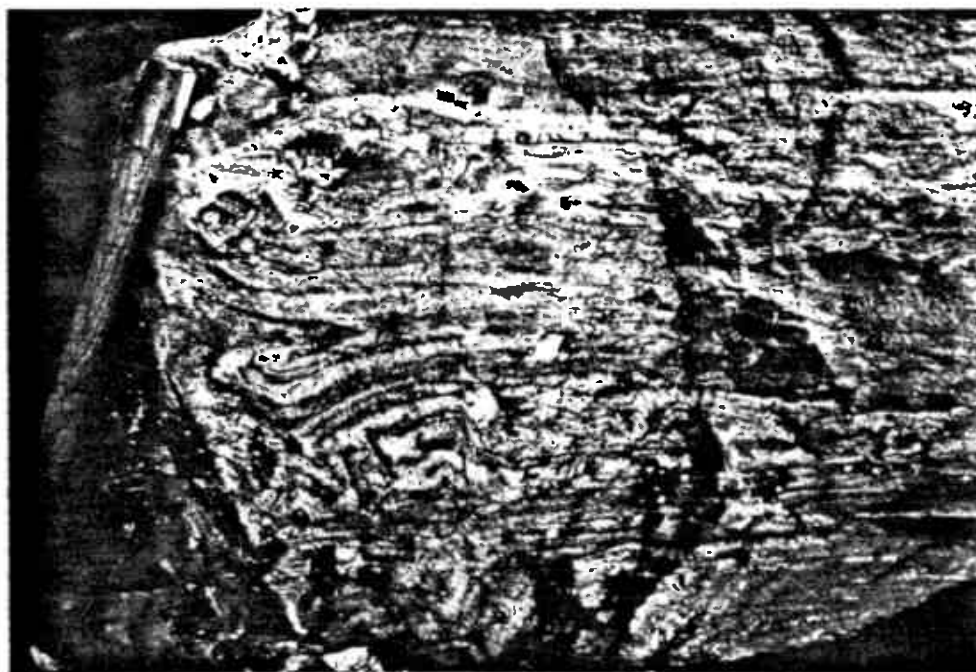


Fig. 14. Liquefaction structures in bedded chert at
the northern end of lake Bonsvatnet.

of subordinate beds of greywacke, arkose and quartzite throughout the Rjukan Group. However, the majority of the Seljord quartzites were apparently deposited later than the main stages of volcanism although the calcareous schists (clayey and silty sediments) with abundant volcanic detritus may represent distal tuffaceous material and thus indicate recurrent volcanism during the deposition of the clastic sediments.

The widespread occurrence throughout the quartzite sequence of sedimentary features indicative of a shallow-water, tidal-flat depositional environment suggest that the majority of the Seljord Group was deposited in slowly subsiding basins with a more or less continuous, and ample input of clastic material (Singh, 1969). Although repudiated by Singh (op.cit.) the localized presence of pebblebeds may represent deltaic point bars or braided stream deposits possibly indicating discharge areas from a hinterland.

The flat, lense-shaped beds of calcareous phyllite and the associated bedded chert reflect periods with stagnation in the input of coarse clastics and the initiation of chemical (siliceous and calcareous) sedimentation. The fine-grained volcanic detritus may have been transported by streams or may have been deposited as a tuff. The chert beds show some evidence of having been deposited as a gel under very shallow water (mudcracks, liquefaction structures). Similar cherts have been described from Lake Magadi in Kenya by Friedman and Sanders (1978). This lake is surrounded by volcanic rocks and the lake water is a sodium-carbonate brine in which hydrous sodium silicate is precipitated annually and later converted to bedded chert. These features, combined with the evidence of terminated beds and the sedimentary structures indicative of shallow water suggest that a substantial part of the Seljord Group may have been deposited in shallow lakes or inland bays, as previously suggested by Wyckoff (1934) and Dons (1960). The presence of localized flat pebble conglomerates in the Rødberg quartzite of the Numedal Group (Fig. 15) similarly testifies

to the relatively stable conditions of deposition. These intraformational conglomerates indicate periods of lithification prior to renewed erosion and the formation of the flat pebbles which occur in an orthoquartzitic matrix. Finally, the rapid decrease in thickness towards the southwest and the concomitant increase in potassium content (Ploquin, 1980) in this direction suggest the presence of a palaeo-basin border of considerable relief in this area.

2.3 CONTINUED SEDIMENTATION AND RENEWED VOLCANISM:
THE BANDAK GROUP; THE LEPTITES AND THE VEDALEN COMPLEX

Rock-units which overlie the Seljord group include the widespread Bandak Group in the west and the so-called Leptites and their northward continuation (the Vedalen complex) toward the east (Dons 1960; Annis, 1980) (Fig. 4). Although no direct correlation is possible between the eastern and the western provinces, the rocks of the two areas are tentatively correlated on the basis of stratigraphic position and lithology.

The Bandak Group occupies a large area from lake Møsvatn in the north to lake Straumsfjorden in the south and from lake Bandak in the east to lake Skyvatnet in the west. (Plates 1 and 2). It comprises a series of basic and acid volcanics interlayered with clastic sediments and subordinate calcareous sediments. Due to a large number of mineral occurrences the Bandak Group is one of the better known units in Telemark. A detailed stratigraphy, established by Dons (1960) for the group in the area to the north of lake Bandak is given below, and this has been expanded to include the northern and western areas by Sigmond (1978; Fig. 2).

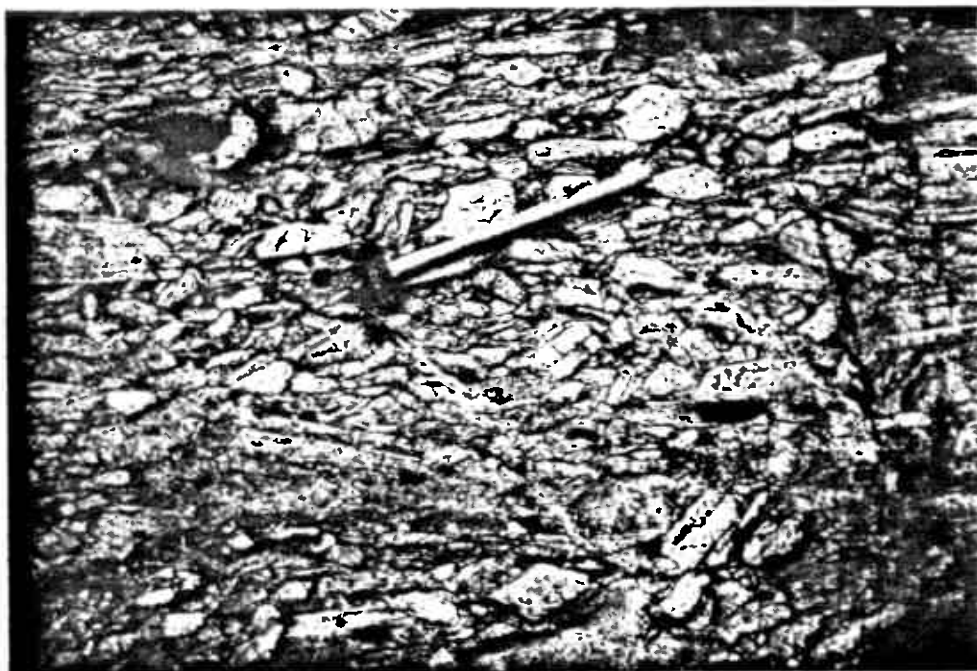


Fig. 15. Flat-pebble conglomerate in orthoquartzite (Rødberg Quartzite) near Turnhovdammen in Numedal.

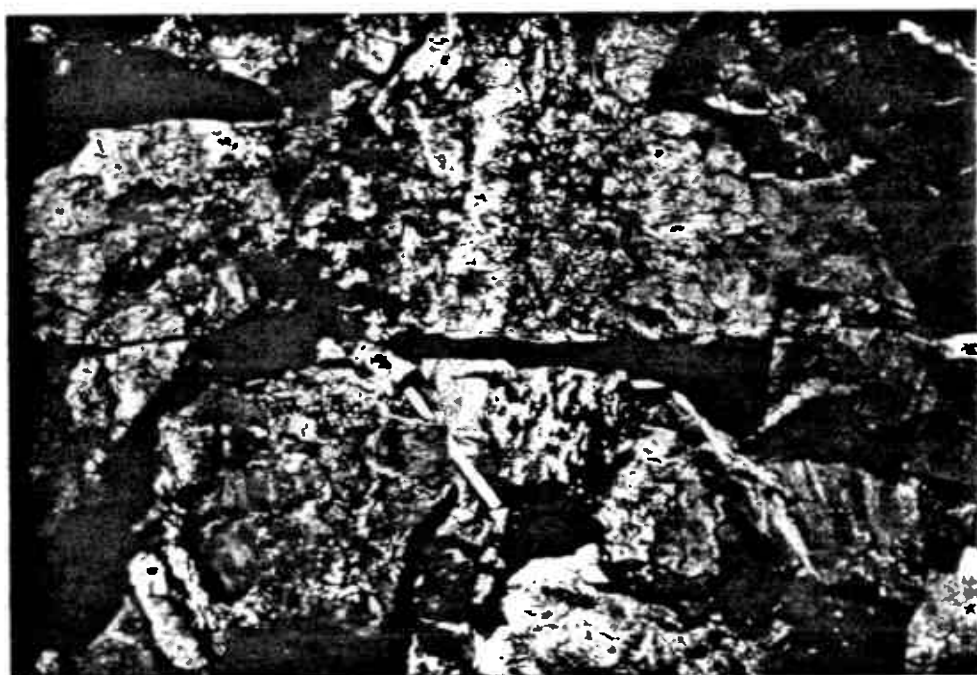


Fig. 16. Securia horizons infilled with pink calcite along the bottom of a basic lava flow. Near the Dalane Cu-Ag mines.

8. Quartz schist with conglomerate.
7. Marble (locally developed).
6. Green lava including one layer of sandstone containing fossils (?).
5. Porphyry (acid lava) (may be missing locally).
4. Green lava with conglomerate, 3-4 beds of quartzite with conglomerate, irregular and locally developed layers of quartz schists.
Cu-Ag-mineralization.

Possible unconformity.

3. Quartzite (with conglomerate) of varying thickness.
2. Porphyry (acid lava) of varying thickness, locally missing.
1. Basal conglomerate and quartzite, the thickness decreasing eastward to zero, where no. 3 forms the base (?).

The basic volcanics vary in appearance from massive amphibolites representing flows to finely laminated chlorite schist which probably are metamorphosed tuffs. The flows include finegrained, aphyric, hornblende/antinite and/or plagioclase-porphyritic types, locally with zones characterized by amygdules of calcite, quartz, zeolite and epidote. Epidote and quartz frequently form semimassive "nodules" up to some m in size. In the least deformed areas, as for instance at the disused Dalane Cu-Ag mines, flow-structures are present and the tops and bottoms of individual flows (which vary in thickness between a few m and a few tens of m) are characterized by scoria beds (Fig. 16). The highly porous scoria has been infilled with purple calcite forming a structure which has been misinterpreted by Dons (1960) as pillow lava. In fact, no structures suggesting extensive deposition of the lavas under water have been observed in the Bandak Group. Petrochemically the basic lavas of this group are characterized by Ploquin (1980) as basalts with spilitic (sodic) trends especially toward the west and the south, and Sigmond (1978) characterizes the rocks as sodium-dominated, subalkaline - to alkaline basalts transitional in chemistry between tholeiites and alkali basalts.

The basic lavas are interbedded with acid volcanic units, two of which have been named the Ofte- and Dalen porphyries (Dons, 1960) (Plate 3). These rocks are massive, isotropic to faintly flow foliated and consist of a finegrained matrix of quartz, sericite and feldspar with phenocrysts of white alkali feldspar and idiomorphic to subrounded, frequently blue quartz grains (Fig. 17). Petrochemically these porphyries are potassic, subalkaline metarhyolites and rhyodacites (Sigmond, 1978) and they represent lavaflows and/or ignimbrites.

Clastic sediments are intercalated with the volcanics throughout the stratigraphic sequence. The most commonly encountered types are light grey to white quartz-sericite schists interdigitating with light grey to grey and green impure (arkosic) quartzites. The quartz-sericite schists are fine-grained and finely laminated and seldom show any sedimentary structures apart from bedding, and as suggested by Sigmond (1978) these rocks may represent acid tuffs. The arkosic quartzites show gradations from light grey massive, finely bedded quartz-feldspar rocks (Fig. 18) to medium grained quartzites composed of (blue) quartz, feldspar and varying amounts of lithic fragments of quartzite and basic volcanics and frequently exhibiting through cross bedding and erosion channels (Fig. 19). The finegrained types show gradations to pelitic schists which have chemical characteristics similar to the schists of the Seljord group (Ploquin, 1980). The coarser grained varieties show gradations to, and are interbedded with matrix supported conglomerate beds composed of pebbles of quartzite, and basic and acid volcanics occurring in an arkosic groundmass (Fig. 20). A conspicuous, medium grained arkose which is very widespread exhibits an irregular banding composed of epidote-rich lenses alternating with quartz-rich lenses (Fig. 21). This "arkose" contains a considerable amount of pyroclastic material (Dahlgren, pers. comm.) and the epidote-rich lenses probably reflect a metamorphic break-down of plagioclase.

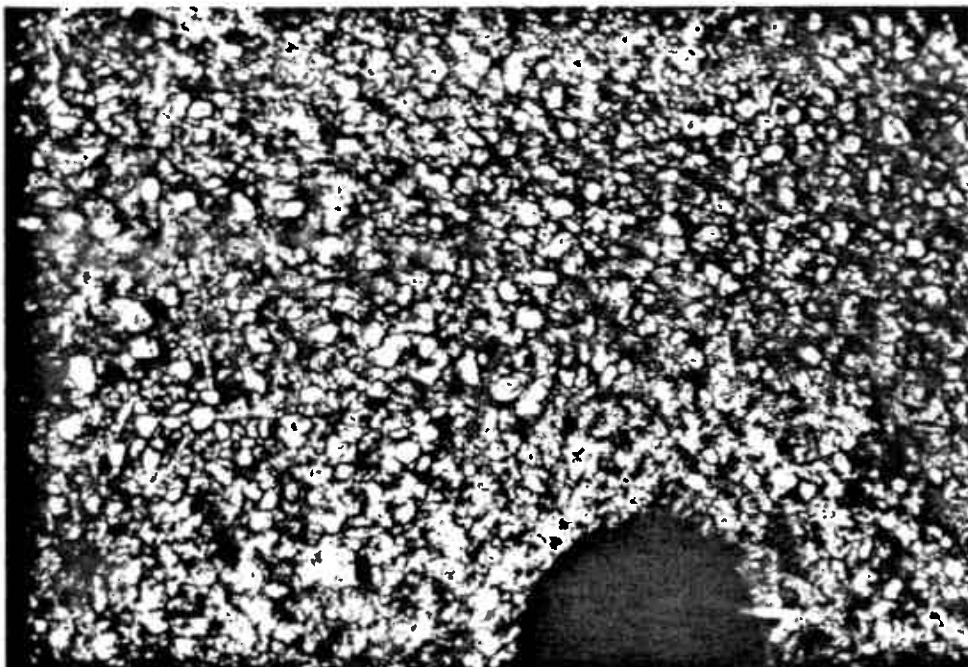


Fig. 17. Acid Dalen porphyry with (blue) quartz- and feldspar phenocrysts. Near the Dalane Cu-Ag mines.



Fig. 18. Highly folded argose of the Lianan Group.

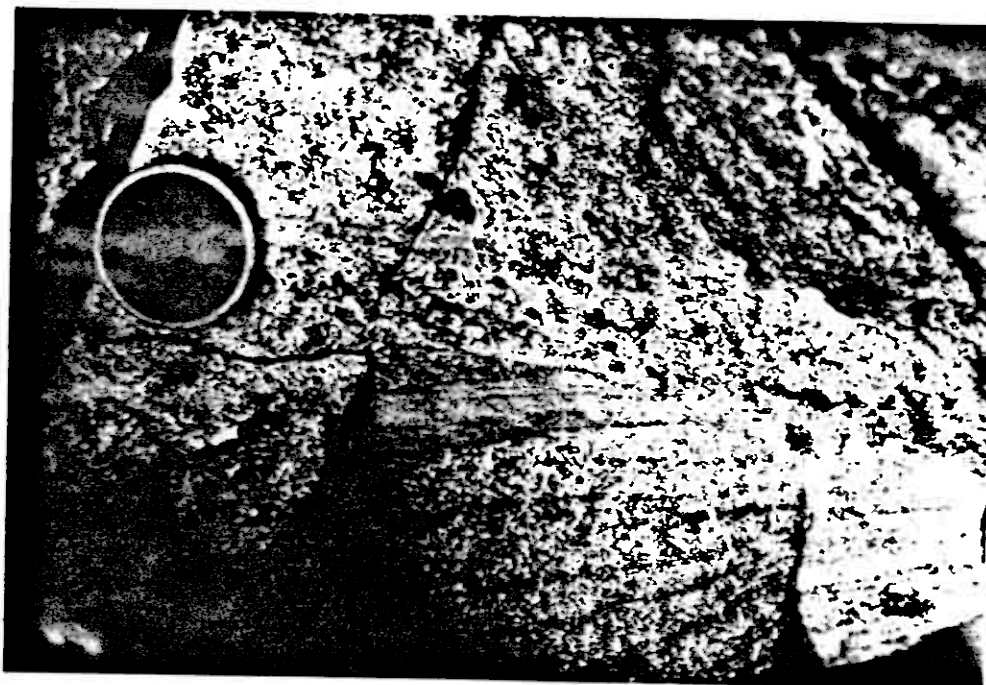


Fig. 19. Erosion channel in quartzites, infilled with fine gravel. Near the Dalane Cu-Ag mines.



Fig. 20. Conglomerate with pebbles and boulders of quartzite, basic- and acid volcanites; near the Dalane Cu-Ag mines.

Metagreywacke and phyllite occur in subordinate amounts in a few localities in the western part of Telemark (Plate 2), and strongly localized, m-thick beds of calcite marble are present at several stratigraphic levels in the Bandak Group (Dons, 1960; Sigmond, 1978).

The eastern lithofacies consists of the so-called "Leptites" in the south (Plate 1) and their possible northern continuation named the Vedalen complex in the Numedal region.

The Leptites comprise a sequence of quartz-sericite schists (probably acid tuffs), acid metaagglomerates, basic tuffs, metaarkose and metaconglomerate. The southern, central Notodden-Follsja-Hjartsjavatnet region (Plate 1) is predominantly characterized by metaarkose with epidote lenses (Fig. 21) which shows gradations to, and interdigitate with polymict conglomerates with an arkosic matrix (Fig. 22). Along the Tuddal road, this arkose apparently grades into the underlying Seljord quartzites. In the east (from Notodden to Follsja) acid crystal tuffs and acid agglomerates (Fig. 23) alternate with basic tuffs, and along lake Tinnsjø in the northern region a gradation is seen from a white quartz-sericite schists (stratigraphically belonging to the leptites) to the quartzites of the Seljord Group. This quartz-sericite schist is finely laminated and contains epidote lenses and mm-thick conformable calcite lenses. Locally it shows gradations to, and interdigitates with phyllite (Fig. 24), and cross-bedding and rare erosion channels have been observed. The basic lavas have a chemistry comparable to the greenstones of the Bandak Group, and the acid volcanics have a rhyodacitic to rhyolitic composition (Ploquin, 1980).

The Vedalen complex of the Numedal Group comprises a more than 3000 m thick sequence of greenstone and greenschist with subordinate metatuff- and phyllite layers (Annis, 1980). The



Fig. 21. Layered "arkose" with epidote-rich (green) laminae. South of lake Bandak.

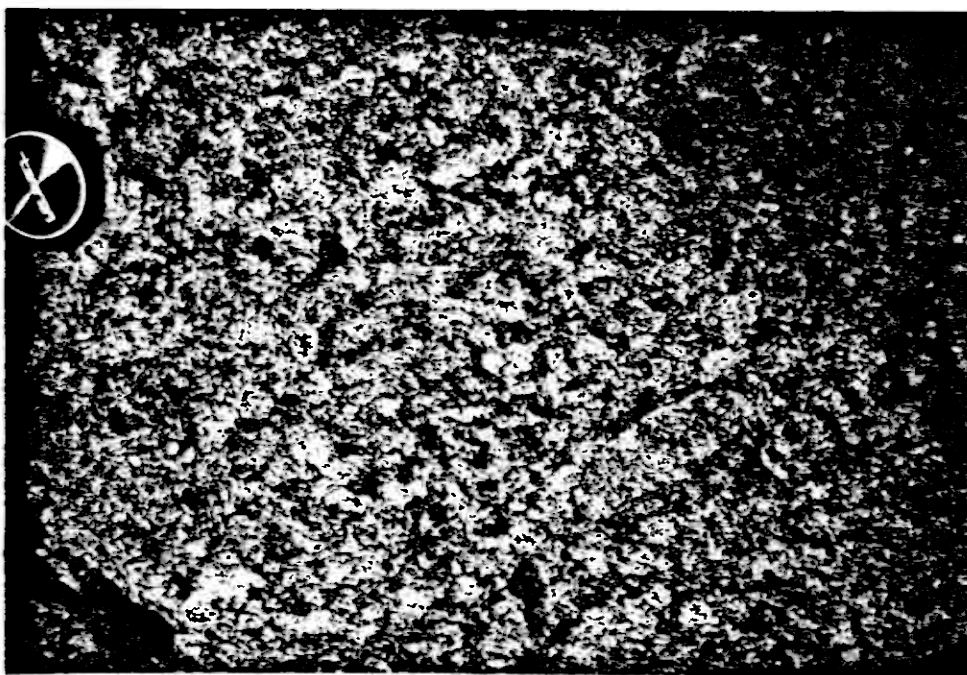


Fig. 22. Polymict "conglomerate" which probably contains a large portion of volcanoclastic material. Along the road from Gransherad to Orvella.



Fig. 23. Acid agglomerate along the road from Motodden to Follsjå.



Fig. 24. Interdigitating quartz-sericite schist (beige) and phyllite (grey). Eastern shore of lake Tinnsjø.

greenstones exhibit pillow structures (Fig. 25) and mudcracks occur in nearby tuff layers at an approximately equivalent stratigraphic level. The greenstones represent lavaflores with a modified sodium-rich tholeiitic chemistry, i.e. largely comparable to the greenstones of the Bandak Group. The acid metatuff layers are up to 100 m thick and 3 km long and appear as flowbanded dense, purple rocks. Annis (1980) interpreted these rocks as welded ash-flow tuffs of rhyolitic to dacitic composition. The chemistry of the Vedalen tuffs and the Ofte porphyry (Bugge, 1931) shows some similarities, although the Vedalen tuffs are characterized by large variations in composition.

Sigmond (1978) suggests that the rocks of the Bandak Group were deposited in a slowly subsiding basin with increasing influx of clastic material towards the east. In the west the basic lavas were deposited on land while the pillow structures and mudcracks present in the Numedal region demonstrate deposition under shallow water. As in the case of the Rjukan Group volcanics, the bimodal character of the volcanics and the large amount of arkosic sediments in the Bandak Group suggest that rift-generated tectonic basins controlled the deposition of these rocks.

2.4 BASIC SILLS OF THE RJUKAN AND SELJORD GROUPS

A large number of basic sills, dykes and small intrusions occur in the Rjukan and Seljord Groups. The sills, which by far are the most widespread, are up to 600 m thick (Dons, 1960) and represent in places a considerable addition of basic magma to the host rocks (Fig. 26). The basic rocks vary in composition between olivine gabbro, gabbro, gabbro-anorthosite (Ofstedahl, 1981) and hornblende-peridotite and frequently exhibit ophitic-, subophitic- and cumulate textures, although in general they show evidence of deformation and metamorphism by having been transformed into amphibolites and hornblendites. The basic rocks are everywhere characterized by up to a few percent disseminated sulphides (mainly pyrite,



Fig. 25. Pillow lava near
Tunnhovddammen in Nuredal.

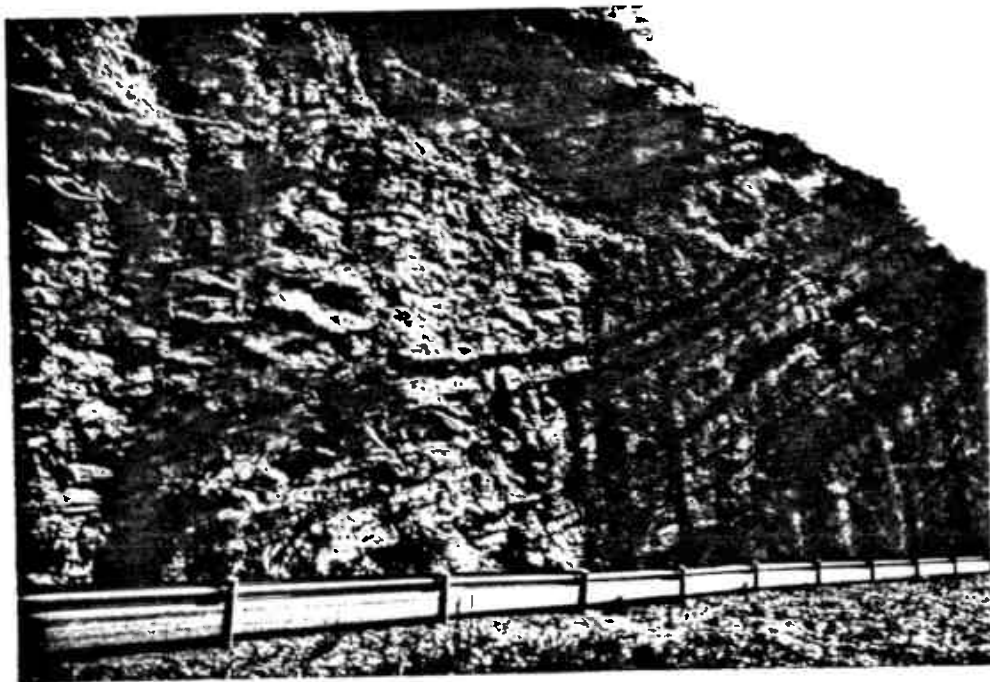


Fig. 26. Orthoquartzites with basic sills or tuff layers
(dark). Eastern shore of lake Seljordsvatnet.

pyrrhotite and chalcopyrite). Assimilation of silica-rich country rocks has in many places led to an increasing quartz-content towards the contacts of the intrusive bodies, while in-part assimilation of large xenoliths of quartzite have led to the formation of spectacular features such as the well known orbicular quartz diorite in the Bleka sill (Bugge, 1931).

Petrochemically the basic sills are comparable to similar rocks of the Bandak Group, although some sills show a strong potassic trend which may be due to contamination (Ploquin, 1980).

2.5 A CHANGE IN VOLCANISM: THE HEDDEVATN GROUP

The thick metaandesites of the Heddevatn Group (Plate 2) conformably overlie the western continuation of the Bandak Group (i.e. the Blåbergås Group) (Sigmond, 1978) and reflects an important change from basaltic to andesitic-rhyodacitic volcanism (Figs. 1 and 2). These volcanics are finegrained, evenly layered grey rocks composed of quartz (15-30%) plagioclase (20-50%), biotite (8-30%) and apatite (1-3%). Sigmond (op.cit.) interprets the rocks as metamorphosed tuffs and ignimbrites with subalkaline and calc-alkaline chemical characteristics.

Thin basalt flows, m-thick beds of rhyolitic, rhyodacitic, and dacitic leptite, and metasandstone are intercalated with the metaandesites. The basalts are porphyritic and amygdaloid and are chemically somewhat different from the basalts of the underlying Blåbergås Group. The metasandstones are derived from the andesites and show evidence of short transport. Volcanic conglomerates form up to 300 m thick intercalations and may represent agglomerates, components of ignimbrites or lahars.

2.6 POSTKINEMATIC GRANITIC MAGMATISM

A suite of postkinematic, Sveconorwegian intrusives was emplaced in southern Norway in the period 1100-850 Ma (Falkum and Petersen, 1980). These rocks include the strongly potassic Egersund anorthosite-charnockite suite, and a large volume of granite of calc-alkaline affinity which forms batholiths as well as small diapirs (Falkum and Petersen, op.cit.). Some of the smaller intrusions are associated with, and were possibly controlled by intense fracturing of the host rock, as for instance the Venås granite situated in the southern end of Tinnsjø (Plate 1).

2.7 TECTONICS AND METAMORPHISM

In his interpretation of the structural evolution of the Telemark supracrustals Dons (1960) advocates a model based on the presence of angular unconformities between the three stratigraphic groups demonstrating that the groups are separated by periods of folding and erosion. This model thus indirectly implies that lower groups should show evidence of a larger number of deformation periods or more intense deformation than upper groups but this is not the case. On the contrary, as stated by Dons (1972) the deformational pattern in the Rjukan Group may be explained by two periods of folding, the pattern in the Seljord Group by two or three deformation phases, and the fold pattern in the Bandak Group by two, three or four phases of deformation. Dons (op.cit.) explains this as a result of a "plissement de couverture" of the Bandak Group together with gravitative folding around the granitic domes.

The existence or non-existence of unconformities in the Telemark supracrustal sequence is one of the keys to the unravelling of the structural evolution of these rocks. Earlier in this report it was demonstrated that, although angular unconformities exist locally between the Rjukan and Seljord Groups these same rock units show a gradational

relationship in other areas. It thus seems likely that clastic sedimentation began contemporaneously with the deposition of these early volcanics and that it gradually took over as the volcanic activity faded. In the present context the postulate of the existence of a universal unconformity between the Rjukan and Seljord Groups is therefore rejected.

The presence of an unconformity between the Bandak Group and the Seljord-Rjukan Groups seems on the other hand well established. In the area to the north of lake Bandak the flat-lying lower boundary of the Bandak Group rests on the steeply dipping contact between the Rjukan-Seljord Groups. The base of the Bandak Group is developed as a conglomerate with pebbles of the underlying, eroded units (Dahlgren, pers. comm.). It is also evident that the lower Groups have been folded around east-west trending axes prior to erosion and deposition of the Bandak Group. (Fig. 27)

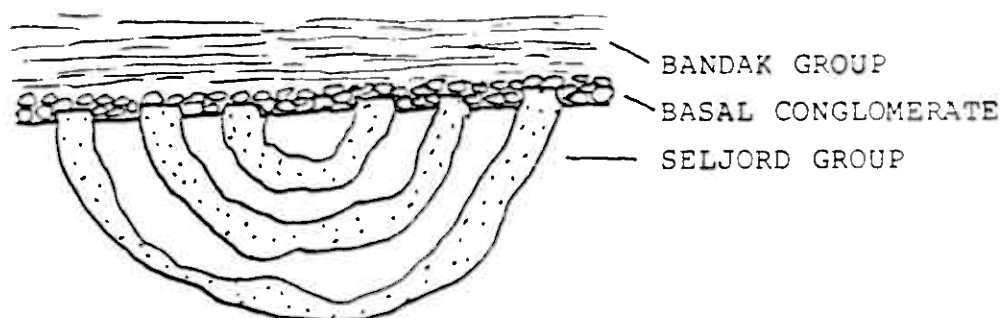


Fig. 27
(Dahlgren, pers. comm.)

An unconformity has been observed at this stratigraphic level elsewhere in Telemark. In the western region Sigmond (1978) noted that the rocks of the Breive Group, which probably correlate with the Rjukan Group, are more intensively folded than the overlying units of the Bandak Group and that a discordance between the two groups appears in the geological map (Plate 2). In the Nissedal area Mitchell (1967) demonstrated the presence of an unconformity between a lower

supracrustal unit, which he correlated with the Rjukan Group, and overlying amphibolites of the Bandak Group. Finally, in the Numedal region Annis (1980) has shown the presence of an unconformity between the Vedalen Complex (corresponds to the Bandak Group) and the underlying Rødberg Quartzite which correlates with the Seljord Group. The presence of an important unconformity between the Bandak Group and the Rjukan-Seljord Groups thus seems well established.

Another important point is -of course- the number, and attitude of fold phases present. The style of deformation in Telemark suggests that several episodes of folding are present and that local deviations in the regional stress pattern greatly modified and complicated the gross-scale structures. However, for the purpose of this report only the major phases of deformation will be considered.

As shown previously (Fig. 27), an early fold phase with east-northeast trending fold axes is present in the Rjukan-Seljord Groups in the area to the north of Lake Bandak. The discordantly overlying Bandak Group shows evidence of later folding around a fan of fold axes with trends varying from east-northeast in the south to north-south in the northwest (Plate 3).

Evidence of an early fold episode is similarly present in the western Breive Group (Sigmond, 1978) (Fig. 2) and in the Numedal region where Annis (1980) described early east-west trending folds in the lower two stratigraphic Groups (corresponding to the Seljord and Rjukan Groups) which predates both the unconformity at the base of the Vedalen Complex (Bandak Group) and a later isoclinal folding with north-south trending fold axes and subvertical axial planes. This late fold phase affected extensive areas in this northerly region. In the Nissedal supracrustals (which

correlate with the Rjukan Group) Mitchell (1967) described an early period of folding producing folds with east-northeast oriented axial plane strikes, followed by a second fold phase with more northerly oriented axial plane strikes that refolded the early folds to produce a series of basin and dome structures. This second phase of deformation was accompanied by extensive granitization.

Modification of previously established folding patterns was introduced by the intrusion of diapiric Sveconorwegian postkinematic granites which in most instances caused substantial doming of the surrounding supracrustals. Later north-south trending regional block-faulting caused drag in the metasediments and displaced at the same time the postkinematic granites.

In general terms the metamorphic grade within the supracrustals increase from north to south (Stout, 1974). Low grade mafic and felsic volcanics interbedded with arkosic sandstones of the Bandak Group are in epidote-amphibolite facies in the lake Bandak area whereas further south in the Fyresvatn area the same sequence has clearly recrystallized in the sillimanite zone. The metamorphic grade continues to increase southward to hornblende - granulite facies and further to granulite facies in the Bamble region. Concomitant with the southerly increase in metamorphic grade, granitic gneisses and granites of probable anatectic origin become volumetrically more abundant relative to metasediments (Stout, op.cit.).

It has not been possible to determine the timing of metamorphism in relation to the two main folding episodes from the available data. However, the increasing metamorphic grade towards the south in lithologies belonging to the Bandak Group indicates that any early metamorphic mineral assemblages in the Rjukan-Seljord Groups recrystallized during the second phase of folding.

The field evidence thus suggest that the following tentative and probably somewhat oversimplified scheme of the tectonic development of the supracrustals may be established:

Youngest:	Dragfolding by late faults
ca. 800 Ma.	Doming around granite diapirs
	Folding around N-S axes in the north and
	around ENE-SSW axes in the south;
	granitization
	Deposition of the Bandak, Blåbergås,
	Leptite, Numedal and Heddevatn Groups

-----UNCONFORMITY-----

Oldest:	Folding around E-W to ENE-SSW axes
ca. 1650 Ma.	Deposition of the Rjukan- and Seljord Groups

Pertinent features of this scheme are shown in Fig. 28 which is based on the latest Geological Survey map of Norway at the scale of 1:1.000.000. Two structural sections from Oftedal (1981) of this area are shown in Fig. 29.

The rift-related start of deposition of the Rjukan-Seljord Groups at approximately 1640 Ma ago and the predominant east-northeast trending fold axes of the subsequent early folding phase make it highly likely that this early folding should be seen in the light of the intense deformation which took place in the Bamble district at ca. 1540 Ma (Oftedal, 1981; Starmer, 1978). The Bamble deformation was accompanied by amphibolite - to granulite facies metamorphism and produced folds with a predominant NE-SW and NW-SE axial trend in the early phases. This was followed by a flattening due to compression at right angles to the NE-SW trending folds producing the prominent NE-SW grain of this region (Starmer, 1978). Folds with a parallel trend can be traced northwards across a large basement dome and into the Rjukan- and Seljord supracrustals. The style of folding and the asymmetry of the folds in the southern part of section A-A' in Fig. 29 suggest

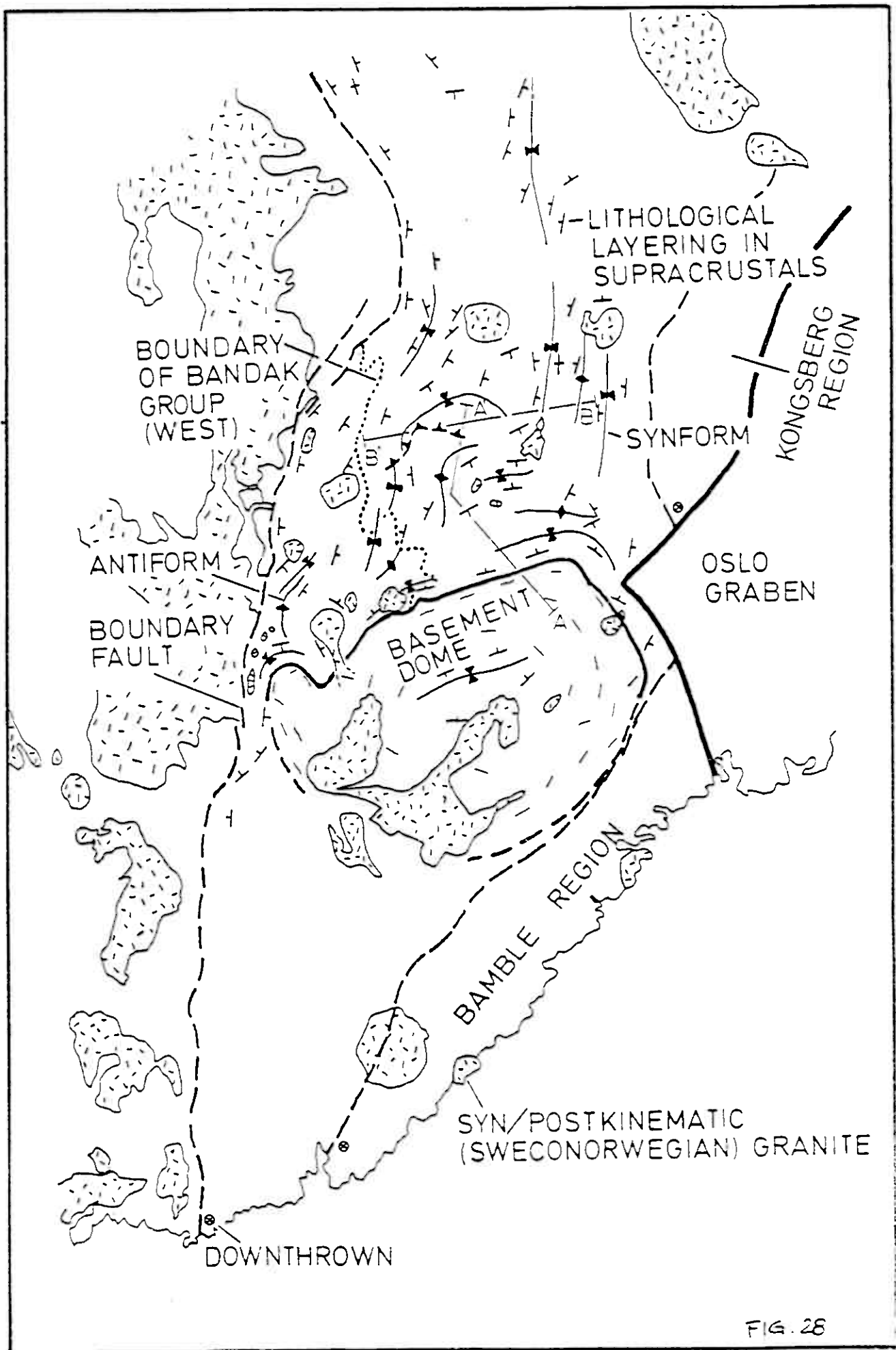


FIG. 28

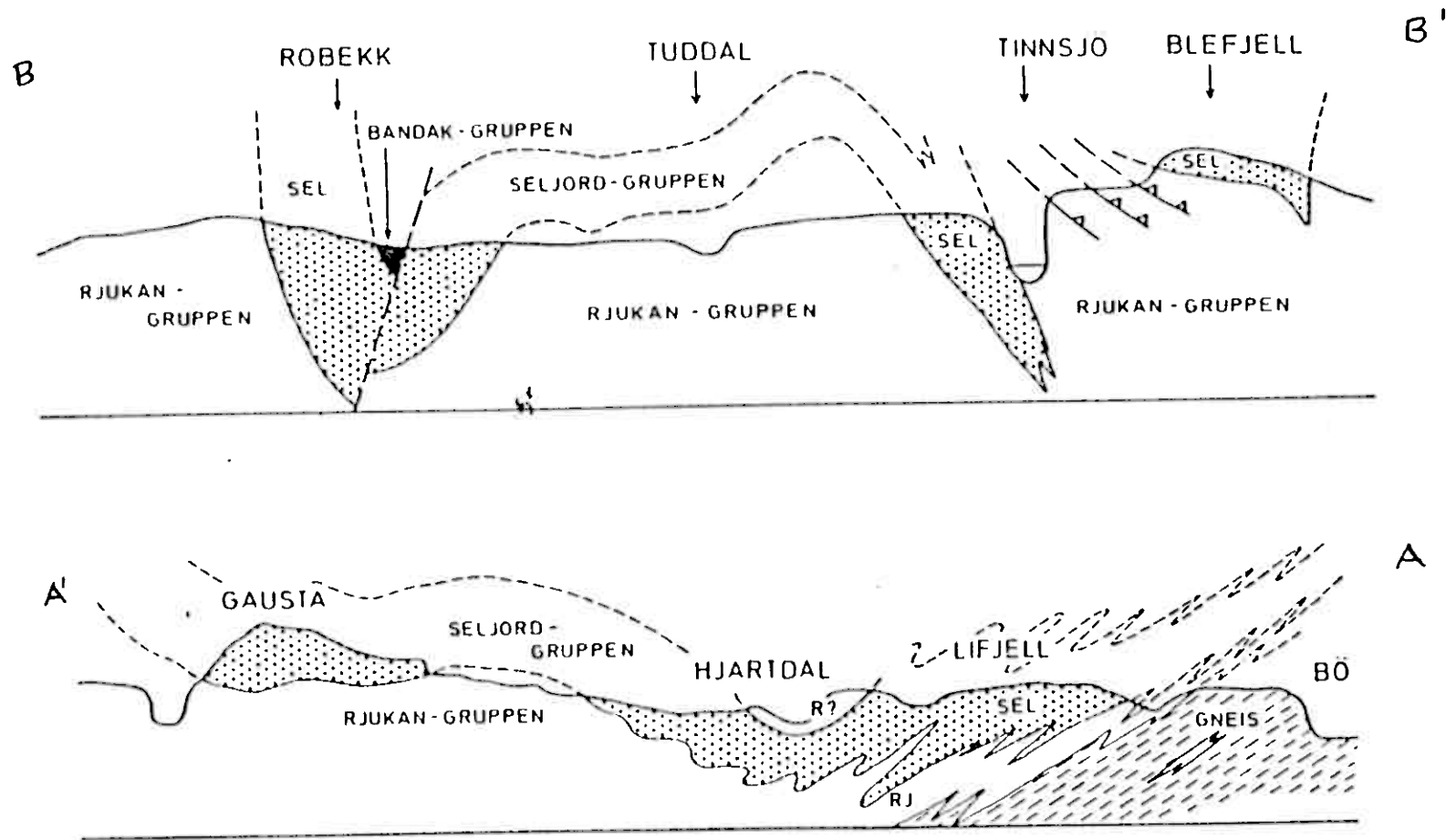


Fig 29

that the deformation of the supracrustals was caused by gravity sliding of the cover rocks off the rising granite-gneiss dome in the south. Along the front of the zone of strongest deformation (between Gausta and Hjartdal) local overthrusting with a northerly direction took place while open-style folding with NE-SW trending axial planes affected the supracrustals as far north as into the Numedal region. The basement dome in the south may represent a plastically deformed former fault block (horst) or it may be an intrusion of batholithic dimensions. The thinning of both the Rjukan- and Seljord Groups along the eastern margin of this dome may indicate that the dome already at the time of deposition of the cover rocks represented an area of considerable relief.

Following this early deformation the Telemark area underwent renewed denudation and probably resedimentation of already lithified quartzites (Fig. 15). This period may have spanned the time interval from ca. 1450 Ma to ca. 1200 Ma. Renewed rift-generated bimodal magmatism initiated at ca. 1200 Ma led to the deposition of the Bandak Group. The numerous mafic dykes and sills occurring in the Rjukan and Seljord groups (but not in the Bandak Group) show chemical characteristics reminiscent of the mafic lavas of the Bandak Group (Moine and Ploquin, 1972) and may represent the feeders to this surficial volcanic activity. Toward the west this bimodal volcanism was followed by the deposition of the thick andesitic volcanics of the Heddevatn Group. The subsequent Sveconorwegian orogeny from ca. 1100-950 Ma probably led to the development of a cordilleran-type orogenic belt with an approximately east-west directed axis of maximum compression (Falkum and Petersen, 1980). The Telemark supracrustals were folded into a series of N-S trending, upright, open - to isoclinal megascopic folds in the northern regions while refolding of the earlier formed east-west trending folds in central and southern Telemark caused complicated fold-interference patterns. Late, renewed folding was associated with the intrusion of late- to postkinematic granites. These small granite cupolas are believed to represent diapirs rooted on a granitic mass of

batholithic dimensions at depth as suggested by the size of the granitic bodies in the deeply eroded western part of the Telemark district (Fig. 28). The intrusion of the smaller granites caused considerable doming of the supracrustals. The large granite masses exposed in the basement dome in the south suggest a deep level of erosion and may thus indicate that renewed doming of this area took place in association with the intrusion of the granites. This may in turn have initiated the formation of late (? gravity induced) east-west trending folds which Dahlgren (pers.comm.) has mapped in the Bandak Group.

Apart from the intrusion of granites the late- to postorogenic Sveconorwegian period was characterized by regional block-faulting. Early faulting along NNE-SSW trending faultplanes caused large blocks in the east to drop down in relation to a western block. The most prominent of these megafractures are now seen as important boundary faults of the Telemark supracrustals (Fig.28), separating these from the western, predominantly gneissic block, and the eastern, downfaulted Kongsberg region. A relatively weakly developed set of faults trending approximately NW-SE may be contemporaneous with the early NNE-SSW faults. Late, approximately NE-SW trending normal faults displace the early formed fractures (preliminary NGU geological map of Norway, 1:1.000.000) and caused the downdropping of the Bamble region in relation to Telemark (Fig.28). The widespread cataclastic breccias and the deposition of large masses of hydrothermal quartz, fluorite and minor base metal sulphides and manganese oxides along the major faultplanes indicate that this faulting took place in the waning stages of granitic magmatism. This timing of events has similarly been suggested for the Venås granite which may have intruded along pre-existing NNE-SSW and NW-SE trending faults.

The Svecokarelian orogeny, as defined by Welin (1974), comprises an early stage of sedimentation and volcanic activity some 2100-1950 Ma ago, followed by the main orogenic phase of deformation, metamorphism, migmatization and formation of granites at 1950-1750 Ma and a post-orogenic supracrustal stage of acidic volcanism, granitic magmatism and sedimentation between 1750 and 1550 Ma ago (Verstevee, 1975). The main phase of the Sveconorwegian orogeny, which in Scandinavia is restricted to SW Sweden and southern Norway, is in general considered to have taken place between ca. 1200 Ma and 850 Ma (cf. Falkum and Petersen, 1980). The intervening, post-Svecokarelian period from 1700 to 1200 Ma is termed the Gothian time period (Lundegårdh, 1971). This period is characterized by events which suggest that the southern part of the Baltic shield underwent extensional tectonism first as a result of crustal relaxation in the wake of the Svecokarelian orogeny and later as a precursory event to the opening of a proto-Iapetus ocean. For the following, the reader is referred to Plate 5.

In SW Sweden the late- to postkinematic period of the Svecokarelian orogeny is characterized by the intrusion of vast volumes of I-type granitoids around 1700-1650 Ma (Wilson, 1980); these intrusives form a continuous, up to 200 km broad belt from the Dalarne area in the north to the Baltic coast in southern Sweden and include the Ratan, Småland and Åmål granitoids (Wilson, 1980). Concurrent with this intrusive activity southern Norway underwent deformation and metamorphism during the so-called Kongsberg metamorphism which began at ca. 1650 Ma (Oftedahl, 1981).

These events may have been related to a late phase of the Svecokarelian orogeny which is considered to have been caused by the northeastward directed subduction of an oceanic plate beneath the Baltic shield. However, Wilson (1980; 1982) suggests that the intrusion of the granitoids reflects the

establishment around 1700 Ma of a new subduction zone with an easterly dip and a related Andinotype orogeny. This zone would be situated in the Dalarne-Karlshamn area, i.e. to the west of the main Svecokarelian trench. The Precambrian rocks to the west of the Kongsberg-Bamble region form the basement of the Telemark supracrustals and are probably of Svecokarelian age, i.e. ca. 2000 Ma old (Falkum, 1982). The age of the geosynclinal Kongsberg-Bamble-Østfold sequence is uncertain but the rocks are older than 1500-1580 Ma which is the age of the overprinting metamorphic event (Oftedahl, 1981). Assuming an age of 1800-1650 Ma for this sequence it would be younger than the two adjoining, Svecokarelian blocks to the east and the west and could therefore represent the oceanic basinal sequence formed in a Wilson cycle which in its late stages caused the formation of an eastward directed subduction zone and an Andinotype orogeny. Another possibility, suggested by Berthelsen (1980), implies the collision between the Svecokarelian continental block in the east and a number of microcontinents from the west due to eastward directed subduction of the oceanic carrier plate.

The overall compressional tectonics of the orogenic events were followed shortly afterwards by a major tensional phase. The earliest recorded event at approximately 1650-1550 Ma is the extrusion of the alkaline, bimodal continental Rjukan Group of Telemark and the time- and chemically equivalent Dala porphyries and associated subalkaline, continental Småland granites. The effusives were related to, and deposited in fault controlled basins. This rift-episode is further reflected in SW Sweden by the extensive Värmland hyperite dyke swarm, a number of E-W dolerite dykes situated to the east of Vänern, and at least three alkaline intrusions with ages of 1580 to 1540 Ma. (Wilson, 1982). Wilson (op.cit.) notes that the basic dykes form a three-armed system, and he suggests that this may be related to incipient rifting away of SW Sweden from the Baltic shield and the possible formation of an aulacogen defined by the E-W dolerite dykes. Contemporaneous events in Norway include the prolonged effects of the

Kongsberg metamorphism. At ca. 1540 Ma the Bamble region and possibly the Telemark area underwent intense plastic deformation related to what has been interpreted as a major right-lateral linear deformation belt (Falkum and Petersen, 1980). When viewed as a whole these events may suggest that the southern Baltic shield during this time period underwent incipient polygonization and plastic deformation related to lateral crustal block movements under a regime characterized by high heat flow. More recent plate tectonic analogies to the tectono-magmatic setting of the Rjukan Group and the Dalane porphyries would accordingly include: back-arc extensional cratonic basins; trilete rift systems or failed rift arms; anlacogens; and collision-related rifts. Of these the back-arc extensional cratonic basin model, especially typified by the Basin and Range province of the western United States, seems to have many features in common with the setting of the Gothian supracrustals. The normal faulting and the related bimodal basalt-rhyolite volcanism of the Basin and Range province developed in the late Cenozoic and was probably caused by the arrival at the subduction zone in the early Miocene of an oceanic ridge system trending oblique to the trench, with consequent initiation of the San Andreas transform fault and development of an expanding triangular area beneath which ocean floor subduction had ceased. This area included by Quaternary time the Colorado Plateau and Basin and Range Province (Mitchell and Garson, 1981). Although it is difficult to apply any model of this sort directly on the Gothian supracrustals, the movement along the Bamble lineament has been compared to transform faulting (Petersen, pers. comm.) and the normal faulting and related bimodal volcanism of the Telemark area did take place subsequent to the main orogenic events of the area. Another possible depositional environment would be a failed rift arm of a type similar to the Oslo Graben, but the rift-events in the present case seem to be so closely related to the waning stages of the Svecokarelian orogeny that they should be seen in the light of this event.

The relatively limited effect of a metamorphic event, the extrusion of calc alkaline volcanics and the intrusion of the Karlhamn granite may reflect a collision-event in southern Sweden ca. 1400 Ma ago (Wilson, 1982). Small, contemporaneous granite bodies in the Bamble district may possibly have formed as late anatexites related to the foregoing metamorphism and deformation.

Renewed continental rifting of the southern Baltic shield in the period 1380-1200 Ma is suggested by the extrusion of the bimodal Bandak Group, by the intrusion of the Tuna, Särna and Åsby dolerite dykes in Sweden and by the numerous and to some extent large hyperite intrusions in Bamble, Kongsberg and Østfold. Starmer (1978) points out that the Bamble hyperites represent a major addition of basic magma to the crust at the start of the Sveconorwegian orogeny and that they were emplaced by permissive injection under anorogenic conditions. This continental rifting eventually culminated at ca. 1200 Ma ago in the opening of an ocean even earlier than the Iapetus, the rotation of the Scandinavian block relative to the Canadian block and finally the development of the Sveconorwegian orogeny which peaked at ca. 1050 Ma (Patchett and Bylund, 1977). This orogeny affected a major part of southwestern Scandinavia including the Telemark supracrustals and the western part of the Dalane complex. The Telemark region was metamorphosed and deformed, and at a late orogenic stage an important suite of post-orogenic granites, mainly formed by anatexis of the basement, forced their way through the supracrustals (Killen and Heier, 1975). Slightly earlier the large Egersund anorthosite complex intruded, probably in the core zone of the orogenic belt (Versteve, 1975; Falkum and Petersen, 1980).

The gross scale tectonic setting of the Bandak Group and the stratigraphically equivalent leptites, Vedalen Complex and Blåbergås Group must be interpreted in the light of the evidence of the widespread extensional tectonism at 1380-1200 Ma. In his regional geochemical study of the supracrustal lithologies of the Telemark-Bamble region Ploquin (1980) noted chemical similarities between the basic lavas of the Bandak Group and the Bamble hyperites and suggested that these could be petrogenetically related. Although this is difficult to demonstrate the intrusion of large volumes of basic magma associated with extensional tectonics could have produced a heating event which caused partial melting of the crust to produce potassic, subalkaline rhyolites and rhyodacites and at the same time give rise to extrusion of alkaline to subalkaline basalts, both of which characterize the bimodal Bandak Group (Suneson and Lucchitta, 1983).

From the central area and toward the southwest the overall lithology of the Bandak Group gradually changes to become dominated by arkose and greywacke (Sigmond, 1978) and in the coastal area of SW Norway metasandstone is the only Bandak Group lithology present (Falkum, 1982). Evidence of a period with world wide continental rifting in the period 1500-1000 Ma has been noted by Sawkins (1976) and Windley (1977). This rifting was typically associated with the accumulation of thick sequences of continentally derived clastic rocks, in some cases associated with dolomitized carbonates. The sequences tend to be thick but localized in occurrence and to contain evidence of contemporaneous basaltic rocks, bimodal basalt-rhyolite suites and alkaline complexes (Sawkins op.cit.). Although slightly older than the Bandak Group, the 1300-1500 Ma Jotnian continental sandstones and Öye basalt of the Dalarne Complex in SW Sweden (Plates 5), and similar Jotnian sandstones and shales in Finland (1300-1400 Ma; Simonen, 1980) similarly appear to belong to this rift episode. Many of these clastic sequences were deposited in aulacogens, i.e. the failed arm in trilite continental rifts of which the two arms developed into a spreading ridge and in

most instances later into a converging continental margin and a subsequent orogeny. The setting of the Bandak Group is clearly on the continental side of the Grenville orogeny of SW Norway as suggested by Falkum and Petersen (1980) and as indicated by the thick arc-related andesitic volcanics of the Heddevatn Group which overlie the Bandak Group in the west. The Bandak Group may therefore represent a continental sequence deposited in a failed riftarm in a former trilete continental rift system.

3. MINERALIZATION OF THE TELEMAR DISTRICT

3.1 INTRODUCTION

Mining for copper, silver, gold, lead, zinc, bismuth, arsenic, molybdenum, manganese and fluorite has been carried out intermittently in the Telemark district since the 16th century, with the last mine closing around 1945. With only a few exceptions these metals were mined from epigenetic vein deposits of small to modest size and the majority of these would be considered to be without any present day economic value.

In general terms exploration in Telemark has by tradition been focused on these ubiquitous epigenetic veins (c.f. Dons, 1963). However, stratabound mineralization has been known for some time at the Dalane Cu-Ag mine (Bugge, 1932; Neumann, 1944), fahlband-like deposits are mentioned by Dons (1963) and Nordrum/van der Wel (1981), and lately Creelman (1982) drew attention to the stratabound volcanogenic nature of the mineralization at the Guldnes Cu (-Ag) mine which hitherto had been regarded as a slightly atypical vein-type deposit (Dons, 1963). In conjunction with the widespread occurrence of bimodal volcanics in the area these indications of an early-formed suite of mineralization represented a weighty argument in favor of a reassessment of the mineralization potential of the Telemark district. Part of this summer's work was therefore concentrated on the gathering of evidence of new, primarily stratabound- and stockwork types of mineralization, and some time was spent on reassessing the potential of vein-type mineralization.

3.2 STRATABOUND MINERALIZATION

Mineralization of this type has been found in all of the major stratigraphic units although the Seljord Group seems somewhat underrepresented. This is primarily due to the fact that the type of mineralization in question is related to volcanogenic processes which are subordinate in the quartzitic lithologies of the Seljord Group. Table 1 summarizes the occurrences included under this heading and it comprises both newly discovered mineralization as well as reinterpreted, previously known mineralization. With the exception of the Tinnsjø occurrence, the locality included in each of the groups represents an abandoned mine.

RJUKAN GROUP

1. Cu-Fe-As-Ag +Au mineralization in acid volcanics.
2. Mineralization in predominantly basic volcanics.
 - a. Cu-Fe-Ag + Au; Tinnsjø.
 - b. Cu-Fe-Ag-Au; Graver.
 - c. Cu-Fe; Johnslie.
 - d. Pb-Zn-Fe-Cu-Ag-Au; Skolterberg.
 - e. As-Cu-Fe-Ag-Au-Pb-Zn; Listøl
 - f. Fe-P; Søftestad

SELJORD GROUP

3. Cu-Fe-Ag in acid volcanics; Guldnes
4. Heavy mineral seams.

BANDAK GROUP

5. Mineralization in basic volcanics.
 - a. Cu-Ag; Dalane.
 - b. Cu-Fe-Ag; Hovin.
 - c. Zn-Cu; Sauda.
 - d. Cu-Fe(-Ag) (-Ni-Co); basic sills in Rjukan-Seljord Groups.
6. Mineralization related to acid volcanism?
 - a. Mn; Bransnuten.

Table 1. Stratabound mineralization in the Telemark suprecrustals.

3.2.1 The Rjukan Group

The distribution of the Cu-Fe-As-Ag+Au mineralization discovered in acid volcanics of the Rjukan Group (Table 1,1) is shown in Fig. 30. This mineralization consists in general of disseminated and/or fracture-bound (stockwork-type) sulphides which in places are associated with hydrothermally introduced quartz, biotite and magnetite. The host rock is rhyolitic to rhyodacitic tuff, welded tuffs or lava flows. Details of the individual localities as shown in Fig. 30 are as follows:

022306B: Rusty, finely laminated tuff with minor micro-fracture bound pyrite, pyrrhotite, chalcopyrite and possibly arsenopyrite.

032306: Quartz-feldspar porphyritic rhyolite porphyry with minor arsenopyrite occurring as disseminations and along the border of high - T quartz-feldspar-biotite microaplite veins. Samples from water-tunnel dump.

042306: Dark coloured massive rhyolite lava, non-porphyritic or with a few minute phenocrysts of feldspar. Flow structures are commonly seen, lithophysae in a few places. This unit is microbrecciated and cemented by hairline infillings of biotite and pyrite.

052306: Rusty, 5 m thick tuff/schist horizon in tuff sequence. Carries disseminated pyrrhotite and possibly minor arsenopyrite.

012906: Muscovite-quartz-garnet-biotite schist, probably representing metamorphosed acid volcanite. Carries finely disseminated pyrite.

052406: Quartz-diorite with quartz-, feldspar- and biotite phenocrysts and 1-3 vol% disseminated pyrrhotite, pyrite and chalcopyrite.

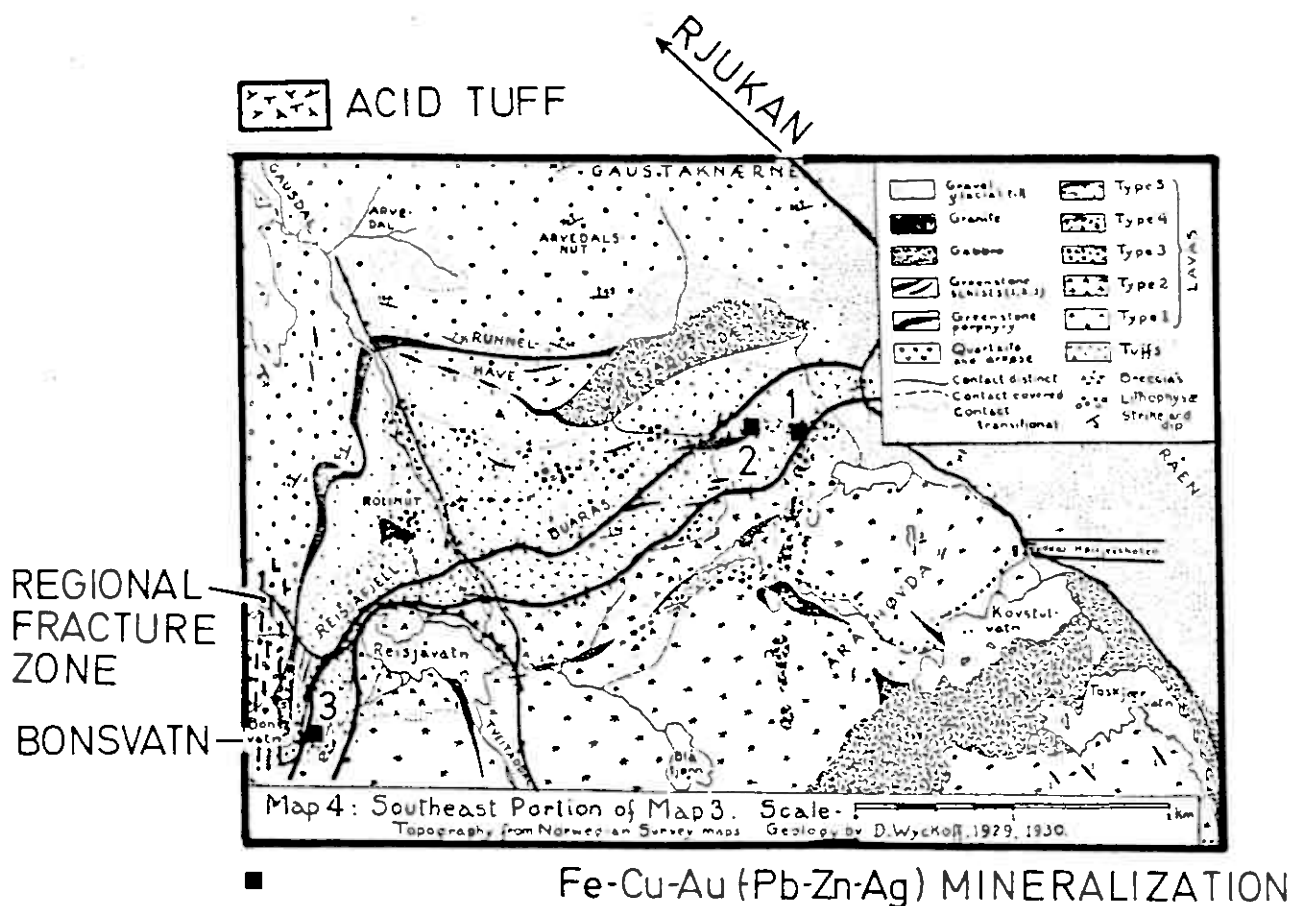
022906: Highly deformed and metamorphosed acid volcanite with elongate quartz - and feldspar porphyroclasts. Carries minor disseminated pyrite.

032906: Deformed and recrystallized acid (rhyolitic) lava? with disseminated pyrrhotite and pyrite. Samples from drift.

012508: Quartz-sericite schist with quartz porphyroblasts/-clasts and disseminated pyrite. Samples from water-tunnel dump.

023008: 4-5 m thick, rusty outcrop of an acid volcanite or quartzite occurring in a sequence of redbrown acid, high-grade metamorphic tuffs. Carries disseminated, up to 1 vol% chalcopyrite and pyrite.

Analogous, but somewhat stronger mineralization has been encountered in both ends of a 4 km long and ca. 300 m thick rhyolitic tuff-unit occurring in the vicinity of the Tuddal Højfjellshotel (Fig. 31). In the north-eastern end (locality 1 and 2) pyrrhotite occurs as finely disseminated "dust"-sized grains and as local, cm-sized semimassive rounded aggregates in a 10 m wide rusty zone in the tuff. Local zones with up to 10% pyrrhotite were traced over ca. 175 m along strike occurring in chert/jasper-like, sericitized aphanitic siliceous rocks. In the southern end of the tuff unit disseminated and microfracture-bound, extremely finegrained pyrite, pyrrhotite, chalcopyrite and arsenopyrite occur in dense siliceous layers of the tuff (Locality 3, Fig. 31 and Fig. 32). This mineralization is situated some 10 to 25 m to the east from a 100-150 m wide regional, quartz-cemented north-south trending fracture zone. In the area of the tuff-hosted mineralization this breccia has been intruded by up to 1 m thick basic dykes and an epigenetic Cu-Fe-As mineralization is associated with one of these dykes. This mineralization consists of a 10-30 cm thick, irregular vein composed of quartz, fuchsite, chlorite, carbonate, arsenopyrite, pyrrhotite, pyrite and pyrrhotite.

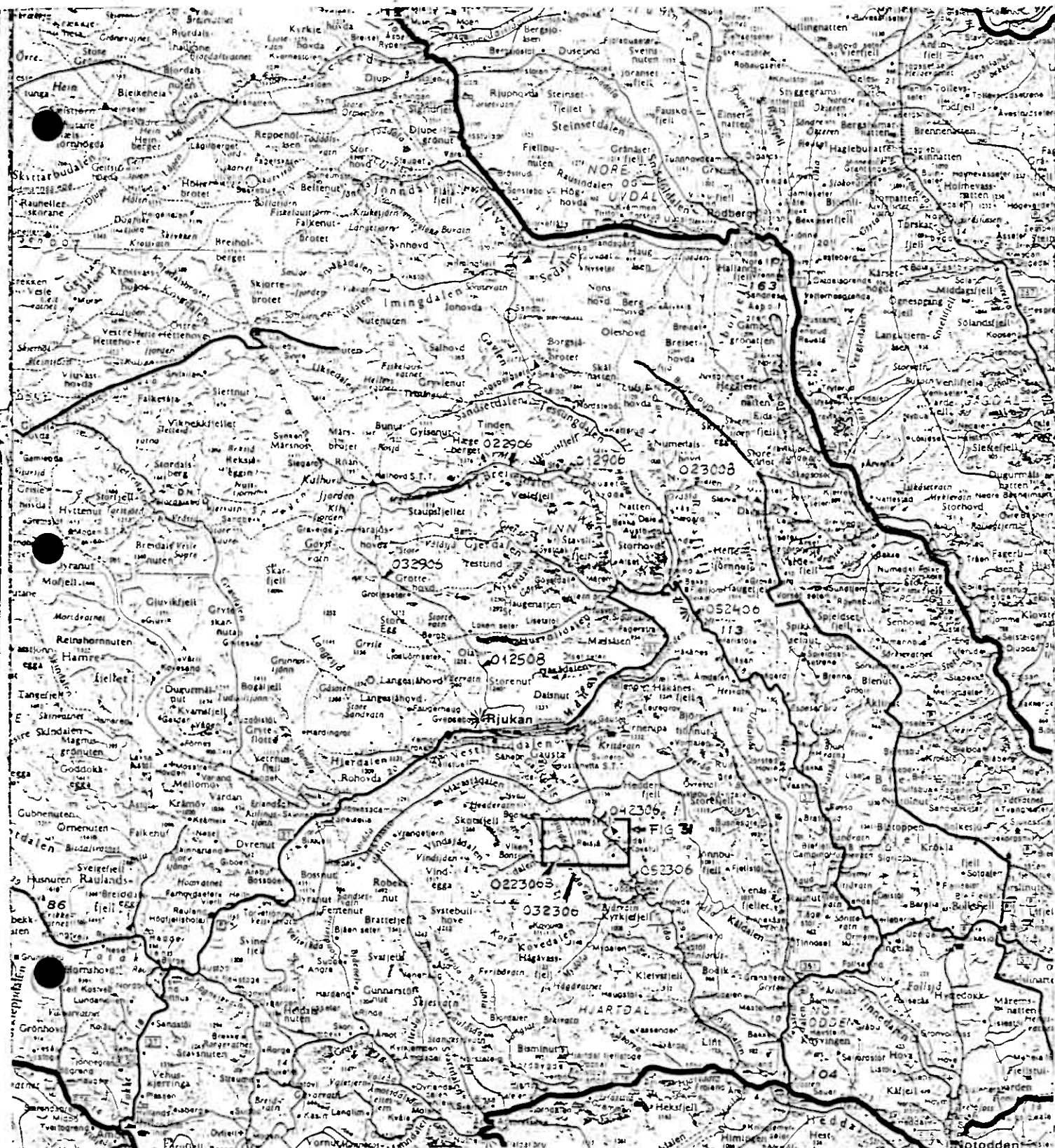


LOCALITY NO	MAP NO	Au Ppb	Cu Ppm	Pb Ppm	Zn Ppm	Ni Ppm	Co Ppm	Ag Ppm	As Ppm	Bi Ppm	W Ppm
032206A	1	395	347	70	43	9	10	0.4	106	10	-1
032206A	1A	-5	96	1385	2422	9	4	3.9	91	5	-1
032206	2	-5	14	17	4	1	2	-0.1	3	1	-1
032206	2A	-5	128	17	47	11	9	-0.1	3	1	-1
022306A	3	590	164	11	14	4	3	-0.1	150	2	2
022306	3A	-5	864	114	218	3	156	1.0	7730	67	-1

3A: ? EPIGENETIC MINERALIZATION ASSOCIATED WITH INTRUSION OF BASIC BRECCIA.



Fig. 32. Rusty, silicified tuffs at locality 3 in Fig. 31. A chip sample of these rusty layers returned 0.6 ppm Au.



SULPHIDE MINERALIZATION
IN ACID VOLCANICS OF THE RJUKAN
GROUP.

	Au ppb	Cu ppm	Pb ppm	Zn ppm	Ni ppm	Co ppm	Ag ppm	As ppm	Bi ppm	W ppm
0223068	-5	33	14	58	6	5	-0.1	50	24	-1
032306	31	83	21	129	5	31	0.5	4	8	-1
032306	-5	83	32	32	6	5	2.1	228	17	1
042306	-5	74	5	69	11	1	-0.1	50	32	1
052306	-5	64	13	45	11	16	-0.1	1	1	-1
02906	-5	12	23	26	5	-1	-0.1	116	2	2
022406	-5	648	10	68	41	33	1.0	2	1	-1
022406	-5	19	17	42	4	3	-0.1	6	-1	-1
032906	-5	132	229	46	20	11	3.0	30	22	4
012509	-4	137	40	23	9	2	-0.1	3	6	2
023008	-4	121	25	5	8	41	0.4	2	1	3

0 KM 10

FIG. 30

It is exposed over 10-20 m along the contact of the north-south striking subvertikal dyke thinning toward the north and disappearing below cover toward the south. The basic dyke is altered to an assemblage of biotite, chlorite and ankerite along the mineralized zone. Although the tuff-hosted mineralization may owe its origin to the hydrothermal solutions which gave rise to this epigenetic vein, it is likewise possible that the metals of the vein were mobilized from a preexisting fumarole-related, stratabound mineralization. The latter interpretation is to some extent substantiated by the trace element content of the tuff-hosted mineralization (3, Fig. 31) which is overall identical to the similar mineralization further to the north (1 and 2, Fig. 31). The epigenetic (3A, Fig. 31) vein shows with the exception of Au and Ni, an overall enrichment of the elements which occur in the stratabound mineralization. It is noted that at this preliminary stage of the investigation of the Telemark area no attempt was made to trace the stratabound mineralization between the northern and southern areas.

The acid volcanic hosted mineralizations have been chipsampled and the analytical results are shown in Fig. 30 and Fig. 31. Three samples (032306; 032206A; 022306A) returned detectable gold, and two of these are not insignificant, showing values of 0.4 and 0.6 ppm Au. Silver is present in 7 samples with a value of 3.9 ppm as the highest (032206A); arsenic occurs in all samples with a highest value of 228 ppm (032306), probably reflecting the occurrence of arsenopyrite.

In general terms the trace-element content of most of the samples are partly comparable with similar data summarized by Rytuba (1980) and Hildreth (1979) for acid ash-fall and outflow sheets which reflect compositionally zoned rhyolitic magma emplaced during collapse of major calderas in the Basin and Range province of the western U.S.A.

Au ppb	Cu ppm	Pb ppm	Zn ppm	Ni pmm	Co ppm	Ag ppm	As ppm	Bi ppm	W ppm
15	1.8	29	38	3	0.3	0.31	15	no	3.3
25	3.0	24	100	3	1.0	0.17			1.0
	7.8	17	150					data	5.4
	7.0	50	182						3.9

Trace element contents of acid volcanics, Basin and Range province.

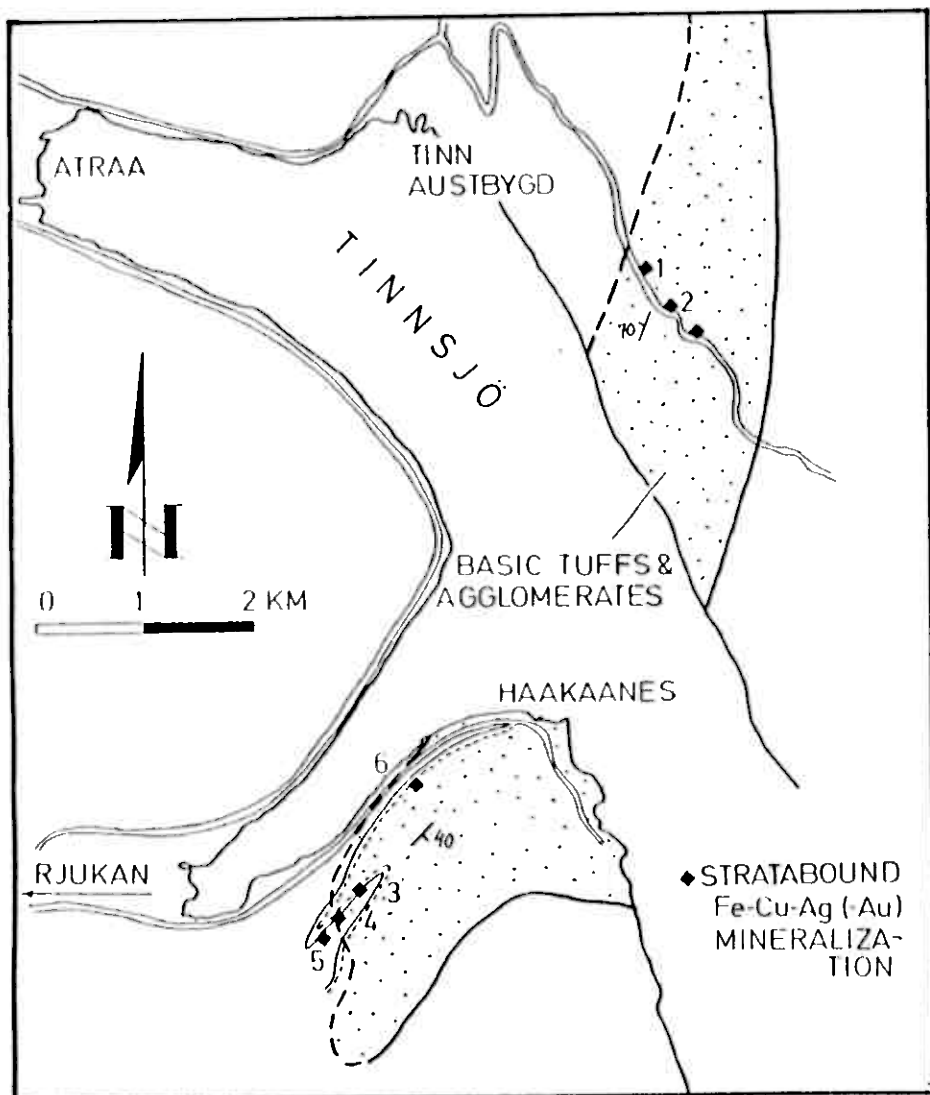
The ash flow tuffs which form early in the caldera cycle are highly enriched in lithophile elements such as Be, Cs, Li, Hg, Mo, Sb, Sn, Th, U and W and are depleted in Ag, Au, As and Cu. These depleted elements may be introduced later in the caldera cycle by resurgent latite- and quartz latite domes and these may in turn generate hydrothermal cells which mobilize metals from both the ash flow sheets and the latite domes and thereby form various types of mineral deposits (Rytuba, 1981). Although the data from Telemark and the Basin and Range province are probably not directly comparable, a cursory glance at the metal values shows that the Telemark acid volcanites are enriched in Cu, (Ni, Co), As and Ag as compared to the Basin and Range volcanics. Two samples (032206A; 022306A) are greatly enriched in gold, while two samples (032906; 032206A) show enrichment in Pb and Zn relative to the Basin and Range samples. An interesting consequence of these considerations could therefore be that the metal-enriched tuff horizons of the Rjukan area represent hydrothermally altered, originally porous beds receiving their load of metals (and silica?) from hydrothermal solutions circulating in, and altering Au - Ag - As - Cu-bearing caldera-related intrusions. As mentioned in a previous section, the part of the Rjukan Group in question exhibits a number of features which are reminiscent of a caldera origin and samples 032306, 052406 and possibly 032906 are macroscopically quite similar to many caldera-related subvolcanic intrusions of the Permian Oslo graben.

However, whatever the origin of the metals the gold values of the mineralized tuff in the Tuddal area (0.4 and 0.6 ppm Au) are considered to be so significant that they warrant further investigation.

Sulphide mineralization with minor precious metals is relatively widespread in basic volcanic lithologies belonging to the Rjukan Group (Table 1,2). One area to the north from lake Bandak is characterized by a number of small, abandoned mines belonging to this group, and in the northern end of lake Tinnsjø a thick basic pyroclastic unit has been found to contain widespread Cu - Fe - Ag ± Au mineralization.

The Tinnsjø mineralization is present along the western and the eastern shore of the lake (Fig. 33). The host rock is predominantly basic tuffs with subordinate intercalations of agglomerates, flows and local pillow-like structures. In this sequence several areas have been encountered consisting of discordant to semiconcordant schlieren, veins and up to 2 m thick boudins composed of masses of epidote, quartz, magnetite, calcite, and fuchsite.

The epidote seems to have formed contemporaneously with, and as a result of the introduction of large amounts of quartz in the form of veins, cm-sized aggregates (augens) and larger, irregular masses; the introduced minerals show clear signs of deformation. A number of the epidote-rich, and especially the quartz-rich zones show an associated disseminated sulphide mineralization consisting of one or more of the minerals pyrite, pyrrhotite and chalcopyrite. The latter may be present in relatively large amounts (up to 1-2 vol%) and it is obvious that the chalcopyrite was introduced, and is limited in appearance to areas with introduced quartz. The largest of the quartz-epidote bodies occurs at locality 6 in Fig. 33, and a sketch of this mineralization is shown in Fig. 34. The sulphides are associated with one or more concordant lenses of



STRATABOUND MINERALIZATION

VEIN-TYPE MINERALIZATION

EPIGENETIC (VEIN) MINERALIZATION INTERPRETED AS METAMORPHIC 'SWEAT OUT' PRODUCTS FROM STRATABOUND MINERALIZATION. 'EPI'-NUMBERS IDENTICAL TO 'STR'-NUMBERS.

	Au ppb	Cu ppm	Pb ppm	Zn ppm	Ni ppm	Co ppm	Ag ppm	As ppm	Bi ppm	W ppm
1	-4	82	52	163	7	13	0.2	-1	1	2
1A	-4	57	43	102	10	27	0.3	-1	1	2
2	13	2400	3	34	7	11	5.4	-1	-1	2
2A	-4	166	178	203	-1	39	1.6	2	-1	2
3	-4	197	13	52	15	20	0.1	-1	1	2
3A	-4	145	136	31	6	2	0.1	-1	10	2
3B	-4	90	32	24	12	7	0.1	-1	1	2
4	-5	649	9	44	5	11	0.5	28	2	4
5	36	460	679	24	110	1590	3.6	45	4800	20000
6	-5	100	8	9	19	30	0.1	26	32	-1
6A	145	672	19	34	18	22	28	2	23	3
1	120	15	52	106	4	8	0.1	1	2	3
2	30	568	24	131	15	34	3.2	3	2	3
3	-4	502	69	65	32	74	0.8	-1	2	2
3A	6005	40980	16	211	29	33	20.8	5	1	1
5	10	375	64	142	107	71	0.3	94	3	-1
5A	5	192	24	193	98	58	0.1	1	8	-1
5B	-5	815	37	18	14	-1	1.4	44	5	1
5C	-5	557	14	39	259	70	-1	16	25	-1

CHIP SAMPLES

SELECTED Cu-RICH SAMPLES FROM EPIGENETIC MINERALIZATION*3A

	Au ppb	Cu ppm	Pb ppm	Zn ppm	Ni ppm	Co ppm	Ag ppm	As ppm	Bi ppm	W ppm
3 I	10	1900	9	15	9	3	0.2	-1	2	7
3 II	10	1500	4	48	16	15	0.1	-1	1	2
3 III	5	3100	12	113	9	40	1.0	-1	1	-1
3 IV	125	25900	12	87	16	15	9.2	-1	1	2

FIG. 33

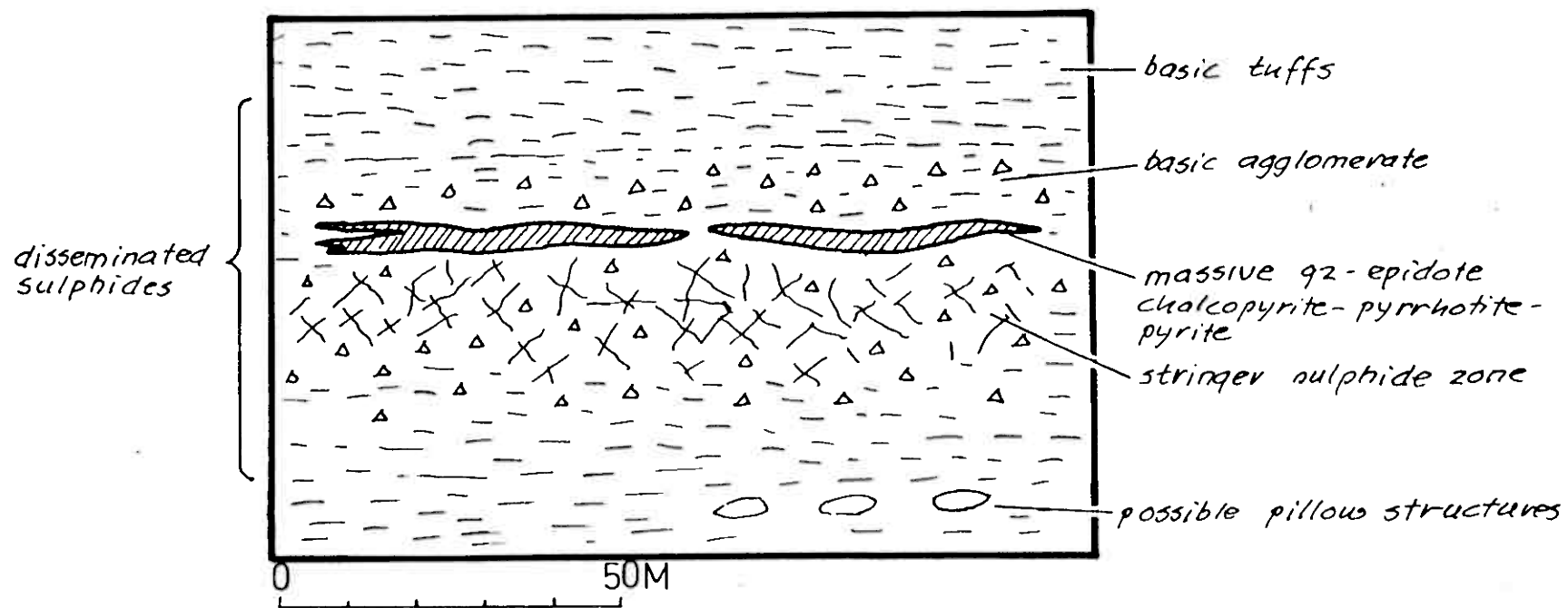


FIG. 34

massive quartz-epidote and intensively silicified basic tuffs and agglomerates, forming bodies of up to 5-7 m in thickness and with a total length in excess of 130 m. This zone is characteristically associated with the appearance of agglomerates and possible pillow structures in an otherwise tuffaceous lithology. The quartz-rich bodies contains up to 5 vol% disseminated pyrite, pyrrhotite and chalcopyrite (Fig. 35) and deformed sulphide stringers occur in schistose agglomerates beneath the quartz-epidote-sulphide lenses (Fig. 35; 36). Surrounding this system is a halo of disseminated pyrite and chalcopyrite. Subsequent to their formation the sulphide-carrying systems have been deformed and metamorphosed and a number of "sweat-out" type quartz veins and irregular bodies have formed (Fig. 37). Some of these veins carry rich chalcopyrite and some precious metal mineralization. Other post-genetic events include the intrusion of gabbroic sills probably related to the deposition of the Bandak Group, the intrusion of granitic aplite dykes and cross-cutting quartz-ankerite-molybdenite-bornite veinlets related to the granitic dykes.

Several modes of origin of the quartz-epidote related mineralization is possible, including exhalative-, metamorphogenic-, and granite-related processes. The discordant, and at the same time concordant nature of the mineralized bodies; the introduction of large masses of quartz and sulphides; the morphology of the sulphide mineralization; the association of the sulphide-bearing horizons with agglomerates and possible pillow structures; and the post depositional deformation point in the present authors opinion toward an exhalative, probably subaqueous origin for the mineralization.

The metal content of the stratabound and the probably related (mobilized) vein-type mineralization is shown in Fig 33. Gold-contents of up to 145 ppb occur in three of the



Fig. 35. Stratabound sulphide mineralization (arrow) with stringer sulphide zone below.



Fig. 36. Detail of the stringer sulphide zone in basic aggregate shown above.



Fig. 37. "Sweat-out" type
quartz-chalcopyrite-
vein in basic tuffs.
Photo shows the locality
numbered 5 in Fig. 33.

"stratabound samples" while silver is present in amounts of up to 5.4 ppm in 7 out of 11 samples. It is noted that there is a tendency for high silver values to be related to "high" copper contents. One sample (no. 5) returned highly anomalous Bi- and W-values; these are presently being rerun. The samples of the epigenetic veins are characterized by more gold and silver values at a generally higher level than the stratabound mineralization. One sample (3A) which in the first batch returned 6 ppm Au was later resampled; as shown, the second batch returned considerable lower values and the high copper-value of sample 3A (4.1%) is considered the cause of the first, high Au-value. Overall, the metal content of the epigenetic veins is in accordance with a mobilization from the stratabound mineralization. If representative, the metal values of the latter mineralization indicate that this type will probably not be a profitable exploration target in itself. However, the indications of sporadic, interesting Au-values in vein-type mineralization that was probably mobilized from the syngenetic quartz-sulphide horizons suggest that the latter may constitute a potential source bed for epigenetic mineralization.

Basic volcanics (?Vemork Formation) of the Rjukan Group is the host for a large number of epigenetic vein deposits and some stratabound mineralization of Cu-Fe, Pb-Zn and As (-Ag-Au) situated immediately to the north from lake Bandak (Fig. 38). Recently some of the small stratabound sulphide deposits were reinvestigated by Nilsen (1983) and interpreted as being of sedimentary origin. However, as it will be shown in the following, most of the stratabound mineralization in the area is probably of exhalative, volcanogenic origin. On the basis of the existing literature (Dons, 1961; Nilsen, 1983) and personal communication with Nilsen (1983), four examples of the stratabound type of sulphide accumulation were chosen to serve as examples: the Skolterberg Pb-Zn mine; the Graver Cu-Fe mine; the Listøl As-(Ag-Au) mine; and the Johnslø Cu(-Fe) deposit (Fig. 38).

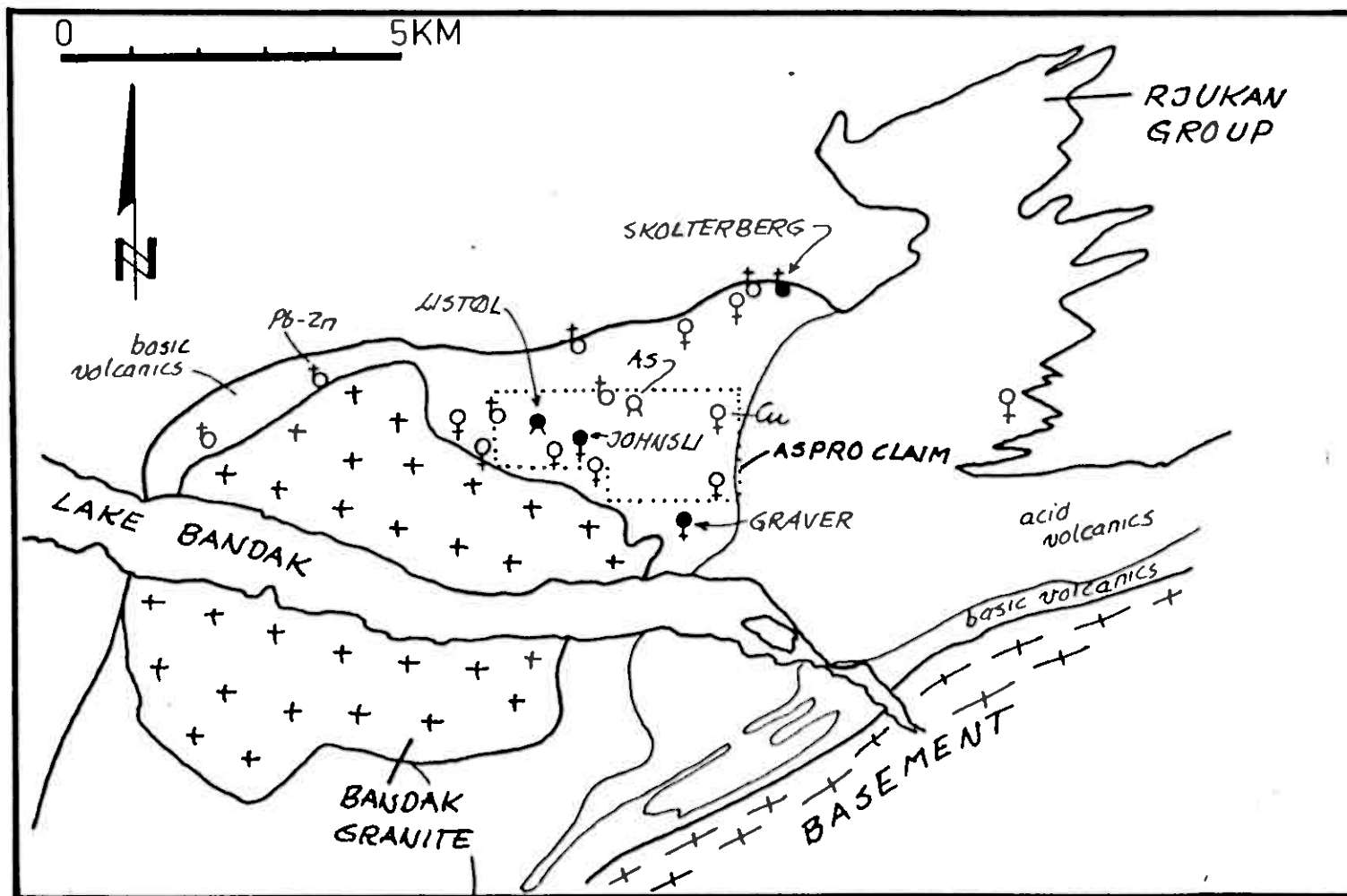


FIG. 38

The Skolterberg Pb-Zn mine occurs in the northeastern end of an intermittently mineralized horizon which may be traced for at least 1 km toward the southwest (Fig. 38). Apparently the metal content changes from Pb-Zn to Cu in this direction, and Pb-Zn vein-type deposits (with some sulphide "impregnation" in the host rock, Dons, 1963) occur along approximately the same lithological horizon further toward the southwest. According to the geological mapsheet 1:100.000, Kviteseid (Plate 3), the same lithological horizon may fold toward the south from Skolterberg and possibly constitute the host rock for the Graver Cu-Fe deposit and at least two other Cu-showings in between the two. As shown in Fig. 38 some of these showings have been claimed by ASPRO. The Skolterberg deposit occurs in a thick sequence of basic tuffs with subordinate agglomerates which have been metamorphosed to more or less massive to finely laminated hornblende-biotite-sericite-chlorite-albite-carbonate schists. Immediately above the Skolterberg mine is a more than 25 m thick conglomerate layer with pebbles of white quartzite. The "mine" consists of a small pit (4x3x2 m) and possibly a more than 10 m deep, waterfilled shaft, and is developed in an up to 2 m thick sulphide impregnated, silicified zone in the basic tuffs. The sulphides include galena, sphalerite, chalcopryrite and pyrite and occurs as mm- to cm-sized aggregates along the bedding planes of a finely laminated quartz-biotite rock. The quartz-rich zone is up to 6 m thick and shows gradational boundaries to the enclosing basic tuffs, indicating that it originated by silicification of the tuffs. VLF-measurements carried out in the area by the NGU (Singsaas, 1979) suggest that the sulphide-bearing horizon may be traced over more than 300 m along strike. Three to four other, somewhat stronger anomalies within the 1500 m x 500 m large investigated area remain unexplained although Singsaas (op.cit.) suggests that they may represent sulphide richer portions of a mineralization. It should be noted, however, that VLF-measurements are not the best method to use on this type of disseminated mineralization.

The mineralized lithologies show signs of deformation and late sulphide-rich quartz-veins cross cut the disseminated mineralization. The stratabound nature of the latter, in conjunction with the associated silicification and its overall similarity with the Guldnes Cu-Fe-Ag mineralization (see below) suggest that it may represent an exhalative and/or subsurface volcanogenic hydrothermal mineralization.

The metal content of the ore is shown below.

Sample no.	Au ppb	Cu ppm	Pb ppm	Zn ppm	Ni ppm	Co ppm	Ag ppm	As ppm	Bi ppm	W ppm
012607	215	8580	1460	349	54	60	19.6	85	2	-1
012607A	255	5460	12300	3137	51	49	16.3	8	2	-1
012607B	255	18500	2263	270	26	30	25.6	183	-1	-1

Metal content of samples from the Skolterberg mine. Sample 012607 represents a chip sample of Pb-Zn rich ore from the mine dump; samples A and B represent typical ore types.

Gold values seem to be relatively constant at ca. 0.3 ppm, while silver shows an average value of ca. 20 ppm. An interesting feature is that gold and silver apparently varies independently of the Cu- and Pb-content respectively.

The Graver Cu-Fe mine is situated to the south from the Skolterberg mine (Fig. 38). It consists of a small water filled open pit with a size of 10x8 m and a depth of 1 m to more than 4 m. The mine is developed in mineralized basic tuffs and lapilli tuffs. The mineralized horizon is ca. 2 m thick at the mine opening and is probably conformable to the layering in the pyroclastics. It consists of an intensively silicified zone with abundant magnetite and lesser amounts of chalcopyrite, bornite and minor pyrite. Locally a skarn-like paragenesis rich in epidote, chlorite, quartz and carbonates

is developed. A smaller, but quite similar mineralization was found in a nearby road section exhibiting a sequence of basic tuffs and coarser pyroclastics. In this section meter-thick, intensively silicified agglomerate/lapilli tuff horizon occur with abundant associated magnetite and minor chalcopyrite and bornite (Figs 39 and 40). On the basis of their general appearance, their close similarity with the Guldnes Cu-Fe-Ag ore and the signs of post-depositional deformation these mineralizations are interpreted as being of volcanic exhalative type.

The metal contents of selected, representative samples from the Graver mine dump are shown below.

Sample no.	Au ppb	Cu %	Pb ppm	Zn ppm	Ni ppm	Co ppm	Ag ppm	As ppm	Bi ppm	W ppm
022607 I	100	1,69	64	745	187	155	115,9	-1	3	-1
022607 II	125	1,65	38	213	52	119	104,4	-1	4	-1
022607 III	75	2,16	29	79	32	103	103,9	-1	5	-1
022607 IV	50	2,36	53	3058	38	86	71,3	-1	6	-1
022607 V	75	0,89	13	138	38	133	42,2	-1	12	-1
022607 VI	20	0,67	33	305	32	139	58,5	-1	6	-1
022607 VII	100	0,75	17	110	30	96	47,5	3	6	-1
022607 VIII	175	1,07	27	157	36	143	68,0	3	6	-1

Metal content of ore samples (hand specimens) from the Graver mine dump.

A characteristic feature is the relatively high Cu-content which is more or less comparable to the Cu-content of the Guldnes mine (see below). Gold is present in amounts of up to ca. 0.2 ppm while the average silver value for the 8 samples is 76 ppm, again comparable to the ore of the Guldnes mine.



Fig. 39. Silicified basic agglomerate in the vicinity of the Graver mine.



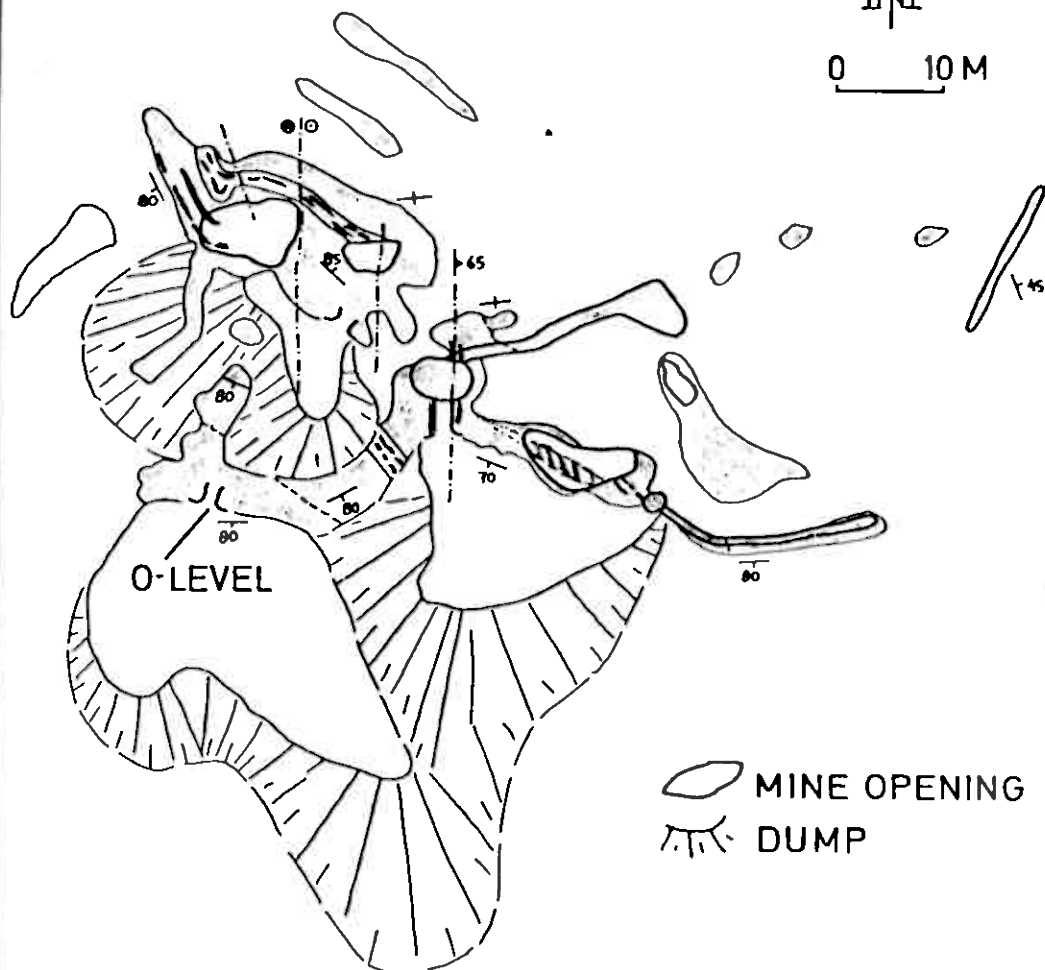
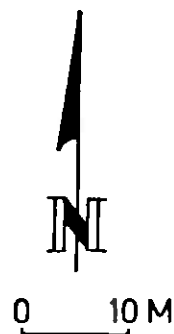
Fig. 40. Close-up of the silicified zone in Fig. 39. Note the malachite staining (arrow) caused by chalcocyanite-bearing quartz stringers.

The Listøl As-Cu-Fe-Ag(-Au) mine is situated 3 km to the northwest from the Graver mine, inside the ASPRO claim area (Fig.38). On the basis of the literature survey this mine was selected before the field season as a possible example of a so-called Haile-type fumarole-related arsenic-gold mineralization (Spence et.al., 1980; Worthington et.al. 1980). The Listøl mine was accordingly investigated and sampled in some detail with the view that it should serve as a possible model for this type of mineralization. However, as it will be shown, the extremely complicated deformation of the Listøl ore body makes any genetic interpretation difficult.

The Listøl mineralization occurs in a thick sequence of Rjukan Group chlorite schists (? basic tuffs), amphibolites (?flows) and quartz-sericite-microcline 'gneiss' (?acid tuffs). The ore body is hosted in chlorite (-biotite) porphyroblastic basic schists, which on either side of the mineralized horizon grade into a rock composed of hornblende needles occurring in a matrix of blue-grey plagioclase and quartz (Fig. 41). A (tectono)-stratigraphy is discernible in the mine area, as schematically shown in Fig. .42, A and Fig. 41. From the lower (north) part of the sequence a boundary is observed between a chlorite porphyroblastic basic schist to a light grey rock primarily composed of quartz and sericite and with varying amounts of biotite, hornblende, tourmaline, garnet and fuchsite. This light grey, massive to foliated gneiss-like rock hosts disseminations, schlieren and massive pods of arsenopyrite mineralization with minor chalcopyrite and subordinate pyrite, and it constituted the main As-ore of the mine. In general this ore zone is concordant to the foliation in the enclosing chlorite schists although it shows sharp as well as gradational boundaries. It may represent an intensively hydrothermally altered zone and it can be traced from the westernmost surface outcrop about halfway through the mine.

GEOLOGICAL SKETCHMAP OF LISTØL AS-MINE

-  QUARTZ-HORNBLENDE GNEISS
-  CHLORITE SCHIST
-  SILICA-SULPHIDE SCHIST
-  MASSIVE SULPHIDE
-  FOLIATION
-  FAULT: ATTITUDE, THROW



SELECTED SAMPLES OF HANDSORTED ORE

	Au ppb	Cu %	Pb ppm	Zn ppm	Ni ppm	Co ppm	Ag ppm	As %	Bi ppm	W ppm
1	725	1,9	1425	1378	245	50	54,9	0,09	170	-1
2	230	0,8	2865	306	44	38	16,4	0,02	1	-1
3	-20	0,8	40	1314	432	654	19,6	27,6	15	-1
4	192	3,6	146	4250	1571	164	55,4	25,5	133	-1
5	4570	0,03	30	113	308	56	2,7	37,3	136	-1
6	277	2,7	1229	3004	497	58	41,6	0,9	108	-1

FIG. 41

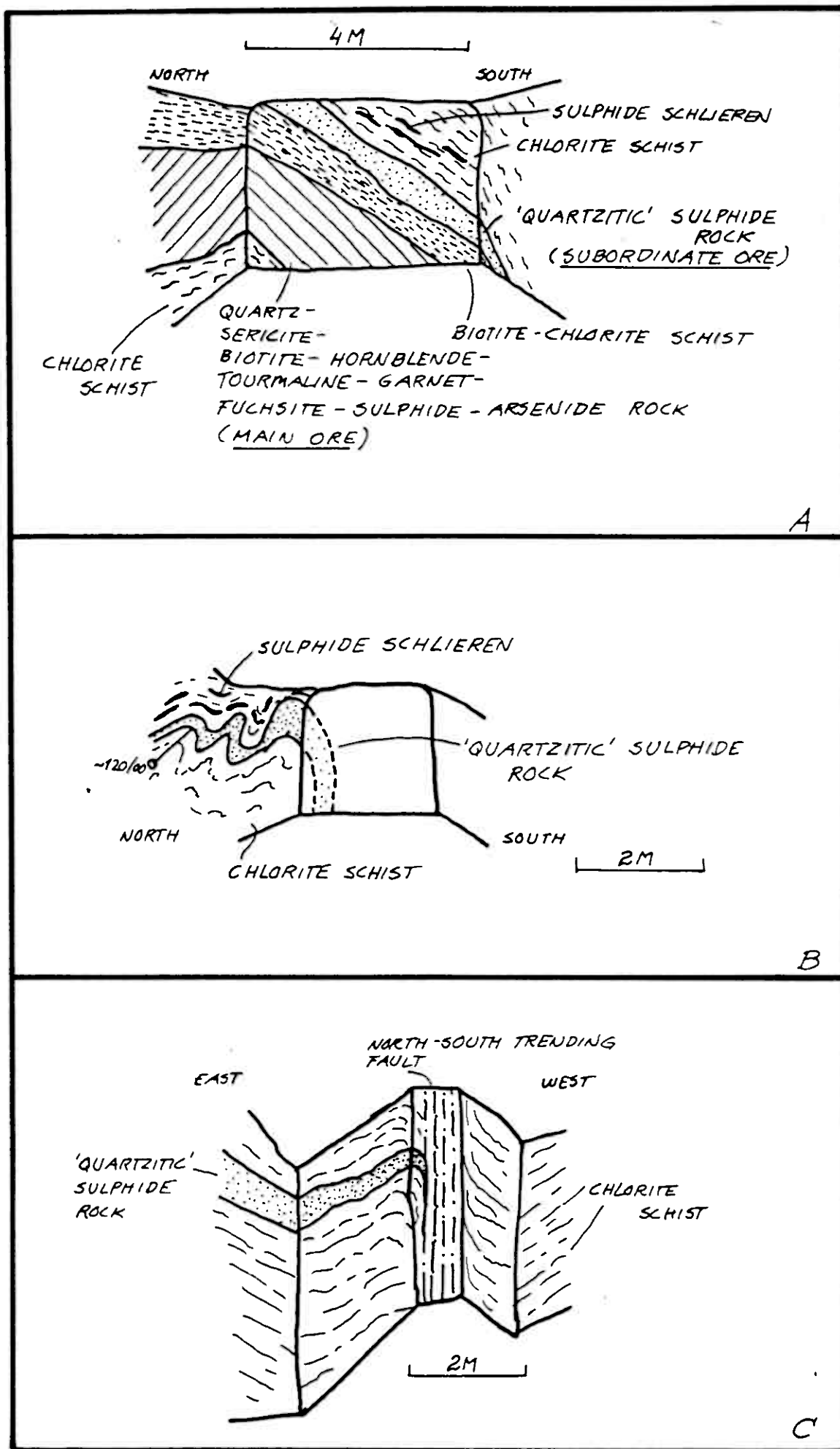


FIG. 42

Above this light grey, silicified zone which varies in thickness between 0,3 m and ca. 3 m follows an up to 1 m thick layer of chlorite-biotite schists. This is in turn overlain by a 5 cm to 2 m (?) thick sulphide bearing quartz-rich layer which may be traced through the mine. The rock resembles a massive, cherty, finegrained "quartzite" carrying minor sericite, biotite and disseminated chalcopyrite, pyrite, pyrrhotite and arsenopyrite. In contrast to the above mentioned arsenopyrite - dominated light grey siliceous rock, the "quartzitic" layer is dominated by chalcopyrite, which also occurs as small massive schlieren in the hanging wall chlorite schist.

Subsequent to the formation of the sulphide zones, the area was folded on a mesoscopic scale around axes which trend approximately $120^{\circ}/00^{\circ}$. (Fig. 41; Fig. 42, B). The fold style is open to tight, with axial planes trending $120^{\circ}/70^{\circ}\text{N}$. Subsequent jointing and minor faulting took place along $90^{\circ}/70^{\circ}$ -trending surfaces transecting the folds. Later block-faulting with downthrow toward the west occurred along a set of normal faults trending $00/65^{\circ}$ - 90°E (Fig. 42, C). During one or more of these deformation phases the sulphide bearing horizons were boudinaged and offset and quartz and sulphides were mobilized into numerous irregular fractures especially on the present southern side of the ore layers. The ore body seems to thin out toward the west and an attempt has been made to follow it toward the east by trenching. Approximately 15 m WSW of the westernmost mine opening a narrow silicified zone occurs with minor quartz stringers and sulphides. This may be traced over ca. 30 m and seems to die out in both directions. Approximately 200 m along strike to the east is another, less intense bleach-zone in the basic tuffs but this shows only minor pyrite mineralization.

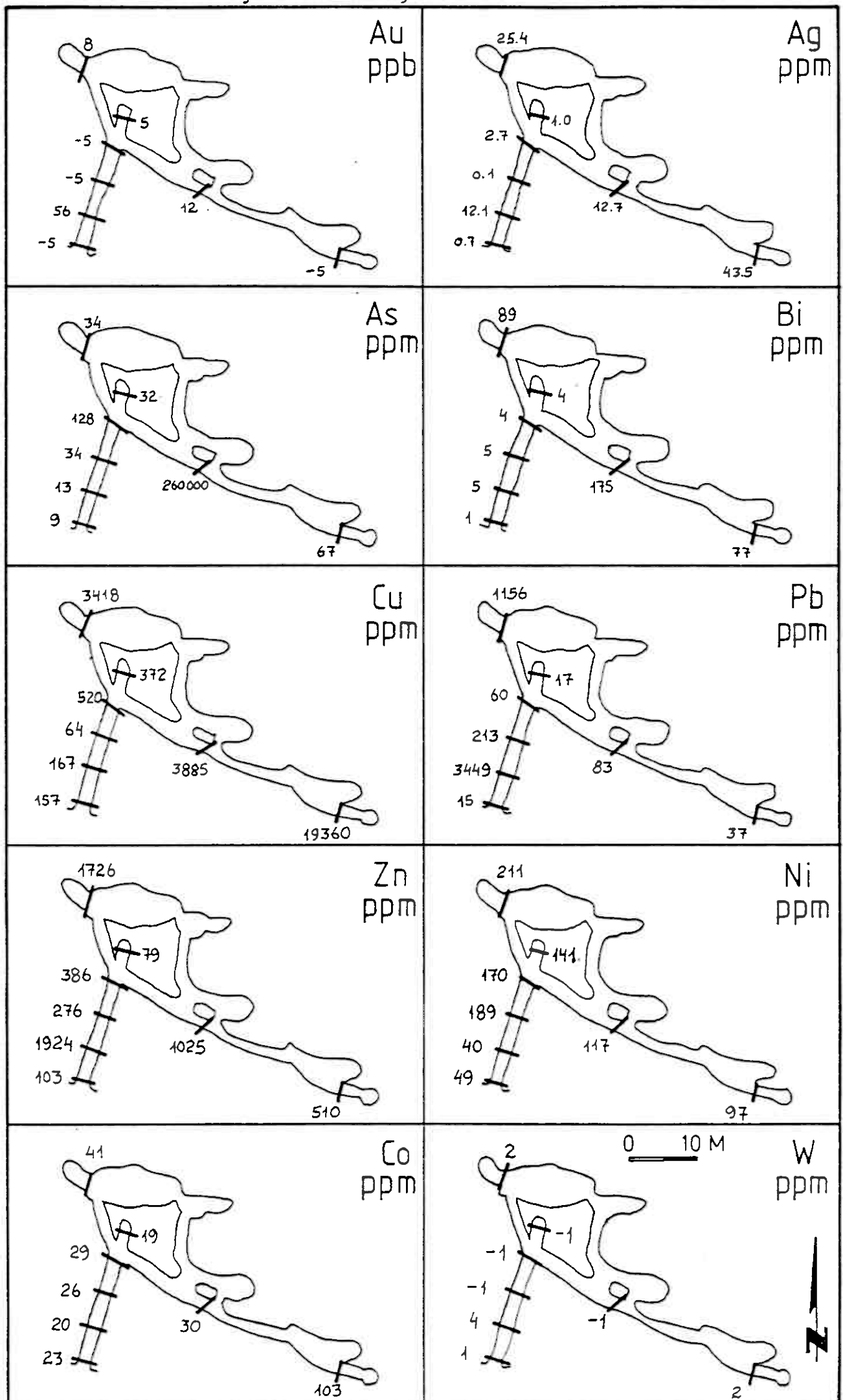
The intense post-ore deformation makes it difficult to interpret the origin of the orebody. The sulphide zones could represent an exhalative system in which the light grey, silicified and arsenopyrite-rich zone constituted a feeder

channel to an overlying stratabound chalcopryrite mineralization. The zones could on the other hand equally well represent two separate or related epigenetic vein systems associated with for instance the Bandak granite occurring immediately to the south (Fig. 38). Further investigations is needed before any definite conclusions can be drawn; however, the ore shows an in part remarkable similarity to the previously described stratabound ores, and it is accordingly tentatively interpreted as a representative of an exhalative (- fumarole?) ore type.

Samples (hand specimens) of chalcopryrite- and arsenopryrite dominated ore were collected on the mine dumps and analysed; the results are shown in Fig. 41. With the exception of one sample (3) all the samples returned detectable gold in amounts of up to ca. 4.5 ppm. Silver, which mainly occurs as a member of the tetrahedrite series is present in amounts of up to 55 ppm, with an average of 32 ppm for the six samples. Massive arsenopryrite ore contains 25-30% As and up to 3.6% Cu, while chalcopryrite-dominated ore contains 1-3% Cu and subordinate As. These results are in accordance with the production figures quoted by Bugge et.al. (1922). During the period 1895-1910 ca. 400 tonnes of ore with 25-30% As were produced. Pure arsenopryrite from the ore contained 2.5 ppm Au and 70 ppm Ag.

In order to investigate possible precious metal zoning around the ore zones a number of chip samples were collected in the lowermost mine addit which trends at a right angle to the ore body (Figs. 41.; and 43). Three chip samples were furthermore collected in the western-, the central-, and the eastern part of the stopes in order to investigate the precious metal content of the thin ore horizon left in these areas. The results are shown in Fig. 43. Apart from one sample in the addit (number two from the south) only the 3 samples of ore from the stopes returned significant quantities of metal. The

CHIPSAMPLING, O-LEVEL, LISTØL AS-MINE



anomalous addit-sample contains fracture bound, remobilized sulphides which explains the analytical values. Overall, the results indicate that no major undetected precious metal mineralization exists outside of the main ore zones.

The Johnsli skjerp is situated ca. 1 km ESE from the Listøl mine and occurs, according to Nielsen (per. comm., 1983) at a stratigraphic level which is equivalent to this. The mineralization consists of chalcopyrite impregnation in a quartz-rich chlorite-biotite schist horizon occurring in a thick sequence of chlorite schists. The thickness of the mineralized zone is less than 1 m and it may be traced over 15-20 m along strike. The quartz in this zone is in part very finegrained and resembles the light grey silicieous zone in the Listøl mine. An analysis of a copper-rich chip sample from the dump at Johnsli returned the following:

Sample no.	Au ppb	Cu %	Pb ppm	Zn ppm	Ni ppm	Co ppm	Ag ppm	As ppm	Bi ppm	W ppm
Joh 1	75	3,94	403	7440	170	30	97,2	1	15	-1

Although somewhat lower in gold the chemistry of this sample resembles the copper-dominated samples from Listøl. The Johnsli mineralization may represent an exhalative horizon similar to Listøl or it may be a metamorphic "sweat-out" product.

The Guldnes Cu-Fe-Ag mine is situated in a predominantly acid volcanic pile at lake Sundbarmsvatnet. Stratigraphically these volcanics form a part of the Seljord Group as shown in Plate 3. However, as suggested in a previous section, the deposition of the clastic sediments of this Group may have taken place concomitant with weak volcanic activity related to

the late stages of the development of the overall underlying Rjukan Group. The Guldnes mine area is furthermore transected by basic dykes which may relate to the deposition of the Bandak Group, and the deposition of the Guldnes mineralization is therefore probably related to late-stage Rjukan Group volcanic activity. This mineralization, which is a good example of a volcanogenic, fumarole-related exhalative sulphide deposit has been investigated by P.M. Ihlen and his report is included below.

OGI-rapport: 06 - 83.

EN GEOLOGISK UNDERSØKELSE AV GULDNES
CU-GRUVER, SELJORD KOMMUNE,
TELEMARK.

Trondheim, 13.9.83



SIV.ING. PETER M. IHLEN

SAMMENDRAG.

Rapporten gir en beskrivelse av geologien rundt Sundsbarmvann med hovedvekt på Cu-mineraliseringene rundt Guldnes gruver. Mineraliseringene er knyttet til en 150 m bred sekvens av felsiske vulkanitter i de stratigrafisk øvre deler av Seljordgruppens kvartsitter. Denne vulkanittformasjon som hittil har vært ukjent består vesentlig av finkornete tuffer og i mindre grad av grovere pyroklastisk materiale. Synvulkanske mineraliseringer opptrer rundt magnetittførende breksjerør i sekvensen. Nær toppen av breksjene som sannsynligvis er dannet i forbindelse med fumarole-aktivitet over subvulkanske plutoner er vulkanittene sterkt serisitt-omvandlet og impregnert med pyritt og koppermis. Utenfor den omvandlingshaloen er sulfidinnholdet lavt og består vesentlig av koppermis. Denne lavgehaltige mineralisering som er anslått å føre 0,1 - 0,2 % Cu har hittil blitt fulgt langs strøket over en lengde av 400 m. Sonens bredde er ca. 100 m. I tillegg til disse mineraliseringer er breksjene ofte gjennomgått av et nettverk av sene kvartsårer som lokalt fører rike ansamlinger av koppermis og bornitt. Denne malmtypen som Guldnes gruver ble drevet på ble sannsynligvis dannet ved mobilisering av metallene i de syn-vulkane mineraliseringer under den regionale deformasjon og metamorfose.

INNHALDSFORTEGNELSE.

	Side
INNLEDNING	1
REGIONAL GEOLOGI	2
GULDNESHALVØYAS GEOLOGI	3
Kvartsitter:	4
Rød laminert tuff	4
Grå båndete tuff	5
Ignimbritt	6
Felsiske intrusiver	6
Breksjer	7
Metadoleritter	8
Deformasjon	8
MINERALISERINGER	9
Vulkanogene mineraliseringer	9
Metamorfogene mineraliseringer	10
INNSAMLING AV PRØVER FOR ANALYSE	11
ANDRE MINERALISERINGER UTENFOR GULDNES-FOREKOMSTEN	11
KONKLUSJON OG TOLKNING	12
ANBEFALINGER	13
BILAG: 4 kart	
19 figurer	

INNLEDNING.

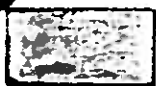
Under en kort befaring av Bob Creelman og Peter M. Ihlen, sommeren 1983 (Creelman, 1982) ble det påvist at Guldnes Cu-forekomst sannsynligvis representerer en mineralisering knyttet til brekksjerør i en sekvens av felsiske vulkanitter. Forekomsten er tidligere beskrevet av Dons (1963) som en epigenetisk kvarts-breksjegang.

De nye opplysninger som fremkom ved befaringene av Guldnes Cu-gruve og tildels Listølli As-gruve ga støtet til at en rekke av de kjente Cu-gangforekomster i Telemark kunne retolkes som syn-vulkanske mineraliseringer. Dette i motsetning til tidligere antagelser at gangforekomstene representerer metamorft mobilisert materiale fra de omgivende suprakrustaler. Denne revurdering av forekomstene førte til at Frank Pedersen foreslo en feltaksjon i Telemark etter Cu-Ag-Au-forekomster (Pedersen 1983 a,b).

Geologiske undersøkelser av Guldnes Cu-forekomst som ligger på SV-siden av Sundsbarmvannet i Seljord kommune ble utført av under tegnede i tidsrommet 18.-30.7.83. Hovedformålene med feltaksjon ble av Pedersen (1983a) definert som følgende:

- 1) Fastlegge hvilken type malm Guldnes mineraliseringene representerer. Et viktig spørsmål i denne forbindelse er relasjonen mellom mineralisering og deformasjon.
- 2) Fastlegge de laterale og vertikale omdannelsesmønstre omkring mineraliseringene herunder forsøke å innplassere f.eks. kaolin forekomsten ved Kalkjuvet og mangan forekomsten ved Koddedal.
- 3) Fastlegge betydningen av, og eventuelt arten av strukturell kontroll på mineraliseringene. Her kan det være tale om både en pre- og post-deformasjon/metamorf strukturell kontroll.
- 4) Prøveta mineraliseringene og omdannelsene med henblikk på base-metall og edelmetall analyser samt eventuelt sporelement analyser til hjelp i definisjonen av omdannelsesmønstre og mulige "guides to ore".

TEGNFORKLARING TIL FIG.1.



POST-OROGENE GRANITTER.



BANDAK - GRUPPEN BIMODALE BASALT-RHYOLITT
VULKANITTER & KVARTSITTER



ØST-TELEMARK VULKANITT KOMPLEKS



SELJORD - GRUPPEN

2. ØVRE KALKSKIFER ENHET
1. KVARTSITTER 3. UNDER KALKSKIFER ENHET



RJUKAN GRUPPEN BASALTISKE OG RHYOLITTISKE
VULKANITTER.



BASEMENT GNEISER

REGIONAL GEOLOGI.

Guldnes Cu-forekomst opptrer innenfor Seljordgruppens bergarter (Dons, 1960, Dons & Jorde, 1978) (Fig. 1) som domineres av feltspatførende kvartsitter og ortokvartsitter. Disse kvartsitter som er metamorfosert under grønnskifer facies varierer i farge fra mørk gråblå til lys grå. Lokalt opptrer også rødfargede kvartsitter bl.a. ved Grønlifjell seter og Stav seter (Fig. 2). Strukturelt har kvartsittene et massivt til båndet eller tykkbenket utseende.

Den vanligste type består av plan-parallelle lag, dm til flere meter tykke, med intern finlamining. De enkelte lag er ofte adskilt ved en tynn (1-10 cm) sone av fyllittisk skifer eller kvartsiserisitt skifer. Når det stratigrafiske nivå for Guldnes vulkannittene er ofte bølgeslagsmerker med assymetrisk snitt utviklet langs kontakten av de fyllittiske innlagringer. De enkelte kvartsittlag viser lokalt krysskikting i tillegg til sedimentære strukturer som antyder slumping og dannelsen av erosjonskanaler.

De massive kvartsitter som bl.a. har stor utbredelse ved Grønlifjell seter har nærmest et glassaktig utseende og mangler klart definerbare sedimentære strukturer.

Innenfor Seljordgruppens kvartsitter finnes det også flere skifer enheter (Fig.1) som av Dons og Jorde betegnes som kalkskifre. En eller flere av disse enheter ble påvist av Creelman (1982) og regional befaring rundt Sundsbarmvann av undertegnede i sommer har vist at disse har stor utbredelse (Fig.2). De representerer sannsynligvis en sydlig fortsettelse av skifersonen som kiler ut i Åmotsdalen (Fig. 1).

Rundt Sundsbarmvann er de såkalte kalkskifre utviklet som en båndet mørk gråblå siltaktig bergart (Fig.3). Bergartens båndete utseende skyldes dm tykke soner av en lys kalkrik (epidot-førende) kvartsitt som danner planparallelle innlagringer mellom massive lag av gråblå siltstein. Sistnevnte viser ofte en intern finlaminert tekstur på mm-skala.

I de stratigrafiske øvre deler av siltstein-formasjonen, nord for Seli, (UTM 664019) finnes det på grensen av kvartsitt innlagringene bølgeslagsmerker og polygonale sandfylte sprekker (Fig.4). Sistnevnte struktur kan tolkes som tørkesprekker.



Fig. 3.

Kvartsitt-båndet siltstein. Svakt utviklet
skifrihet loddrett på lagene. UTM 664019.



Fig. 4.

"Tørkesprekker" og bølgeslagsmerket på kontakten
mellom kvartsittbånd (lys) og siltstein (mørk).
UTM 664019.

I områder hvor siltsteinen er relativt sterkt deformert får den et skifrig eller nærmest fyllittisk utseende. I de skifrige partier er ofte kvartsittlagene brudt opp og fragmentene orientert parallelt med den penetrative foliasjon i form av utdratte linser. Dette har medført at det ofte kan være vanskelig å påvise den primære lagning i skifrene på disse steder.

Siltsteinsformasjonen like nord for Sæli (UTM 673016) med sine karakteristiske lyse kvartsitt bånd kan også sees ved lav vannstand (Befaring av Creelman & Ihlen, 1982) på øya (UTM 680015) mellom Mannerøsfjorden og Sælifjorden. På grunnlag av bergartenes strøkretning i området mellom Sæli og Guldnes er det sannsynlig at ihvertfall siltsteinsformasjonen ved Sæli opptrer i samme stratigrafiske nivå som vulkanittene på Guldneshalvøya.

Meta-doleritter og meta-gabbroer som fører hornblende som dominerende mafisk mineral er vanlig innenfor kvartsittene. Disse eruptiver som danner gjennomsettende ganger og konkordante plateformete legemer (sills) har i store deler bevart sin primære struktur. I områder hvor gangene antas å følge større forkastningsstrukturer er de ofte sterkt omvandlet til amfibol, biotitt- og kloritt-førende bergarter. Denne omvandling er tildels knyttet til kvarts-åre breksjer.

GULDNESHALVØYAS GEOLOGI.

Guldneshalvøyas berggrunn utgjøres av en ca. 150 m bred sekvens av pyroklastiske vulkanitter som er innlagret i Seljord-kvartsitten (Fig. 2). Bergartenes primære lagning stryker NNV-SSØ med 50-100° fall mot vest. De felsiske vulkanitter gjennomsettes på den sydlige del av halvøya av tre separate breksjerør eller "stringer" soner (Kart 1). Guldnes gruver ble tidligere drevet på Cu-mineraliseringer i kanten av disse breksjer. I tillegg er vulkanittene og breksjene også gjennomgått av sene meta-doleritt ganger.

Beskrivelsen av de litologiske enheter på Guldneshalvøya som følger under er vesentlig basert på detaljerte undersøkelser i gruveområdet eller innenfor Kart 1. Kart 2 viser lokalitetene for fotografiene i rapporten og spesielle blotninger nevnt i teksten (Lok. A, B etc.).

Kvartsitter:

Kvartsittene på Guldnes er relativt homogene og består av dm til flere meter tykke benker som er adskilt av 1-5 cm mektige soner av fyllittisk skifer. Kvartsitten er middelskornet og de enkelte benker er relativt massive med bare en svakt utviklet intern laminering.

Ligg-grensen til vulkanitt formasjonen er utviklet som en mørk grå til svart kvartsitt (Kart 1). Denne mørke kvartsitt danner både meter tykke massive lag i veksellagring med lys kvartsitt eller fremstår som en finlaminert bergart med svarte og hvite planparallelle bånd (1-10 mm tykke). Opptreden av finkornete svarte slirer i kvartsitten kan antyde at kvartsittens mørke farge skyldes tilblanding av finkornet felsisk aske. Slirene representerer sannsynligvis ikke pelitter da en vil forvente at disse ville være rekrySTALLISERT til en fyllittisk bergart.

Grensesonen mot kvartsittene i heng av vulkanitt-sekvensen utgjøres av skifrige kvartsitter og kvarts-serisitt skifre som viser gradvis overgang til både de overliggende kvartsitter og underliggende skifrige vulkanitter.

Rød laminert tuff:

Denne enhet som opptrer som en linseformet kropp i ligg av vulkanitt-formasjonen (Kart 1) kjennetegnes ved sin rosa eller rødlig forvittringshud. Bergarten viser, som regel, en finbåndet eller laminert struktur. På friskt brudd består bergarten av vekslende finkornete bånd som viser farger i nyanser av rødt og grått. Enkelte tykkere lag (0,1-0,5 m) i enheten kan være bygget opp av avlange linser som bergartens laminering bøyer rundt. Denne tekstur gir inntrykk av at ihvertfall deler av denne enhet utgjøres av sveise tuffer.

Den rødlig tuff enhet synes å ha en gradvis og innfingrende kontakt mot de overliggende grå båndete tuffer. Ligg-grensen mot kvartsittene synes å være relativt skarp.

Grå båndet tuff:

Denne båndete grå tuff er den dominerende bergartstype innenfor Guldnes vulkanitt formasjon. Den består av en finkornet mørk grå bergart med planparallelle innlagringer av en lys grå nærmest kvartsittisk bergart. Mektigheten og tettheten av disse innlagringer varierer sterkt. Derfor veksler de grå tuffer mellom sekvenser med bånding utviklet på dm skala til 10 meter tykke lag adskilt av tynne "kvartsittiske" bånd.

De mørke grå lagene er ofte skifrige og har et skittent grått utseende på forvitret overflate. Bergartens overflate kjennetegnes også ofte ved tilstedeværelsen av mm-store forvittringshuller som skyldes disseminerte korn/aggregater av brunlige til grå karbonater (Ankeritt-Fe-dolomitt).

De lyse innlagringer er ofte mer grovkornete og viser en massiv til laminert struktur. Enkelte lag viser også en antydning til lentikulær struktur som lokalt på fuktige flater gir tilkjenne at bergarten kan være bygget opp av utdratte fragmenter. I dagbrudd II ble det dessuten funnet en blokk av et av de massive lag som inneholdt en oval konsentrisk båndet konkresjon. Denne konkresjon kan representere et geysir "egg" (F. Pedersen, pers.meddel.).

De grå båndete bergarter fører også 1/2-1 meter tykke lag (Lok.A, kart 2) bestående av linseformete fragmenter i en finlaminert matriks som også inneholder små inneslutninger. Lamineringen bøyer rundt de enkelte fragmenter. Denne struktur synes sterkt å antyde at lagene representerer sveise tuffer. Lag av typen som vist i fig. 5 har også relativt stor utbredelse og opptrer både med grå- og rød-fargete fragmenter. Laget på fig. 5 representerer sannsynligvis en lateral utfingring av den røde laminerte tuff. Slike lag med grove fragmenter utgjør også den dominerende del av en rød tuff sekvens som er blottet på den østlige bredd av den nordligste del av Guldneshalvøya.

Ved lokalitet B finnes rødlig, "chert"-lignende lag i tuff-enheten og ved C en horisont med litofyser eller chert-konkresjoner (geysir-egg?) utviklet (Fig.6).



Fig. 5.

1/2 m tykk sone av grove pyroklaster innenfor de grå båndete tuffer. Sonen fører også et tynt lag av rød sveiset tuff. Laget er forskjøvet langs en mindre forkastning.

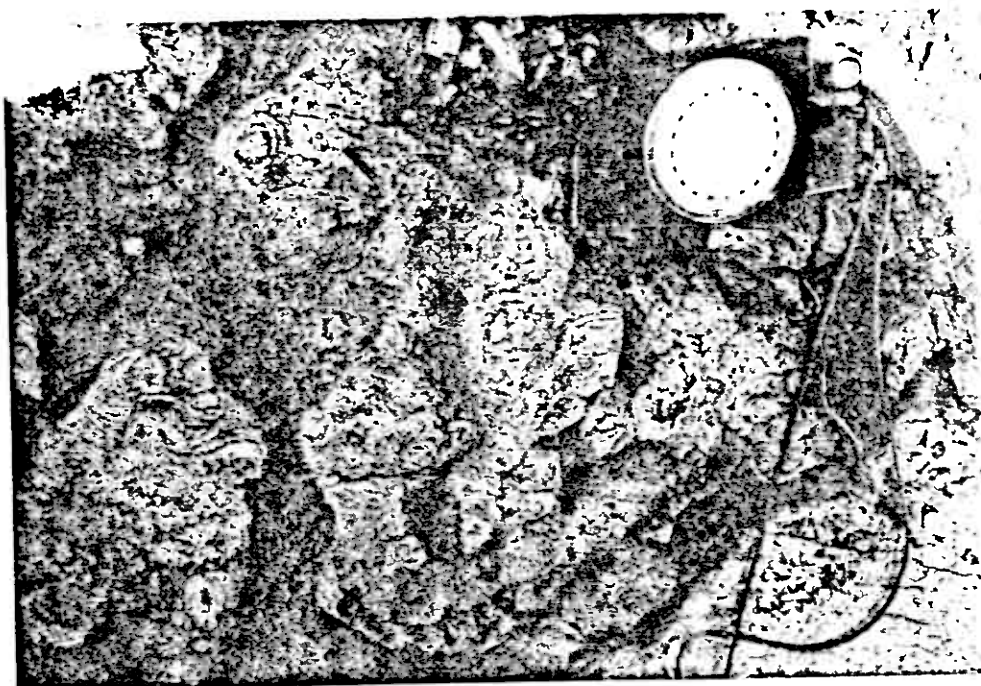


Fig. 6.

Litofyser eller konkresjons-lignende strukturer innenfor et "kvartsittisk" lag i de grå båndete tuffer.

Rundt det trigonometriske punkt (Lok.D) finnes et område hvor den mørk grå tuff har et massivt utseende (Kart 1). Bergartens forvitrete overflate er mer knudret enn vanlig og har dessuten en mer brunlig farge. Den knudrete overflate skyldes tilstedeværelsen av noen cm-tykke og dm-lange inneslutninger av en lys finkornet bergart. Disse inneslutninger kan enten representere fragmentering av opprinnelige tynne sammenhengende lag ved syngenetisk slumping eller ved senere deformasjon eller litofyser i en lava/pyroklastisk strøm.

Like syd for dagbrudd II (Kart 1) er det en rekke blotninger som antyder at den røde ignimbrittiske enhet lateralt innfingrer med de grå båndete tuffer (Lok. A,C,E og F). I dette området øker mengden av rødlig tuff-lag i tillegg til at lys grå eller rødlig grå horisonter med disseminerte biotitt/kloritt korn begynner å opptre.

Ignimbritt:

Denne bergart er betegnet ignimbritt fordi den teksturelt klart adskiller seg fra de røde laminerte tuffer. Bergarten har en rød farge på forvitret overflate, mens den på frisk brudd varierer fra rødlig grå til grå. Den er massiv og viser often en flammeaktig struktur, noe som skyldes flatklemt linseformete bergartsfragmenter i en laminert finkornet og grålig mellommasse (Fig. 7). Horisonter dominerte av slirer som opptre i en kloritt/biotitt rik grunnmasse er også vanlig.

Bergartens flamme lignende struktur antyder at tuff-enheten representerer en sur sveise tuff eller ignimbritt strøm.

Felsiske intrusiver:

En ganglignende felsisk intrusiv finnes på nordsiden av det trigonometriske punkt ved Guldnes. Gangen er 5-6 m bred og har et steilt fall mot NNV. Gang-grensen som er blottet ved lokalitet Ger utviklet som en relativt finkornet breksje med flytebånding utviklet. Denne breksjering i tillegg til den brå overgang mellom røde laminerte tuffer i syd og grå båndete tuffer i nord antyder at gangen kan være intrudert langs en forkastning.



Fig. 7.

Løsblokk av ignimbritt med flammeaktig og laminert struktur. De mørkere partiene mellom de utdratte linsene er rike på kloritt/blotitt.



Fig. 8.

Felsisk intrusiv med uregelmessige nettverk av finkornete kvartsårer. Disse antas å være relatert til breksje-dannelsen.

Gangbergarten har en rød forvittringshud, men fremstår på friskt brudd som en grå, finkornet og massiv bergart. Store deler av gangen er gjennomført av et uregelmessig nett av kvartsårer (Fig. 8) eller et sett av parallelle årer (Fig. 9). I disse områder med kvarts-gjennomvevning viser lokalt bergarten en flekkvis kvarts-serisitt omvandling og får dessuten ofte et skifring utseende. Den hydrotermale omvandling synes knyttet til utviklingen av den østlige breksje sone som gangen gradvis glir over i.

Lignende massive intrusiv-bergarter med kvartsårer finnes dessuten ved lokalitet H og I. Dessuten sees en grå massiv bergart i den nordøstlige vegg av dagbrudd II og like under kontakten av breksjen.

Breksjer:

Det har hittil blitt påvist tre breksje-sentre (Kart 1). Breksjene har relativt skarp kontakt mot de omliggende vulkanitter som i partier er kvarts-serisitt omvandlet. Det nordlige breksje-senter som er best blottet har en utstrekning på 90x25 m. De andre sentrene har en minimumsstørrelse på ca. 45 x 20m.

I de minst deformerte partier består breksjene av cm- til dm-store fragmenter som er fullstendig silifisert eller serisitt omvandlete. (Fig. 10, 11 og 12.) Fragmentene opptrer i en grunnmasse av finkornet kvarts (Fig. 10), K-feltspat+magnetitt (Fig. 11, 12 og 13) eller kvarts+magnetitt som utgjør mindre enn ca. 20 % av breksjen.

Magnetitt+K-feltspat førende grunnmasse er spesielt utbredt i den østlige breksje-sone mens den nordlige vesentlig fører en magnetitt+kvarts+K-feltspat paragenese. I den østlige breksje-sone opptrer dessuten røde fragmenter (Fig. 13) som sannsynligvis heller representerer uomvandlete ignimbitter, eller felsiske intrusiver enn en gjennomgripende K-feltspat omvandling.

Selv om bergarten i partier klart kan erkjennes som en breksje så er den i de fleste områder utviklet som en kvarts-serisitt skifer. I denne skifer som ofte er gjennomvevet av kvarts-fylte tensjons-sprekker gir bare de avlange nett av magnetitt-årer tilkjenne bergartens breksjerte natur (Fig. 12).

Regionalt synes breksje-kroppenes utgående å ha et mer nordlig strøk enn lagningen i de omkringliggende vulkanitter. Det tredimensjonale bilde som fremkommer ved studier av dagbrudd I, II og III antyder at breksjene representerer et rørformet legeme med ovalt tverrsnitt og med lengste akse stupende 70° mot N eller NNØ.



Fig. 9.

Subhorisontale tensjonsprekker med grovkornet kvarts
i felsisk intrusiv.

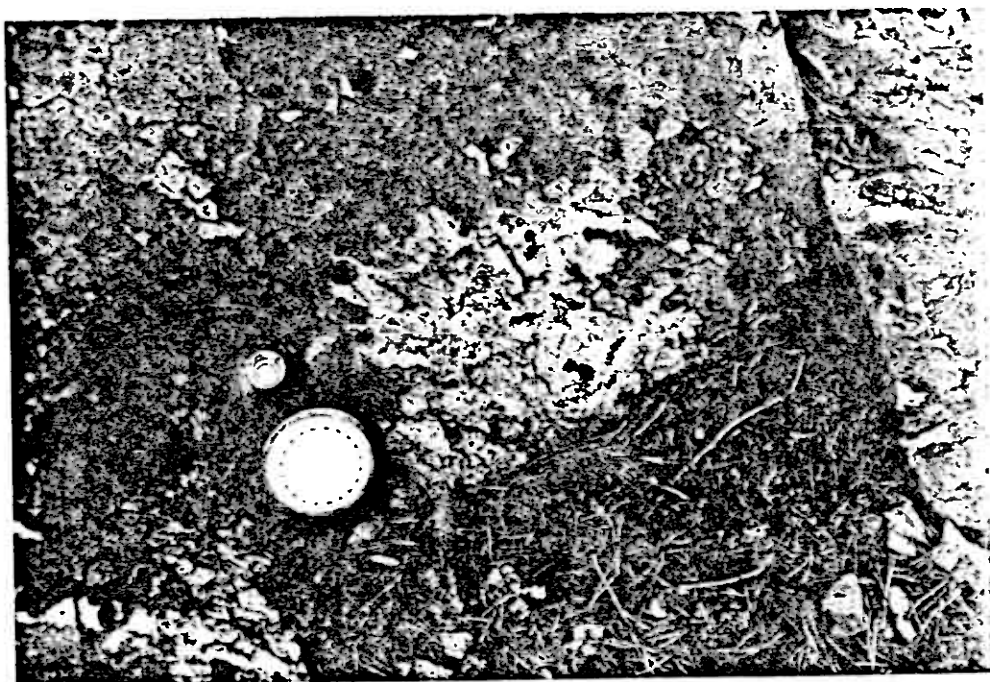


Fig. 10.

Breksje med serisitt-omvandlete fragmenter i matriks
av finkornet kvarts. Nordlige breksje-sone.

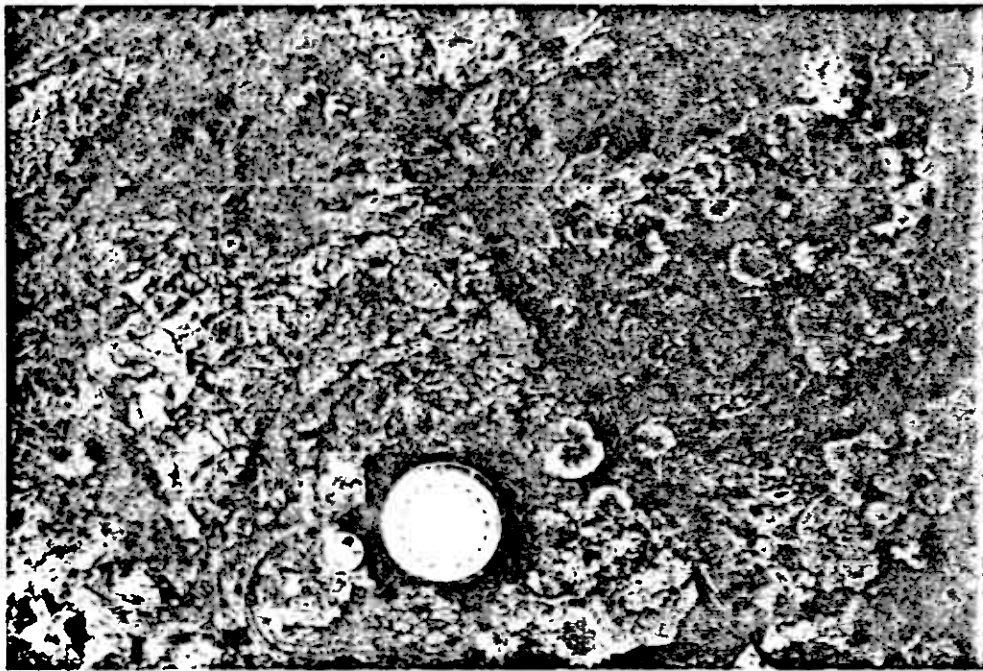


Fig. 11.

Breksje med serisitt-omvandlete fragmenter i matriks av magnetitt+K-feltspat. Nordlige breksjesone.

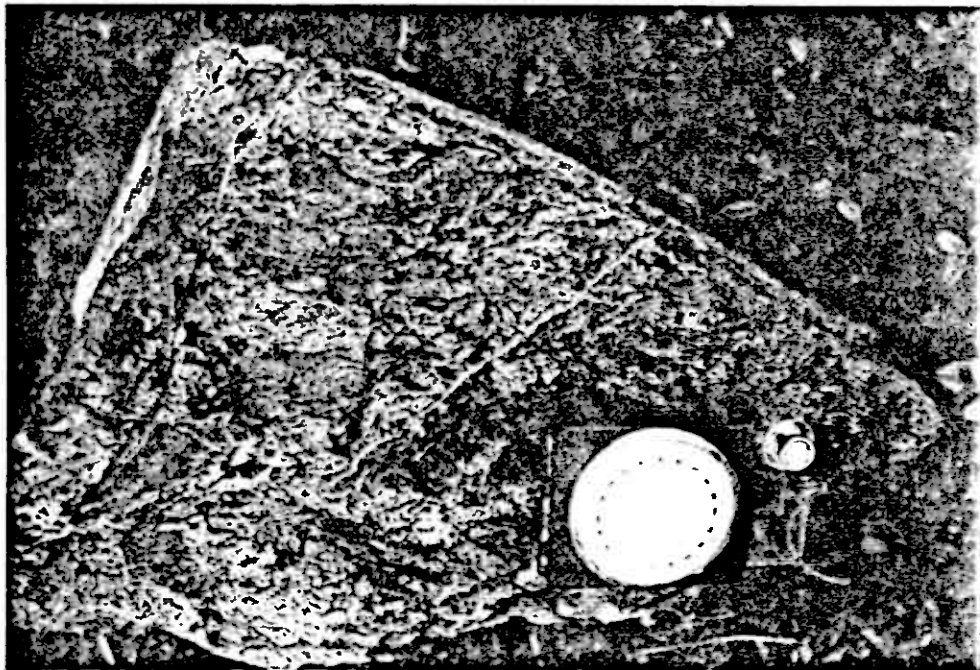


Fig. 12.

Svakt deformert breksje som består av kvarts-serisitt fragmenter i en magnetitt+K-feltspat matriks. Breksjen er også gjennomsett av en tensjonssprekk fylt med kvarts. Østlige breksjesone.

Meta-doleritter:

Områdets bergarter og breksjer er gjennomgått av mørke meta-doleritt ganger (Fig. 14,15). Hornblende er det dominerende mafiske mineral i gangene som også fører feltspat og hulrom fylt med karbonat. Gangene er relativt massive, finkornete til middelskornete, og varierer i mineralsammensetning mellom hornblende-dioritter og hornblenditter. Disse sammensetningsmessige ytterpunkter finnes bare utviklet innenfor det store meta-doleritt massivet nord for huset på Guldnes.

Gangene er steiltstående og har et relativt rettlinjet forløp. De fremherskende gangretninger er VNV-ØSØ, VSV-ØNØ og SSV-NNØ. Enkelte av gangene (Dagbrudd I og II) har mindre forgreninger som vist på Kart 1. Et typisk trekk ved gangenes opptreden er også at bergartene på begge sider er forkastet med et horisontalt sprang på noen meter. Siden gangene i liten grad virker tektonisert er det sannsynlig at gangenes uregelmessige forløp (Dagbrudd II) og forgreningenes strøkretning skyldes fremherskende sprekkeretninger og forkastninger fremfor regional deformasjon.

Deformasjon:

Vulkanitt formasjonen på Guldnes som har et steilt fall mot vest er generelt bare svakt tektonisert. Bergartenes strøk, NNV-SSØ, er relativt ensartet på hele Guldneshalvøya med unntak av dens sydlige ende hvor en mindre fleksur er utviklet.

Selv om de fleste bergarter er svakt skifrige så er det bare i områdene rundt og i breksjesonene at forskifring og dannelselse av foliasjonsplan er fremherskende. Dette gjelder spesielt de biotitt-kloritt førende og serisitt-omvandlede litologier. Denne noe sterkere deformasjons-påvirkning står sannsynligvis i forbindelse med den tektoniske bevegelse eller rotasjon av breksjesonene under den regionale foldning. Breksjene har oppført seg som stive legemer i en mer plastisk masse (vulkanittene). De tektoniske bevegelser førte også til at det i de kompetente bergarter, breksjer, meta-doleritter og feldiske intrusiver ble utviklet sub-horisontale tensjons-sprekker som senere ble fylt med kvarts og/eller Cu-sulfider (Fig. 9 og 16).



Fig. 15.

Meta-doleritt gang (tusj-streket) som gjennomsetter meta-vulkanitter og breksjer. Breksjen til høyre er forkastet fremover mot fotografen. Dagbrudd I og til venstre for Fig. 14.



Fig. 16.

Subhorisontale kvartsfylte tensjonssprekker i den nordlige breksjesone. Den vertikale meta-doleritt gang (stiplet) til høyre for midten av fotoet er også gjennomgått av disse mineraliserte årer. Dagbrudd II.

Forkastningene som synes å predatere meta-dolerittene synes i liten grad å ha blitt modifisert under foldningen siden intrusiv kontaktene (med unntak av den felsiske gang) i liten grad er tektonisert.

MINERALISERINGER.

Guldnes forekomsten fører to typer mineraliseringer som henholdsvis kan klassifiseres som vulkanogen og metamorfogen.

Vulkanogene mineraliseringer:

Denne mineraliseringstype som hittil har vært upåaktet av geologer består av en lav-gehaltig disseminasjon av kopperkis og pyritt i vulkanittene.

Mineraliseringen er sterkest utviklet langs sydenden av den nordlige og sydlige breksje-sone. I disse partier er breksjene omgitt av en halo med kvarts-serisitt omvandling. En omtrentlig begrensning av denne omvandlingstype er gitt på Kart 3.

Spesielt de mørk grå lagene i de båndete tuffene er hydrotermalt påvirket.

Sulfid-mineraliseringene i vulkanittene nær breksjekontakten kan inndeles i følgende hovedtyper:

- 1) Tynne årer og disseminerte korn og aggregater av sulfider som opptrer i de lyse innlagringer i den grå båndete tuff. Finnes i dagbrudd I og II. Kopperkis >> pyritt i mengde.
- 2) Finkornet disseminasjon av sulfider i kvarts-rik serisitt skifer. Dagbrudd II og I. Kopperkis > pyritt.
- 3) Alternierende striper eller bånd (1-10 mm tykke) av kopperkis eller pyritt som opptrer i kvarts-rik serisitt skifer. Dagbrudd II. Kopperkis ~ pyritt.
- 4) Sulfid disseminasjon i en fettaktig serisitt+(talk+Mg-kloritt?) skifer. Dagbrudd I og II. Pyritt >> kopperkis. Denne sulfid-skifer opptrer som linseformete kroppar med en mektighet på flere meter og med en utstrekning på ca. 10 meter. På overflaten fremstår de som rust-fargete horisonter (Fig. 17 og 18).

Selvom enkelte tynne sulfidskifer horisonter (skjematisk angitt på kart 1 og 3) finnes et stykke utenfor breksje-sonene så forandrer

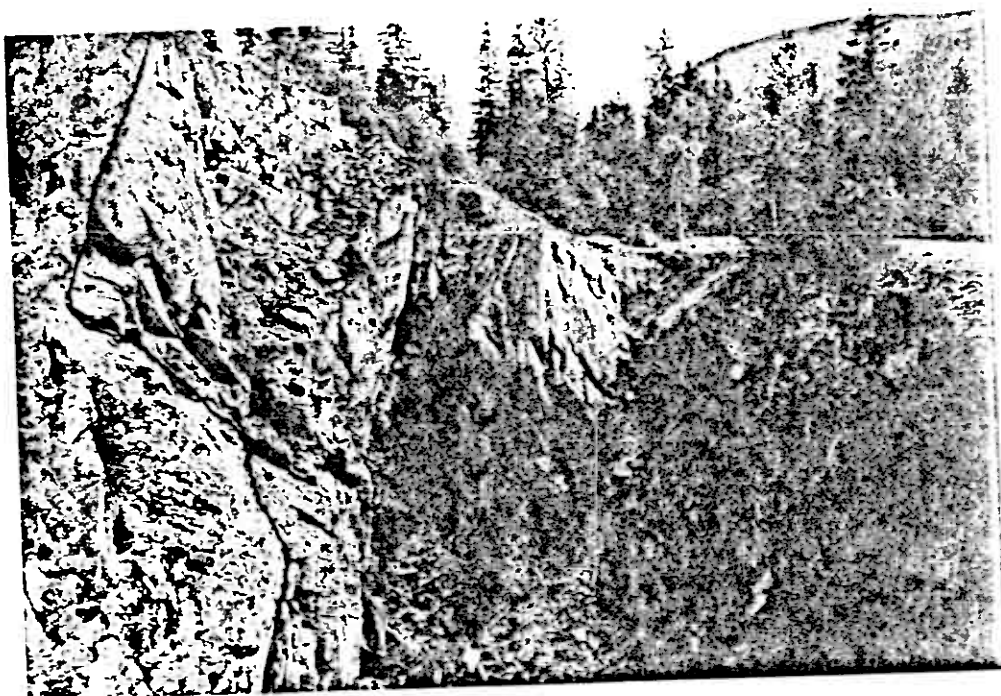


Fig. 17.

Soner med rustskifer i den sydlige ende av Dagbrudd II. Kontakten til breksjen er angitt med en svart linje.



Fig. 18.

Tynne soner med rustskifer i skifrige meta-vulkanitter langs kontakten av den sydlige breksjesone (lyst parti). Meta-doleritten på fig. 14 er streket opp som referanse.

mineraliserings-mønstret seg drastisk når man fjerner seg fra breksjen. I de nærmeste 10-30 m fra breksje-kontakten er sulfid-innholdet høyt og kan nå opp i ca. 10 % av bergarten. Kopperkis mengden er anslått til et maksimum av ca. 5 %.

I større avstand fra breksjen avtar mengden av sulfider hurtig samtidig med at pyritt begynner å forsvinne. Mineraliseringen blir dermed av en lavgehaltig disseminert type som domineres av kopperkis. Denne kopperkis disseminasjon er grovt definert til å opptre innenfor en 100 m bred sone med en hittil kjent utstrekning på 400 m (Kart 3). Alle vulkanittene i denne sone fører kopperkis, men spesielt de massive eller ikke skifrige lag er anriket på kobber. Selv om sonen i mindre partier fører flere prosent kopperkis så er det realistisk å anta at det generelle nivå ligger rundt 0,1 - 0,2 % Cu.

Et typisk trekk ved mineraliseringene på Guldnes er at sulfider ikke er tilstede som matriks mineral i breksjene, men derimot bare magnetitt. En annen viktig anmerkning er at den østlige breksje-sone ikke synes å omgi seg med en halo med serisitt-omvandling og sulfid-anrikning.

Metamorfogene mineraliseringer:

Den regionale deformasjon førte til dannelselse av tensjonssprekker i de kompetente bergartene. Disse sprekker ble etterhvert fylt med kvarts, kalkspat, K-feltspat, magnetitt, kopperkis, bornitt og/eller kopperglans. Barytt skal også ifølge S. Nordrum (pers.meddel.) være tilstede i gangene.

Denne mineraliseringstype som bare finnes innenfor breksjene og meta-dolerittene i disse (Fig. 16, 18 og 19) ga grunnlaget for den tidlige drift ved Guldnes gruver. Malmen består av et tett sett med subhorisontale kvarts ganger som fører rike, men uregelmessige ansamlinger av vesentlig kopperkis og bornitt. Kvartsårene finnes i meget liten grad utenfor breksje-sonene (15 og 18). Av kart 1 fremgår det fra dagbruddenes fordeling at den beste Cu-malmen opptrådte nær breksje-kontakten og i områder hvor vulkanittene har et høyt sulfid-innhold.

Dette skyldes sannsynligvis det forhold at kontaktsonen ble utsatt for størst tektonisk påkjenning og grad av fragmentering. Den østlige breksjesone er også sterkt gjennomvevet av sene kvartsganger, men disse har et meget lavt innhold av kopperkis og bornitt. Siden

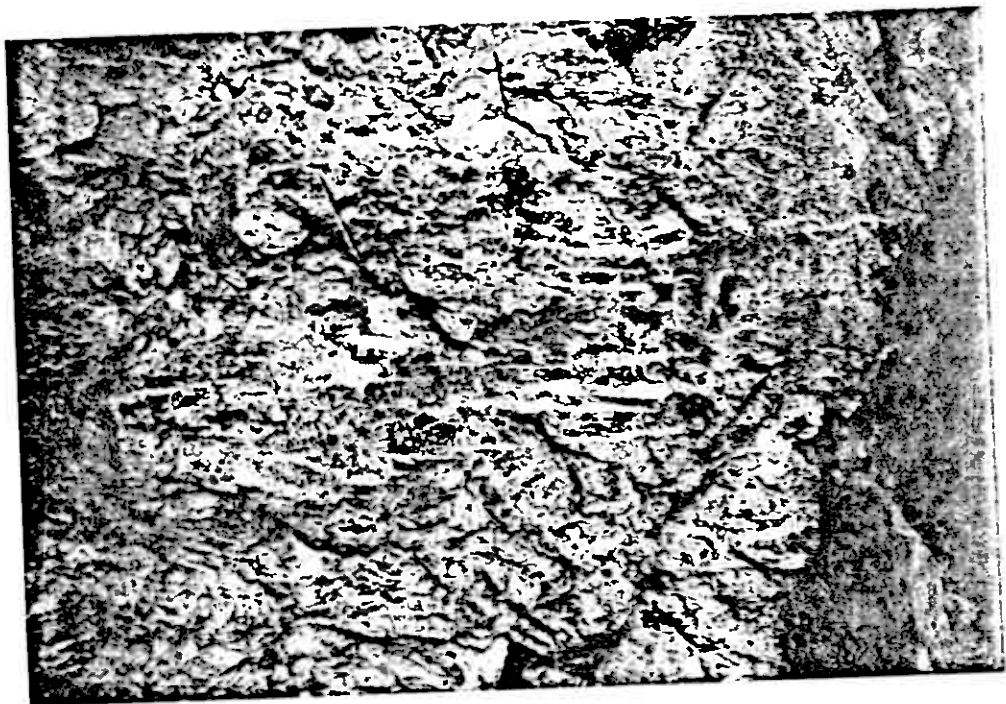


Fig. 19.

Nærbilde av kvartsfylte og mineraliserte tensjonssprekker
i den nordlige breksjesone. Dagbrudd II. Flatens høyde
er 3 m.

denne breksje i motsetning til de andre ikke er omgitt av en sulfidhalo er det mulig at metallene er mobilisert fra de omgivende vulkanitter under den regionale deformasjon og metamorfose.

INNSAMLING AV PRØVER FOR ANALYSE.

Prøver av de mineraliserte breksjer, kvartsganger og vulkanitter ble innsamlet for analyser. Prøvelokalitetene fremgår av Kart 4 mens en beskrivelse av det innsamlete materiale er gitt i tabell 1.

Under innsamlingen ble det lagt vekt på å prøveta den Cu-disseminerte sone i vulkanittene som kan ha potensialer som en lavgehaltig Cu-Ag-Au-malm. Prøvene ble tatt slik at de skulle gi en størst mulig variasjonsbredde med hensyn til både sulfidinnhold og litologi. Prøvetakningen er derfor på ingen måte systematisk. Prøvemengden er dessuten for liten og prøvene for små, $\frac{1}{2}$ - 1 kg, til at et troverdig bilde av sonens edelmetall-innhold kan gis.

Det ble også tatt noen prøver av de Cu-rike mineraliseringene langs de sene kvartsgangene i breksjene. Dette ble gjort for å få inntrykk av det maksimale edelmetall innhold som kan forventes i de rene sulfidfaser.

ANDRE MINERALISERINGER UTENFOR GULDNES-FOREKOMSTEN:

Det ble også gjort forsøk på å finne andre skjerp som er kjent fra området rundt Sundsbarmvann (Dons, 1963). Disse omfatter Kvål, Hyttebekk, Sundsbarmkjelleren, Grønlifjellseter og Fuglebekkåsen skjerp (Fig. 2). Av disse ble bare Grønlifjellseter skjerp funnet.

Skjerpet er anlagt på kalkspat ganger langs kontakten mellom grovkornet meta-gabbro og kvartsitt. Gabbroen som det er foretatt noen prøvesprengninger i er sterkt forskifret, men fører ingen synlig mineralisering.

Hyttebekk og Sundsbarmkjelleren skjerp ligger nå under vann p.g.a. oppdemning av Sundsbarmvann. I veiskjæringene i området hvor skjerpene skal ligge er det mange ganger av meta-doleritt. En av disse (Fig. 2) er sterkt gjennomvevet av kvartsganger og fører malakkitt på sprekker. Kvartsittene rundt gangen fører sub-horisontale kvartsårer i et sett av fleder-spalte systemer. Slik kvartsgjennomveving er et vanlig fenomen i kvartsittene rundt Sundsbarmvann.

Av tidsmessige grunner ble Kalkjuvet kaolin- og Koddedal Mn-forekomster ikke besøkt.

KONKLUSJON - TOLKNING.

Sommerens arbeid har vist at Guldnes Cu-forekomst opptrer innenfor en hittil ukjent vulkanitt-sekvens (Guldnes-formasjonen) i Seljordgruppens kvartsitter. Disse vulkanitter som vesentlig finnes på Guldneshalvøya glir lateralt (nordover) over i kvartsittbåndete siltsteiner. Disse opptrer sannsynligvis i samme stratigrafiske nivå som de øvre kalkskifer-enheter i den nordlige del av Telemark (Dons og Jorde, 1978).

Tilstedeværelsen av mulige tørkesprekker i siltsteinene og bølgeslagsmerker samt erosjonskanaler i kvartsittene antyder at bergartene representerer gruntvanns-avsetninger (Elvesletter, tidevannsflater, grunthav eller -innsjøer).

Flere steder ble det funnet strukturer i vulkanittene som antyder at disse tildels representerer felsiske sveisetuffer og pyroklastiske strømmer. Et typisk trekk ved vulkanittene er dog at de er finkornete og strukturløse og i liten grad viser grove pyroklastiske avsetninger.

Disse trekk kan antyde at Guldnesformasjonen utgjør en distal facies av et vulkanitt-senter. Den store laterale utstrekning av båndete siltsteiner og kalkskifre som synes å opptre på Guldnes-formasjonens nivå kan antyde at disse er distale ikke-sveisete asketuffer (airfall tuff).

En alternativ tolkning av de generelt finkornete tuffer på Guldnes er at de er et produkt av phreato-magmatiske erupsjoner. Dette vil medføre at vulkanittene kan være avsatt relativt proksimalt til et vulkansenter.

Tilstedeværelsen av kvartsittlignende lag i vulkanittene og siltsteinene gjør det sannsynlig at klastisk og vulkanoklastisk sedimentasjon foregikk samtidig med den ekstrusive aktivitet.

Mineraliseringene på Guldnes er både av syn-vulkansk og metamorf opprinnelse. Den synvulkanske type synes å være knyttet til breksjerør som gjennomsetter vulkanittene. Mineraliseringene består av stratiforme kopperkis+pyritt ansamlinger og uregelmessig disseminasjon i serisitt-omvandlede tuffer nær breksjene. I tillegg finnes

en lavgehaltig kopperkis impregnasjon i uomvandlete tuffer. Den sistnevnte type kan følges langs strøket som et 400 m langt og 100 m bredt belte.

Breksjene er sannsynligvis et produkt av en langvarig hydrotermal aktivitet i spesifikke sentre. Dessuten antyder tilstedeværelsen av felsiske intrusiver under noen av breksjene at sub-vulkanske plutoner kan ha kontrollert denne aktivitet.

Det romlige forhold mellom mineraliseringene og breksjene antyder videre at breksjedannelsen har skjedd gradvis og har kontinuerlig trengt gjennom vulkanittlagene ettersom de ble avsatt. Dette har medført at sulfidene både er avsatt på tuffenes overflate fra vulkanske ekshalasjoner og fra hydrotermale løsninger som har trengt inn langs permeable lag i breksjenes sidesten.

Under den regionale deformasjon og metamorfose ble det dannet et tett nett med sub-horisontale kvartsganger i breksjene og i meta-doleritt gangene. Disse kvartsganger fører rike ansamlinger av vesentlig kopperkis og bornitt. Metallene er sannsynligvis mobilisert fra de sulfid-førende vulkanittene. Denne metamorfogene malmtypen var det Guldnes gruver tidligere ble drevet på.

ANBEFALINGER.

Hvis de innsamlete prøver gir positive resultater anbefales det at store litologiske prøver fra hele vulkanitt-sekvensen på Guldnes systematisk innsamles i et gridnett. Denne prøvetakning skal ikke bare ha til hensikt å gi et estimat av mulige malmpotensialer, men også gi grunnlag for en vurdering av mulig metall-soneringer i systemet. Slike soneringer kan bl.a. være til hjelp ved leting etter malm på dypet eller påvise breksjesoner som ikke går i dagen. I områder med overdekning bør jordprøvetakning anvendes. I tillegg bør også magnetiske og I.P.målinger utføres.

De sentrale deler av Guldnes-forekomsten må kartlegges mer detaljert på et stikningsnett. Dette er viktig ikke bare for å bringe på det rene malmenes genese, men også for å få et bedre bilde av mineraliseringsmønsteret.

Hvis Guldnes-forekomsten representerer en prospekteringsmessig interessant mineraliseringstype, så er det viktig at undersøkelsene kan gi mest mulig informasjon for bruk ved den videre regionale prospektering i Telemark.

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Feltaktion i det østlige Telemark. Internt notat for Norsk Hydro, 2 s.

Tabell 1.

PRØVER INNSAMLET FOR ANALYSE MERKET G1 - 83 etc.

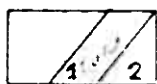
X	G1-83	Grå massiv tuff med et cp.aggr. og litt diss..
X	2	Kvarts-serisitt skifer. Meget svak cp.disseminasjon.
	3	Mørk grå kloritt-biotitt stripet tuff. Litt cp. disseminasjon.
X	4	Grå massiv tuff med disseminert py.
	5	" " " med cp-py "veinlet".
X	6	" " " med cp-py disseminasjon.
	A	Grå biotitt-spettet tuff med cp-py disseminasjon.
X	7 B	Grå rød porfyrisk tuff med cp-veinlets og diss..
X	8	Mørk tuff med kloritt-slirer. Cp.-"veinlets".
	9	Massiv grå tuff. Svak cp. disseminasjon.
X	10	Kvartsitt med py.-disseminasjon.
X	11	Rød biotitt-spettet tuff. Ørlite cp. som aggr..
X	12	Rødlig tuff med biotitt-kloritt aggr. og striper. Litt cp-py diss.
X	13	- " - - " - - " -
X	14	Mørk "welded" tuff. Meget svak cp.diss..
(	15	Kopperkis-bornitt aggr. i kvarts-breksje.
(	16	" " " " "
(X	17	" " " " "
X	18	Kvarts-serisitt skifer. Finkornet cp-py.diss.
X	19	" " " . Kisrik. Parallelle cp-py striper.
X	20	Kvarts-serisitt skifer. Sterk py.disseminasjon.
X	21	" " " Cp-rike striper i py.dis
X	22	Mørk rødlig "chert". Spredte cp.aggregater.
X	23	Magnetitt-førende og kalifeltspat-serisitt omv. bergart.
X	24	Mørk grå skifrig tuff med py.diss.
(	25	Mt-cp. aggregat i kvarts-breksje.
(	26	Bornitt-kopperkis-kvarts-kalkspat åre i grå tuff.
(	27	Cp-årer i kalifeltspat breksje.
X	28	Grå massiv tuff. Rik på cp.aggregater - diss.
X	29	Lys grå tuff. Rik på cp.aggregater - diss.
X	30	Kvarts-serisitt-skifer. Py-disseminasjon.

tabell 1 forts.

ghall	X	31	Cp.-br. aggregater i kvarts-breksje.
	X	32	Mørk grå massiv tuff med cp. og py.aggre.-diss.
	X	33	Kvartsitt med cp. diss.
	X	34	Mørk grå massiv tuff med cp.aggr. - diss.
		35	" " " " " "
ghall		36	Cp.-br. aggr. i kvarts-breksje

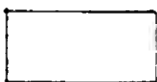
X Angir prøver som oppbevares ved Geologisk Institutt, NTH

TEGNFORKLARING TIL KART 1.

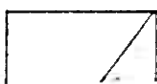


KVARTSITT

1. Svart kvartsitt
2. Kvarts-skifer.



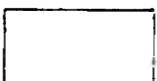
RØD LAMINERT TUFF



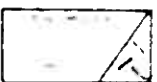
GRÅ BÅNDET TUFF/MASSIV TYPE



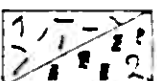
„RUST“ SKIFER



IGNIMBRITT



FELSISK INTRUSIV/KVARTSÅRET



BREKSJE.

1. Kvarts ± K-feltpat matrix
2. Magnetitt ± K-feltpat matrix.



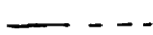
META-DOLERITT



STRØK/FALL (100°) AV PRIMÆR LAGNING.



STRØK/FALL (100°) AV FOLIASJON.



BERGARTSGRENSE. SIKKER/USIKKER



GRENSE FOR BLOTTNING/GODT BLOTTET OMRADE



DAGBRUDD/GRUVE. I, II & III



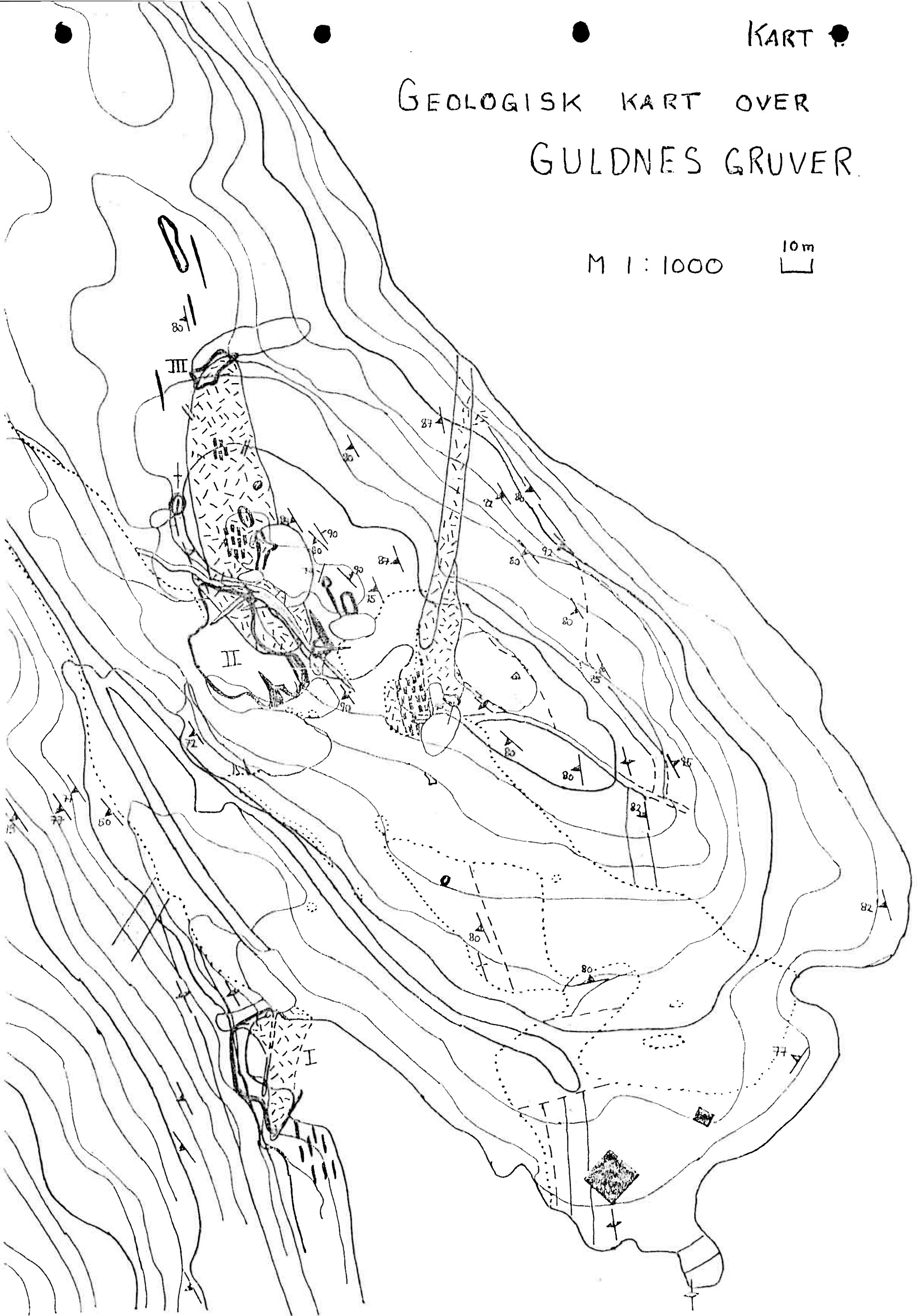
OVERDEKKE/BERGHOLD.

KART 1

GEOLOGISK KART OVER GULDNES GRUVER.

M 1:1000

10m



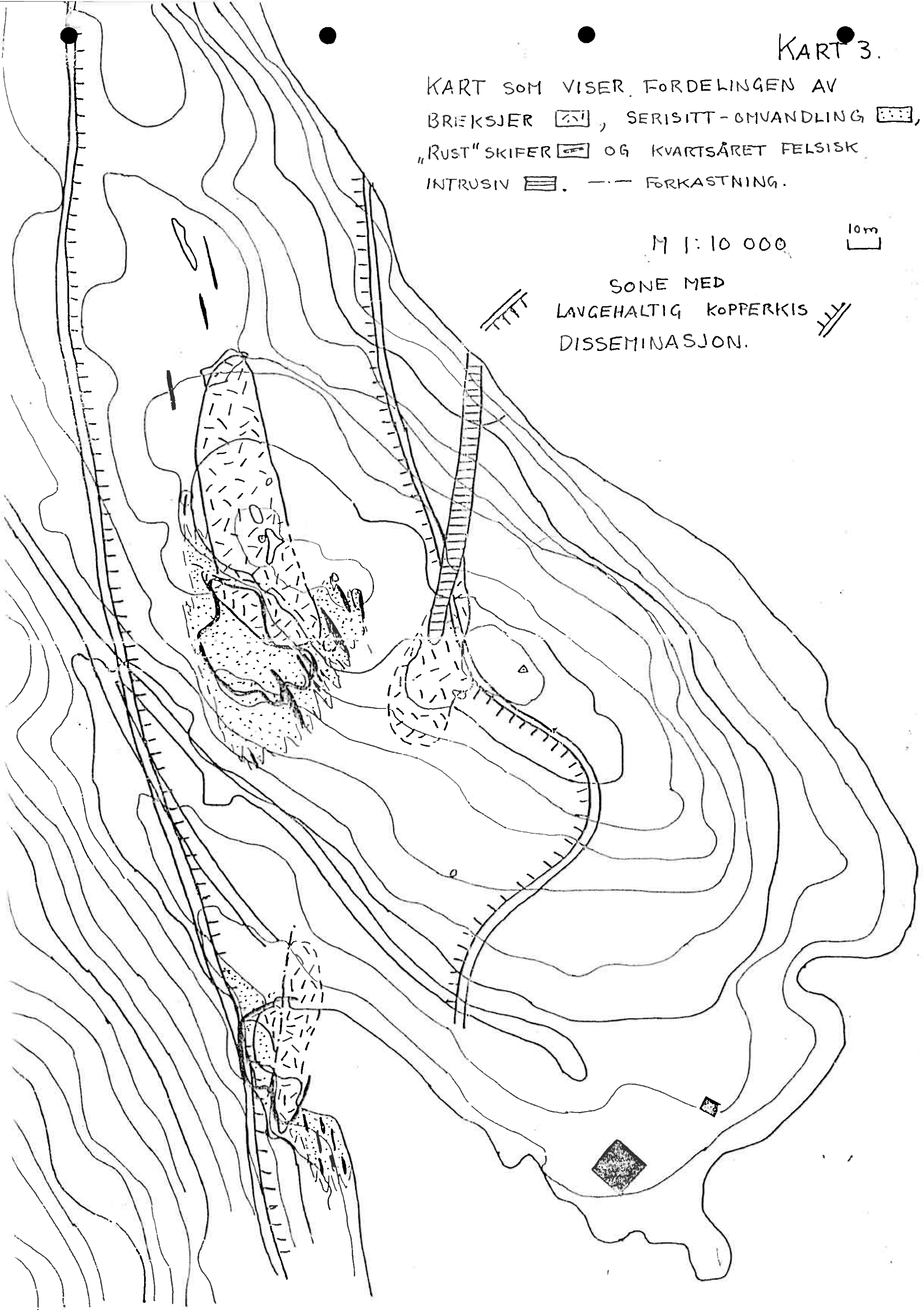
KART 3.

KART SOM VISER FORDELINGEN AV
BREKSJER , SERISITT-OMVANDLING ,
"RUST" SKIFER  OG KVARTSÅRET FELSISK
INTRUSIV . --- FORKASTNING.

M 1:10 000

10m

SONE MED
LANGEHALTIG KOPPERKIS
DISSEMINASJON.



KART 3.

KART SOM VISER LOKALITETER
OG FOTOGRAFI-LOKALITETER GITT
I RAPPORTEN

M 1:1000.



LOKALITETS-KART FOR INNSAMLETE PRØVER
MERKET G1-83 GEN. M 1:1000.

KART 4



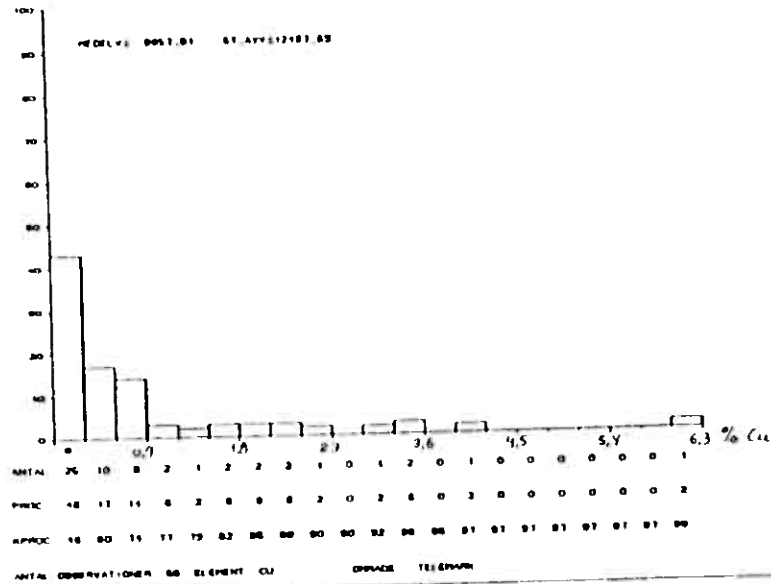
The geochemical assays of the samples collected at Guldnes
(see Ihlen, Table 1 and Kart 4) are shown in below.

Sample no.	Au ppb	Cu ppm	Pb ppm	Zn ppm	Ni ppm	Co ppm	Ag ppm	As ppm	Bi ppm	W ppm
G 1-83	20	1781	5	43	27	37	6,4	8	4	-1
G 2	20	3505	2	23	8	10	4,0	1	-1	-1
G 3	-20	280	11	63	23	12	-0,1	1	-1	-1
G 4	-20	942	8	22	11	16	8,5	5	2	-1
G 5	-20	1075	27	63	22	9	1,4	71	3	-1
G 6	-20	45	8	43	12	29	-0,1	4	1	-1
G 7	-20	3847	12	43	33	13	1,5	2	-1	-1
G 8	-20	2888	10	53	22	24	2,6	1	-1	-1
G 9	-20	497	8	37	22	20	-0,1	2	-1	-1
G 10	-20	254	12	6	2	13	1,5	2	1	-1
G 11	-20	481	9	17	14	5	0,5	1	-1	-1
G 12	-20	1517	11	39	21	25	1,2	4	-1	-1
G 13	-20	520	8	44	24	13	0,2	2	-1	-1
G 15	445	13500	7	3	10	13	50,5	-1	-1	-1
G 16	125	8290	5	4	3	4	20,5	-1	-1	-1
G 17	75	11500	2	4	72	5	8,5	-1	-1	-1
G 18	-20	2769	3	13	15	30	6,4	2	-1	-1
G 19	75	2920	5	25	14	151	49,1	2	-1	-1
G 20	-20	209	14	46	37	67	0,9	9	1	-1
G 21	350	41300	15	19	66	229	145,2	1	1	-1
G 23	20	3455	4	9	4	5	0,9	1	-1	-1
G 24	-20	5990	13	39	41	48	0,8	12	2	-1
G 25	125	34500	7	9	2	10	18,5	1	1	-1
G 27	305	32400	15	7	2	6	53,8	1	1	-1
G 28	50	5600	4	18	15	21	1,9	5	-1	-1
G 29	50	7040	4	16	17	112	2,8	17	-1	-1
G 30	20	4140	24	159	21	50	31,9	3	4	-1
G 31	20	5780	15	46	33	35	3,7	3	-1	-1
G 32	-20	3823	9	50	30	56	1,6	2	-1	-1
G 35	-20	3207	15	41	25	41	0,8	9	-1	-1
G 36	360	64000	17	14	12	6	295,9	-1	1	-1

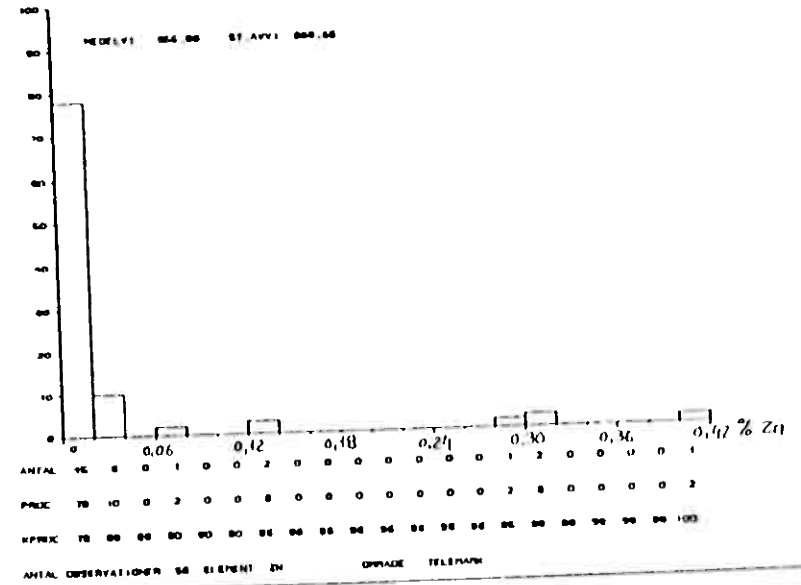
These figures demonstrate that the Guldnes mineralization is dominated by Cu, Ag and Fe (not shown). The mean copper content of the samples is 0,68% and the mean silver content is ca. 15 ppm. Gold occurs sporadically in amounts of up to 0,5 ppm and it is exclusively tied up with high copper values. However, the figures include samples of ore as well as of the low grade halo surrounding the high grade ore. When isolated, the ore samples (numbers 1, 2, 4, 15, 16, 17, 18, 19, 21, 24, 25, 27, 28, 29, 30, 31, 36) return considerably higher grades, averaging 1,45% Cu, 41,7 ppm Ag and 0,01 ppm Au, and the potential of the Guldnes mineralization is thus clearly dependent upon the amount of high grade ore present in the area. An indication of this may be obtained via the preliminary geophysical survey which has been carried out over a part of the Guldnes area (Elstad, 1983, Appendix 3). This survey includes ground mag. and IP/resistivity measurements and shows that high grade sulphide mineralization is characterized by, and may be detected by the presence of high IP values, while the magnetite-bearing feeder channels stand out as areas with high susceptibility. One anomaly with an area of approximately 125 m x 400 m occurs along strike toward the northwest from the northernmost of the two large open pits (Ihlen, 1983, kart 1) and is characterized by high susceptibility and high IP values. It is situated in an area covered by drift, and blast-type samples are needed in order to explain the anomaly.

In summary, this group of mineralization, including Tinnsjø, Skolterberg, Graver, Listøl, Johnslø, Guldnes and others, are related to siliceous, probably fumarolic emanations which took place in predominantly basic volcanic piles with subordinate acid volcanic intercalations. The mineralizations are dominated by copper and silver, other elements being subordinate. Fig. 44 shows that approximately 75% of the total number of copper analysis of this group fall below 1% Cu and that the remaining 25% show an even spread up to ca. 4% Cu. Pb is quite

Cu



Zn



Pb

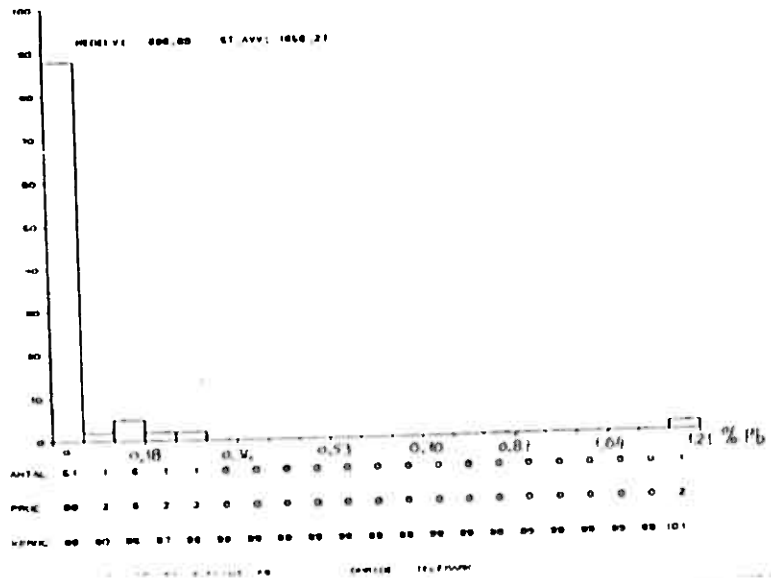


FIG. 44

insignificant in that 95% of the analysis fall below 0,2% Pb, and 95% of the Zn analysis fall below 0,3% Zn. The presence of Pb and Zn may nevertheless be significant because these elements may be helpful in establishing zoning patterns. The mineralization at Guldnes suggest that a "normal" zoning pattern has been established in this particular area with Cu having been deposited close to the feeder channel. The Pb-Zn mineralization at Skolterberg may thus reflect a peripheral ("distal") position in an exhalative system and it is interesting to note that the Pb-Zn-bearing part of the Skolterberg mineralization apparently grade into a copper-bearing (?proximal) mineralization toward the west (Fig. 38). The available data are too scarce to allow any predictions of how precious metals would be distributed in possibly zoned sulphide systems. Silver (Fig.45) shows a fairly wide scatter in values, 95% of the analysis being below ca. 125 ppm, while 95% of the gold values fall below ca. 0,3 ppm. A positive coefficient of correlation between 0.8 and 0.9 exists between copper and silver, while gold apparently shows no correlation with other elements. This may be reflected in the plot of Au versus Ag shown in Fig. 46 which indicates that the large fluctuation in copper values in for example Guldnes and Listøl is reflected in a similar distribution of silver values. These considerations may thus reflect - if the presented analysis are representative of wider areas of Telemark - that precious metals in this type of mineralization is dominated by silver and that this predominantly is tied up with the occurrence of copper.

Finally the Søftestad Fe-P deposit should be mentioned because it occurs in rocks belonging to the Rjukan Group. This deposit was not visited during this summers field work, and the following account has been borrowed from Bugge (1978).

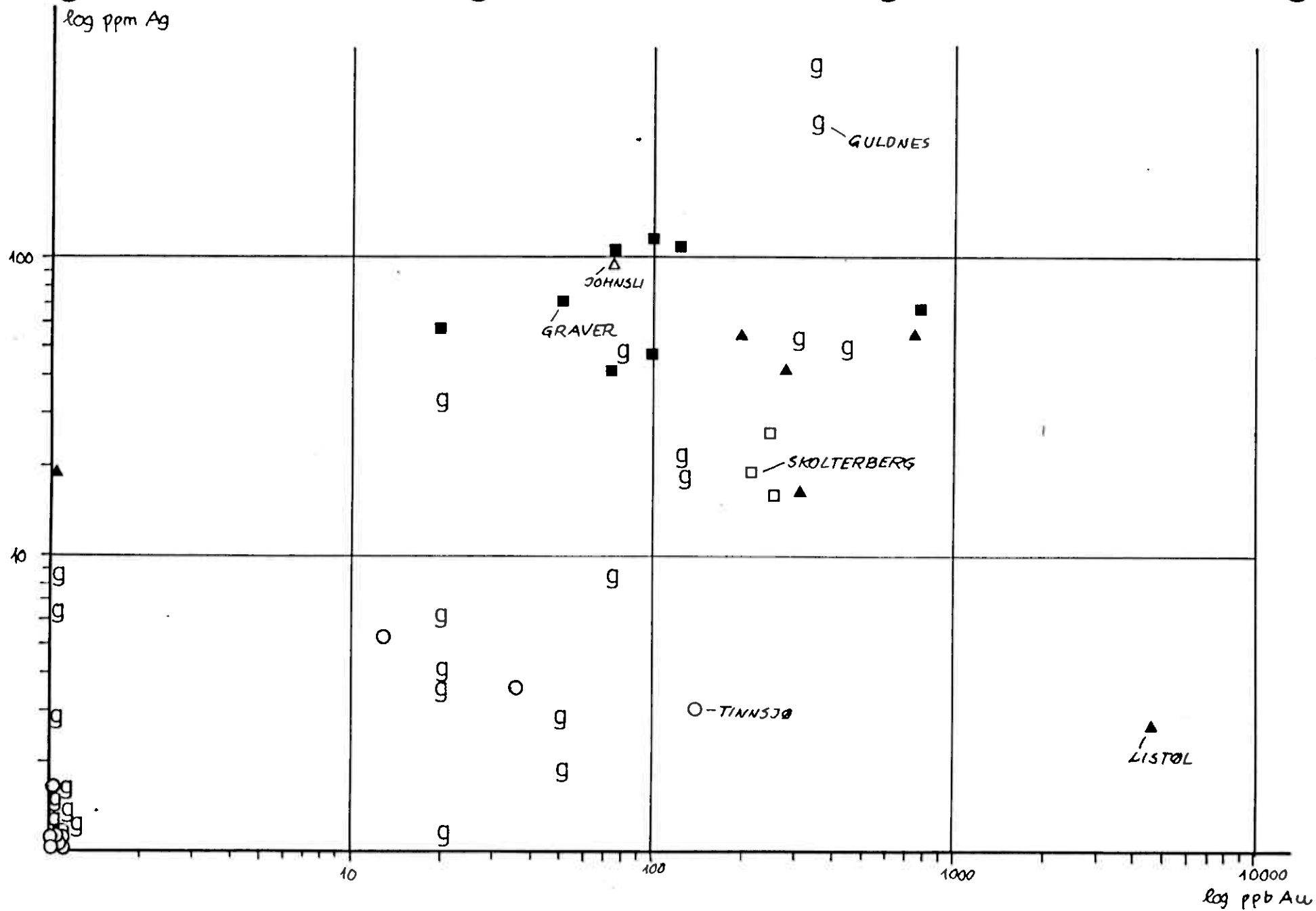


FIG. 46

Søftestad iron mine on the eastern side of Lake Nisser (Plate 1) is a small magnetite-hematite deposit averaging 55% Fe and 1-1.5% P. The orebody is 450 m long and 1-3 m wide. It is tabular in form with a 40° easterly dip and a north-south strike parallel to the foliation of the surrounding rocks. It consists in the northern part of two parallel lenses.

Magnetite and hematite are generally present in about equal amounts, but the hematite content is locally as low as 1%. The apatite is a fluorapatite with a small percentage of yttrium. The gangue minerals are feldspar, amphibole (magnesian hastingsite), clinopyroxene, quartz and calcite. Reserves are of the order of 500.000 tonnes at 55% Fe and 1.7% P. Production was 35.000-50.000 tonnes per year. The orebody is cut by granite pegmatites of two generations and also by camptonite dykes and a few calcite-chlorite-filled fissures.

The Precambrian Søftestad gneiss, in which the deposit is situated, is a quartz-hornblende-biotite gneiss of andesitic and dacitic composition. There are several points of resemblance between the Søftestad deposit and the much larger Gällivarre apatite-magnetite ore deposit in northern Sweden. The mode of formation is considered to be magmatic.

Mining operations took place between 1920 and 1965 and started after a railroad was built from Arendal to the south side of Lake Nisser.

3.2.2 The Bandak Group

As shown in Table 1 stratabound mineralization occurring in the Bandak Group comprise the metals Cu, Ag, Fe, Zn and Mn. The majority of occurrences are hosted by predominantly basic volcanics, while one, the Bransnuten deposit, may be related to acid volcanism.

The Dalane Cu-Ag mines have been known for a long time as important occurrences of native copper and silver. The mineralized zone occurs near Landsverk (north of lake Bandak, Plate 3) and was claimed by ASPRO in 1977. As the mine workings presently are almost inaccessible only a short visit was paid to the area by the present author. The following description is from Dons (1963). In summary the mineralization consists of impregnations of native Cu and Ag occurring in sandstone along the contact to an overlying basic volcanic flow. The ore may be interpreted as having formed either during the diagenesis of the sandstones by metal-carrying groundwater, or during the regional metamorphism by fluids leaching metals from the basic volcanics and depositing them in their native form in the porous, underlying sandstone. The economic potential of this very rich, but apparently sporadic type of mineralization is very difficult to ascertain, but it should be pointed out that the claims of ASPRO will expire in 1984 unless this company files an application for "utmål"

I Bergarkivet og «Bergverkstatistikken» finnes dessuten en mengde opplysninger.

Lok: 2°23', 59°27,5'. Ved å kombinere opplysninger fra flere eldre kart og rapporter, og ved å snakke med folk på stedet, særlig Sveinung Dalen, nå ca. 80 år gammel, er oppnådd følgende rekkefølge av navn regnet fra vest mot øst idet man følger den kontakten som fører gedigent kobber og sølv:

Landsverk skjerp 427c, **Bekken skjerp** 427b, **Haugjuvet grube** ved hovedveien gjennom Dalane 427a, **Kloppedalen skjerp** 428e, **Åsleiv (berg) skjerp** 428d, **Bustigen skjerp** (= Gamle Dal grube) 428c, **Aspestigen grube** 428b, **Spendivegg grube** 428a, **Bergdal grube** 429b, **Gjeitenuten grube** 429a, **Åsen skjerp** 430b, **Kjerstøl grube** 430a, **Snønten skjerp** 430c, **Stardalslåtten skjerp** 430d, **Huvestad skjerp** 430e. Sistnevnte sted ligger 1800 m øst for hovedveien gjennom Dalane. Alle de nevnte gruber og skjerp gjelder gedigent kobber og sølv, mens de følgende (431b, 431a, 432, 433) er anlagt på kobberkistførende kvartsganger.

Grødeskjerpene 431b ligger ca. 100 m nord for Gjeitenuten, antakelig på grensen av et lokalt grønnstensfelt innen kvartsitten. **Heiskar grube** (Heiskarbakken = Øvre Dals grube) 431a, ligger 100 m nord for Aspestigen. **Lørnett grube** 432 ligger 1400 m nord for Aspestigen og er også kalt Launuten og Langnuten eller Langnute osv. **Kovedgjuvet** (= Kalvgjuvet) 433 ligger i nærheten av en gård med samme navn umiddelbart syd for skolen i Dalane.

Ifølge oppgave fra Østlandske Bergdistrikt av 31/3 1960 har Christiania Minnekompani opprettholdt følgende anvisninger: mutning nr. 480 og 481 på gården Landsverks grunn, mutning nr. 482 på gården Dalens grunn, mutning 339 på gården Nordre Dalens grunn, mutning 340 på gården Landsverks grunn, Aspestigen skjerp, Øvre Grøe skjerp, Nedre Grøe skjerp, **Høire Buksefjærs skjerp** på gården Dalens grunn, **Øvre Landsverk skjerp**, **Haugjuvet sølv- og kobbergrube**, **Spendivegg sølv- og kobbergrube**, **Gjeitenuten sølv- og kobbergrube**, **Huvestad sølv- og kobbergrube**, **Kjerstøl skjerp** på søndre Dalens grunn, **Bergdalen på Bjørnslåtens grunn**, **Åsleivberget grube**, **Bustigen grube**, **Snønten grube**, **Åsen grube**. De 5 siste er opprinnelig muter etter siste krig. Videre har Minnekompaniet: **Gamle Dals grube**, **Heiskarbakkens grube**, anvisning 100 m syd for Løvnetgangen, mutning nr. 479 mellom Løvnetslåtten og Vargarene. I Berge—Huvestadsutmark har Peder Olsen, O. Sinding og O. Smestad opprettholdt anvisninger fra 1935 på **Kringlemyr skjerp** og **Bytterjønntulen skjerp**.

De ovenfor anførte nummer 480, 481 osv. er mutningsnummer og har intet å gjøre med den serie tall Foslie har anvendt i sin publikasjon av 1925. Stedene for slike mutninger er vanskelige å finne, idet de kun har nummer, intet navn. Høire Buksefjærs skjerp kjente man ikke til ved besøk på Dalen gård 1961. Heller ikke kjente man der til den nøyaktige beliggenhet av Kringlemyr skjerp og Bytterjønntulen skjerp. De må ligge helt østligst i feltet i nærheten av Nystaul og Tustekjøsi. Mutning 479 (Løvnetslåtten = Vargaran) ligger nær Løvnett grube. I malmsamlingen ved Geologisk Museum finnes et stykke merket: «Gedigent kobber, Kringlemyr skjerp i Huvestad utmark, Peder Olsen, By Kjøpt av K. Stenvig.»

Da man ved grubedriften i Dalanefeltet både har arbeidet på forekomster med gedigent kobber og sølv og forekomster med kobberkis, blir det hele behandlet under ett.

Mineraler: Gedigent kobber og gedigent sølv. Kobberet foreligger som små korn, plater, tråder og takker, vanligvis under 1 mm tykke og under 2 cm lange. Det skal være funnet fingertykke takker. Sølvet dannet uregelmessige plater i kobbermassen eller på dens overflate. Anslagsvis er sølvmengden 1 % av kobbermengden. Ifølge eldre oppgaver varierer forholdet mellom 0,24 % og 6,7 %. I polerslip sees hvorledes kobber omslutter glimmerkorn. Neumann meddeler at kobber synes til en viss grad å ha inntratt kvartskornenes plass ved oppløsning av disse. Cuprit finnes som overtrekk på kobberet og som selvstendige små rødt eller sorte korn i bergarten. Spor av gull skal finnes i kobbertrådene. I stoffene som ligger ved det gamle vaskeriet (fra Spendivegg, Haugjuvet, Gjeitenuten, Kjerstøl) sees spor av kobberkis og sekundære kobbermineraler, særlig malakit. N.G.U.'s geologer har ved geigerteller (i 1960) påvist at her finnes ett eller flere radioaktive mineraler. Foreløpige undersøkelser tyder på at det er kalsium-uran-vanadatet tyuyamunit ($\text{Ca}(\text{UO}_2)_2\text{V}_2\text{O}_{11} \cdot 5-8\frac{1}{2} \text{H}_2\text{O}$). En analyse utført ved N.G.U.'s labo-

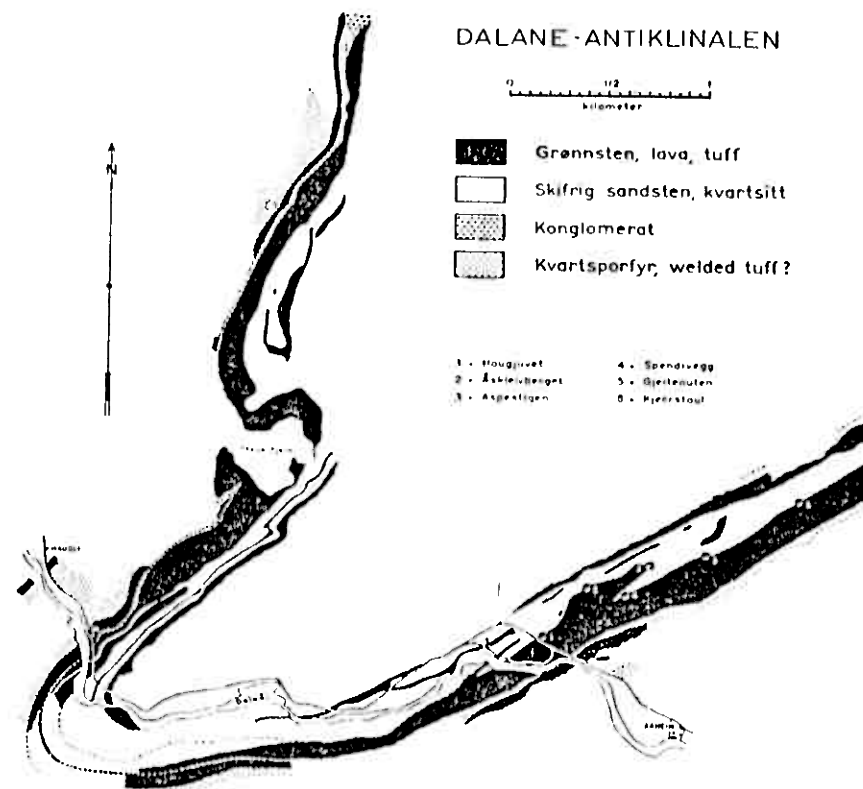


Fig. 3. The Dalane anticline. Black: «Greenstone», lava, tuff. Dots: Quartz porphyry, welded tuff? Shaded: Schistose sandstone, quartzite. Rings: Conglomerate. Some of the native copper and silver mines are indicated.

ratorium (høsten 1961) på selve den malmsførende bergart skal ha gitt uvanlig høyt vanadiuminnhold. I Kovedgjuvet skjerp skal det være funnet kobberglans.

I Lørnett og Heiskar og Grøe skjerpene er det den helt vanlige paragenese: Kobberkis og jernglans. I Heiskar er det dessuten observert små magnetitt-oktaedre og bornit.

Forekomstmåte.

Grubefeltet i Dalane, se fig. 3, ligger i sydøstre flanke og i indre del av en antiklinal hvis foldningsakse faller mot sydvest, stadig mer jo lenger mot sydvest man kommer. Hvor hovedveien gjennom Dalane skjærer antiklinalen er akschellingen ca. 70°. Lagpakken består av en veksling mellom opprinnelig basisk lava og sandstener. Polymikte konglomerater forekommer også. Gedigent kobber og sølv finnes som impregnasjon i en lengde av ca. 1½ km langs kontaktflaten mellom sandsten og den overliggende basiske lava. Flaten har strøk ca. N 60 og fall 65—90° mot sydøst. Impregnasjonen finnes i sandstenen (ofte utviklet som tykkbenket mørkegrå kvartsskifer eller lysere noe feltspat-kalkspatholdig kvartsitt) og spores noen dm ned i denne. Lokalt kan impregnasjonen være 2 m, andre steder bare noen cm. I malmhaugen ved veien er funnet stryker rike på kalkspat, inneholdende ganske små gryn og tråder av kobber og

sølv. I kvartsitten finnes ofte kobbertrådene omgitt av finkornet kalkspat. Når man slår opp den kobberholdige bergarten hender det ofte at stykker man får slått løs ikke faller ned, men blir hengende og dingle i kobbertrådene. Impregnasjonen i den overliggende lava (grønnstenen) er ubetydelig hvis den i det hele tatt finnes. Noen malmførende kvartsgang som ellers er så alminnelig, finnes altså ikke her.

I flere eldre publikasjoner gjengis profiler over malmforekomstene som viser at malmføringen er knyttet til flere grenseflater av samme type som beskrevet ovenfor. Dette er ikke riktig, og misforståelsen er sikkert fremkommet ved at man i tidligere dager ikke hadde et geologisk kart over området, hvorved man kom i skade for å kombinere profilene galt. I en av grubene har Vogt (1888) observert et system av kvartsganger med fall 40—60° mot NØ som skjærer loddrett over grensen som fører de gedigne metaller. C. Bugge, som arbeidet i disse traktene bl. a. 1922, 23, 29, påpeker ganske riktig i sin avhandling av 1931 at det finnes en kalkspatbreksje (grønnstens bruddstykker kittet sammen med rødt kalkspat) langs med og nær den malmførende kontakt. Den nye kartlegging har vist at slike breksjer neppe er bundet til noe bestemt stratigrafisk lag. Andre steder hvor de er funnet er det ingen spesiell malmdannelse.

Ved Heiskar grube er det kalkspatførende kvartsgang på 12—50 cm mektighet med retning østnordøst og med en lengde av minst 250 m. Den ligger i grønnsten. Berghallen utenfor stollen er meget stor og kan inneholde ca. 1000 tonn.

Løvnetgangen er 45—100 cm mektig og inneholder foruten kvarts også noe kalkspat ved siden av malm-mineralene. Dens retning er nær øst-vest og den er fulgt i en lengde av mere enn 250 m.

Angående mulige tyndinger av malmannelsen henvises til p. 74.

Utført arbeid — historisk oversikt.

Gamle folk har kunnet fortelle om to menn, oppsitteren på Tveit, Olaf Grå, og eieren av Dalen gård, som ca. 1660 i stillhet hentet fram sølv og kobber fra noen gamle gruber. Antakelig var dette i Spendivegg hvor det enda skal kunne sees spor etter brenning.

Da arbeidet ble tatt opp i større målestokk etter 1883, i en periode med utpreget skjerpfeber, ble det hugget en 4 m bred gate i skogen fra et sted Gullkopp vest for Dalaå til Huvestads utmark. Denne basislinje, hvis retning er ca. østnordøst, skal være snorrett. Den blir av folk i dag omtalt som barslina. Om navnet skriver seg fra «snau, bar» eller «basis» eller personnavnet «Bahr» vites ikke. Langs linjen ble det slått ned bolter med firkantet tverrsnitt (sidelengde ca. 1½ cm). De stikker 10—20 cm opp over fjellet. En av disse står mellom Spendivegg og Bergdal, en annen over Gjeitnuten. Den uthuggete gate er nå grodd igjen.

Den kontakt mellom skifrig sandsten (kvartsitt) og grønnsten (amfibolitt) som er fulgt ved grubedrift gjennom tidene, finnes i en syd-sydvest vendt dalside med tildels stupebratte sider. Haugjuvet gruber ligger nede i dalen, mens Spendivegg ligger 150 m over dalbunnen, Gjeitnuten ca. 300 m og Kjerstøl ca. 350 m over dalbunnen. Høsten 1883 eller våren 1884 fant prof. J. H. L. Vogt og Aslak Dalen gedigent kobber, visstnok i et gammelt skjerp (fra Grå's tid?). I løpet av sommeren og høsten 1884 ble det utskedet første sorts malm til analyser, således 7 tonn (av 192 m³ berg) fra Haugjuvet, 7 tonn fra Spendivegg og 8 tonn fra Gjeitnuten. Malmen holdt 5—10 % Cu, og 0,1—0,7 % Ag med særlig sølvrikdom i Haugjuvet.

Det fortelles at det var en engelskmann (?) Thaulow som drev grubene i 1884 og at han solgte dem i 1885 til det franske selskap «Compagnie Française des Mines de Bamble» (som også drev Bleka gullgrube i Svartdal og apatitgruber i Bamble). Dette selskap foretok en ubetydelig forskningsdrift, første året med dårlig resultat således: Gjeitnuten 43 m øst og 16 m synk (508 dagsverk), gedigent sølv eller kobber ikke funnet i øst, men kobberglans på slepper. Ved Haugjuvet tapte man malmen, men fant den igjen ved drift i felt. I Spendivegg forsvant malmen på en sleppe. Kompaniet hadde (midt-sommer 1885) 15 ertsanvisninger hvorav 7 med gedigne metaller, resten med sulfidiske erts på kvartsganger. Foruten de allerede nevnte arbeidssteder, viser rapporter av 1885 at man også arbeidet i Askleivberget, Aspestigen (strosse med gedigent kobber og sølv i et knippe av kvarts og kalkspat), Kjerstaul, Bergdal skjerp (oppfaret 14 m lengde,

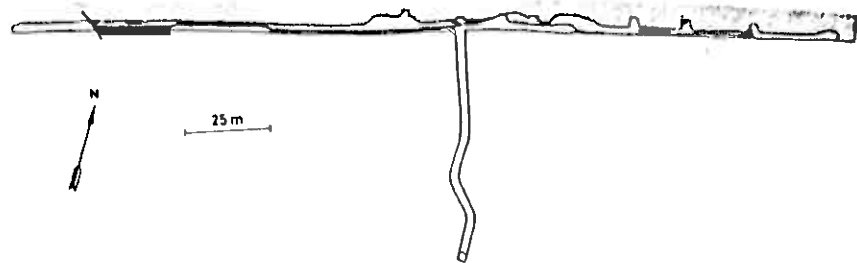


Fig. 4. Nedre Spendivegg grube. Man har så nøyaktig som mulig fulgt grensen mellom de kvartsrike sedimentene (skyggelagt) og «amfibolitt». (Kart etter stiger P. Dahl).
Lower Spendivegg mine. The border between quartz-rich sediments (shaded) and «amphibolite» has been followed as closely as possible.

10 m dyp, sølv skal være funnet), Heiskar (kobberkis og bornit i kvarts oppdaget 1883), Landsverk skjerp (kobbererts på slepper mellom hornblendeskifer og kvartsskifer). Det fremgår altså at det ble drevet både på gedigne metaller og på andre kobbermalmer.

Årene 1886—87—88 gikk med liten drift, 200—300 m³ hvert år, og bare spor av gedigent kobber og sølv. I 1889 ble Heiskar undersøkt ved stoll 52 meter. Noen nevneverdig produksjon var det ikke her, men i Spendivegg ble det i kvartsslagets heng inn-drevet stoll 38 m, hvor man i de siste 5 m fant et ertsparti 2,5 m høyt, 0,1—0,9 m tykt, som ga 3800 kg. malm med sølvholdig gedigent kobber av 4 %. Stollen ble forlenget 22 m i 1890 hvor man undertiden fant de gedigne metaller. Strossing vest for Spendivegg ble foretatt 1889 og 1890. Spendivegg-stollen ble forlenget 37 m i 1891 med sporadiske funn av gedigne metaller, og ytterligere 30 m i 1892 med nærmest jevn føring av gedigent kobber og av og til gedigent sølv. Man påbegynte sistnevnte år to tverrslag fra denne stoll. Samme år ble det ferdig et geologisk kart 1:5000 over feltet. Mens det franske selskap på denne tid holdt 17 anvisninger under frist, hadde hr. A. Beck, London, 40 mutte anvisninger av kobber og sølv, hvorav Løvnetgangen ble oppdaget og avdekket 1891. Ifølge bergmester Dahll's utsagn skal det her være en meget lovende kobberkisgang. Beck drev i et par år i Løvnet (og muligens Heiskar).

I 1893 ble det foretatt forskningsdrift ved det franske selskaps grube Kjerstøl (gedigent kobber), og ved skjerpene Åsen og Snørtten. Spendivegg-stollen ble fortsatt 15 m med gedigent sølv og kobber, og tverrslaget mot nord fra denne stoll ble fortsatt mot nord-grensen, altså ut mot det som kanskje kan antas å være en anormal kontakt, hvor det ble funnet endel kis. En ny stoll (nedre Spendivegg), 27 m under og sydvest for den tidligere (nå 100 m lange) stoll i Spendivegg, ble påbegynt. Ved å føre denne inn 60 m mot nord ville man nå kontakten med gedigent kobber og sølv. I 1894 var man nådd 23 m inn. Fra den opprinnelige øvre stoll var det da også drevet tre oppsynker langs kontakten, stadig med sølv og kobberføring. Ved Kjerstøl og Snørtten var kontakten blottlagt i en lengde av 230 m, og tildels avstrosset uten nevneverdige funn. Til bergbrytning var dette år medgått 879 dagsverk. I et skeidehus ved munningen av Spendivegg-stollen ble i oktober av 10 mann behandlet 76 tonn. (Skeidehuset er senere flyttet lenger opp i Dalane og er nå ungdomslokale).

1895 gikk med i alt 380 dagsverk uten særlig malm i Spendivegg-stollen og dens 3 oppsynker og et tverrslag. Den nye og lavereliggende stoll nådde i dette år som planlagt kontakten hvorfra man fortsatte driften med en feltort mot vest og en mot øst, stadig med funn av gedigent sølv og kobber (feltorten mot vest er i dag 128 m, og den mot øst 107,5 m). En tredje stoll også med nordlig retning ble påbegynt og 80 m lavere enn den første (øverste). Den vil nå den malmførende kontakt etter 145 m inndrift. Det ble mutet på Heiskarbekken grube og et sted 100 m syd for Løvnetgangen.

Fra driften i 1896 rapporteres at den tredje Spendivegg-stollen er drevet inn 50 m. I 1897, 1898 og 1899 var virksomheten minimal og langt fra lovende, og februar 1900

ble driften innstillet. Det er berettet at selskapet mistet retten til drift ved juridisk forsyrmelse.

I 1907 drev Christiania Minekompani avbygningsarbeider, avstrossinger i dagen ved Gjeitnuten og i den ene av Spendivegg-stollene. Det ble utvunnet 38 tonn malm med 5—8 % gedigent kobber og 1—2 kg. sølv pr. tonn.

Omkring 1910—11 skal en engelskmann ved navn Valley ha drevet her. Han bodde på stedet ca. 1½ år og drev antakelig bl. a. Løvnnett.

Den neste rapport er fra 1916. Et annet fransk selskap som hadde kjøpt forekomstene begynte da prøvedrift ledet av ingeniør A. Henni Sinn, Paris (opprinnelig sveitser), på 6 kobber-sølv gruber i Dalane. Foruten ing. Sinn arbeidet her også 1 ingeniør, 1 assistent, 1 bokholder og kasserer, 1 stiger, 16 mann i grubene og 13 i dagen. Det ble arbeidet i Spendivegg grube (orter, stoller, synker, oppsynker og strosser), 2 stoller i Haugjuvet grube (orter, stoller, synker, oppsynker og strosser), Kjørstøl grube (synker, oppsynker og strosser), Løvnnett grube (orter, stoller og strosser), Gjeitnuten grube (brudd i dagen, drift i synk og strosser) og Heiskar grube (synk). Under arbeidet i Gjeitnuten skal man ha gjort en feil slik at man kom 7—8 m ut til siden for den malmførende sonen.

Til sammen ble det utfordret av grubene 2780 tonn hvorav 1384 tonn bergart var malmholdig. I alt ble det dette år utført 5525 dagsverk. Endel av arbeidet omfattet også oppførelse av hus på ing. Sinns personlige eiendom «Aaheim», således våningshus, brakke, materialbod, smie og anlegg for malmens oppredning. Om sistnevnte opplyses at det ikke var ferdig montert ved årets utgang. Det er restene etter dette oppredningsverk eller vaskeri som nå finnes mellom veien og elven med Haugfossen. Langes begge sider av veien som fører hit inn ligger det fremdeles hauger av malm fra Spendivegg, Haugjuvet, Gjeitnuten og Kjerstaul. Antakelig var det i denne tid det ble bygget en kontorbygning eller bolig, nå kalt «Frankrike», oppe mellom Dalen-gårdene. Det egentlige navn er Flaten. Taubane fra Gjeitnut og fra Spendivegg hit ned ble antakelig bygget noe tidligere (ca. 1907?). I januar 1917 ble prøvedriften nedlagt og er ikke tatt opp igjen siden. Lønnsomheten av framtidig mulig drift regnet man den gang å få et begrep om, ved oppredning av vaskemalm. Det franske selskap kunne ikke etterkomme forpliktelsene, så forekomstene falt tilbake til de norske eiere, vesentlig bergingeniør Olaf Dalen og Christiania Minekompani. Aaheim ble solgt til Thommassen, Kviteseid, som senere har solgt det til A. Bjørnflaten.

Det har vært en rekke befaringer og det finnes forskjellige rapporter og vurderinger. Under første verdenskrig var det mulig å få kjøpt alle rettigheter samt 1400 mål skog og dyrket mark for 600.000 kroner. Et selskap, A/S Kviteseid Kobbergruber, planla konsesjonsandragende en gang. Av en rentabilitetskalkyle utført etter 1936 framgår at det er utført analyser ved Heidenreichs laboratorium og flotasjonsforsøk ved Høleden. Man forstår at ingeniør Sinn har noe utstyr som vil kunne anvendes, og at han beriget seg fraksjer i et eventuelt nytt selskap. Driften skulle foregå i grubene, og berghallene skulle også utnyttes. Advokat Hægland og senere saksfører Hals har hatt endel rettigheter her før Christiania Minekompani igjen overtok dem.

I 1947 foretok Geofysisk Malmleting, Trondheim, med 10 mann i ca. 2 måneder geofysiske målinger for Kongsberg Sølvverk i antiklinalens ombygning i området sylvest for en linje Stortj.—Haugjuvet grube. Som geologisk grunnlag ble anvendt Neumanns kart 1:25.000. Ved de avsluttende målinger fikk de et nytt geologisk kart 1:8000, oppratt av stiger R. Kongsgaard.

Målinger gjort på stuffer tydet på at man under ideelle forhold kunne påvise kontakten mellom kvartsitt og grønnsten ved elektriske potensialmålinger. Malmstuffer avvek lite i ledningsevne fra bergartene forøvrig. Dette skyldes antakelig det forhold at kobberrådene er korte og usammenhengende. Direkte påvisning av malmen ved elektriske eller elektromagnetiske målinger syntes derfor umulig, og målingene i felt ga også lite resultater. De magnetiske egenskaper kunne imidlertid utnyttes. (Kvartsittens susceptibilitet: $35 \cdot 10^{-6}$, grønnsten $3300 \cdot 10^{-6}$, det siste høye tall skyldes vel jernglans eller magnetitt). Ved detaljmålinger fikk man frem et pent bilde av antiklinalens form.

En rekke nye punkter ble mutet, og man håpet å ta opp ny drift her og særlig i det gamle området. Malmen skulle eventuelt etter en enkel skedling transporteres til Kongsberg Sølvverk, som på det tidspunkt enda ikke var nedlagt. Planen ble ikke gjennomført.

The Hovin Cu-Ag-Fe deposit occurs on the eastern shore of lake Tinnsjø where this makes a bend from N-S to NW-SE (Plate 1). This and other similar deposits were investigated this summer by Schönwandt, and his report is included below.

The Sauda Zn-Cu mines occur at the head of Saudafjorden in the western part of mapsheet Sauda (Plate 2). The deposits were not investigated by the present author as they are positioned outside this summer's main working area. However, they represent an interesting case of a stratabound Cu-Zn mineralization which may be syngenetic volcanogenic and/or diagenetic in nature. The following account is from Nordrum and van der Weel (1981). The deposits contain tin-bearing minerals which may indicate some acid volcanogenic affiliation, arsenopyrite and löllingite are present, and the mineralized zone may be in the order of 2 to 3 km long. According to Nordrum et.al. (op.cit.) the deposits have not been investigated in recent times, and the above mentioned features make them a worthwhile reconnaissance target for 1984.

FELTRAPPORT OVER HOVIN KOBBERVERK,
TELEMARK.

Hans Kristian Schönwandt
hanskristianschönwandt
dec. 1983.....

INDHOLDSFORTEGNELSE

	Side
RESUME	1
INDLEDNING	2
TIDLIGERE RAPPORTER	3
FELTBESKRIVELSE	11
LITHOLOGI	11
STRUKTUR	17
MINERALISERINGER OG OMDANNELSE	20
MODEL FOR MINERALISERINGEN	27
EFTERSKRIFT	29

4 kort, 4 tabeller & 5 figurer.....

RESUME.

Tidligere rapporter over Hovin Kobberverk betragtede mineraliseringen som epigenetisk og antog implicit at amfiboliten virkede som en art 'kemisk fælde'. Trods denne genetiske tolkning formodedes mineraliseringen at have en planar struktur parallelt med amfiboliten. Boringer og stoll-arbejder blev foretaget ud fra denne model. Alle hidtidige undersøgelser konkluderede at mineraliseringen ikke var drivværdig.

Denne undersøgelse peger på, at mineraliseringsbilledet er mere kompliseret og at det skal opdeles i en syngenetisk og en epigenetisk del.

Den syngenetiske mineralisering sidder i en magnetit-diorit, og dens primære størrelsen og strukturen af magnetit-dioriten, der er afgørende for malm-potentialet i Hovin Kobberverk. Magnetit-dioriten menes at være et lineært legeme af cylindrisk karakter.

Endelig konklusion samt anbefalinger afventer nogle laboratorie undersøgelser.

INDLEDNING.

I forbindelse med Norsk Hydro's Telemark projekt 1983 skulle Hovin Kobberverk besøges, og der skulle foretages undersøgelser i et sådant omfang, at malmens relation til den omgivende geologi i store træk blev fastlagt.

Beliggenhed. Hovin Kobberverk ligger på østsiden af Tinnssjøen på jord tilhørende Sigurd Vasstveit på gårdene Nordre og Søndre Vasstveit. Man kommer lettest frem til Hovin Kobberverks grundstøtte ved fra Rigsvej 37 at tage bygdevejen til Hovin Brygge. Omkring 300 m før bryggen går der en bonveg^{+) af rød øst. Bonvejen følges ca. 1 km hvor den passerer tæt forbi ruinerne af vaskeriet, der ligger umiddelbart syd for vejen.}

Hovin Kobberverk består af et dagbrud (Storekaas) samt en skakt med tilhørende stoller i 3 niveauer, her kaldet Storekaas Grube. Desuden en række skjerp og yderligere 4 stoller fordelt over en nord-syd strækning på ca. 1 km mellem Tinnssjøen og gården Søndre Vasstveit (kort 1).

Udført kortlægning. Der er foretaget kortlægning i 1:500 (kort 2) med tilhørende prøveindsamling omkring Storekaas dagbrud dækkende en nord-syd strækning på ca. 400 m og dermed omfattende hovedparten af de bedst mineraliserede skjerp og stoller der udgør Hovin Kobberverk. Kortlægningen er baseret på en basis-linie med enkelte tværlinier. Dette net er blevet udlagt med målebånd og kompas.

^{+) Nogle til bonvejen kan lånes hos Sigurd Vasstveit.}

TIDLIGERE RAPPORTER.

I NGU's bergarkiv foreligger der et stort antal rapporter over Hovin Kobberverk (= Vasstveit forekomsterne), men hovedparten af disse indeholder ikke væsentlige informationer (H. Bjerlykke, 1964).

C.W. Carstens (5/11, 1940) giver en sammenfatning af tidligere rapporter. Følgende rapporter har været til rådighed for dette arbejde:

Chr. A. Münster (1910)⁺⁾ : Kobberanvisninger i Hovin og Grans herred. Bergarkivet rapp. nr. 466

C.W. Carstens (6/7 1940): Notat til Hr Ingeniør F. Egeberg Oslo - Ad. Vasstveit Kobberforekomst. Bergarkivet rapp. nr. 1582.

C.W. Carstens (5/11 1940)⁺⁾ : Das Kupfervorkommen von Vasstveit (Hovin in Telemark) Bergarkivet rapp. nr. 878.

H. Bjerlykke (1964): Rapport over orienterende undersøkelser av Vasstveit kopperforekomster, Hovin, Telemark. Bergarkivet rapp. nr. 3481.

S. Bergstøl (1974): Årsrapport for Norsk Hydro's forskingsbidrag for 1973 til Geologisk Institutt, NTH. NH Arkiv.

S. Bergstøl (1977): Foreløbig rapport om malmegeologiske undersøgelser ved Vasstveit Grube, Hovin, Telemark. NH Arkiv.

Nedenstående vil der blive givet et kort sammendrag af de nævnte rapport med speciel vægt på rapporternes geologiske aspekter.

Münster (1910) nævner at skjerpnningen startede i 1890'erne og at en egnetlig drift blev påbegyndt i 1907. Der gives følgende geologiske karakteristik af forekomsten:

⁺⁾ Kort og/eller kortskitser forefandt ikke i de anvendte kopier.

1. Gabbroen (amfiboliten) er moderbjergart for kobber-mineraliseringen.
2. Ag/Cu forholdet er rimelig konstant ca. 5.3/1000.
3. Mineraliseringen er ikke jævn fordelt men optræder partivis i amfiboliten.
4. Mineraliseringen opdeles i følgende tre strukturer a. finkornet imprægation b. mineraliserede småsprækker c. hydrotermale kvarts-kalcit-gange.
5. I dagbruddet optræder en granitoid bjergart med sulfid imprægation.

På strækningen mellem Tinnasjø og gården Søndre Vassstveit (ca. 1 km) er der foruden Storekaas dagbrud også 12 skjerp (kort 1). Münster siger sammenfattende om disse skjerp, at de kun i meget beskedent omfang er mineraliseret, hvis de overhovedet er mineraliseret. Typisk for en del af skjerpene er, at der er blevet skjerp på tynde (25 cm) hydrotermale kvarts-kalcit årer. Storekaas dagbrud er det eneste sted hvor sulfiderne i gabbroen (amfiboliten) når op i 'ore grade'. Der er ifølge Münster brudt ca. 8500 tons malm ækvivalerende et overflade areal på 370 m². Endvidere skønnes det, at maksimalt et overflade areal på 500 m² vil være drivværdigt. Dagbruddet vil således kun i beskedent omfang kunne udvides i henholdsvis nord- og sydlig retning.

Münster konkludere at hornblendegangen (amfiboliten) er kobberfri eller inverterfald så kobberfattig, at den ikke er drivværdig. Kun ved Storekaas dagbrud er der 'ore grade' men chancerne for en større tonnage er beskedne. Münster understreger videre, at der ikke er fundet noget tips om hvor malmen bør søges og at en yderligere opskjerpning af amfiboliten på den baggrund vil være et lotteri.

Til trods for denne negative vurdering foretages der

omfattende grubeanlæg og yderligere skjerpning i 10-året 1910-20 (Carstens 5/11 1940). Det største arbejde finder sted i forbindelse med Storekaas dagbrud. Her sænkes en skakt fra dagbrudets bund og ned til 245 m niveauet, hvorfra skakten over en 150 m lang stolle (grundstollen) står i forbindelse med overfladen (kort 2). Fra grundstollen går der i amfibolitens lig et 65 m langt tværsag i sydlig retning.

I niveau 283 m går der fra skakten en ca. 100 m lang stolle (feltort) i nordlig retning. Fra denne feltort går der to tværsag på ca. 10-15 m's længde i østlig retning. I 274 m niveauet går der en 60 m lang feltort i sydlig retning. Denne stolle er forsynet med 3 østlige tværsag på 10-15 m's længde. Sammenlagt er der udført omkring 0,5 km stoll og skakt. Dette system af stoller og skakt i forbindelse med dagbrudet vil blive betegnet Storekaas Grube (kort 3).

Udover Storekaas Grube blev der i nævnte 10-år udført følgende stoller (nævnt fra syd mod nord): Tinnsjø stoll (240 m), 274 m niveauet, 340 m niveauet og Havestollen (345 m) med en samlet længde på ca. 240 m.

Foruden stollerne blev der skjerpet yderligere 7 grofter, således at antallet kom op på 19 grofter ialt.

I forbindelse med Carstens undersøgelser i 1940 blev alle 19 grofter samt stollerne i Storekaas Grube og stollen i 340 m niveauet chip samlet. Det prøvetagne interval er noget varierende men typisk ligger det på ca. 5 m og ækvivalerer en gennemsnitlig prøvevægt på 150-200 kg. Ud over denne prøveindsamling blev der foretaget 3 boringer (se fig. 1). I Tabel 1 er nogle karakteristika ved boringerne sammenstillet.

Lithogeokemien repræsenteret ved chip sample og borekærner er tilsyneladende ikke blevet sammenstillet. Derimod præciserer denne undersøgelse en række af mineraliseringens paragenetiske forhold som f. eks.

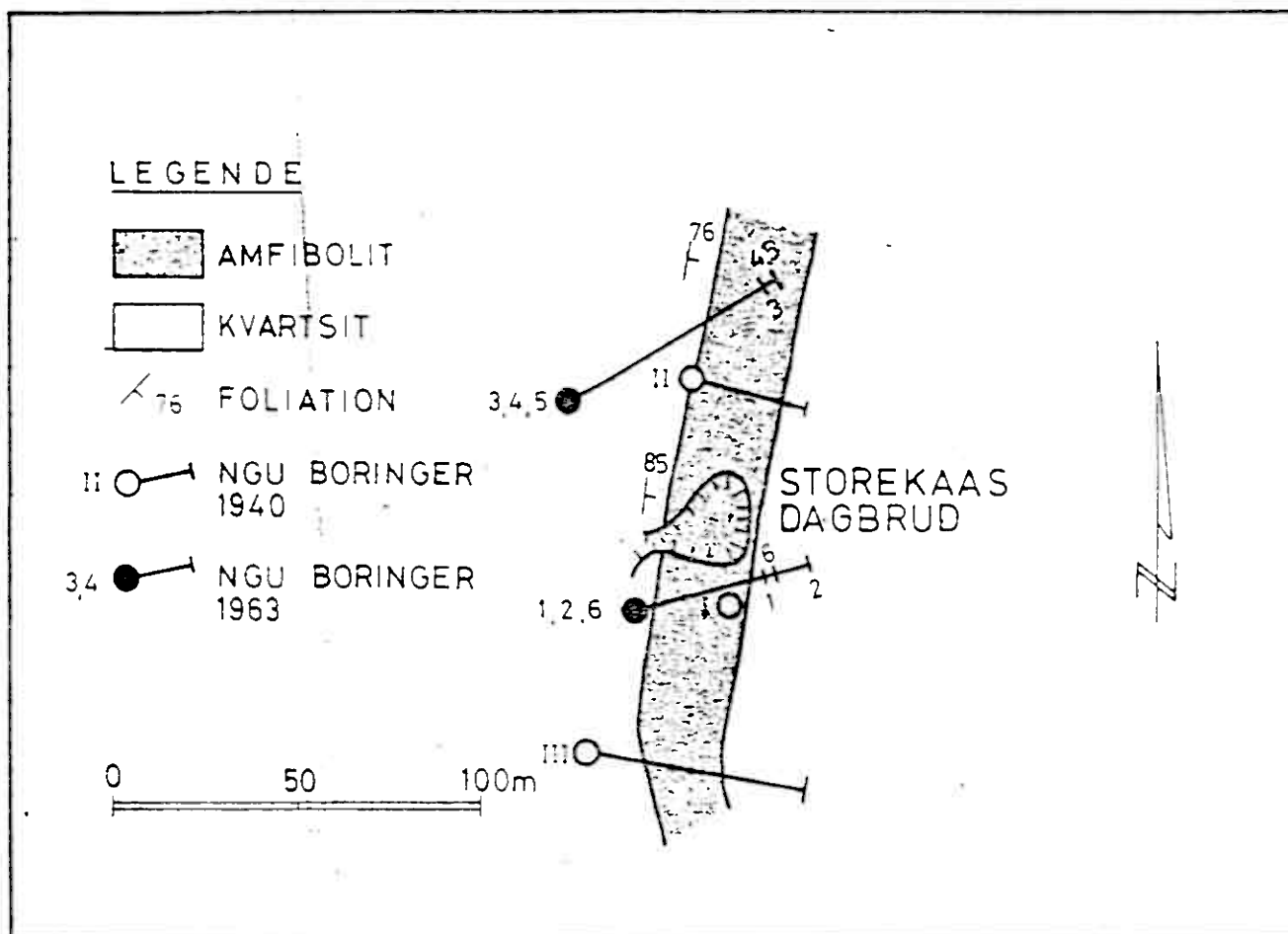


FIG. 1.

TABEL 1.

NGU BORINGER VED HOVIN KOBBERVERK, 1940.

Nr. ¹⁾	LENGDE	GENNEMSNITLIG CU-INDHOLD I AMFIBOLITEN. -% -	BEDST MINERALISEREDE ⁺⁺) DEL AF KERNEN.
1.	58,7 m	0,2%	10 m med 0,34% Cu
2.	61,0 m	0,13%	14 m med 0,55% Cu
3.	86,0 m	0,04%	Ingen mineraliserede partier.

¹⁾ For lokalisering se fig. 1⁺⁺) Ikke korrigeret for eventuel skæv skæring af mineraliseringen.
Mineraliseringens strukturelle forhold er ikke kendt.

At kobberkis og bornit er hovedmineralerne medens chalcocit optræder i underordne mængder
 at aldersrækkefølgen er kobberkis-bornit-chalcocit
 at bornit dominerer i de hydrotermale kvarts-kalcit årer og
 at molybdänglans optræder som accessorisk mineral
 at Ag-indholdet er 70 g pr. 1% Cu i råmalmen, men at
 analyserne viser en meget stor variation i Ag/Cu forholdet
 at de mineraliserede partier af amfiboliten er hydrotermalt omdannet (rødfarvet) og
 at de rigeste partier findes i dagbrudets umiddelbare nærhed og at Cu-indholdet hurtigt aftager med dybden.
 Carstens konkludere at Cu-indholdet er for lille og at højere gehalter kun optræder sporadisk. Endvidere at Cu-indholdet hurtigt aftager med dybden. Grundet disse forhold anses forekomsten for ikke at være drivværdig.

I 1962 foretog Bjørlykke (1964) en befaring af Hovin Kobberverk. Det var ikke muligt at danne sig et indtryk af gehalterne under denne befaring idet, som Bjørlykke skriver "... den finkornede mineralisasjon av broket kopper og kopperglans er ofte meget vanskelig a se med det blotte øye...". Bjørlykke foreslog derfor, at sætte 6 korte borehuller gennem malmzonen for at få konstateret om der forelå en jævn mineralisering med drivværdige gehalter.

Boringerne blev udført i 1963. Nedenstående er data fra boringerne sammenstillet i tabellarisk form (Tabel 2). Boringernes placering er vist på fig. 1.

Konklusionen på disse boringer var, at mineraliseringen i malmzonen er meget ujævn og at gehalterne ligger betydelig under det, der må anses for nødvendig for drift. Videre arbejde kunne ikke anbefales.

Bergstøl's to rapporter (1974) og (1977) dækker en mere regional undersøgelse foretaget i årene 1973-76 under projektbetegnelsen NUMHOV. Disse rapporter nævner om Hovin Kobberverk at der foruden den mineralisering som findes i

TABEL 2.

NGU BORINGER VED HOVIN, KOBBERVERK, 1963.

Nr. ⁺⁾	LENGDE	GENNEMSITLIG CU-INDHOLD I AMFIBOLITEN.	BEDST MINERALISEREDE ⁺⁺⁾ DEL AF KÆRNEN.
1.	40 m	0,1%	0,2% Cu over 16 m
2.	60 m	0,27%	1,02% Cu over 10 m
6.	64 m	0,18%	0,45% Cu over 13 m
3.	69 m	0,03%	0,22% Cu over 6 m
4.	82 m	0,01%	Ingen mineraliserede partier.
5.	139 m	0,14%	0,36% Cu over 11 m.

+) For lokalisering se fig. 1

++) Da mineraliseringens strukturelle relation til amfiboliten ikke er kendt, kan der ikke foretages korrektioner for skæv skæring af mineraliseringen.

malmzone amfiboliten, også optræder mineralisering i en vest for liggende amfibolit kaldet imprægnationszone amfiboliten.

Desuden peger rapporten på den mulighed, at mineraliseringen eventuelt kunne være knyttet til et NW-SØ gående sprækkesystem, der i så fald kan opfattes som sekundær sprækker til et N-S-gående hovedsprækkesystem.

Endvidere gives der i Bergstol's rapporter følgende supplerende oplysningerne om mineral-paragenesen i mineraliseringen: At digenit og covellin også optræder i paragenesen og at følgende mineraler findes i accessoriske mængder gedigen kobber, wittichenit, betekhtinit samt stromeyrit.

Sammen drag. Summeres den geologiske viden om Hovin Kobberverk forud for denne undersøgelse bliver det, at mineraliseringen er epigenetisk og at amfiboliten har virket som en art 'kemisk fælde' for de hydrotermale opløsninger. De hydrotermale opløsninger har muligvis anvendt 2. ordens sprækker til et N-S-gående hovedsprække system. Mineraliseringens paragenese, der tidligere blev anset for at være supergen, menes i de senere rapporter at have en klar hypogen karakter.

FELTBESKRIVELSE.
LITHOLOGI.

Hovin Kobberverk ligger i en amfibolit (kort 1), der jævn før Bergstøl (1977) betegnes malmzone-amfiboliten. Malmzone-amfiboliten udgør sammen med en række andre amfiboliter konkordante bånd i en stejltstående nord-syd-gående kvartsitisk sekvens.

Kvartsiten. Kvartsiten varierer fra en m til dm båndet kvartsit med enkelte grus og konglomeratiske indslag til en cm til mm lagdelt phyllit- og/eller epidotholdig kvartsit. På kontakten til amfiboliten bliver kvartsiten væsentlig mere phyllitisk og kan stedvis antage karakter af phyllitskifer (fig. 2).

Malmzone-amfiboliten. Malmzone-amfiboliten varierer mellem 10 og 40 m i bredden og domineres af to hovedbjergarter en amfibolit og en biotit-førende amfibolit. Disse to bjergarter glider uden skarp kontakt jævnt over i hinanden.

Hver af hovedbjergarterne varierer så meget, at de kan opdeles i en række subvarianter. Amfiboliten kan således opdeles i Amfibolit, Porfiroblastisk Amfibolit, Hornblendit medens den anden hovedbjergart kan inddeles i Biotit-førende Amfibolit og Melanokratisk Biotit-Skifer. Kortlægningsmæssigt er der ikke skelnet mellem de forskellige subvarianter, men de mest markante zoner med den biotit-førende hovedbjergart er angivet på det geologiske kort (kort 2).

Af det geologiske kort (kort 2) fremgår, at de biotit-førende bjergarter helt overvejende findes på eller nær kontakten til kvartsiten. Ser man nærmere på relationen mellem de biotit-førende og ikke biotit-førende amfibolit varianter, finder man ofte en glidende overgang mellem disse hovedbjergarter. Desuden findes lenseformede partier af ikke biotit-førende amfibolit i den biotit-førende amfibolit. Den strukturelle

HOVIN VEJPROFIL I MALMZONE AMFIBOLITTEN
NIVEAU 240 M.

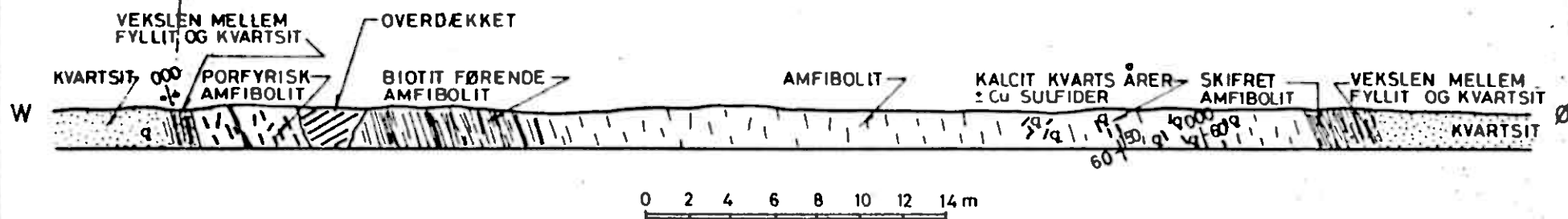


FIG 2.

relation mellem hovedbjergarterne antyder, at de biotit-førende varianter repræsenterer et shearet domæne i malmzone-amfiboliten.

I det følgende gives en kort håndstyks-beskrivelse af de forskellige subvarianter i malmzone-amfiboliten. Vejprofilen (fig. 2) er et eksempel på hvorledes de forskellige varianter veksler inden for amfibolit-båndene.

Den porfyriske amfibolit er den almindeligste af amfibolit-varianterne. Den består af prismatiske til tenformede grønsorte hornblende krystaller med en størrelse omkring 1 x 10 mm. Mængden af hornblende porfyroblaster varierer normalt mellem 5 og 20 vol%.

Porfyroblasterne sidder i en mellem- til finkornet matrix bestående af hornblende og plagioklas med et varierende, men næsten altid erkendbart magnetit indhold. Porfyroblasterne fremhæver bjergartens foliation.

Den porfyroblastiske amfibolit glider stedvis jævnt over i en mellemkornet amfibolit, svarende til et aftagende porfyroblast indhold. Modsat vil en øgende mængde hornblende porfyroblaster resultere i en ofte skifret hornblendit.

Den biotit-førende amfibolit er en mellem- til finkornet melanokratisk, biotit-plagioklas-hornblende bjergart. Bjergarten veksler mellem en massiv og en nogenlunde folieret type. Generelt er bjergarten dog ikke særlig velfolieret. Stedvis ville bjergarten kunne betegnes som en melanokratisk biotit-gneis og/eller diorit gneis. Dette antyder at bjergarten muligvis burde splittes op i yderligere en række enheder, men dette har for nærværende ikke været praktisk.

Med et voksende biotit-indhold får den biotit-førende amfibolit en mere udtalt foliation for gradvist at glide over i en skifret struktur. I disse tilfælde

er der tale om en melanokratisk biotit-skifer.

Der er tidligere gjort opmærksom på at de biotit-førende varianter sandsynligvis repræsenterer shearede domæner i amfiboliten. De to subvarianter er formodentlig blot udtryk for forskellig grad af deformation med biotit-skiferen som repræsentant for det mest deformerede.

Amfibolitens subvarianter repræsenterer ikke nogen væsentlig lithologisk forskel, men er nok snarere udtryk for eventuelle små forskelle i kemisk sammensætning og/eller forskellig deformations-grad under den isoklinale foldning.

Af det geologiske kort (kort 2) fremgår, at de geologiske forhold i og omkring Storekaas Dagbrud er væsentlig mere kompliceret end på den øvrige strækning mellem Tinnsjø og Vasstveit. Dette skyldes, at der foruden de sædvanlige bjergartsvarianter inden for malmzone-amfiboliten, optræder et kompleks af bjergarter omfattende følgende typer: Magnetit-diorit, Feldspat-porfyr og mafit⁺ samt disse bjergarters deformerede ækvivalenter. Dette bjergartskompleks findes især på malmzone-amfibolitens hæng side, det vil sige i dagbruddets østlige del.

Magnetit-diorit er en mellemkornet, svag rosa farvet bjergart. Det karakteristiske magnetit indhold har givet bjergarten sit navn. Stedvis bliver magnetit-dioriten svag feldspat porfyrisk med fennokryster på 2-3 mm's længde. Bornit og chalcocit optræder som karakteristiske accessoriske bestanddele dissemineret i magnetit-dioriten.

⁺) Mafit er en melanokratisk ækvivalent til felsit.

Langs dagbruddets nordvæg er der mellem magnetit-dioriten og malmzone-amfiboliten en shearet overgangszone. I overgangszonen er magnetit-dioriten så stærk deformeret, at den bør betegnes som en gneis (rosa farvet, fin sliret magnetit-gneis). I magnetit-gneisen optræder mm tykke og op til cm lange slirer af bornit og chalcocit. Overgangen mellem magnetit-gneis og magnetit-diorit er sine steder i dagbruddet karakteriseret af en brecciezone, hvor magnetit-dioriten er brudt op i et stockverk af årer bestående af chlorit-kalcit-Cu-sulfider[±] kvarts.

Malmzone-amfiboliten er i dagbruddet også stærk deformeret. Langs nordvæggen er der en jævn overgang mellem magnetit-gneisen og en deformeret amfibolit (skifret amfibolit [±] biotit). Dagbruddets sydvæg består af en biotit-førende amfibolit med vekslende mængder joints og/eller sprækker, der kan være mineraliseret med chlorit-kalcit-bornit-chalcocit [±] kvarts. Den biotit-førende amfibolit langs sydvæggen har ikke nogen særlig iøjnefaldende struktur, men en omtrentlig øst-vest-gående planar fabric ses antydningvis.

Normalt udgøres ligsiden af malmzone-amfiboliten af en vekslen mellem phyllit og kvartsit (fig. 2), men i dagbruddet er overgangen lidt mere kompliceret idet en ca. 8 m bred overgangszone adskiller porfyrisk amfibolit fra kvartsit. Overgangszonen er opbygget af to melanokratiske zoner på 3 m og 2 m's bredde adskilt af en ca. 3 m bred kvartsitisk zone (kort 2). De melanokratiske zoner består af biotit-førende amfibolit, mafit og pelitrig kvartsit.

De to melanokratiske bånd kan ved nærmere undersøgelse vise sig at være en tektonisk repetition af et enkelt bånd.

Mafit indslagene i de melanokratiske zoner har en mægtighed på 1 til 1/2 m. Mafit båndene er kun kendt fra dagbruddets vestlige del og er ellers mineraliseret med kvarts-biotit-chlascocit-bornit slirer op til flere cm lange.

Den sidste af bjergarterne i bjergartskomplekset er ikke blottet i selve dagbruddet, men findes umiddelbart nordøst for Storekaas dagbrud (kort 2). Feldspat-porfyren består af 5-10 vol% feldspat fenno-kryster med en diameter på 1-2 mm. Fennokrysterne er hvide og ligger i en tæt grå matrix.

Selv om relationen mellem magnetit-dioriten, feldspat-porfyren og mafiten ikke er kendt, så er det på grund af disse tre bjergarters nære rumlige kontakt naturligt i første omgang at betragte dem som et bjergartskompleks. Håndstyksmæssig kan magnetit-dioriten og feldspat-porfyren glimrende være nært beslægtede bjergarter, med feldspat-porfyren som en vulkansk repræsentant og magnetit-dioriten afspejlende et mere plutont miljø.

Mafitens relation til de to andre bjergarter er straks mere spekulativ, og bør egentlig afvente en nærmere laboratorie undersøgelse. Koblingen kan eventuelt være at mafiten repræsenterer en submarin exhalit til duoen feldspat-porfyre/ magnetit-diorit.

STRUKTUR.

Kvartsit-amfibolit sekvensen stryger nord-syd og er stejltstående med en overvejende østlig hældning (kort 2).

I de rene kvartsiter er strukturelementer sjældne, men stedvis ses knækfolder hvor aksialplanerne optræder som nord-syd-gående knusningszoner.

I de mere pelitiske og/eller epidot-førende, finlaminerede kvartsiter ses isoklinafolder med stejltstående nord-syd strygende aksialplaner. Lignende folder er også observeret i amfiboliterne.

Amfiboliternes mest markante strukturelement er de stedvis velfolierede biotit-førende amfiboliter. Disse optræder som meter brede zoner (kort 2), men kan også ses som cm brede slirer i f.eks. den porfyroblastiske amfibolit (fig. 2). De nord-syd-gående biotit-førende amfiboliter opfattes som aksialplansdeformationer i forbindelse med isoklinafoldningen.

I malmzone-amfiboliten findes der mindre tværgående strukturer i form af kvarts-kalcit-Cu-sulfid mineraliserede små-forkastninger (fig. 3, kort 3).

Disse tværretninger, der ofte optræder som fleksurer i nord-syd-gående forkastninger, ser ud til at tilhøre det stress system, der er forbundet med en nord-syd-gående shear bevægelse.

I Storekaas Dagbrud findes en række tværgående strukturer i form af mineraliserede forkastninger og biotit-førende amfiboliter (kort 2). Disse strukturer har dog sådan en orientering, at de ikke umiddelbart kan sættes i forbindelse med en nord-syd-gående shear bevægelse.

Magnetit-dioriten er på mesoskala selv en tværgående struktur i malmzone-amfiboliten (kort 2), medens den i håndstyksskala optræder konkordant med amfiboliten.

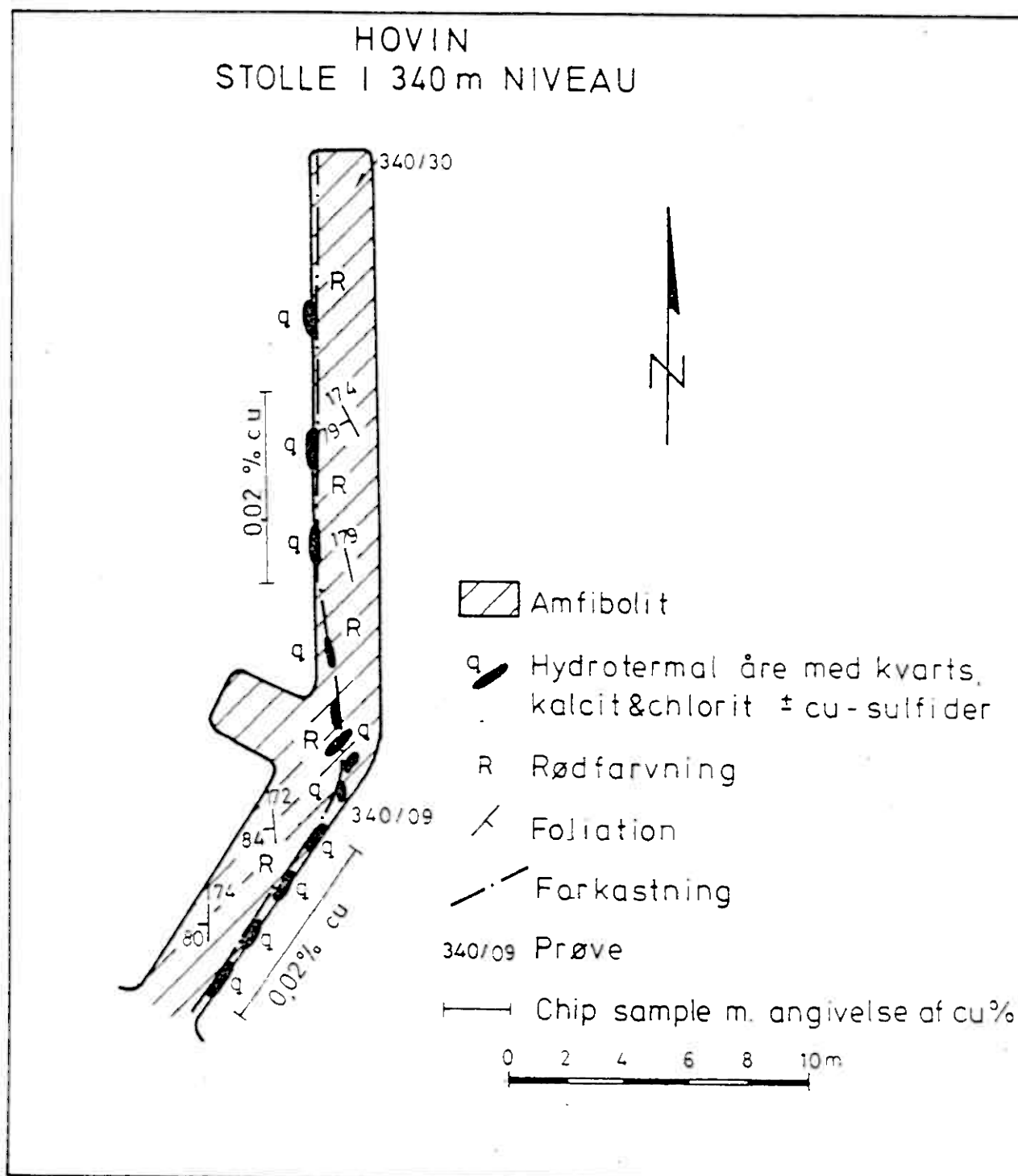


FIG. 3.

De afvigende strukturer i dagbruddet er formodentlig dannet som en kombination af en prækinematisk lithologisk tværstruktur (amfibolit/magnetit-diorit) og en isoklinafoldning med eventuelt tilhørende aksialplans shear.

Den kraftige deformation gør det vanskeligt på basis af denne undersøgelse at få rede på en række af de primære strukturer og bjergartsmæssige relationer, og dermed også på de deformerede bjergarters strukturer. Det ser dog ud til, at magnetit-dioriten oprindeligt har været et tværgående strukturelement i eller til malmzone-amfiboliten, og at dette element efter deformationen muligvis optræder som en liniation på amfibolitens hængside.

De foretagne boringer (fig. 1) og stoller (kort 3) giver rigeligt plads til et sådant legeme. De foretagne boringer og stoll-arbejder er klart gået ud fra det synspunkt, at mineraliseringen skulle opfattes som et planart fænomen i lighed med amfiboliten, og placeringen af boringerne har primært været foretaget med henblik på at teste dette.

MINERALISERINGER OG OMDANNELSER.

Kort 4 giver et groft indtryk af Cu-fordelingen i malmzone-amfiboliten. Dette kort er baseret på de af Carstens (5/11, 1940) indsamlede og analyserede chip samples. Da der som tidligere nævnt ikke har været noget kort til rådighed, er lokaliseringen af de enkelte chip samples sket på grundlag af en ofte mangelfuld lokaliseringsbeskrivelse. Ved fremstilling af kortet er det antaget, at de indsamlede chip samples har været repræsentative for det prøvetagne område.

Ovennævnte antagelser er så vidtdrevne, at kort 4 kun i grove træk afspejler Cu-fordelingen. Til trods for svaghederne peger kort 4 dog på følgende vigtige faktor, at mineraliseringen ser ud til at være omgivet af en Cu-aureole. Antallet og størrelsen af aureolerne er bemærkelsesværdig på baggrund af feltbeskrivelsen af malmzone-amfiboliten i de tidligere rapporter, hvor den stort set betegnes som steril uden for Storekaas Dagbrud.

Årsagen til aureolerne kan ikke med fuld sikkerhed besvares, men der ligger i de tidligere rapporter nogle brikker til en forklaring. Den går ud på at mineraliseringerne uden for Storekaas Dagbrud, det vil i dette tilfælde sige, inden for de to anomali-områder nord for dagbruddet (kort 4), består i det væsentlige af hydrotermale årer. Paragenesen i de hydrotermale årer er kalcit-kvarts-chlorit-bornit[†] kobberkis. Associeret med de hydrotermale årer er gerne mineraliserede småsprækker eller semikonkordante slirer med kobberkis og/eller bornit. Stedvis er der rapporteret imprægnation af kobberkis og bornit. Hovedindtrykket af mineraliseringerne i de to anomaliområder er epigenetisk.

Årsagen til de to Cu-aureoler er derfor sandsynligvis forårsaget af disseminerede sulfider og mineraliserede semikonkordante slirer og småsprækker. Disse mineraliseringer vil, hvis de domineres af bornit, være vanskelige

at se og under alle omstændigheder ikke virke spektakulære sammenlignet med en Fe-rigere paragenese bestående af kobberkis og pyrit.

I Storekaas Dagbruddet er mineraliseringsbilledet noget mere kompliseret end i anomalionråderne nord for, idet der både er epigenetiske og syngenetiske mineraliseringer repræsenteret i dagbruddet. I Tabel 3 er de forskellige mineraliseringstyper sammenstillet. Mineraliseringerne er inddelt efter værtsbjergart, sulfidparagenese og mineraliseringstype.

De syngenetiske mineraliseringer, der er særegne for Storekaas Dagbrud i modsætning til den øvrige del af malmzone-amfiboliten, er knyttet til de for dagbruddet specifikke bjergarter som magnetit-diorit og mafit. I begge bjergarter optræder sulfiderne (bornit og chalcocit) dissemineret. Mængden varierer mellem ca. 1 og 5 vol%. Sammen med sulfiderne sidder der en del magnetit, der specielt i den udeformerede bjergart kan vanskeliggøre identifikationen af sulfiderne. Sulfiderne indgår sammen med magnetit som en accessorisk bestanddel af dioriten.

Til de i bredeste forstand syngenetiske mineraliseringer hører også et stockværk af mineraliserede årer i magnetit-dioriten. Årene har en bredde, der normalt ligger på 2 - 5 mm. Paragenesen i disse årer er chlorit-kilacit-bornit-chalcocit-kvarts. Årene ser ikke ud til at være omgivet af en brønne af hydrotermale omdannelser. Stockværket optræder i magnetit-dioriten sammen med de disseminerede sulfider, og man kan således sige at stockværk mineraliseringen overpræges den disseminerede mineralisering i magnetit-dioriten.

Mængden af disseminerede sulfider er noget lavere (0,1 til 1 vol%) i mafiten end i magnetit-dioriten.

TABEL 3. OVERSIGT OVER MINERALISERINGSTYPER I STØBEKÅS DAGBÆJD.

VÆRTSBERGART	SYNGENETISKE MINERALISERINGER		EPIGENETISKE MINERALISERINGER	SULFID PARAGENESE
	SENSU STRICTO	SENSU LATO		
MAGNETIT-DIOPT MAGNETIT-GRÆS	DISSEMINERET	STOCKVÆK AF ÅER	HYDROTHERMALE ÅER	BORNIT + CHALCOCIT
KAFIT	DISSEMINERET	—	—	BOENIT + CHALCOCIT
AMFIBOLIT/KVÆSIT	—	—	HYDROTHERMALE ÅER.	BORNIT + CHALCOCIT
AMFIBOLIT	—	—	SMÅSPRÆKKER	BOENIT + CHALCOCIT
AMFIBOLIT	—	?	SEMikonKORDANTE SLØER + IMPREG- NATION	BORNIT + KOBBERKIS.
BIOTIT-FÆRDE AMFIBOLIT	—	?	SEMikonKORDANTE SLØER + IMPREGNA- TION	BORNIT + KOBBERKIS
AMFIBONIT	—	—	SMÅSPRÆKKER	KOBBERKIS.

Kornstørrelsen er også væsentlig mindre, hvor den i magnetit-dioriten ligger omkring 1-2 mm ligger den på 0,1 til 0,5 mm i mafiten. I mafiten ses stedvis cm tykke slirer bestående af chalcocit-bornit-kalcit-biotit. Mængden af disse slirer er dog beskeden (under 5 vol%) men de hjælper med til at blive opmærksom på de disseminerede sulfider i mafiten.

De epigenetiske mineraliseringer varierer, som det fremgår af Tabel 3, fra hydrotermale årer over mineraliserede småsprækker til semikonkordante slirer og imprægnationer. Denne variation reflekterer også en forskel i dimension. De hydrotermale årer har en bredde på 1 til 10-15 cm, og de kan normalt følges over en strækning på flere meters længde. Disse mineraliseringer er altid knyttet til forkastninger eller shear planer.

De mineraliserede småsprækker og semikonkordante slirer er normalt ikke bredere end 0,5 cm og længden overstiger sjældent 5 cm. Medens paragenesen i de hydrotermale årer er kalcit-chlorit-bornit-chalcocit-epidot-kvarts så består paragenesen i småsprækkerne og de semikonkordante slirer næsten udelukkende af sulfider, der til gengæld varierer fra bornit-chalcocit over bornit-kobberkis til ren kobberkis.

Omdannelsen af sidestenen ser kun ud til at være knyttet til de hydrotermale årer. Omdannelsen består i en rosa farvning af plagioklas og skyldes formodentlig hæmatit skal. Rodfarvningen ses også som en belægning på joints og små-forkastninger. Rodfarvningen ser ikke ud til at påvirke hornblendens. Omdannelsen optræder ikke som en veldefineret omdannelsesbrømme til forkastninger/hydrotermale årer men er mere domænevis, dog altid i nær relation til en forkastning/gang mineralisering.

Af Tabel 3 fremgår, at de epigenetiske mineraliseringer helt

overvejende har malmzone-amfiboliten som sidesten, kun i meget beskedent omfang optræder de i kvartsiten.

I Tabel 4 er kemiske analyser af håndstykker (1-2 kg) fra Storekaas Grube sammenstillet. Håndstykkerne er karakteriseret ved værtsbjergart, mineraliserings-type og mineraliseringsparagenese. I fig. 4 er analyserne fra Tabel 4 plottet i et log-log diagram.

Af fig. 4 fremgår, at der er en rimelig lineær korrelation mellem $\log \text{Cu}\%$ og $\log \text{Ag ppm}$ for de mineraliseringer, der har en sulfid-paragenese bestående af chalcocit og bornit. For sulfid-paragenesen bornit-kobberkis er der også en antydning af en lineær korrelation, derimod ser der ikke ud til at være nogen korrelation mellem Cu og Ag i kobberkis paragenesen.

Fig. 4 viser også, at kobberkis-bornit paragenesen gennemsnitlig er fattigere på Ag end chalcocit-bornit paragenesen. Talmæssigt ligger Ag-indholdet i chalcocit-bornit og kobberkis parageneserne på henholdsvis ca. 54 ppm og ca. 31 ppm per 1% Cu.

TABEL 4.

LOKALITET	NR.	BJERGART	MINERALISERINGSTYPE	PARAGENESE	Cu%	Ag ppm
STREKKAAS DAGBR.	H10	MAGNETIT-DIORIT	DISSEMINERET	BORNIT-CHALCOCIT	0,52	7,2
"	H11	"	"	"	2,23	151,6
"	H12	"	"	"	1,89	108,6
"	H8	MAGNETIT-GRIS	DISSEMINEREDE SLIRER	BORNIT-CHALCOCIT	3,50	142,9
24 HALL VED 245m	H18	"	"	BORNIT-CHALCOCIT-CHLORIT	1,17	71,2
24 HALL VED 300m	H13	MAGNETIT-DIORIT	STOCKVÆR AF ÅRER	CHLORIT-KALCIT-Cu-SULFIDE:Q	2,19	120,5
"	H14	"	"	"	2,45	117,8
"	H15	"	"	"	1,99	109,2
TOREKKAAS DAGBR.	H4	FELIT	DISSEMINERET	BORNIT-CHALCOCIT	1,15	45,9
"	H5	"	"	"	0,21	17,2
"	H6	"	"	"	0,34	26,0
"	H7	PELITISK KVARTSIT	HYDROTIZENAL ÅRER	KALCIT-CHLORIT-Cu-SULFIDE:Q	1,93	219,4
"	H9	PORPHYROBLASTISK ANFIBOLIT	"	"	0,49	41,6
24 HALL VED 245m	H21	KVARTSIT	"	"	1,24	37,1
"	H22	PORPHYROBLASTISK ANFIBOLIT	"	"	2,48	101,6
"	H19	"	MINERALISEREDE SNØSPRÆKKER	"	0,9	38,6
"	H27	"	"	"	1,82	148,6
TOREKKAAS DAGBR.	H1	BIOTIT-FRENDRE ANFIBOLIT	DISSE. + GEHINKORDANTE SLIRER	BORNIT + KOBBLEKIS	9,398	5,3
"	H2	"	"	"	0,47	31,8
"	H3	"	"	"	2,97	118,8
24 HALL VED 245m	H17	PORPHYROBLASTISK ANFIBOLIT	"	"	2,43	50,4
"	H20	"	"	"	1,23	19,6
"	H25	"	"	"	0,945	60,4
"	H23	BIOTIT-FRENDRE ANFIBOLIT	"	"	1,77	60,8
24 HALL VED 300m	H16	PORPHYROBLASTISK ANFIBOLIT	DISSE. + GEHINKORDANTE SLIRER	KOBBLEKIS	5,79	4,2
24 HALL VED 245m	H24	"	"	"	0,22	4,5
"	H26	"	"	"	3,14	12,9

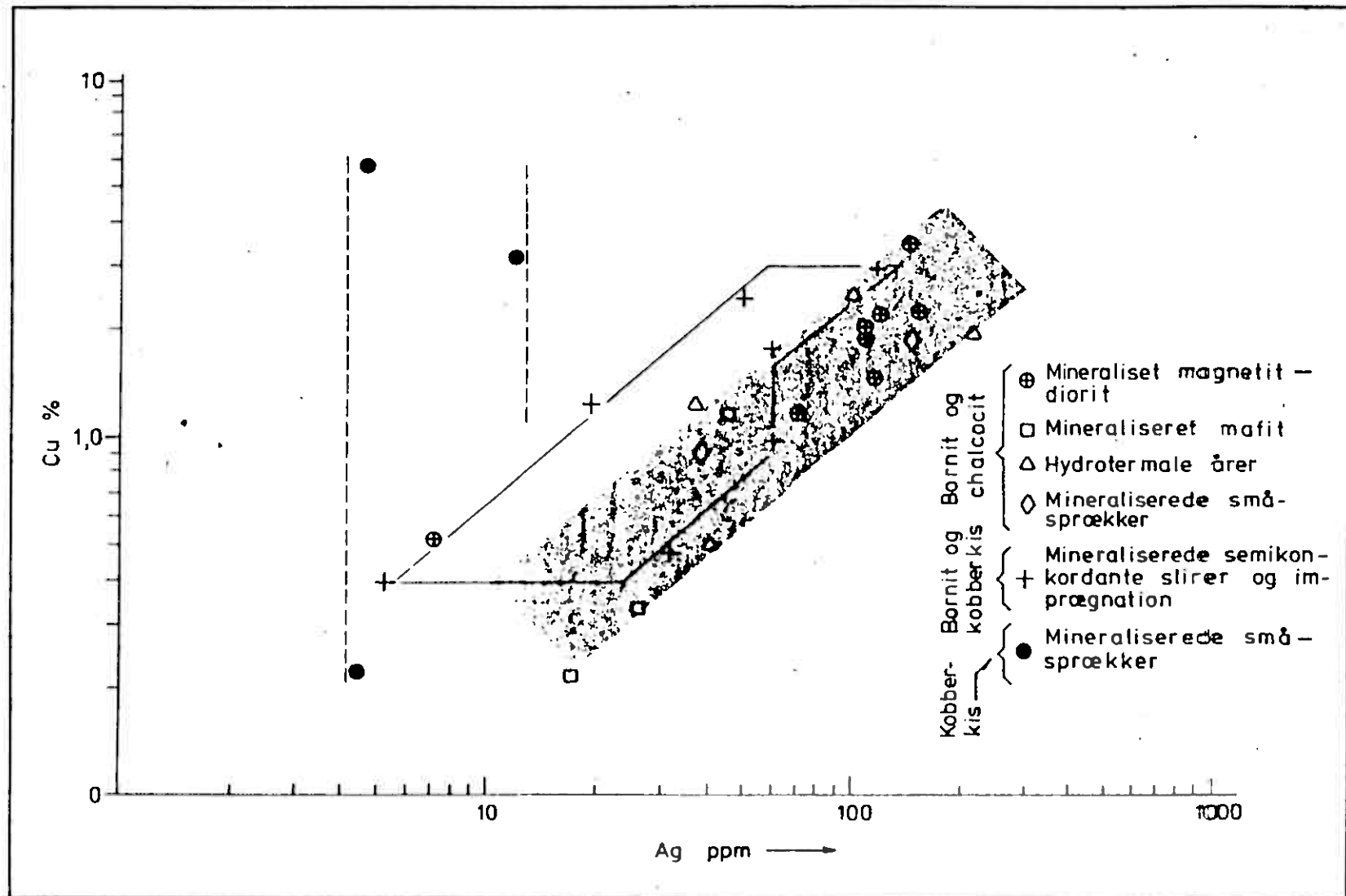


FIG. 4.

MODEL FOR MINERALISERINGERNE.

På basis af feltundersøgelserne synes følgende model at være sandsynlig. Sulfidernes placering i magnetit-dioriten giver indtryk af at de er en intergreret del af bjergarten og dermed syngenetisk med denne. Magnetit-dioriten og dens mulige exhalative associerede er de primære mineraliseringer.

Den isoklinale foldning med tilhørende metamorfose har dels modificeret den primære mineralisering til eksempelvis sulfid-slirerne i magnetit-genisen og muligvis også stockværk mineraliseringen og dels har den mobiliseret mineraliseringen i form af de epigenetiske mineraliseringer. Af disse ser bornit-chalcocit paragenesen ud til at have bevaret største delen af mineraliseringens primære præg, medens kobberkis paragenesen viser den største afvigelse fra det oprindelige. Bornit-kobberkis ligger mellem de to yderpunkter.

Afvigelsen fra den primære mineralisering afspejler også i nogen grad afstanden fra magnetit-dioriten. Det skal forstås på den måde, at hyppigheden af epigenetiske mineraliseringer med kobberkis og bornit-kobberkis parageneser vokser med afstanden fra magnetit-dioriten. Dette er for nærværende ikke tilstrækkelig underbygget til at der kan sættes tal på, men mobilisering på over 100 m synes ikke at være almindelig.

På basis af ovenstående model, er bedømmelsen af Hovin Kobberverks potentiale helt afhængig af størrelsen af magnetit-dioriten. En vis idé om størrelsen giver fig. 5, der viser hovedtrækkene i Cu-fordelingen i Storekaas Grube baseret på analyser fra borer og chip samples. Med det nuværende kendskab til mineraliseringen og geologien omkring Storekaas kan fig. 5 tolkes som følger: 1) Cu konturen svarer nogenlunde til udbredelsen af magnetit-dioriten. De øvrige konturer afspejler intensiteten af de epigenetiske mineraliseringer.

LÆNGDEPROFIL GENNEM HOVIN KOBBERVERK VISENDE
HOVEDTRÆKKENE I CU-FORDELINGEN

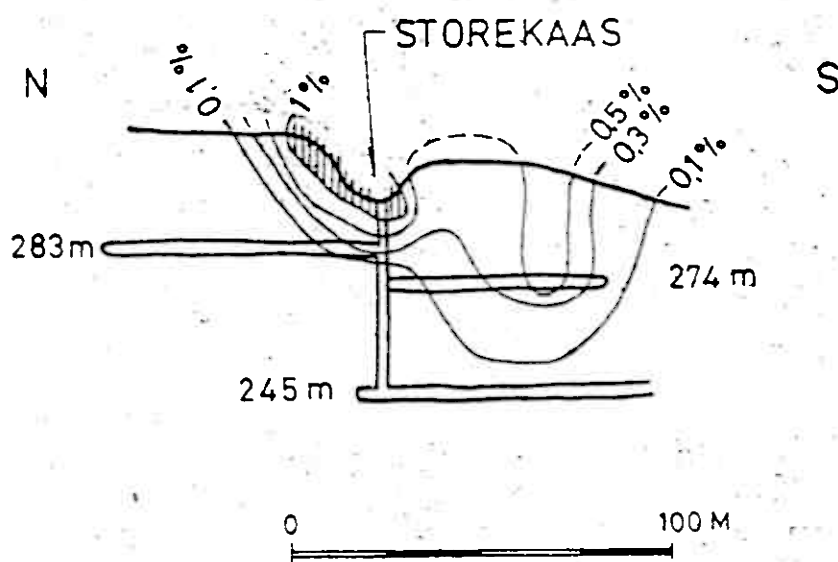


FIG. 5

Med andre ord magnetit-dioriten snitter nord-syd-planet i en ellipse hvor stor og lille-akse er henholdsvis 40 m og 15 m. De foretagne boringer og stoll-arbejder giver desværre ingen muligheder for at vurdere den videre størrelse og orientering af magnetit-dioriten. Mest sandsynlig forekommer et rørformigt legeme i malmzone-amfibolitens hængside, men størrelsen på dette legeme er meget usikker.

De to anomaliområder nord for Storekaas Dagbrud (kort 4) kan efter ovenstående model tolkes som en metamorf genereret mobiliserings aureole omkring en dybere liggende magnetit-diorit. Holder modellen giver det en ikke uvæsentlig forøgelse af potentialet.

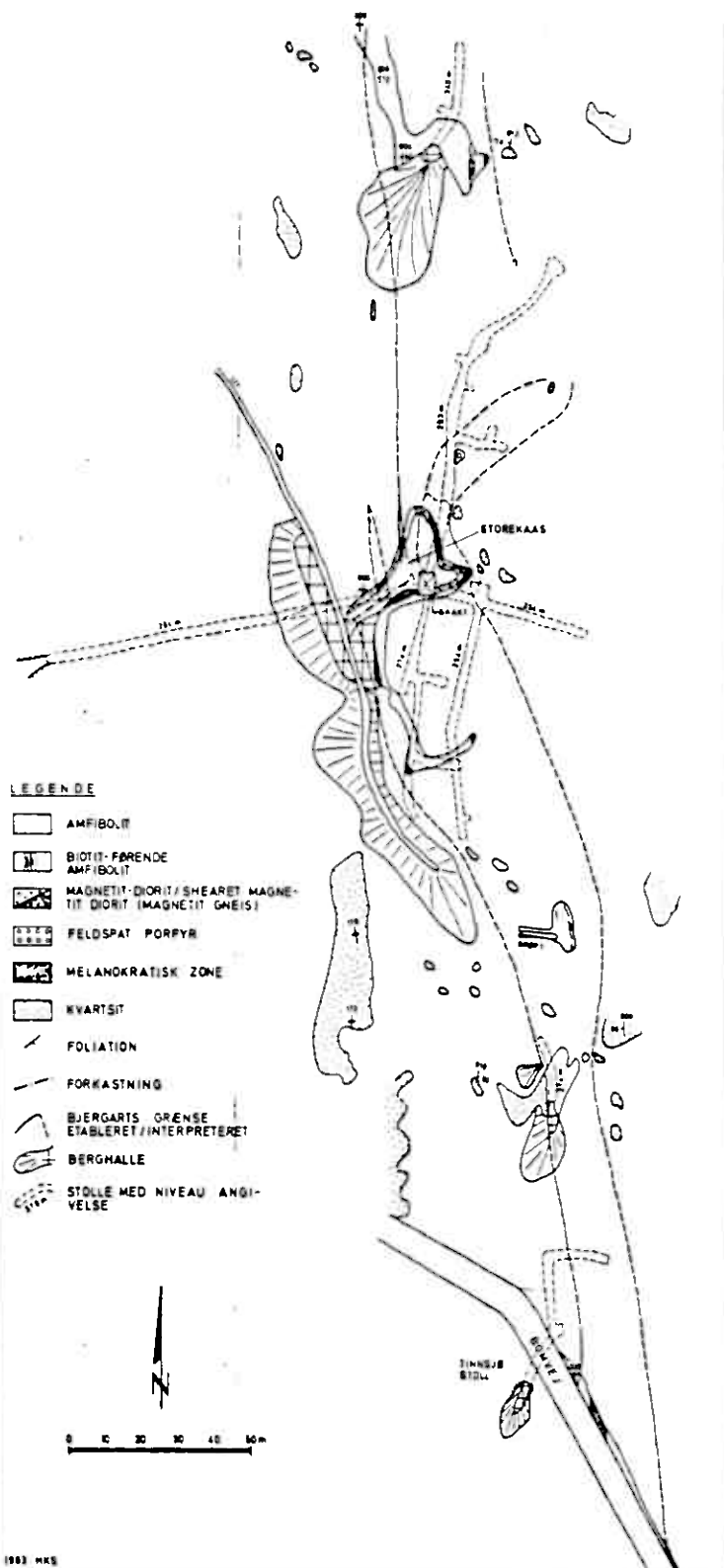
EFTERSKRIFT.

Den opstillede model bygger udelukkende på feltarbejde, modellen vil blive komplimenteret med laboratorieundersøgelser i første række i form af mikroskopering. Det vil derfor være hensigtsmæssigt, at vente med konklusioner og anbefalinger til disse undersøgelser er foretaget.

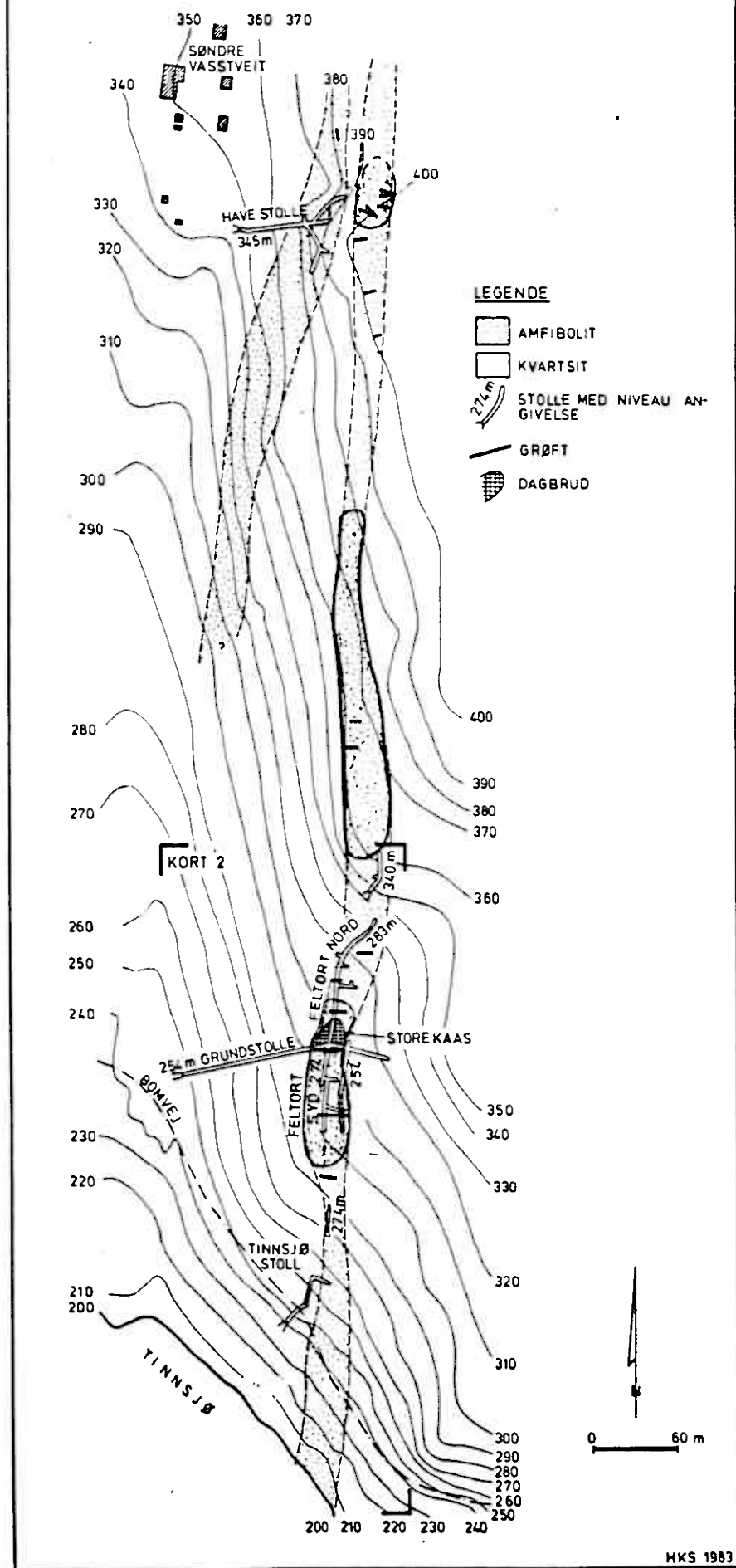
1



GEOLOGISK-KORT OVER DEN SYDLIGE
DEL AF HOVIN KOBBERVERK



HOVIN KOBBERVERK TELEMARK



Sauda sinkgruver er de eneste sinkforekomster av betydning innen kartbladet. Subparallelle, sinkførende soner opptrer i suprakrustalbergarter (hovedsakelig metavulkanitter), som antagelig tilhører Telemarksuiten (Sigmond 1978). Når forekomstene opptrer det en gjennomsettende granitt. Granittiske ganger opptrer i suprakrustalene.

De sinkførende sonene (i de fleste rapporter kalt ganger) kan ofte følges flere hundre meter i strøkretningen. De er i store trekk parallelle både med skifriheten i bergartene og en markert sprekkeretning (Sigmond 1978). I følge Hornemann (1918) løper enkelte av sonene sammen i dypet. Hornemann påpeker dessuten at det er en sonering med henblikk på metallføring.

Sonene er kvarts- og klorittrike, og inneholder mange steder granat og grovkornet amfibol. De er enkelte steder tydelig breksiert, og i tilknytning til breksjene finnes vanligvis kalkspat og stilbitt.

Sinkblende er det vanligste ertsmineral, men det finnes også kobberkis, magnetkis, blyglans, arsenkis, svovelkis, lollingitt, cubanitt, mackinawitt, molybden-glans og magnetitt. Et tinn-mineral (trolig tinnkis) er funnet i små mengder i en av forekomstene.

Det er ikke utført grundige undersøkelser av sinkforekomstene, og forekomstene har vært utsatt for metamorfose. Dette gjør det vanskelig å tolke forekomstenes opprinnelige dannelsesmåte. Det har pågått hydrotermal aktivitet, men dette kan ha sammenheng med den metamorfe påvirkningen. Om metallanrikningen har sammenheng med den vulkanske aktivitet og sedimentære avsetning som fant sted da suprakrustalbergartene ble dannet eller utelukkende skyldes senere hydrotermal aktivitet er derfor usikkert.

Beliggenhet: Sauda kommune i Rogaland. Kartblad Sauda (1314 III). Feltet omfatter flere forekomster, blant annet Heiabakken, Storlidal, Birkeland, Holmen, Breidkvam og Legdene. For koordinater, se den enkelte forekomst og fig. 11.

Mineraler: Sinkblende er det viktigste ertsmineral.

Geologi: Sinkmineralene finnes i flere drag som synes å følge lagningen til de omkringliggende suprakrustalbergarter. Suprakrustalbergartene tilhører Telemarksuiten. Det opptrer en prekambrisk granitt nær forekomsten. Granitten gjennomsetter suprakrustalbergartene og er om lag 900 millioner år gammel.

Litteratur: Reusch (1886, 1913), Helland (1886, 1901), Holmsen (1886), Vogt (1886a), Strom (1888), Hornemann (1918), Wangen (1976), Berg (1977), Aktieselskapet Saudefaldene. Sauda (pers. medd. 1977), F. Nixon (pers. medd. 1977), van der Wel (dagbok 1977, 1978), Sigmond (1978), Nordrum (dagbok 1978), NGU bergarkiv rapp. 52 (usignert).

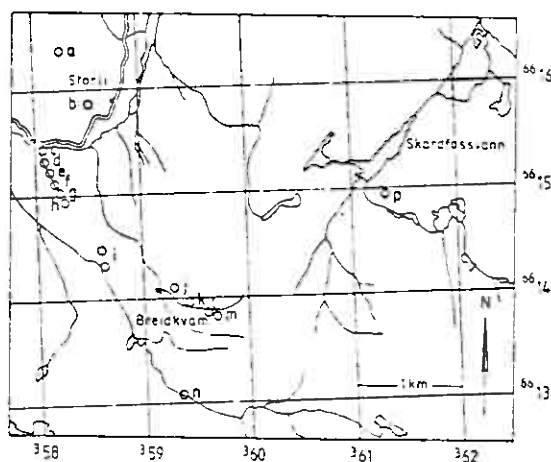


Fig. 11. Sauda sinkfelt, kartskissen viser beliggenheten av gruveåpninger og registreringer. a - Heiabakken (218a), b - Storlidal (218b), c-h - Birkeland (216a), i - Holmen (216b), j-m - Breidkvam (216c), n - Legdene (216d), p - Skardfosshei (bly) (217).

The Sauda zinc mines; map with details of the position of the mines and showings. a - Heiabakken, b - Storlidal, c-h - Birkeland, i - Holmen, j-m - Breidkvam, n - Legdene, p - Skardfosshei (Pb).

II 218 a Heiabakken

Koordinater: 582/163 (k), fig. 11, punkt a).

Mineraler: Sinkblende, svovelkis, magnetkis, kobberkis, blyglans, kvarts, alkali-feltspat, plagioklas, tremolitt, sericitt, flogopitt, epidot og kloritt.

Geologi: I en av dagstrossene opptrer sinkblende som impregnasjon i den øvre del av en klorittskifer. Kisen opptrer i tilknytning til en kvartsåre. Den samlede mektighet av skifer, erts og kvartsåre er omkring 0.7 meter. Ertssonen er opp-til 0.2 meter bred. I hengen opptrer granitt og i liggen en kvartsitt. Løsblokk-materiale fra synkene viser at det har foregått breksjering. Mellommassen i breksjen utgjøres av kalkspat.

Bemerkning: Det er drevet ut to synker og to dagstrosser.

II 218 b Storlidal

Koordinater: 585/159, (fig. 11, punkt b).

Mineraler: Svovelkis og sinkblende.

Geologi: Mineraliseringen opptrer i en 10-20 meter bred og 100-200 meter lang rustsone.

II 216 a Birkeland

Koordinater: Birkelandsfeltert omfatter en rekke gruveinnslag. Feltets ytterpunkter gis ved grunnstollens åpning nær dalbunnen 585/154 (k) og Dahlls gruve 583/151 (fig. 11 (punkt c-h) og fig. 12).

Mineraler: Sinkblende, kobberkis, magnetkis, cubanitt, svovelkis, blyglans, molybdenglans, arsenkis, lollingitt, magnetitt, kloritt, aktinolit, kvarts, stilbitt og kalkspat.

Geologi: I hovedtrekk kan feltet deles opp i tre parallelle ertsdrag som følger

en nordvestlig retning og har et steilt fall mot nordøst. Fra øst mot vest opptrer Gilbertgangen, Hovedgangen og Vestgangen. Hovedgangen og Vestgangen løper sammen. Gangene har utkilinger og forgreninger. Mektigheten er opptil 3 meter. Gilbertgangen er bygget opp av et sett med parallelle drag.

Ertsdragene har både overgangsmessige og skarpe grenser mot sidesteinen (felsiske suprakrustalbergarter). Sinkblendeinnholdet er høyest i den midtre del av gangene, mens mengden av kobberkis, svovelkis og magnetkis er størst mot sidene. Kloritt, kvarts og aktinolit opptrer som gangmineraler. Langs erts-sonenes flanker opptrer stedvis kvartsbånd som fører kobberkis og sinkblende. Ertssonene er ofte omgitt av en granatrik hornblende-kvarts-biotitt-kloritt-sone, som også opptrer i deres forlengelse. Sonen fører endel kobberkis, sinkblende og svovelkis som impregnasjon.

En større porfyrgranitt opptrer like øst for forekomsten. Enkelte av granittpegmatittgangene i området fører små mengder av sinkblende, kobberkis og molybdenglans. Noen av pegmatittene er sonerte og har en kvartskjerne. Granittaplittårer gjennomsetter ertssonene.

Historikk: Hovedforekomsten (Birkeland) ble funnet av husmannen Gregorius Birkeland i 1881 og drift ble igangsatt samme år. Den første tiden ble gruen drevet av «Saude Grubecompani», men i 1887 ble forekomsten kjøpt av et engelsk firma som kalte seg «The Norwegian Zinc Co. Ltd.». Fra 1888–1892 var mellom 50 og 100 mann sysselsatt. Det ble bygget et vaskeri (1888) og et kontorbygg ved Gjuvastøl. I 1892 overtok en av selskapets aksjonærer (C. D. Gilbert) gruvene. Gruvene ble nedlagt i slutten av 1899.

I 1905 ble det gitt konsesjon til Athely Magnus Co., London, men gruen kom antagelig ikke i drift. I 1911 ble gruvene lenset og undersøkt. Elektrokjemisk A/S kjøpte gruvene i 1918 og foretok prøvedrift fram til 1919.

Gruven ble bygget ut med flere stoller og synker (se fig. 12). I tiden 1881 til 1895 ble det utdrevet 24 000 m³ berg, hvorfra det ble utvunnet 12 000 tonn sinkmalm med et gjennomsnittlig innhold på 32.5% Zn, vel 1% Cu, 12% Fe, 23% S og spor av bly og kadmium.

II 216 b Holmen

Koordinater: 586/145 (k) og 586/143 (k) (fig. 11, punkt i).

Mineraler: Sinkblende, svovelkis, kobberkis, cubanitt, magnetkis, blyglans og molybdenglans.

Geologi: Ertsmineralene opptrer i kloritt-kvartsbånd og i felsiske suprakrustalbergarter av usikker opprinnelse.

Bemerkning: Det har ikke funnet sted noen omfattende drift i dette feltet, kun to synker er drevet, Hopkins og Holmen.

II 216 c Breidkvam

Koordinater: Ved Breidkvam er det minst fem synker. Feltet ytterpunkter kan antageligvis angis ved 593/141 – 597/138 (k) (fig. 11, punkt j-m).

Mineraler: Sinkblende, blyglans, kobberkis, svovelkis, arsenkis, cubanitt og mackinawitt.

Geologi: Som ved Holmen.

Bemerkninger: Ved 593/140 er det tre synker. Omtrent 400 tonn sinkmalm er drevet ut. Et tinnholdig mineral (trolig tinnkis) er påvist.

II 216 d Legdene

Koordinater: 594/131 (fig. 11, punkt n).

Mineraler: Sinkblende, blyglans, kobberkis, svovelkis, molybdenglans og fluspat.

Geologi: Som ved Holmen.

Bemerkning: Det er drevet en liten dagstrosse og en synk.

Basic sills occurring in the Rjukan- and Seljord Groups are frequently mineralized with magnetite, ilmenite, chalcopyrite, pyrite, pyrrhotite and possibly minor Ni-Co arsenides as suggested by the not infrequent occurrence of erythrine on weathered surfaces of these rocks. The sulphides in general form interstitial anhedral grains and rare globules and are believed to represent orthomagmatic immiscibility products. A sample of a sulphide-bearing sill from the Tinnsjø region returned the following analysis:

Sample no.	Au ppb	Cu ppm	Pb ppm	Zn ppm	Ni ppm	Co ppm	Ag ppm	As ppm	Bi ppm	W ppm
062406	-5	85	87	188	242	61	0,7	68	7	1

The Bransnuten Mn deposit occurs in the vicinity of Mt. Bransnuten, some 10 km to the west from lake Byrtevatn (Plate 2). This deposit probably represents a volcanogenic fumarole- or exhalite type manganese mineralization or a diagenetic cementation product (Westerveld, 1960). It was briefly investigated and sampled by the present author because it shows some similarity with the so-called Waterloo-type bulk tonnage silver deposits of the western U.S.A. The Waterloo deposit is the size of a small porphyry copper and run grades of approximately 100 ppm silver finely disseminated and "encapsuled" in silica throughout the basal portion of a lakebed sequence. An important feature of this deposit is the presence of sometimes abundant manganese oxide staining (Wayson, 1977). Earlier accounts of the Bransnuten Mn-deposit (Westerweld, 1960; Nordrum et.al., 1981) mentions no analysis for silver or gold, and the deposit was therefore sampled. The

following account of the geology of the Bransnuten mineralization is from Nordrum et.al. (1981) and includes a description of the Hovden Mn-deposit which may represent a feeder (stockwork) system to a stratabound manganese mineralization of the Bransnuten type; the Hovden deposit is situated near lake Hartevatnet, some 20 km WNW from Mt. Bransnuten (Plate 2), and it was not sampled this summer.

1 466 BRANDSNUTEN

Beliggenhet: Tokke kommune i Telemark. Kartblad Sæsvatn (1414 II), 244/968 (k) og 245/969 (k).

Mineraler: Braunnitt, rhodonitt, jakobsitt, hausmannitt, manganepidot, mangano-fyllitt, johannsenitt, rhodokrositt, pyrofanitt, hematitt, flusspat, svovelkis, tefroit, l ngbanitt og gedigent kobber.

Geologi: Manganen er vesentlig bundet i silikater og oksyder. Manganmineralene opptrer i b nd og linser i flere niv er i metasandsteinen parallelt med lagningen (fig. 6 og 7). Linsene er usammenhengende og som regel sm  (noen f  centimeter brede og en eller flere meter lange, den største linsen var omkring 1,5 meter bred og 15-20 meter lang). Manganmineraliseringen kan f lges omkring 2 kilometer i str kretningen. Linsene er som regel sonert oppbygget med en sentralsone best ende av manganoksyder og mangansilikater omgitt av en manganoksydfri randsone, hvor kvarts og feltspat i tiltakende grad opptrer sammen med mangansilikatmineraler. Randsonen har varierende bredde.

Historikk: Forekomsten ble funnet f r 1845 og mutet i 1849 av Knut P. Blom (L rdal), landhandler Wohl og lensmann Chr. Blom (begge Kviteseid). Den ble fors ksdrevet av tyskere rundt 1903 og unders kt av et nederlandsk firma i 1952 og 1953.

Litteratur: Scheerer (1845b), Mutingsbrev (22.09.1849), Poulsen (1940, 1956), Westerveld (1961), van der Wel (1974a, b, c og 1979b).

Brandsnuten manganforekomst er den største av de tre manganforekomstene innen kartbladet. B de Brandsnuten- og Hovden manganforekomst opptrer i suprakrustalbergarter tilh rende Telemarksuiten (van der Wel under forbedelse), mens forekomsten i Lysenuter opptrer i dekkebergarter.

Forholdene ved Brandsnuten tyder p  at mangan opprinnelig ble utfelt som (oksy)hydroksyder. Utfellingen foregikk samtidig eller umiddelbart etter avsetningen av kvarts-feltspatsand. Manganinnholdet i metasandsteinen omkring hovedforekomsten ved Brandsnuten  ker noe langs et tverrprofil fra  st mot vest over forekomsten. Innenfor noen desimeters avstand fra selve hovedlinsen  ker manganinnholdet i metasandsteinen meget raskt. Det er mulig at utfelningene m  sees i sammenheng med atmosf rens utvikling. P  et tidspunkt da kvarts-feltspatsanden ble avsatt (minimum 1100 millioner  r siden) var oksygeninnholdet i atmosf ren antagelig bare 30% av n tidens innhold (Jacobsen 1975). Den gradvise oppbyggingen av dette trykket kan ha f rt til  verskridelsen av en terskel for kjemisk utfelling av mangan, slik at Mn^{2+} ble oksydert til Mn^{4+} (eventuelt ogs  Mn^{3+}). Alger og bakterier kan dessuten ha medvirket til at oksidasjonen av Mn^{2+} fant sted (Cloud 1965), men dette forhold er ikke helt klarlagt (Berger 1968). En annen mulighet er at manganet ble tilført av vulkanske l sninger eller lutet ut av basaltiske lavaer (som enn  finnes som amfibolitter og som tolkes som omvandlede basalter). Kvartsb ndene som opp-

trer parallelt med manganlinsene (fig. 7), kan tolkes som «chert» dannet som utfelling fra kiseltsyre-rike vulkanske løsninger. Under den videre geologiske utviklingen, har forekomsten vært metamorfosert, delvis oppknullt og påvirket av hydrotermale løsninger. Forekomstens mineralsammensetning tyder på at det ikke ble oppnådd kjemisk likevekt under disse prosessene. Eksempler på dette er at det finnes både långbanitt og braunitt og at manganoksydofasene er skilt fra kvarts og feltspat ved randsoner bestående av rhodonitt og/eller granat (van der Wel 1974a).



Fig. 6. Granat (manganrik andraditt) i bånd og en linse med rhodonitt, spessartin og braunitt i metasandstein. Linsen har et sort belegg på overflaten. Belegget skyldes oksydasjon av manganriklikatene. Den sorte linsen er omkring 2 cm bred. Brandsnuten manganforekomst.

Bands of manganese-rich andradite and a lens with rhodonite, spessartine and braunite in metasandstone. The lens appears black due to oxidation of the manganese minerals. The black lens is about 2 cm in width. Mt. Brandsnuten manganese deposit.

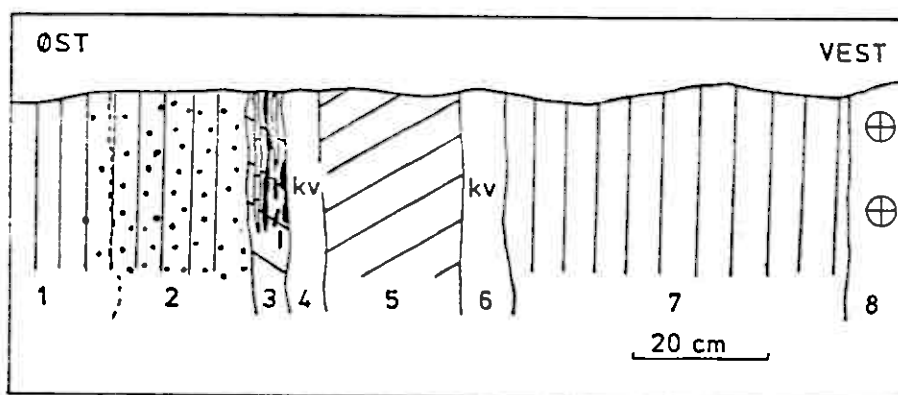


Fig. 7. Bånding i en av sonene ved Brandsnuten manganforekomst. 1 - og 7 - metasandstein, 2 - metasandstein med granat (manganrik andraditt) i årer, 3 - rhodonitt med spessartin og braunitt i linser i metasandstein, 4 - og 6 - kvartsbånd, 5 - rhodonitt med granat (spessartin) og braunitt, uregelmessig sammenvokset, 8 - porfyrisk granittåre (etter van der Wel 1974a).

Banding within the manganese zone at Mt. Brandsnuten manganese deposit. 1 - and 7 - metasandstone, 2 - manganese-rich andradite in veins in metasandstone, 4 - and 6 - quartz lenses, 5 - manganese-rich lens with rhodonite, spessartine and braunite, and 8 - vein with porphyritic granite (after van der Wel 1974a).

II 455 HOVDEN

Beliggenhet: Bykle kommune i Aust-Agder. Kartblad Breive (1414 III), 053/042 (k) og 058/056.

Mineraler: Braunitt, rhodonitt og spessartin.

Geologi: Manganoksyder og -silikater opptrer i tynne årer (2 til 15 centimeter brede) i en kvartsrik metasandstein. Årene krysser hverandre og skjærer båndingen i bergarten. Metasandsteinen er enkelte steder piemontittrik. Analyser viser et varierende manganinnhold opptil 28% og et jerninnhold opptil 3,5%.

Bemerkning: Byklehei har også vært brukt som navn på forekomsten.

Litteratur: NGU-bergarkiv, Poulsen (1940, 1949, 1956), C. Bugge (dagbok 1941), van der Wel (dagbok 1977).

Hordenut manganforekomst er ikke inngående undersøkt. Manganmineralene (blant annet rhodonitt og braunitt) opptrer i kryssende årer. Piemontitt finnes dessuten i små mengder i enkelte lag i et høyere stratigrafisk nivå i den omgivende metasandsteinen. Det kan ikke utelukkes at det finnes bånd tilsvarende de man har ved Brandsnuten manganforekomst, men disse ble ikke påvist. Forekomstens opptreden i suprakrustalbergarter av samme alder som de ved Brandsnuten manganforekomst kan imidlertid tyde på at den kan ha vært dannet på samme tid og ved tilsvarende prosesser. Kryssende årer med manganmineraler kan da tolkes som rester etter tilførselskanaler, og de piemontittførende lag kan tolkes som et resultat av variasjoner i tilførselen av mangan.

Lysenuten manganforekomst opptrer i dekkebergarter. Wad (myrmangan) som opptrer i forekomsten, er dannet ved en anrikning av mangan ved overflatevitring og utfelling ved oksydasjon. Nærmere detaljer om forekomster er ikke kjent.

Assay values of manganese ores from the Brandnuten veins.

Sample	Fe %	Mn %	Cu ¹⁾ %	Al %	P %	S %	SiO ₂ %
I	1.79	47.15	0.29	2.50	+	0.04	14.93
II	4.38	55.61	0.10	0.54	—	0.05	10.48
III	2.86	18.51	+	3.16	+	0.12	50.38
IV	2.64	33.96	0.01	3.49	+	0.12	32.86
V	1.72	4.10	0.04	5.00	—	0.18	68.02
VI	4.59	48.03	0.04	3.80	—	0.18	17.22
VII	2.28	49.48	0.07	2.32	—	0.09	15.23

1) Pb and Zn are absent — absent + trace.

- I. Sample taken from the old excavation, main vein.
 II. Richest ore from a spot 1 m S of a small tributary of Botne brook, test excavation 1953, main vein.
 III. Average of a few tons of poor ore from a spot 40 m N of the small tributary of Botne brook on the NE. slope of Mt. Brandnuten, test excavation 1953, main vein.
 IV. The same from a spot some 5 m higher in the main vein zone.
 V. Poor ore from the continuation of the main vein N of the Botne valley.
 VI. Rich ore from the continuation of the main vein N of the Botne valley.
 VII. Sample taken from the parallel vein at 60 m E of the old excavation.
 Judging from the mineralogical composition of the ore, more detailed analyses would certainly also have detected the presence of small quantities of Ca, K, Na, F, and CO₂.

Older analysis of the Bransnuten deposit (Westerveld, 1960) are shown above, while analysis of samples from this summers work are given below.

Sample no.	Au ppb	Cu ppm	Pb ppm	Zn ppm	Ni ppm	Co ppm	Ag ppm	As ppm	Bi ppm	W ppm
010807 A	-5	1554	157	328	12	97	10	112	25	2
010807 B	-5	159	10	34	10	1	-0.1	189	2	1
010807 C	-5	169	18	126	13	18	-0.1	359	3	-2

Sample 010807 A is a chip sample of massive ore corresponding to sample I above. Sample 010807 B is a chip sample from the same locality and consists of low grade Mn ore ("host rock"). Sample 010807 C is a chip sample of rich ore from the lower excavation, corresponding to sample II above

The analysis show that the silver content of the Bransnuten deposit is negligible. However, silver is present in one sample, and the Hovden deposit should therefore be sampled as it may represent a more proximal position in an exhalative system which could exhibit precious metal zoning.

In summary, stratabound mineralization of the central part of the Bandak Group, i.e. east of the large N-S trending boundary fault, is characterized by various types of Cu-(Fe)-Ag deposits with a clear affiliation to basic, alkaline volcanics. The deposits show a range from minor, orthomagmatic immiscibility products in intrusive feeder rocks (sills) to the basic volcanics, through the Hovin-type volcanogenic or assimilation-type Cu-Ag deposit, to the diagenetic or metamorphic, near surface mineralization of the Dalane mines. Gold is present in very small amounts, and the economic potential of this group of mineralization is tied up with the Cu- and Ag contents.

As shown previously an important facies change towards more calc-alkaline lithologies takes place westward from the N-S boundary fault and this change may be reflected in the mineral occurrences: The Zn-dominated, stratabound Sauda mineralization and the Hovden and Mt. Bransnuten Mn-deposits. However, more information from these occurrences is needed before any conclusions can be drawn about the precious metal potential of this part of Telemark.

3.3

VEIN-TYPE MINERALIZATION

Epigenetic quartz veins with various metals including Fe, Mo, Cu, Zn, Pb, Ag, Au, Bi, Te and minor Ti, Ni, Co, Cd, Sn, In, W, and Se formed the basis for the past mining history of the Telemark district. The veins are in general a few dm wide and some tens of meters long although a few are considerably larger being up to 5 meters wide and several hundred meters long.

Early workers (e.g. Vogt, 1886, 1888) suggested that the quartz veins are fissure fillings genetically related to the late granites while later authors suggested a genesis related to the regional metamorphism of the area (Bugge, 1978). The latest data suggest that the ages of many of the quartz veins postdate the regional deformational and metamorphic peak and that the veins are contemporaneous with the emplacement of late- to postkinematic granites. The present investigation similarly indicates a close genetic relationship between the veins and the granites and it is suggested that only few, in general weakly mineralized quartz veins were generated during the regional metamorphism.

Field investigations and a study of the available literature indicated that a division of the mineralized quartz veins based on their general P-T characteristics could be established (Table 2). By far the majority of the quartz veins are dominated by copper sulphides showing a change in paragenesis from copper-iron sulphides associated with magnetite in the pneumatolytic-hydrothermal stages to iron poor copper sulphides (bornite, chalcocite, digenite) in the pneumatolytic-pegmatitic stages. Lesser groups of quartz veins are dominated by molybdenite, while other groups contain abundant Pb-Zn sulphides; the latter form a distinct group to the north of lake Bandak and no doubt reflect the presence of syngenetic Pb-Zn mineralization of the Skolterberg type in this area.

1. Pegmatitic-pneumatolytic veins.

- a) Li - Sn - Mo - REE (Nissedal).
- b) Mo - Bi - Cu (Klovereid, Nissedal).
- c) Cu - Ag - Mo (Moberg, Mosnap).

2. Pneumatolytic-hydrothermal veins.

- a) Mo - Cu (Dalen, Listulli).
- b) Au - Bi - Fe - Ag - Cu - Pb - Se - W
(Bleka, Gjuv, Gausta, Viken)

3. Hydrothermal veins.

- a) Cu - Ag (-Au) (Morgedal, Heddalsvatnet,
Duses, Brennbekk); Locally
U-bearing: Lauvåsen).
- b) F (Haukås)

Types 1 - 3a in general contains minor Ag, Au, Co, Ni, W and Bi, and tourmaline is abundant in type 2.

Table 2 Epigenetic vein-type mineralization

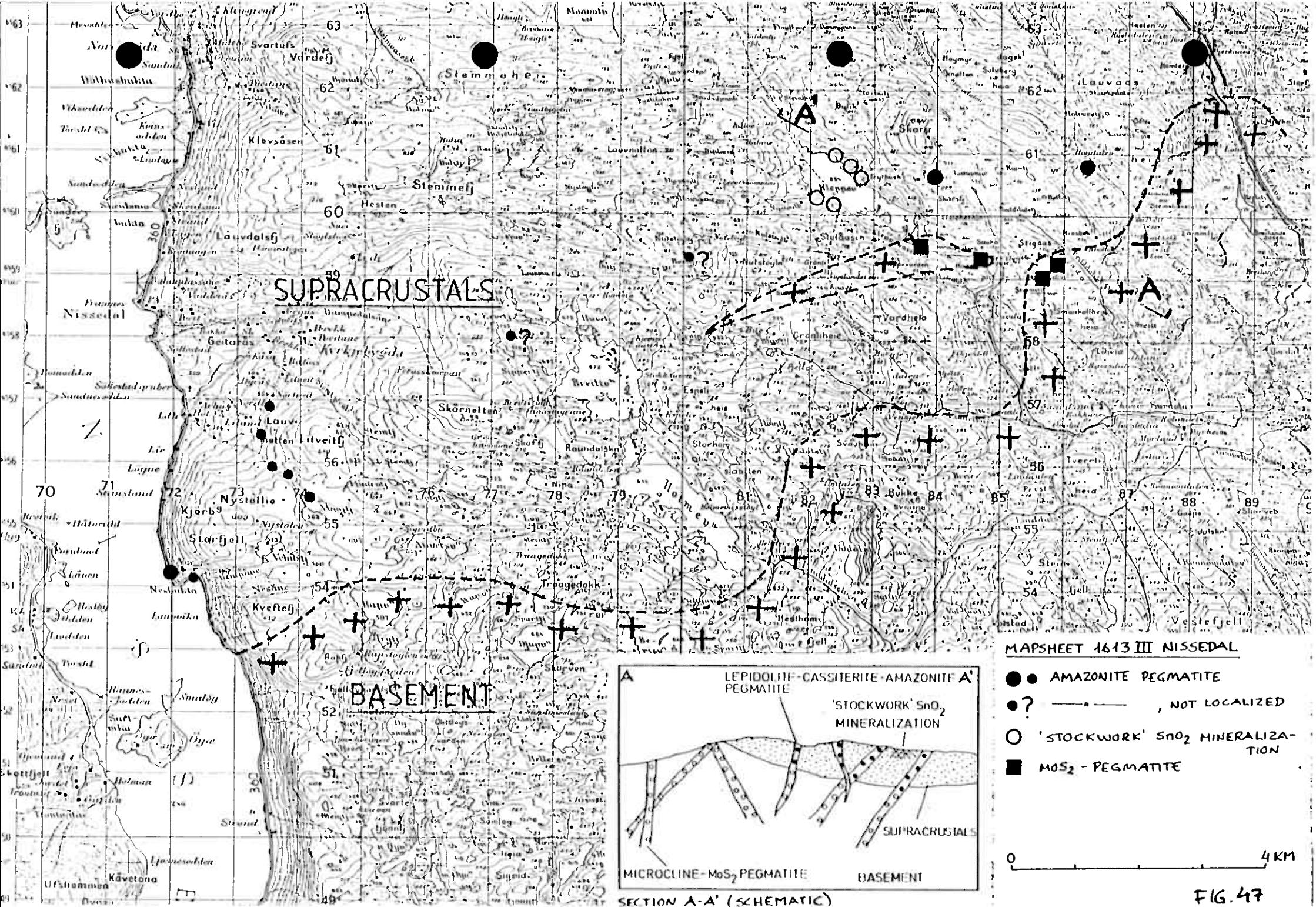
The description of the veins, the associated alteration and the genetic understanding of individual deposits have only improved fractionally since Vogt gave his classic paper on "Den Thelemark - Sæterdal'ske ertsformation" in 1886 and 1888. Later contributions have offered more detail on individual deposits but the description and classification of the veins by Vogt is still very useful, perhaps even more so because Vogt at his time had access to mines and parts of mines which now are inaccessible. In the following a brief description of the various vein types is given, exemplified predominantly by localities visited during this summer.

3.3.1 Pegmatitic-pneumatolytic veins

3.3.1.1 Li - Sn - Mo - REE

Lepidolite- and cassiterite-bearing amazonite-cleavelandite - quartz pegmatites have been known for some time near Kleppsvatnet and Høydalen in the Nissedal area (Fig.47) (Ofstedal, 1942). This area was recently visited by Asheim and Larsen, both employed at PF and enthusiastic mineralogists, who made a new discovery of lepidolite-, cassiterite-, and gadolinite-bearing amazonite pegmatites near Nes and of a hitherto unknown cassiterite mineralization near Kleppsvatnet related to what they described as quartz veins. The latter mineralization was claimed for the Norwegian state by Nordrum, while Norsk Hydro shortly afterwards claimed a total of 64 blocks on Sn and REE in the area between Høydalen and Nes; following a short investigation these claims were lifted in august - september.

A large area surrounding lake Nisservatn is characterized by an abundance of granitic pegmatites. Where these occur in the granitic to granodioritic basement they are of "normal" type, i.e. composed of red microcline, grey plagioclase, quartz, biotite, muscovite and accessory magnetite, fluorite and pyrite; textures vary between pegmatitic, aplitic and graphic. In a number of places south of Kleppsvatnet pegmatites of this type have been mined for coarse grained molybdenite (Fig. 48). The largest of these occurrences is situated near Stigaas (Fig.47) and consists of a 2-5 m wide and approximately 100 m long zone of aplite, pegmatite and graphic granite with irregular, sporadically occurring patches of molybdenite. Similar pegmatites occur in a number of places in the basement to the north of the Nissedal supracrustals and a few have been found in the Telemark supracrustals north of the large basement dome (see later). Where the pegmatites transgress especially the



highly metamorphosed acid volcanics of the Nisservatn supracrustals the feldspars gradually change to amazonite and cleavelandite, the micas to lepidolite (zinnwaldite) and the asseccory minerals include biotite, topaz, muscovite, beryl, fluorite, calcite, fluocerite (tysonite), pyrite, sphalerite, molybdenite, magnetite, garnet, cassiterite, gadolinite, euxenite, zircon, struverite and yttrotantalite (Larsen, pers.comm.) (Fig.49). Whether this change in composition reflects a higher position in the crust at the time of formation of the pegmatites, reaction with the host rock or differences in trace element content is uncertain, but amazonite pegmatites have so far only been discovered in the supracrustal cover rocks. The largest amazonite pegmatites are the ones at Kleppsvatnet and Høydalen which are up to 5 meters wide and several tens of meters long. According to Oftedal (1942) they locally contain up to 4% LiO although the present investigation shows that the overall LiO-content is considerably lower. The content of Sn and REE is negligible, and at present these pegmatites do not represent a profitable exploration target.

The newly discovered quartz-vein cassiterite mineralization occurs along both shores of lake Kleppsvatnet (Fig.50) where it covers an exposed area of ca. 0,5 km². It consists of mm - to dm wide, weakly rusty veins composed of quartz, feldspar, beryl, pyrite, fluorite, molybdenite, magnetite, cassiterite and bismuthinite, i.e. essentially the same minerals which occur in the pegmatites. In general less than one of these veins occur along 10 m of exposure, but locally up to five have been observed and at one locality a slightly larger number of veins define an open stockwork structure. The veins show an overall preferred orientation along 120° - 150°/90° - 60° SW.

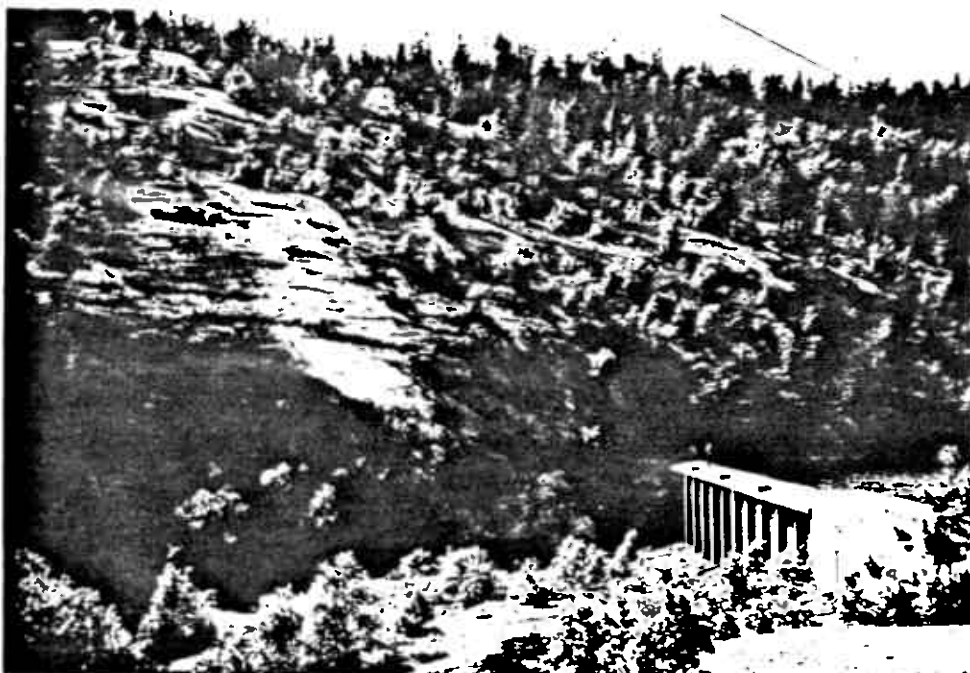


Fig. 48. Pegmatite(white) transecting basic volcanics belonging to the Nisservatn supracrustals. At lake Kleppsvatnet; note scale on dam.



Fig. 49. Close-up of the Kleppsvatnet amazonite pegmatite carrying zinnwaldite(grey).

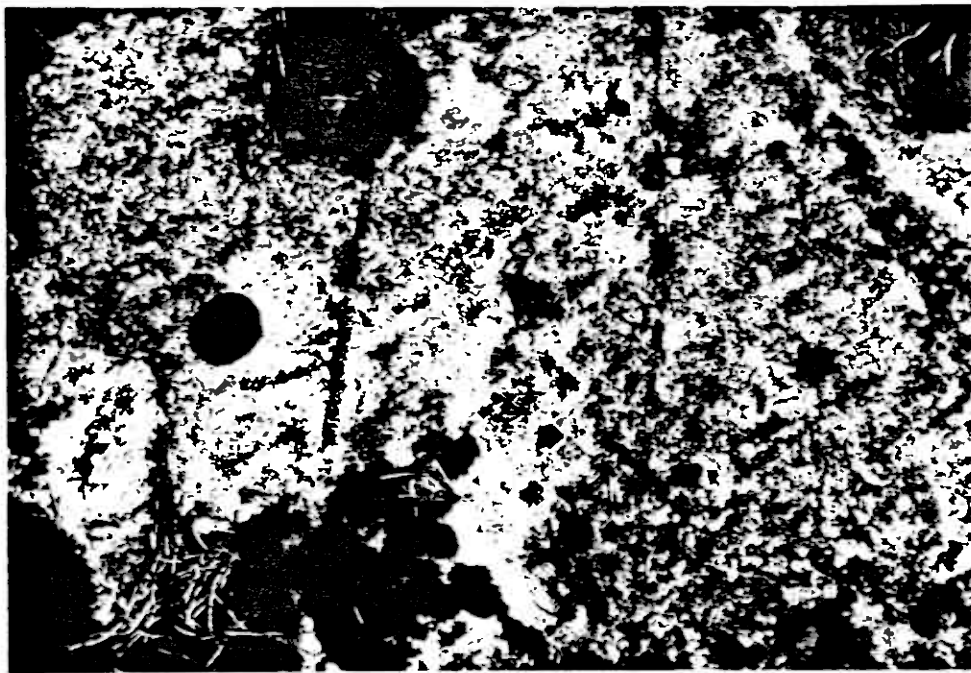


Fig. 50. Cassiterite-bearing pegmatites in acid volcanics near lake Kleppsvatnet.

The individual veins are frequently zoned with feldspar, cassiterite and molybdenite along the borders and quartz in the central parts. The veins both cut and are being cut by amazonite pegmatites and may be considered a special structural type of the latter. The average cassiterite content is negligible and no further action is recommended in this area.

3.3.1.2 Mo - Bi - Cu

The above described thin pegmatites with molybdenite, bismutinite etc. probably belong to the present class of deposits. Another area which was not visited this summer is situated in the Bandak granite, between lakes Bandak and Vråvatn and has been described by Vogt (1886) and Bugge (1963); further information was provided by Asheim (pers. comm., 1983) (Fig. 51). The late - to postkinematic Bandak granite and its immediate surroundings is characterized by numerous deposits of Cu, Cu-Bi, Bi, Mo and Mo-Bi associated with granitic pegmatites, aplites and high temperature quartz veins. The old molybdenite mines were developed on small, irregular, rich pods of ore along granite dykes transected by pegmatites and quartz veins. The ore minerals and associated fluorite occur as disseminations in the granitic dykes and as in part large massive pods in the pegmatites and quartz veins. The Kløvereid Cu-Bi deposits consists of a set of steep, parallel, E-W trending quartz - and pegmatite veins which frequently occur in swarms with a distance of 0.1-1 m between individual veins. Each of the veins may be up to 1 m thick although the average width is considerably smaller. The border zones of the quartz veins and the immediate host rock contain abundant muscovite while the central part of the veins contain chalcopryrite, bismuth, bismuthinite and galenobismuthinite. The granite surrounding the Kløvereid deposits contains disseminated chalcopryrite in an up to 0,5 m wide zone along the veins and is altered to a high temperature greissen. According

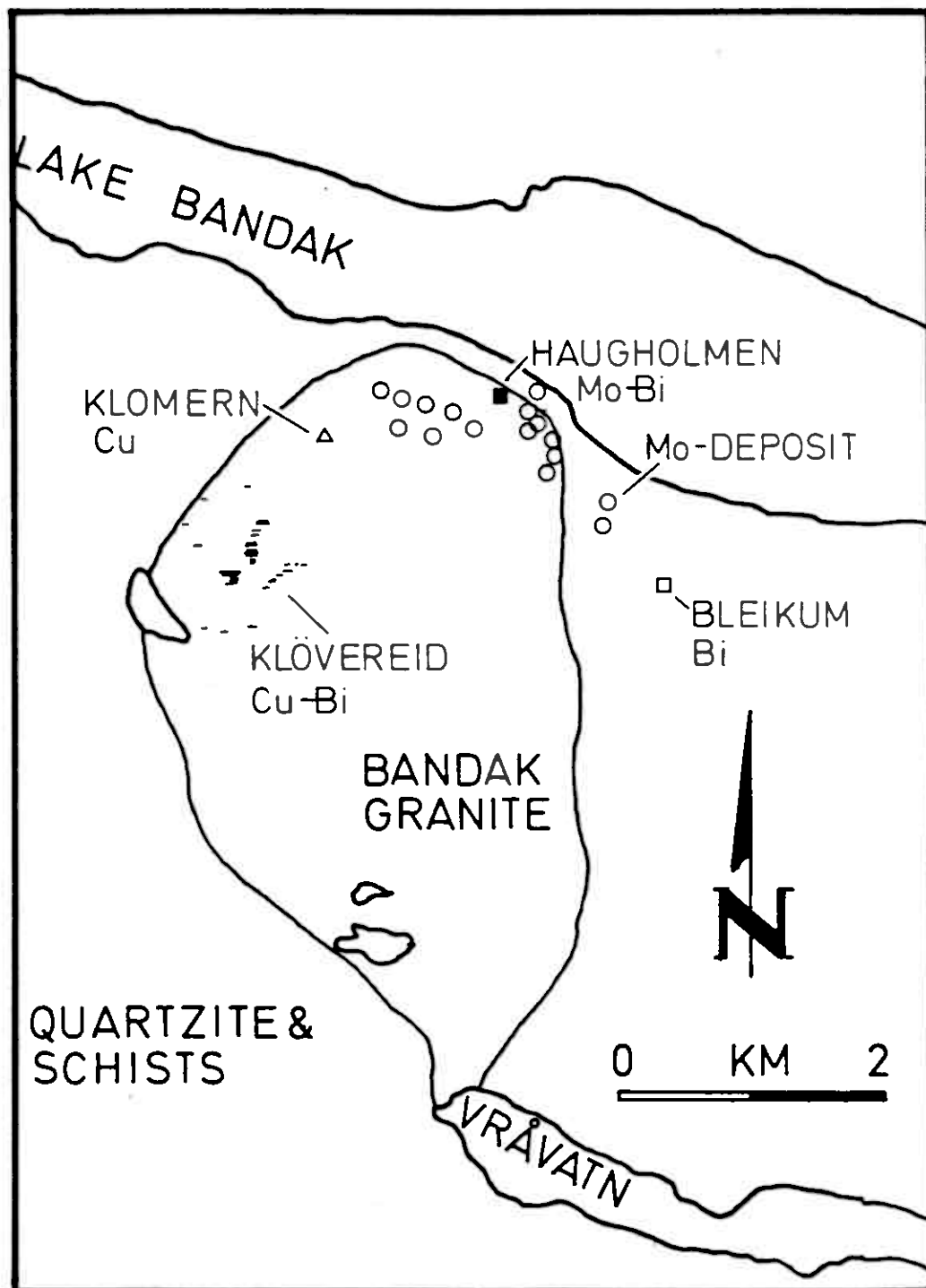


FIG. 51

to Vogt (1888) the ore in the veins carry up to 2 ppm Au. Similar deposits occurring in the Amdal granite to the south from the Bandak granite contain bornite instead of chalcopyrite.

Pegmatite deposits with other metal constellations occur at Klomern (Cu), Haugholmen (Cu-Bi) and Bleikum (Bi) indicating that local conditions controlled the deposition of the various metals which must have been supplied by a common source, the residual melt fractions of the Bandak granite.

3.3.1.3 Cu - Ag - Mo

According to Vogt (1886) this class of deposits is associated with granitic dykes cross cutting the supracrustals and it includes the mineralization at Næsmark, Mosnap, Moberg, Naper, Donstad (at Bandak), Eiang, Haukum, Romunddalen and Strømshejen.

These deposits show many similarities with the previously described pegmatitic-pneumatolytic Mo-Cu-Bi veins but they are dominated by copper sulphides with a relatively high silver content.

The Moberg and Mosnap occurrences stand out due to their size, and they were accordingly visited and sampled. The deposits occur south of lake Bandak in a suite of Bandak Group quartzites, conglomerates and basic schists (Fig. 52). To the east the district is bordered by the Amdal granite and to the west by the large boundary fault of the Telemark supracrustals. Numerous small granite intrusions, dykes and pegmatites cross cut the supracrustals as well as rare, E-W trending dykes of quartz porphyry. The Moberg and Mosnap deposits occur in, or are closely associated with granitic dykes. The Moberg deposit consists of a more than 600 m long and up to 5 m wide quartz vein emplaced along the border zone of a suite of chlorite and hornblende schists (Fig. 52).

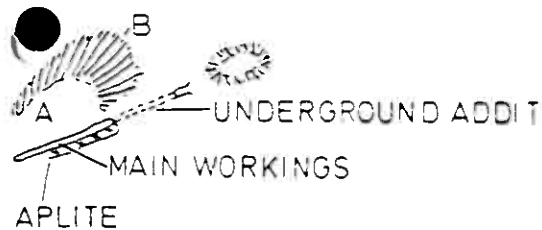
SKETCHMAP OF THE MOBERG Cu-Ag VEIN

	Al ppm	Cu %	Pb ppm	Zn ppm	Ni ppm	Co ppm	Ag ppm	As ppm	Bi ppm	W ppm
A	1513	5.2	26	4	8	3	203	-1	9	-1
B	940	6.2	26	7	3	2	229	1	1083	-1
C	1790	0.4	33	3	4	3	257	-1	613	-1
D	1058	0.4	5	7	7	3	106	6	269	-1

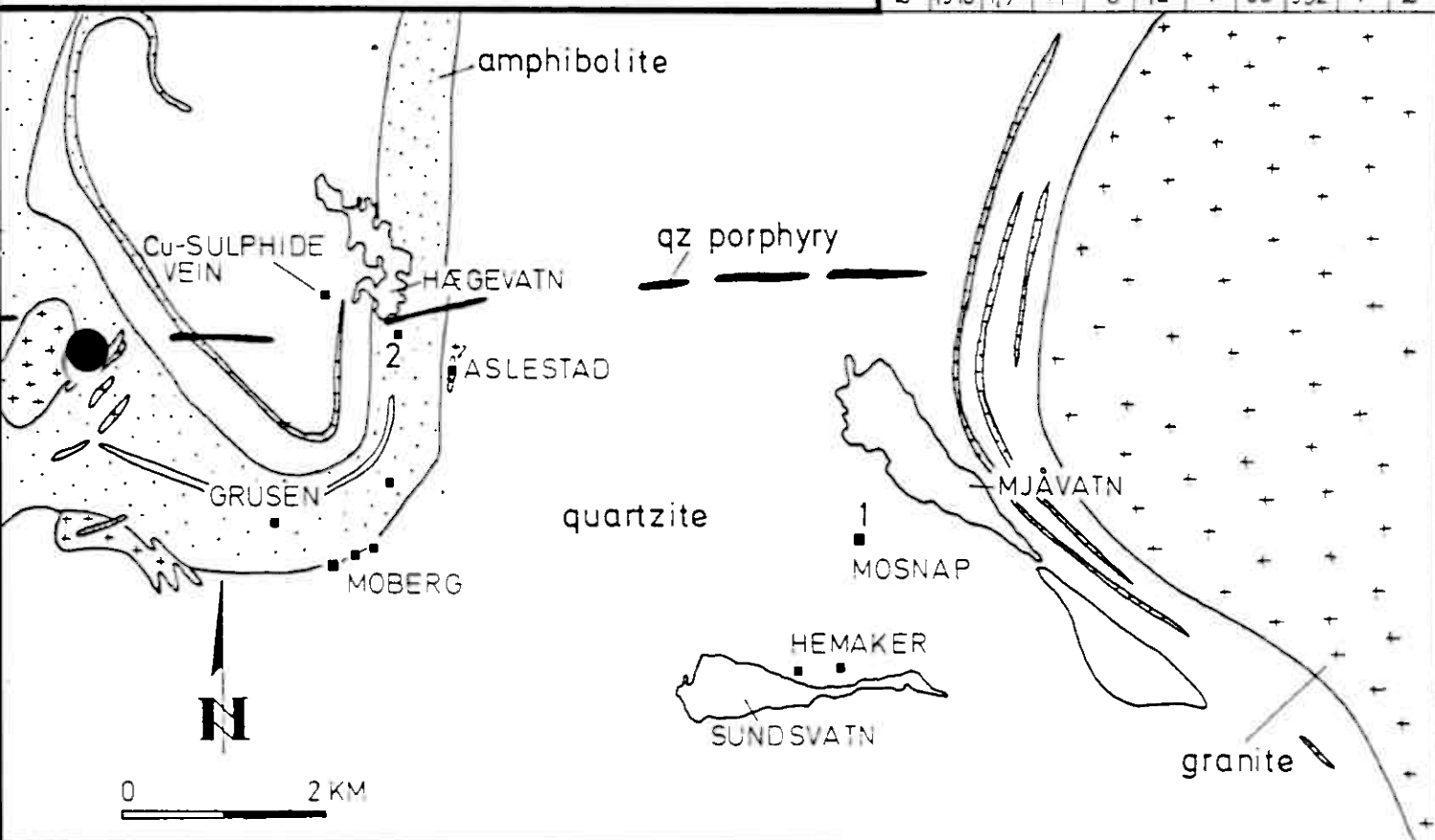


0 100 M

C DITCH



	Al ppm	Cu %	Pb ppm	Zn ppm	Ni ppm	Co ppm	Ag ppm	As ppm	Bi ppm	W ppm
1A	150	4.7	52	33	3	4	179	20	339	-1
1B	454	3.6	35	24	2	5	122	2	232	-1
1C	-20	12.7	93	107	5	15	464	465	836	-1
1D	100	2.9	30	25	5	6	64	423	126	-1
1E	73	0.9	32	23	6	6	49	18	1	-1
1F	-20	2.3	69	22	13	10	60	22	170	-1
1G	-20	0.3	24	199	38	30	2	15	2	-1
2	1310	1.9	14	6	12	1	53	332	-1	2



GEOLOGY (GYØRY, 1972) AND MINERALIZATION OF THE ASLESTAD AREA

The southeastern part of this vein has been emplaced adjacent to a granitic dyke and has been mined to a depth of ca. 15 m along a 50 m long section. Further to the northeast this vein has been test mined at a number of places. No attempt was made to follow the vein further to the southwest from point A in Fig. 52, but according to Vogt (1888) it continues at least for another 100 m in this direction; toward the northeast the vein was lost below the cover. The mineralization consists of sporadically occurring rich pods of chalcocite and bornite. Minor phases include (Nordrum et. al., 1981): chalcopyrite, digenite, molybdenite, telluro-bismuthinite, hessite, wittichenite, electrum, galena, silver and hematite. The alteration surrounding the vein is of greissen-type. Samples of ore collected from the dumps along the vein returned the analysis shown in Fig.52. Gold-contents is between 1 and 2 ppm and silver shows a high average of ca. 200 ppm; it is considered significant that high silver values are apparently unrelated to high copper values and that gold not exclusively follows bismuth.

The Mosnap mine is hosted in hornblende-quartz schists, conglomerates and quartzites some 6 km to the east from Moberg (Fig.53). This deposit consists of one large and a smaller parallel granite dyke which are mineralized with chalcopyrite, bornite, pyrite and molybdenite; minor phases include (Nordrum et.al., 1981): wittichenite, hessite, chalcocite, tellurobismuthinite, galena, scheelite, magnetite, and hematite. The larger of the dykes is shown in Fig.53; the ore minerals occur as disseminations and in cross-cutting quartz veins and pegmatites (Fig.54).

SKETCHMAP OF THE MOSNAP Cu-Ag MINE

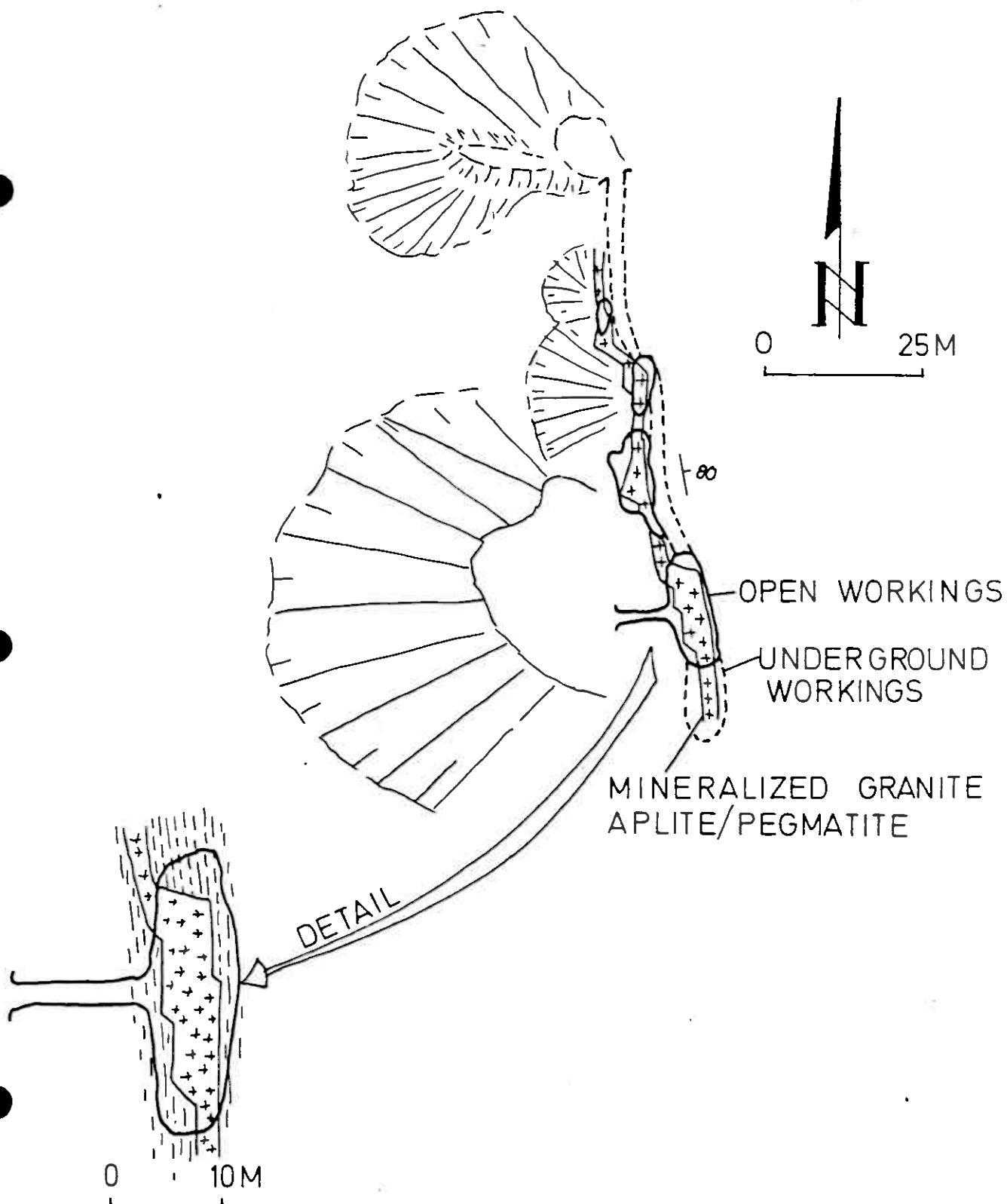


FIG. 53



Fig. 54. The main aplite vein (solid arrow) at Mosnap, carrying copper sulphides (open arrow). The host rock is a hornblende-quartz schist.

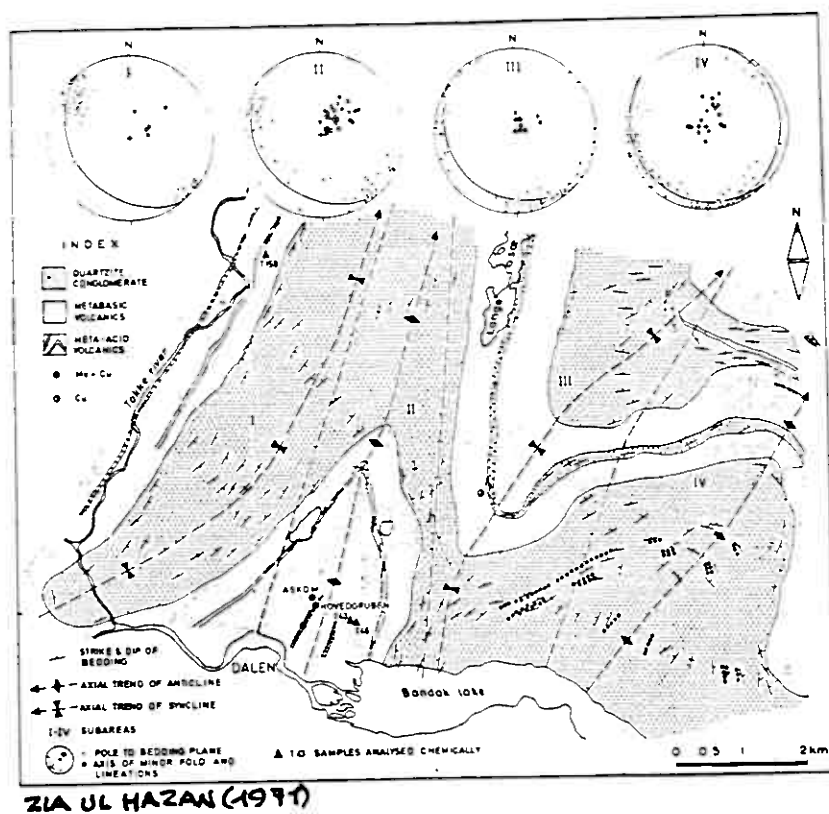


Fig. 55. The Dalen-Askom Mo-Cu veins.

The granitic dykes were injected along the foliation of the schists, and the richest parts of the deposit are situated where the dykes "jump" from one foliation plane to another, thereby increasing to twice or three times in thickness (see detail of Fig.53). The larger of the dykes may be traced over ca. 150 m and is from 0,5 m to 5 m thick. Samples of ore collected on the dumps are shown in the table in Fig.52, 1A to 1G, and they represent the following:

- A: chip sample of good quality bornite-chalcopyrite ore.
- B: hand specimen of rich bornite ore in quartz vein.
- C-F: various types of copper ore; hand specimens.
- G: weakly mineralized hornblende schist (wall rock); hand specimen.

As shown, gold is present in some of the samples in amounts of up to ca. 0,5 ppm, silver shows some variation but the level in general corresponds to the silver values of the Moberg samples, although some Mosnap values are lower; silver apparently to some degree reflects the Cu-content of the samples.

A number of other Cu-Ag $\pm$ Mo deposits occur in the area under consideration, and two of these were visited. The Aslestad skjerp is a true copy of the Mosnap deposit, although considerably smaller. A small mine to the south of Hagevatn was developed in a copper-sulphide-bearing quartz vein, less than 1 m thick and some meters long. The analysis returned more than 1 ppm Au and 55 ppm Ag at a copper value of 1,9% (2 in the table of Fig.52).

The analytical values of especially Ag, Au and to some extent of Cu, the size of some of these deposits and the relatively large number of deposits within this particular district necessitates a small scale field action during 1984. A total of 85 claim blocks have been pegged, covering the Moberg and Mosnap areas (see Appendix 2). A preliminary stream sediment survey has already been run over the area although with rather limited results (see later).

3.3.2 Pneumatolytic-hydrothermal veins

3.3.2.1 Mo-Cu

In the present context the term pneumatolytic-hydrothermal merely refers to quartz veins which show a relative lower-temperature mineralogy and wall rock alteration than the above described high-temperature veins. Pneumatolytic-hydrothermal Mo-Cu veins occur in a number of places in Telemark. They show many similarities with the higher temperature Mo-Cu veins described above and the most logical explanation of their genesis links them in the present authors opinion with these high temperature veins in the sense that they formed at a slightly larger distance from the parent granite magma. A similar view was taken by Bugge (1963) and Nilsen (1983). Important examples of this class include the Dalen-Askom veins which have been described in detail by Bugge (1963) and Hasan (1971) and the similar Listulli vein occurring some 100 m south of Listøl As-mine (Dons 1963); both of these localities were visited during this summer.

The Dalen - Askom veins occur in a sequence of basic- and acid volcanics and quartzites and is situated immediately north of Dalen (Fig.55). The host rock to the flatlying veins is a quartzite or acid metatuff.

The veins formed subsequent to folding of the host rock and the fluids were introduced along a thrustplane (?) which trends N-S and dips ca. 20° W. Late movement along this plane has caused minor deformation of the veins and faulting along two directions ($45^{\circ}/90^{\circ}$; $120^{\circ}/90^{\circ}$) offsets the veins. The mines were developed on three subparallel veins, each less than 1 m thick and up to 200 m long. These have a layered appearance and consist of quartz, tourmaline, molybdenite, bornite, chalcocite, chalcopryrite and minor pyrite. The vein mined in the Dalen mine was found to split in two separate veins in the northern part of the workings and the lower part was enriched in copper relative to the upper part. Alteration of the host rock is limited due to the inactive nature of the quartz-rich rocks; a thin (0,5 cm) halo of green sericite was observed locally. Late, subvertical cm-thick veins composed of hematite, calcite, quartz and pyrite transect the Mo-Cu veins and were found to be a regional phenomenon. For further details of these veins the reader is referred to the above mentioned papers.

The Dalen veins were sampled and returned the following analysis:

	Au	Cu	Pb	Zn	Ni	Co	Ag	As	Bi	W
Sample no	ppb	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
012007 A	-20	2164	19	10	11	7	14,9	4	- 1	- 1
012007 B1	-20	3827	14	4	6	2	29,3	8	- 1	- 1
012007 B2	-20	2996	8	5	5	2	18,5	132	- 1	- 1
012007 C	-20	7450	15	6	11	6	53,9	7	- 1	- 1
012007 D1	-20	245	13	17	5	7	-0,1	4	- 1	- 1
012007 D2	40	506	10	15	4	6	1,9	18	3	- 1
012007 E	-20	3942	23	40	7	13	28,6	3	1	- 1

- A: Chipsample of tourmaline-rich MoS_2 ore.
- B: Chipsample of lower part of split vein.
- C: Chipsample of upper part of split vein.
- D: Chipsample of host rock between upper and lower part of split vein (ca. 1,5m).
- E: Chipsample of late hematite-quartz-calcite-pyrite veins.

As shown, the Au-content is negligible, the only sample containing gold being the wall rock between the upper and lower split parts of the Mo-Cu vein. Silver contents are relatively high, clearly being related to the coppercontent of the ore. However, the size and metal content indicated for these veins do not encourage further action.

3.3.2.2 Au - Bi - Fe - Ag - Cu - Pb - Se - W

In the present context this is a very important class of deposits because it includes the only (abandoned) gold mine, Bleka, in Telemark. Other mines which may belong to this group are Gjuv, Gausta and Viken (Fig.56). Common to these deposits is that they occur in basic sills in the Seljord Group in areas where this is underlain by a thick sequence of acid volcanics of the Rjukan Group. It is furthermore noteworthy that indications of underlying granite intrusions are present in the form of dykes and irregular bodies of granite in the immediate vicinity of the deposits.

Characteristically the basic host rocks show a narrow greissen-like alteration along the subvertical veins, rarely extending for more than 1 m on either side. The alteration of the amphibolites is seen as bleached zones consisting of pyrite, magnetite, sericite, biotite, epidote, ankerite and chlorite which toward the veins carry an increasing amount of quartz. The gangue of the veins consists of quartz, ankerite (calcite, dolomite), tourmaline, epidote, hornblende and muscovite.



Fig. 56. Bleka-type mines and showings.

In the Bleka- and Gjuv areas tourmaline is abundant, in some instances constituting a large portion of the gangue, while further north, at Gausta and Viken, quartz predominates in the gangue.

The Viken and Gausta veins are less than 1 m wide and less than 30 m long. They contain aggregates of pyrite, chalcopyrite, sphalerite, galena, bismuthinite and hematite. Samples from these deposits returned the following analysis:

	Au	Cu	Pb	Zn	Ni	Co	Ag	As	Bi	W
Sample no	ppb	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
041606 A	3230	27230	1765	15750	9	40	144	7	189	- 1
041606 B	202	1656	14050	3255	11	26	740	9	2410	8
041606 C	60	107	59	313	8	30	1,1	16	16	7
012206 A	298	4022	53375	195	37	17	349	11	620	1
012206 B	- 5	131	133	141	17	26	2,0	78	2	3

041606 A, B, C: Chipsamples of ore from Gausta

012206 A: Chipsample of ore from Viken

012206 B: Chipsample of altered, 0,5 m wide zone of wall rock amphibolite.

Gold is present in significant amounts in the three most copper-rich samples, while silver to some extent reflects the combined copper and lead contents, analogous to the bismuth content. The veins are small and without any economic significance, hence no further action is recommended.

The Bleka mine is developed in one of a set of complex metal-quartz-tourmaline-ankerite veins which constitute the Svartdal gold field (Fig.57). This area and its mineralization has previously been described by Vogt (1886, 1888), Svinndal (1952) and Dons (1963) and the reader is referred to these papers for details. The Bleka mine occurs in a more than 500 m thick amphibolite sill which, together with the enclosing sequence of calcareous and siliceous schists, quartzites and amphibolites has been folded into a steeply SW plunging anticline (Fig.57). Subsequent to this deformation the area was intruded by dykes and a small plug of biotite granite and the area was mesoscopically fractured along three directions, E-W, ENE-WSW and NW-SE. All of these fracture directions have been invaded by the hydrothermal fluids. As indicated in Fig.57 especially the ENE-WSW direction was favorable for deposition, hosting more than two thirds of the veins noted by Vogt (1888).

The major physico-chemical control on the deposition of sulphides and gold was provided by the amphibolite, only one example being mentioned by Vogt (1888) where a gold-bearing vein occurs in the adjacent schists. The general steep attitude of the amphibolite sill in this area in conjunction with the subvertical orientation of the gold-bearing veins make room for a very large possible mineralized vertical interval (section A-A' and B-B', Fig.57). The Bleka vein is one of the largest of the veins known in this partly covered area. It has been followed over more than 1100 m along the surface and to a depth of about 125 m below the surface. The latter figure corresponds with the depth of the lower workings of the mine as shown in section A-A'; according to Svinndal (pers. comm.) the deepest shaft was abandoned due to pinch-out of the Bleka vein which in the upper workings attain a thickness of between 0,1 and 2,5 m.

SKETCH MAP AND SECTIONS OF THE BLEKA GOLD MINE

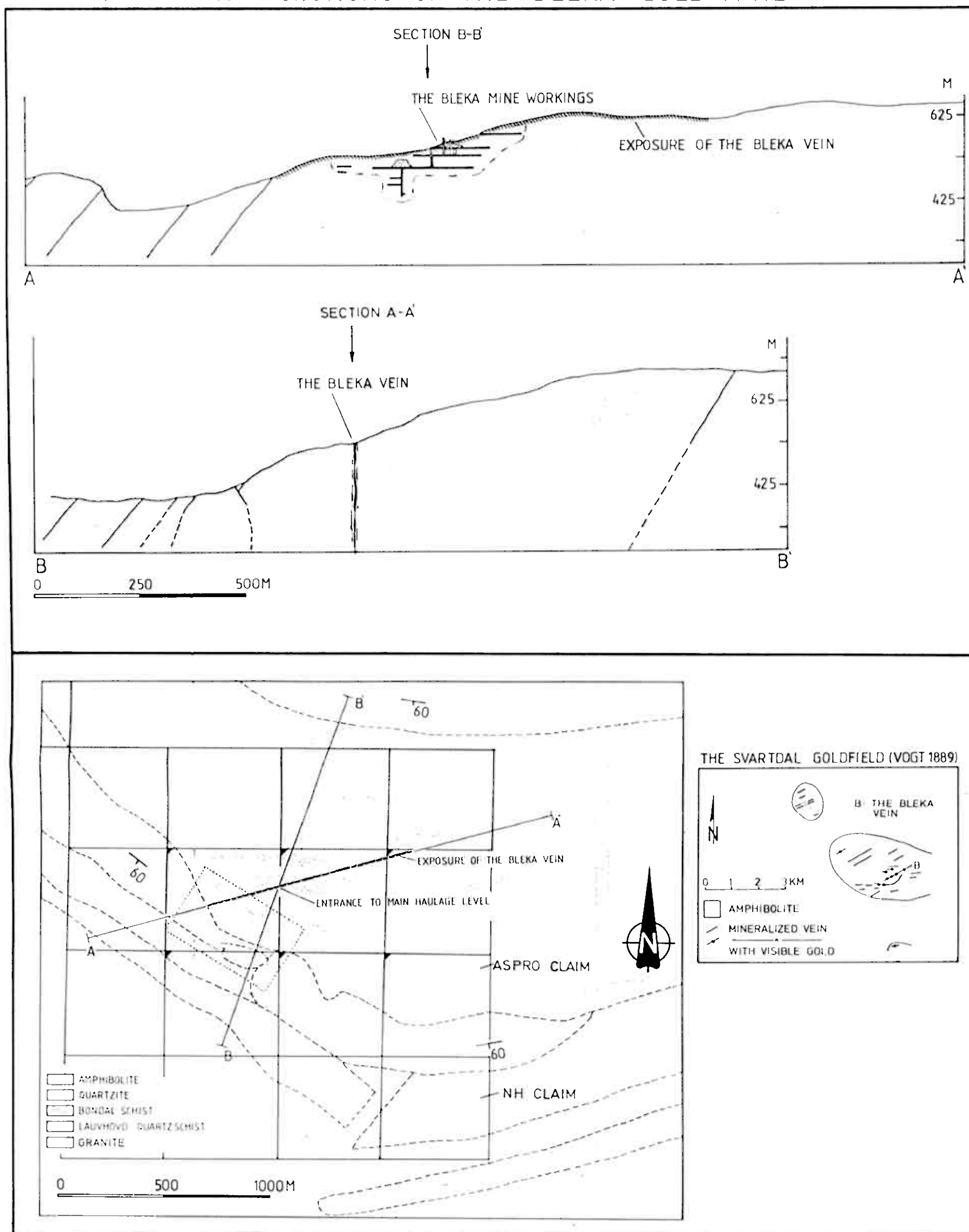


FIG. 57

An underground visit this summer revealed that the vein obviously is deposited along a major slightly irregular fault-structure, which explains the pinch-out in the lower part of the deepest shaft where the two fault blocks would be in close contact. In other areas the fault blocks have been separated due to curves in the faultplane and a hydrothermal vein up to 2,5 m in width has been deposited. With this in mind, a glance at the maps and sections of Fig.57 reveals the large potential for undiscovered mineralization in the Bleka area. The veins which at the present surface are thin or irregular may at depth expand into pockets of thick, rich ore such as was mined at Bleka. It is equally apparent that that part of the potential volume of the Bleka vein which has been tested by mining and trenching is negligible, and no diamond drilling has been carried out in the area. Finally no search has been made for large-tonnage disseminated - or stockwork-type mineralization outside the veins. On the other hand, if the morphology of the Bleka vein as it occurs in the mine is representative for rich gold ore in this particular area, then a somewhat negative economic aspect would be the size of the ore pockets. No production figures are available for Bleka, but the ore pocket investigated with underground workings measures 300 m x 100 m x 2,5 m x a density of 3,0, equal to 225.000 tonnes of "ore". The size of the stoped area indicates that the actual size of the pocket was smaller. In this case a critical feature would therefore be the spacing and of course the size of these pockets.

The mineralogy of the Bleka vein changes along the surface exposure, i.e. essentially with altitude. In the lower parts a complex paragenesis occurs, consisting of gold, silver, pyrite, chalcopyrite, bornite, bismuthinite, galenobismuthinite, galena, clausthalite, scheelite and emplektite (Svinndal, 1952). Tourmaline is abundant in the quartz-ankerite gangue.

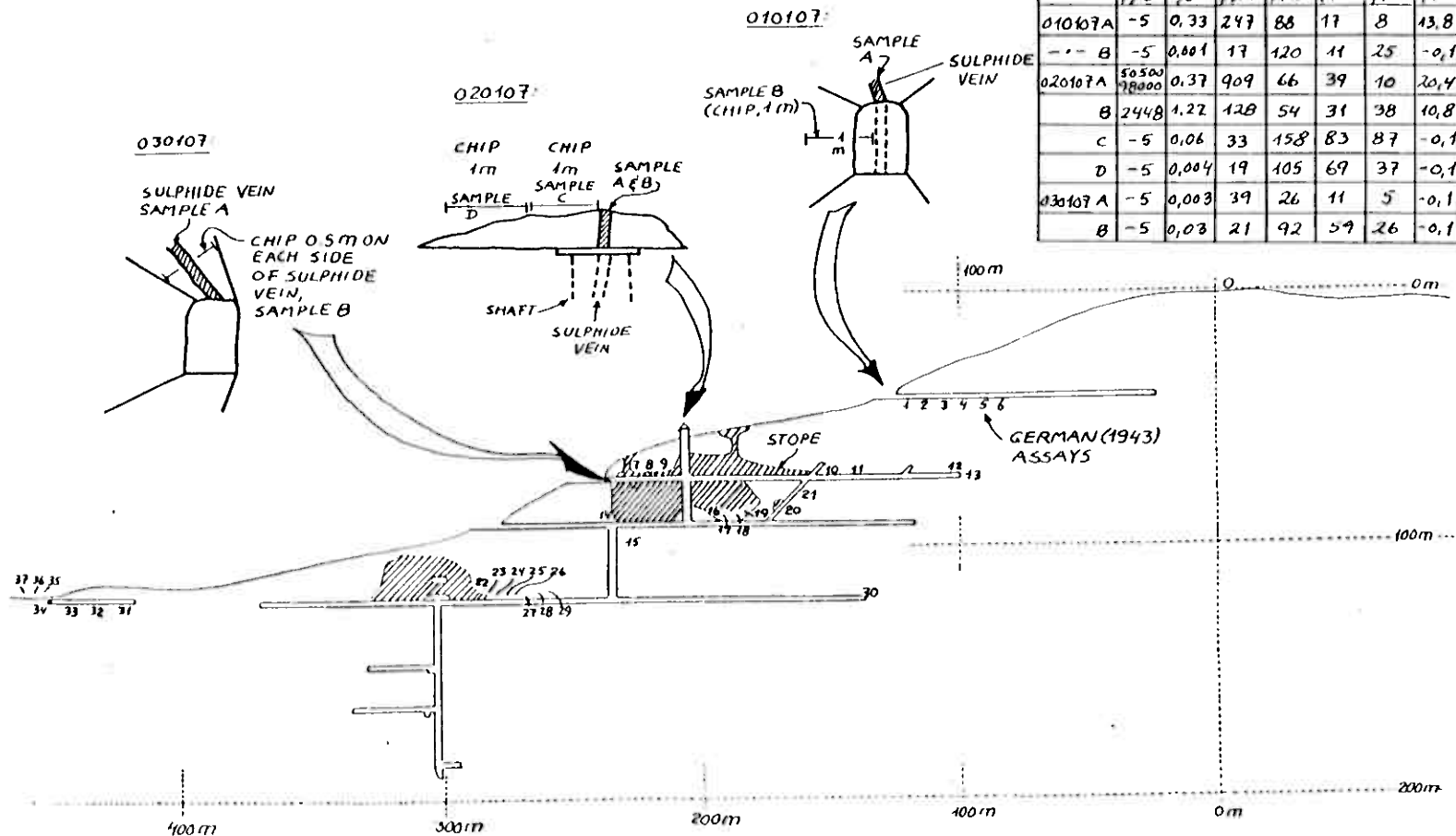
In the upper part of the surface exposure a more simple paragenesis is observed consisting of pyrite and chalcopyrite in a quartz-ankerite-chlorite gangue, characteristically devoid of tourmaline. No macroscopic change in alteration was observed, the amphibolite being altered to a greissen-type rock to a width of 0,5 m - 1 m on either side of the vein. The apparent change in vein mineralogy may be important in the localization of other ore pockets as it has been shown from several other similar deposits that gold and its associated minerals in most instances precipitate at a specific level in the crust determined by the level of boiling of the hydrothermal fluid.

Analysis of the ore mined in 1892, quoted by Dons (1963) showed the following: Au: 24,45 ppm; Ag: 25,18 pp.; Bi: 0,753%, while an analysis from 1901 returned: Au: 24,51 ppm; Ag: 43,28 ppm; Bi: 0,78%. Analysis of samples collected in the drifts and stopes by the Germans in 1943 are shown in Fig.58. It is noteworthy that only three samples (14,22 and 23) returned economically interesting Au-contents. Samples collected this summer were taken from exposures of the gold vein at the surface and underground and as chipsamples of the altered wall rock to distances of up to 2 m from the vein. The latter were collected in order to detect any low grade mineralization outside of the vein. As shown in Fig.58 only two samples (020107 A and B) from the vein near the main shaft return detectable gold. Sample A is rich sulphide ore, and two parallel analysis returned as shown 50 and 98 ppm respectively. The same two samples have high Bi-values, emphasizing the earlier established principle that gold follows bismuth (Dons, 1963). The wall rock is virtually unmineralized except for its low grade pyrite and chalcopyrite dissemination.

MINE SECTION AND LITHOGEOCHEMICAL SAMPLE POINTS, THE BLEKA GOLD MINE

SAMPLE NO	Au ppm	Bi %	Cu %
1	2,4	0,05	0,64
2	0,5	0,04	0,41
3	1,2	0,04	0,61
4	0,2	0,04	0,38
5	<0,1	0,01	0,27
6	0,2	-	0,11
7	0,2	0,01	0,11
8	0,8	0,01	0,22
9	0,7	0,04	0,28
10	<0,1	-	0,06
11	0,4	0,03	0,52
12	<0,1	tr	0,22
13	<0,1	tr	0,05
14	15,2	0,08	0,18
15	0,2	tr	0,13
16	<0,1	0,02	0,25
17	<0,1	0,04	0,24
18	<0,1	-	0,16
19	<0,1	-	0,04
20	0,3	0,03	0,38
21	<0,1	0,01	0,23
22	9,1	0,09	0,13
23	3,0	0,2	0,18
24	tr	tr	0,08
25	0,3	0,01	0,08
26	0,9	0,01	0,11
27	0,3	0,02	0,17
28	0,3	0,01	0,20
29	<0,1	0,01	0,39
30	<0,1	0,01	0,84
31	0,3	0,02	0,22
32	0,6	0,02	0,69
33	0,6	0,04	0,04
34	1,5	0,01	0,08
35	2,6	0,28	0,38
36	1,5	0,13	0,38
37	1,3	0,08	0,25

GERMAN (1943) SAMPLES



MINE SECTION FROM
SUNNDAL (1952)

tr = trace

These figures suggest that gold and silver are restricted to (bismuth-rich) sulphide-bearing parts of the mineralized veins.

The Gjuv Bi-mine occurs some 8 km to the east from Bleka (Fig.56). It was developed in a 0,1 to 2,5 m thick and more than 50 m long quartz-tourmaline vein trending $020^{\circ}/30^{\circ}$ NW. It is hosted in a ca. 100 m thick amphibolite sill occurring parallel to, and above the Bleka amphibolite (Plate 3). The mineralization consists of bismuthinite, pyrite, chalcopyrite, galena, galenobismuthinite and bismuthspar. The alteration of the host amphibolite is similar to the greissen bordering the Bleka vein. An older analysis (from 1917-18, quoted by Dons, 1963) returned: Bi: 0,97%; Pb: 0,09%; Cu: 0,03%; Au: 6,84 ppm.

Two chipsamples of ore and wall rock collected on the mine dumps this summer returned the following:

	Au	Cu	Pb	Zn	Ni	Co	Ag	As	Bi	W
Sample no	ppb	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
041506 A	41	310	469	19	31	75	0,5	29	11500	15
041506 B	- 5	141	20	133	17	33	-0,1	4	2	- 1

A is a sample of rich ore, B represents altered wall rock.

Although the gold content of sample A is negligible there is no doubt that the Gjuv vein is equivalent in type to the Bleka veins, and that its position -as Bleka - is controlled by the presence of an amphibolite sill.

Older reports mention that several other, similar veins occur between Bleka and Gjuv and as shown in the index map by Vogt (1888) (Fig.57) mineralized veins also occur to the northwest from the Bleka area.

In summary, the potential for discovering new gold mineralization in the Bleka area is considered high. However, more information is needed in order to make us able to evaluate the economic aspects, and further field work is accordingly recommended (see later).

With the Bleka veins as a reference it was recognized early during the field season that basic sills and dykes occurring in the Rjukan- and Seljord Groups has a large potential for acting as a trap ('blotting paper') for metals in hydrothermal cells established around the late kinematic granites and circulating in major, deeply penetrating fractures.

A number of samples were accordingly collected from altered basic intrusives bordering major structures in order to test their potential for Au-mineralization. In the area immediately to the west from the Bleka mine a number of major fractures and alteration zones transect the Bleka amphibolite in the vicinity of the small Svartdal biotite granite plug (Fig.59). Samples of pyritized and greissen-altered amphibolite (B, C, D) returned low grade gold values and in one sample (?) a silver value of 5,7 ppm was detected, probably reflecting the presence of galena. One of the smaller veins (dm-thick) shown by Vogt (1888) (Fig.57) was also sampled, returning ca. 1 ppm Au and 80 ppm Ag.

A number of other sampling localities are shown in Fig.60. These represent in all instances basic sills and dykes hosted in quartzites. The basic rocks have been altered to an assemblage of chlorite, muscovite, ankerite and minor quartz. Disseminated pyrite with minor

associated chalcopyrite are ubiquitous, in places constituting up to 5 vol% of the altered rocks. The sills are transected and surrounded by up to 50 m wide aureoles with quartz-ankerite veinlets carrying minor pyrite, chalcopyrite and galena, and it is tempting to interpret the minerals of these veinlets as being related to the breakdown of the basic sills in the presence of siliceous hydrothermal fluids. The analysis of chipsamples of these altered dykes returned detectable, low grade gold in 3 samples (Fig.60) and silver in amounts of up to 8 ppm in 9 out of the 16 samples. Arsenic was detected in most samples; one sample with 486 ppm As contains elevated Co-values and may thus reflect the presence of Ni-Co arsenides. Elevated bismuth-values occur in five samples but show no direct correlation with gold. For comparison one analysis of an 'unaltered' (metamorphosed) basic sill from Tinnsjøen is shown.

It is apparent that the hydrothermally altered basic rocks have been somewhat enriched in Au, Cu, Zn, Ag and Bi, and depleted in Pb, Ni, Co, As and W. Although these figures are probably not representative, it is interesting to note that the 'enriched' elements are equivalent to the metals occurring in Bleka-type gold veins. However, the altered sills, which may be compared with the Bleka vein wall-rock, do not seem to contain interesting precious metal mineralization and no further action is recommended at present.

3.3.3 Hydrothermal veins

3.3.3.1 Cu - Ag - (-Au)

This class of vein type deposits is predominant in Telemark and more than 100 individual veins with copper mineralization is known. The deposits are all small, i.e. less than ca. 1 m wide (most frequently less than 0,5 m) and up to a few tens of meters long. The

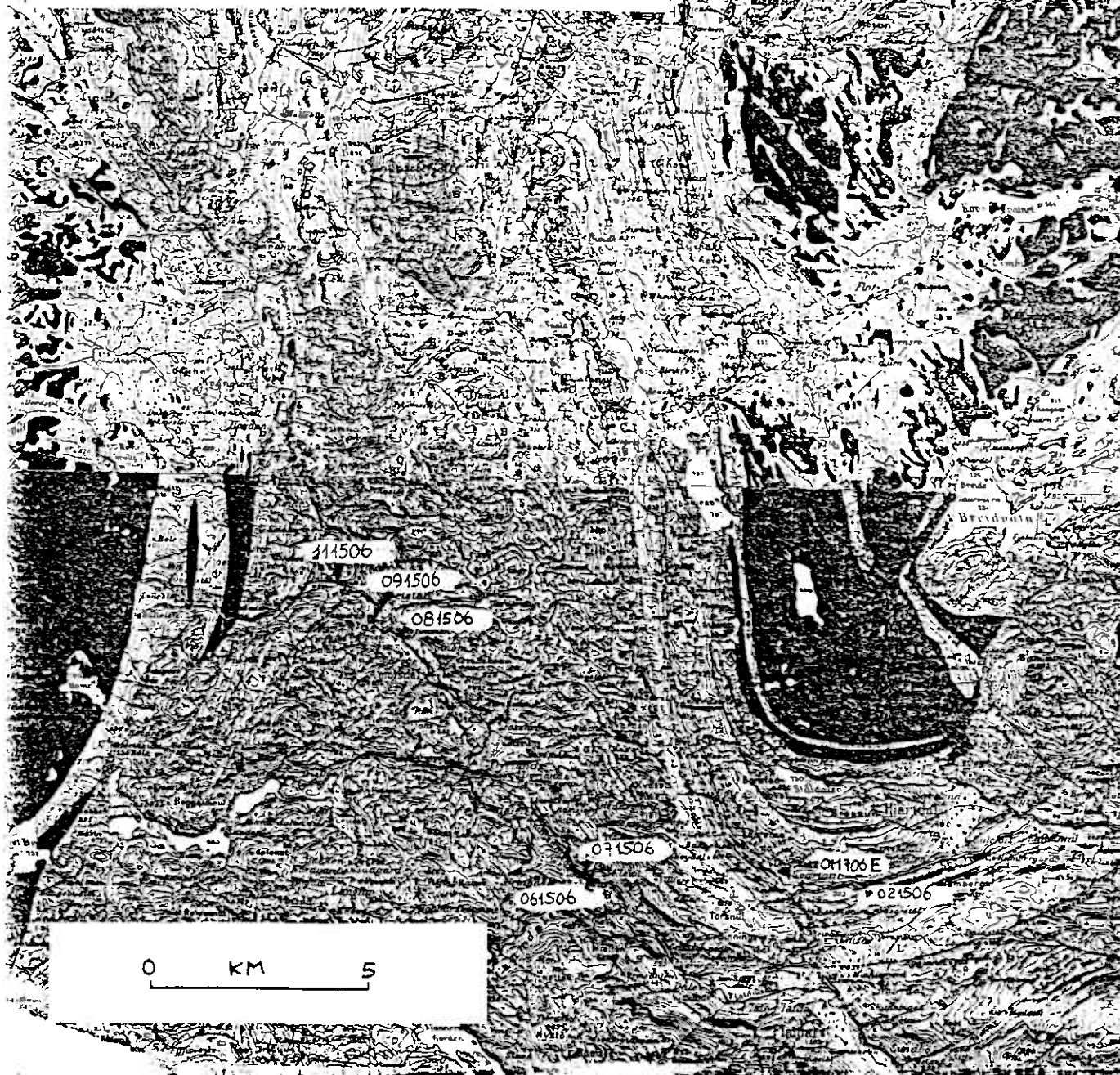
DISSEMINATED AND VEIN-TYPE (QZ-AUNKERITE)
MINERALIZATION IN HYDROTHERMALLY
ALTERED BASIC SILLS IN THE RJUKAN-
AND SELJORD GROUPS.

FIG. 60

	Au ppb	Cu ppm	Pb ppm	Zn ppm	Ni ppm	Co ppm	Ag ppm	As ppm	Bi ppm	W ppm
021506	-5	38	46	88	4	20	0.8	1	14	2
021506A	-5	30	66	69	4	31	7.8	11	13	15
061506A	-5	742	6	18	14	18	1.1	3	1	-1
061506B	-5	3250	8	79	10	24	2.3	34	1	-1
071506A	-5	349	584	248	35	37	2.5	9	3	3
071506B	300	1067	41	396	40	50	1.8	15	3	-1
071506C	-5	155	296	109	43	31	1.2	3	2	-1
081506	-5	42	32	150	42	38	0.1	2	9	-1
091506	-5	369	34	147	49	37	0.5	3	27	-1
111506	-5	66	19	112	56	43	0.1	2	4	-1
011706E	-5	140	18	74	71	59	0.1	82	1	-1
012306	-5	74	10	114	45	46	0.1	78	2	-1
022306C	-5	42	17	93	32	27	0.1	3	20	-1
012806	52	117	27	286	34	344	1.3	486	5	-1
022806	31	65	76	176	55	58	0.1	3	25	9
042906	-5	314	16	66	22	31	0.5	2	1	-1

'UNALTERED' (METAMORPHOSED) BASIC SILL
(TINNISJO)

062406	-5	86	87	188	242	61	0.7	68	7	1
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mineralization consists of chalcopyrite, bornite, chalcocite and hematite, magnetite or pyrite; minor phases include arsenopyrite, galena, sphalerite and Au. Wall rock alteration is negligible, in most cases consisting of cm-wide sericite-rich, silicified zones or zones rich in chlorite. Host rocks are dominated by basic volcanics although acid volcanics and quartzites occur. One very important feature of these deposits is that they almost exclusively occur in Bandak Group lithologies (see later). A few deposits were visited and sampled in order to test their precious metal content (Fig.61). Duses and Morgedal are typical representatives of this group and are clearly dominated by Cu and Ag. Lauvåsen and Brennebekk contain anomalous U-contents, but are otherwise similar to the first mentioned. The small occurrences at Heddalsvatnet were visited by H.K. Schönwandt (see Appendix 4) because they were known to contain anomalous gold values (Nordrum, pers.comm.).

Chipsamples from two of the 'mines' returned ca. 4 ppm Au and 184 and 254 ppm Ag respectively at Cu-contents of 2,6% and 3,5%. A further clearly anomalous feature when compared to the other occurrences is the As-contents of 850 and 706 ppm (all samples are chipsamples of rich ore). Further details on these deposits are given in Vogt (1886, 1888), Dons (1963), Annis (1982) and Schönwandt (Appendix 4).

As a whole the known deposits of this class are all small, the Au content is low (a few tens of ppb) and the silver content moderate (a few tens of ppm), hence no further follow-up is recommended. The Heddalsvatnet deposits seem to be anomalous in this picture. They occur immediately above the basement and may thus belong to for instance the more attractive group of pegmatitic-pneumatolytic Cu-Ag veins instead of the lower temperature hydrothermal group.

SAMPLE NO	Au ppb	Cu ppm	Pb ppm	Zn ppm	Ni ppm	Co ppm	Ag ppm	As ppm	Bi ppm	W ppm	LOCALITY
01907A	-20	279	31	11	3	5	0,1	10	-1	-1	MORGEDAL
- - - B	-20	8020	85	37	4	7	13,8	3	-1	-1	- - -
- - - C	40	41008	82	12	4	7	426	21	2	-1	- - -
DUSES 1	-4	21400	12	17	14	1	17,8	-1	-1	1	DUSES
- - - 2	-4	18500	10	86	75	58	28,5	-1	-1	2	- - -
010209	20	53500	17	7	11	1	50,1	-1	-1	3	LAUVÅSEN
020209	100	23800	2	21	20	2	54,6	-1	-1	-1	BRENNBEKK
6383	-4	119	52	75	10	4	2,5	-1	9	2	HEDD.VATN.
6583	3715	26300	19	102	5	5	184	850	-1	-1	- - -
7083	3840	35500	48	38	5	2	254	706	-1	-1	- - -
7283	215	40000	28	81	3	1	65,1	1	-2	-1	- - -

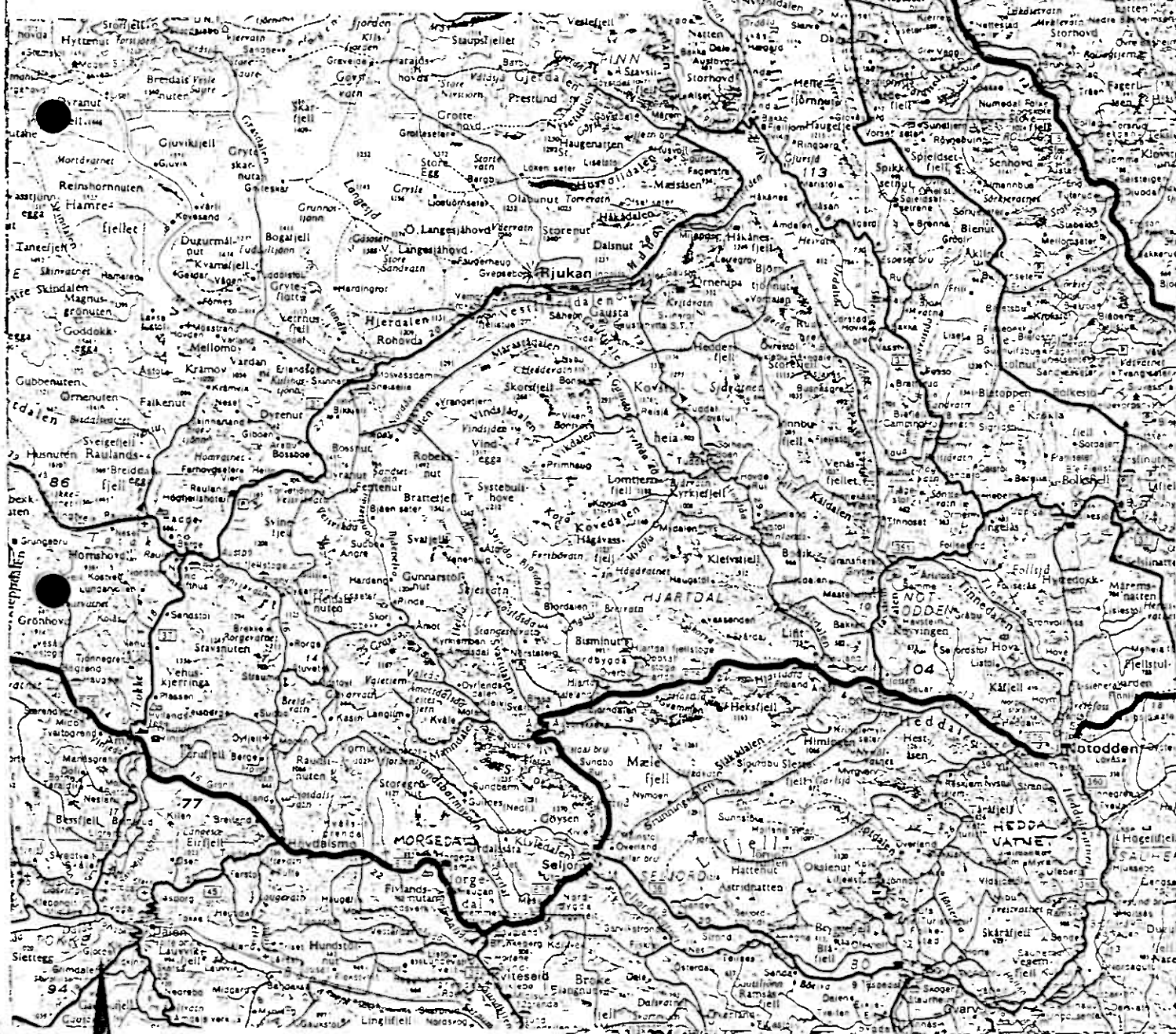


FIG. 61

HYDROTHERMAL Cu-Ag (-Au-W) VEINS

3.3.3.2 Fluorite

A number of fluorite (-calcite-quartz) veins occur in Telemark, showing clear affinities to the late- and postkinematic granites on the one hand and base-metal-bearing veins on the other. A number of these deposits were described by Pedersen and Dannow (1972) including the Haukås- and Tveiten-Barskor veins. Fluorite is an important constituent of the earlier described pegmatitic-pneumatolytic Mo - Bi - Cu veins in the Bandak granite, and it occurs as a primary phase in the Bessefjell granite. The nearby Byrtevang-fault, which represents a segment of the large western boundary fault of the Telemark supracrustals, is mineralized with fluorite, chalcopyrite, sphalerite, galena and pyrite, and along the extreme southern part of this fault the Bergehei fluorite - chalcopyrite - digenite - bornite - wittichenite - chalcocite - hessite deposits occur in granite pegmatites (Nordrum, 1981).

3.3.4. The epigenetic veins in space and time

The description of the epigenetic mineralization presented in the previous sections indicates that the metalliferous, hydrothermal veins should be considered products of essentially one major process in the development of the Telemark area, namely the action of hydrothermal cells set up by a heating event produced by the intrusion of late kinematic granites and a concurrent anatexis of the basement. This is primarily suggested by the overlap in metal associations and the observed changes in paragenesis of the veins when moving from the clearly granite-generated pegmatitic deposits through the pneumatolytic to the hydrothermal veins. (Table 2). The close association between the metalliferous veins and granite formation in the basement thus seems well established, as previously suggested by Vogt (1886, 1888), Dons (1963), Hasan (1971), Bugge (1973) and Nordrum et.al. (1981).

The metals occurring in the veins may originate from the basement, from the supracrustals, or both, and clues to the parentage of individual elements are provided by plots of the elements against major lithologic units. Figure 62 shows a plot of all known epigenetic copper (-silver) occurrences in the Telemark district against the occurrence of Bandak Group and equivalent lithologies. It is apparent that a very strong correlation exists between these two, although some of the copper veins plot outside of the major areas covered by the Bandak Group. However, on closer examination many of these veins are seen to occur in the basic dykes and sills intruding the underlying units and considered to be feeders to the basic volcanics of the Bandak Group.

The basic volcanics of this group contain syngenetic Cu-Ag mineralization and a few analysis of "unaltered" basic rocks show the presence of trace amounts of these elements.

It is accordingly suggested that a major part of the copper and silver occurring in the epigenetic veins in Telemark was derived by hydrothermal leaching of the syngenetic mineralization and basic volcanics of the Bandak Group. As suggested previously the Bandak Group and equivalent stratigraphic units were deposited in a continental rift-setting reminiscent of an aulacogen, some 1200 - 1000 ma ago. It is hardly a coincidence that similar rift-related bimodal volcanic suites and continental clastics of this age are known from all the major continents, and that widespread syngenetic Cu-Ag mineralization in basic volcanics and Cu-Ag (-Co) ores in thick epicontinental clastic piles are associated with these lithologies (Watson, 1978; Sawkins, 1976; Windley, 1977). As in Telemark many of these ores are characterized by a sulphur-poor copper paragenesis, reflecting their setting in a low SO_4^{2-} continental environment.

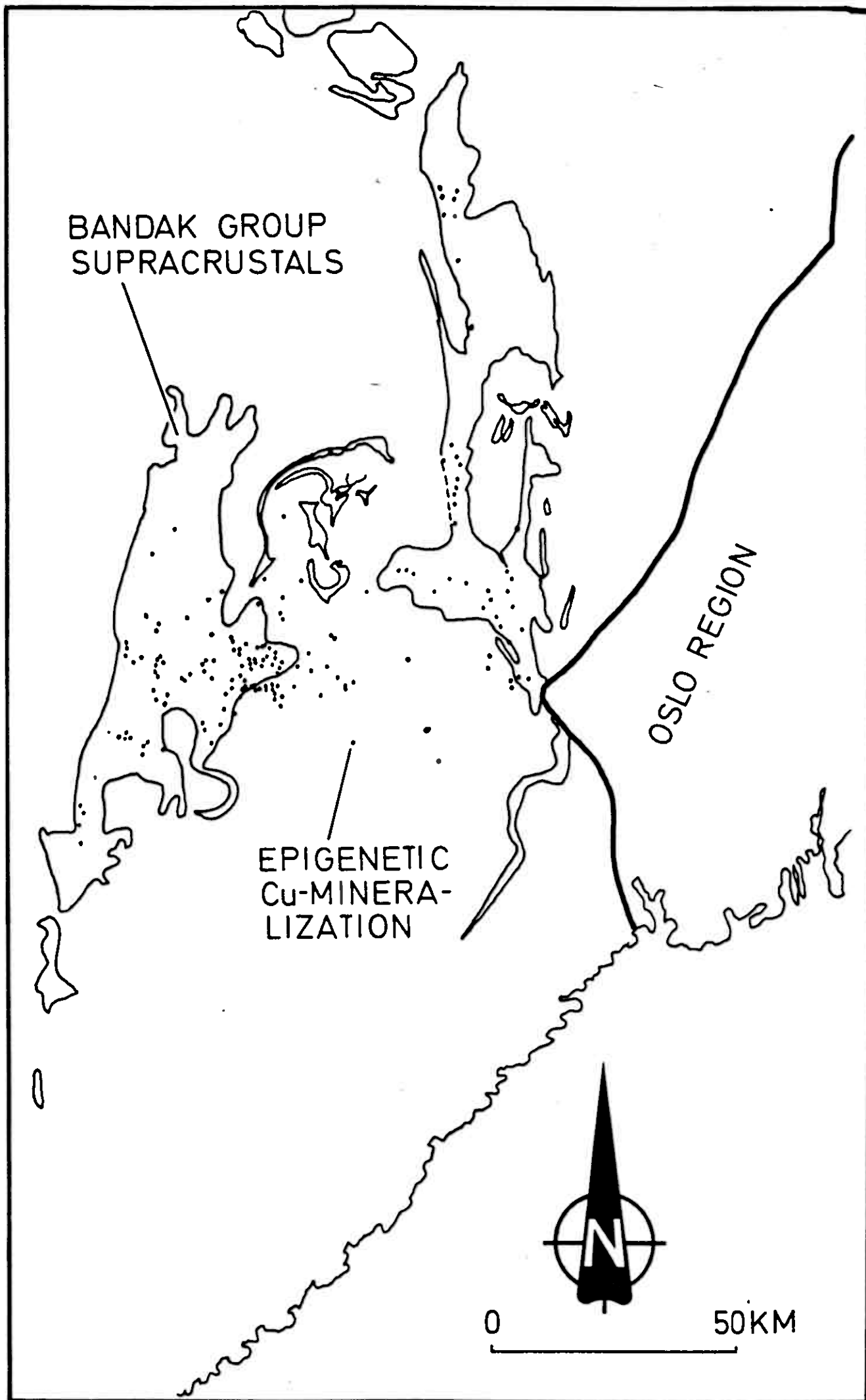
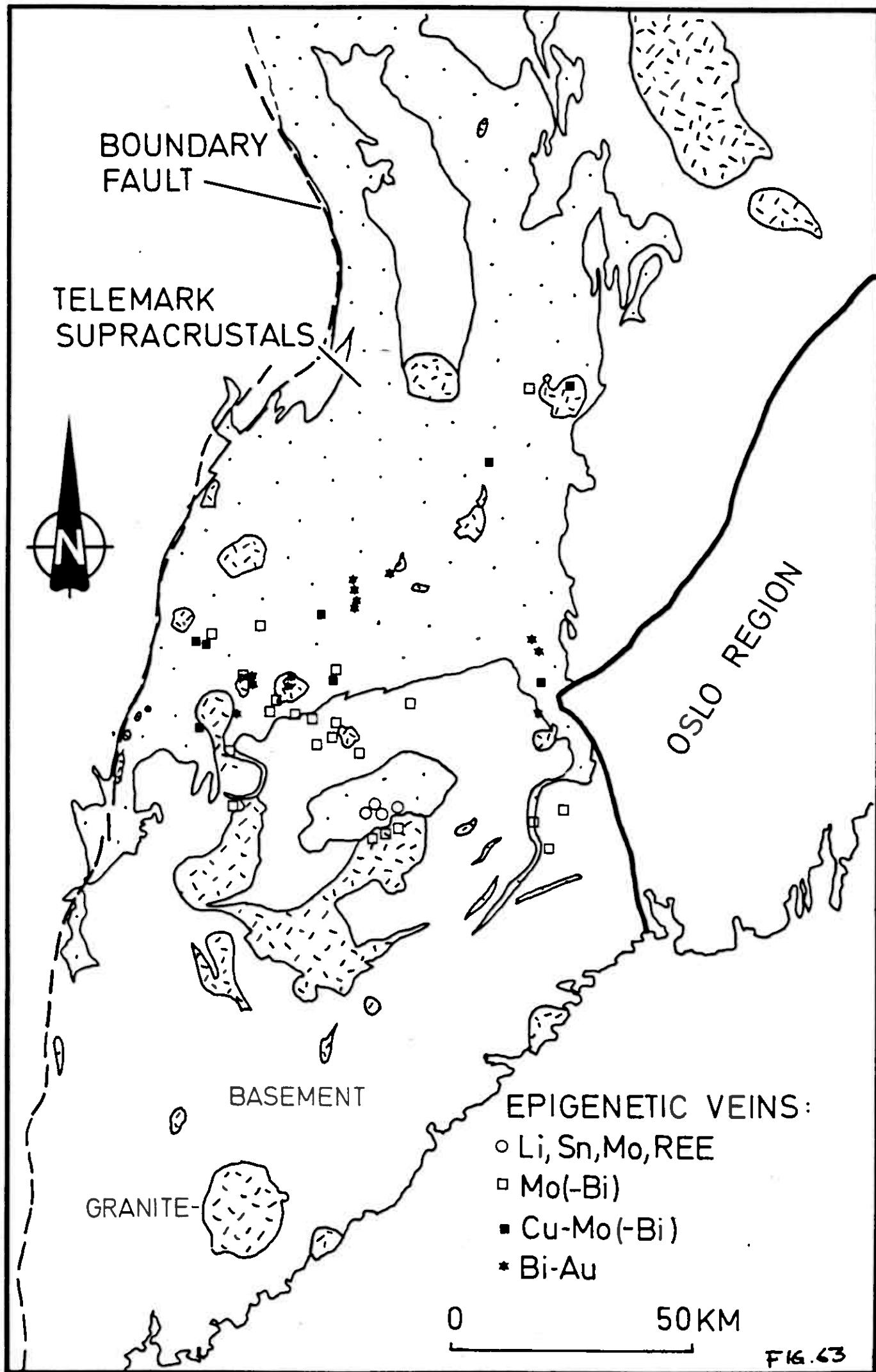


FIG.62

The distribution of the Mo-(Bi) and Li - Sn - Mo - REE pegmatites and pneumatolytic veins (Fig. 63) suggest that these essentially lithophile and incompatible elements are closely related to the basement. It is well known that the probably Svecokarelian, essentially coast-parallel Mo-province of southern Norway passes through the area under consideration. It is therefore highly likely that elements such as Sn, W, B, F, Mo, Bi, Li, Be and base metals rapidly would partition into the anatectic melt, lower the liquidus and solidus and be concentrated in the late stage aqueous fluids and residual melt fractions to form the observed pegmatitic-pneumatolytic deposits (see for instance Plimer, 1980). In this model it is considered very significant that high temperature copper-bearing Mo-Bi deposits exclusively occur in the adjacent Bandak Group cover rocks, probably reflecting contamination of Cu from the basic volcanics to the essentially basement-derived Mo-Bi-bearing hypercritical fluids.

Veins with a significant gold content occur essentially in the same area as the high-temperature Cu-Mo-Bi veins, i.e. in the supracrustal cover rocks immediately to the north from the basement dome, and in almost all instances in the vicinity of late granites (Fig. 63). The veins are frequently characterized by a complex element association including Au, Bi, As, Ag, Fe, Cu, Pb, Se, W and B, i.e. probably a mixture between the Bandak Group Cu-Ag dominated association and another, more varied association. Gold, silver and arsenic have been reported from the basement surrounding the Telemark supracrustals in a number of places including Kongsberg - Modum, Bamble and Valle. The same elements have been found to occur in minor amounts in acid and basic volcanics of the Rjukan Group, and wolfram occurs locally in significant amounts in association with molybdenum in the Svecokarelian Mo-province of southern Norway (Bugge, 1963). The present distribution of epigenetic veins with a significant gold content thus seems to be predominantly



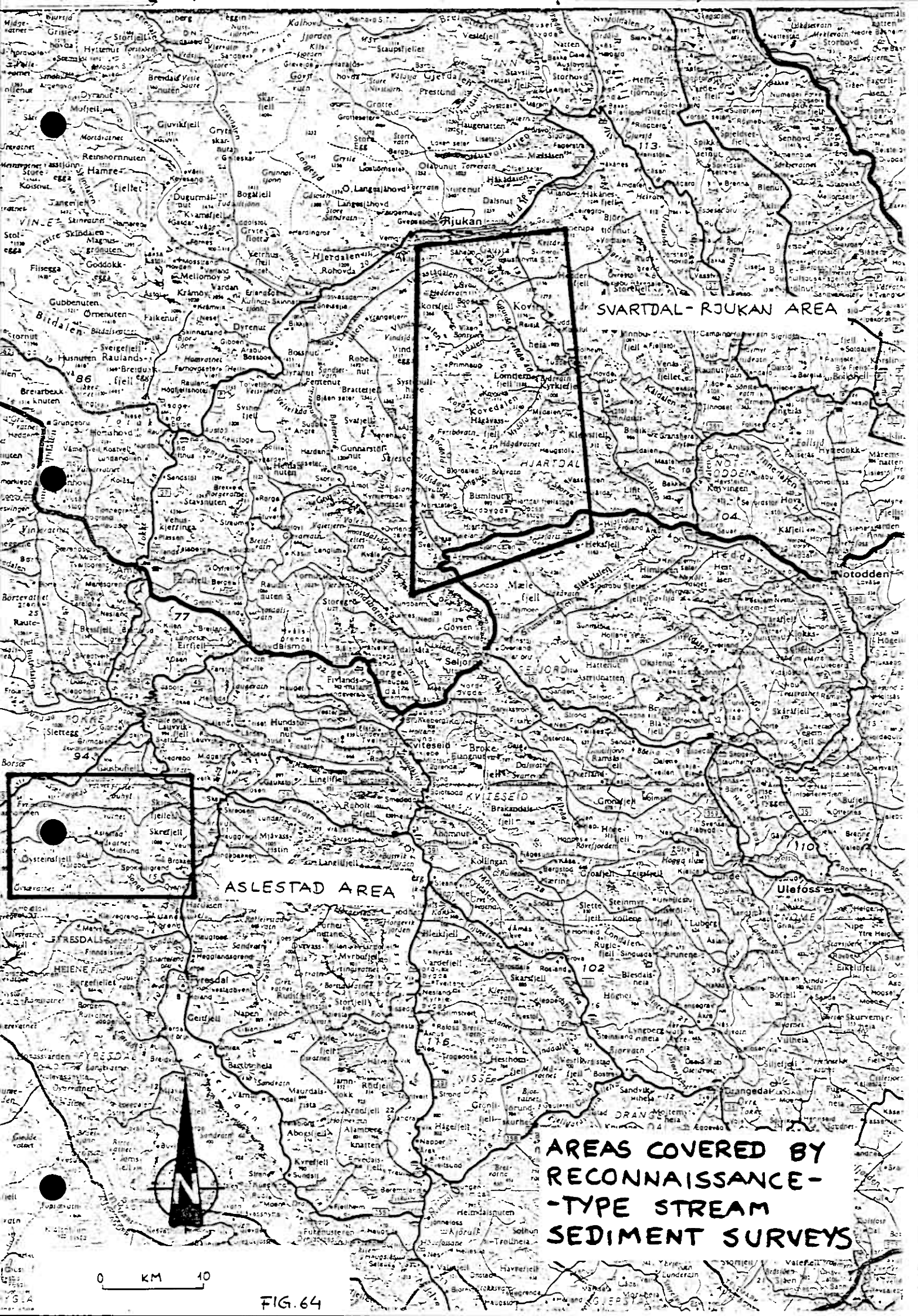
governed by a specific P-T zone reflecting a certain, critical distance to the mobilized basement and its associated granites. The element association in these veins probably represent a complex mixture derived from the basement, the acid (-basic) volcanics of the Rjukan Group and the basic volcanics of the Bandak Group. It is in this context interesting to note that the Bleka area is underlain by a thick sequence of Rjukan Group acid volcanics which hosts the newly discovered stratabound Au-Cu-Pb-Zn-Ag mineralization. A direct consequence of these reflections is that the presently most promising target area within the Telemark supracrustals for vein-type gold exploration would be the 10 to 30 km wide and 100 km long northern border zone of the basement dome where emphasis should be placed on structurally complex areas within the basic volcanics which have been shown to represent a prime trap for the gold-bearing fluids.

Other areas resembling this zone should be sought; especially the western part of the Bandak Group along the boundary fault should be kept in mind as it seems to exhibit most of the features of the gold-carrying zone. Finally it should be emphasized that the surrounding Svecokarelian and/or Gothian basement represents a potential area for gold exploration. Norsk Hydro is currently investigating this basement for precious metal mineralization to the east of the Oslo fjord, Arco has been active in the Bamble region this summer, and Folldal Verk has investigated a part of the Kongsberg-Modum region.

4. STREAM SEDIMENT SURVEY

One of the aims of this summers reconnaissance in Telemark was to find a suitable regional exploration tool which eventually could be used in a 1984 programme. The exposure and topography of Telemark suggested that stream sediment sampling would work; two test areas were accordingly selected and a total of 236 samples were collected. The test areas were chosen so that they included the Bleka area and as wide a selection of the different lithologies as possible, in the northern area with emphasis on acid volcanics, basic sills and calcareous schists, in the southern area with emphasis on quartzites and greenstones (Fig. 64). Both areas include a number of small and medium sized postkinematic granite intrusions.

The sampling method was wet sieving to the - 80 mesh fraction and an attempt was made to collect 50 grammes of material at each sample point. However, the glaciated outcrops and high degree of exposure made this very difficult in especially the high plateau areas. Sample sizes accordingly varied between 5 and 50 grammes with an average of 24 grammes for the 236 samples. This variation is probably much too high for gold exploration and must be taken into account in the interpretation of the results. Furthermore, if this or a similar method is chosen for 1984, a more uniform sample size must be attained. To obtain this, and to eliminate variations induced by the lab processing, the employment of a method similar to SELCO's should be considered. Subsequent to the wet sieving the samples were dried and shipped to Mercury in Ireland for analysis for Au, As, Ag, Cu, Pb, Zn, Bi, Ni, Co and W. Details of the analytical procedure are given in Dannow (1983). One set of Au-standards and blanks were included in the second batch of samples and returned the following, acceptable values:



**AREAS COVERED BY
RECONNAISSANCE-
-TYPE STREAM
SEDIMENT SURVEYS**

FIG. 64

STANDARD	BP NORGE	MERCURY
	Au	Au
TSPB 1	$\pm$ 0,465 ppm	0,210 ppm
TSPB 2	$\pm$ 5,00 ppm	6,270 ppm
TSPB 3	$\pm$ 0,93 ppm	1,090 ppm
TSPB 4	$\pm$ 0,2325 ppm	0,210 ppm
LPBP 1	< 10 ppb	< 20 ppb
LPPB 2	0	< 20 ppb
LPPB 3	< 10 ppb	< 20 ppb
LPPB 4	< 10 ppb	< 20 ppb

Gold standards and blanks supplied by BP Norge Minerals a.s. TSPB 3 and 4 are CANMET standards, TSPB 2 is from Alligator Ridge. LPPB 2 is glass sand.

The results of the sampling are given in Plates 6 to 21. Intervals of the metal distributions were chosen in a subjective manner on the basis of histograms. For the Svartdal-Rjukan area Ag, W and Ni are not shown as these elements returned no significant assays or assays above detection limit. The same applies to Au, Ag and Ni for the Aslestad area.

4.1 THE SVARTDAL-RJUKAN AREA

Five samples in this area returned detectable gold. Two samples are from the stream draining the Bleka area while two samples situated immediately to the NNW from this drain an area of the Bleka amphibolite where we know that small gold-bearing quartz-tourmaline veins occur (Fig.57). The Bleka area is furthermore somewhat anomalous in As, Bi, Cu, Zn, Pb and Co. One similar composite anomaly (Au, As, Zn, Pb, Co) occurs to the south from lake Breidvatn and warrants follow-up. It is situated along a major fault offsetting the Bleka amphibolite (compare with Plate 3), i.e. in a structural setting similar to Bleka.

An isolated Bi (Cu, Zn) anomaly situated to the east from Bleka (Plate 8) must similarly be checked due to the importance of Bi in the Bleka deposit.

Other anomalous areas which should be checked are characterized by isolated high As assays or composite anomalies of As and one or more of the metals Cu, Pb, Zn and Co. Especially the following anomalous geological units stand out (compare with Plates 3 and 4): Basic sills occurring in acid volcanics and quartzites to the north and east from Bleka; the contact zone of the Fjellstadfjell granite (SE from Breidvatnet); the layer of Bondal schist intruded by basic sills occurring immediately to the south from Breidvatn; and acid volcanics in the eastern end of lake Bonsvatnet (between lakes Heddersvatnet and Vindsjøen south of Rjukan). The latter anomaly may reflect the presence of the gold-bearing acid tuff shown in Fig.31; samples collected in streams draining this zone further to the east are anomalous in Pb, Zn and Cu.

In summary, stream sediments collected in the Svartdal-Rjukan area closely reflect known mineralization and highlight other areas with a similar metal distribution pattern which are to be followed up in 1984.

4.2 THE ASLESTAD AREA

This area includes the mineralization at Moberg, Mosnap, Grusen etc. (see Fig.52). Only one area with significant anomalies was found, occurring along what may be a major lineament hosting the Mosnap Cu-Ag deposit. Two samples from this lineament return anomalous Cu-, Pb-, Zn-, (and W-) values and may reflect the presence of Mosnap-type mineralization outside of the abandoned mine area. However, the Mosnap deposit was operated in conjunction with the Amdal Verk during five periods (Nordrum et.al., 1981) which means that ore from this deposit must have been transported from Mosnap to Amdal Verk.

The easiest route would be at winter across the lake north of Mosnap, following the anomalous stream northwards. This could explain the two very significant anomalous samples, although they will have to be checked in the field.

The Grusen deposit stands out as a weak Pb-Zn anomaly (sample 238) and the locality of sample 224 should be checked for similar mineralization due to the Pb-Zn anomaly in this area.

5. SUMMARY AND CONCLUSIONS

A. The Telemark Supergroup comprises a sequence of supracrustals with a total thickness of more than 7 km. It may be divided into four major lithological groups, deposited over a wide time span:

1000-1200 Ma:	The Heddevatn Group
1000-1200 Ma:	The Bandak-, Numedal-, Leptite-, and Blåbergås Groups.
1200- ca.1600 Ma:	The Seljord Group
1650-1600 Ma:	The Rjukan Group and similar supracrustals in the following regions: Numedal, Brunkeberg- Seljord, Nisservatn- Fyresvatn, Amli, Søsuvatn-Valldal.

B. The bimodal volcanics of the Rjukan Group and equivalent lithologies were deposited in fault-controlled basins on the Baltic shield, possibly under a gross-scale tectono-magmatic regime reminiscent of the Basin and Range province of the western U.S.A. A caldera-related origin for the bulk of the acid volcanics is inferred, while the basic volcanics may have been related to fissure eruptions or shield volcanoes.

C. The Seljord Group quartzites were similarly deposited in fault-controlled basins on a continental plate, partly synchronously with the Rjukan Group and partly surpassing this in time. The depositional environment was characterized by large shallow-water lakes or inland bays.

D. The Bandak Group and equivalent lithologies comprise a sequence of bimodal volcanics and relatively immature clastic and volcanoclastic sediments related to renewed continental rifting. The bulk of these rocks was deposited on land while localized mudracks

and pillow structures in the eastern districts suggest deposition under shallow water. Taking the regional geological setting into consideration it is proposed that this lithological group was deposited in a failed rift arm (aulacogen) in a former trilete continental rift system.

- E. The andesitic volcanics of the Heddevatn Group were deposited on land and reflect the build-up of a Grenvillian arc in the westernmost part of the Telemark district.
- F. Major deformation and metamorphism took place at ca. 1540 Ma and 1050 Ma. Late stage granites were emplaced at 1100-850 Ma and subsequent block faulting took place along three directions: NNE-SSW; NW-SE; and NE-SW.
- G. Stratabound precious metal bearing sulphide mineralization is present in all of the major lithological units. High background values of Cu, Fe, As, Ag (and Ni, Co) characterize sulphide bearing acid volcanics of the Rjukan Group and may reflect the products of compositionally zoned rhyolitic magmas, possibly emplaced during collapse of calderas. Acid, silicified tuffs with higher Au (-Cu, Pb, Zn, Ag, As) background values occurring in the same general area may represent altered porous beds that received their load of metals from hydrothermal cells operating in the above mentioned lithologies.

Sulphide mineralization with minor precious metals occurring in basic volcanics of the Rjukan Group are related to siliceous, probably fumarolic emanations. This group is dominated by Cu (Pb, Zn) and Ag while gold has been found to be subordinate. However, the Listel As-Cu-Ag(-Au) deposit may belong to this group or it may be a highly deformed epigenetic vein deposit.

Stratabound sulphide mineralization occurring in the central part of the Bandak Group is characterized by various types of Cu-(Fe)-Ag deposits showing a clear affiliation to basic, alkaline volcanics. Gold is present as a very minor constituent and the economic potential of this group is tied up with its Cu and Ag contents. The western part of the Bandak Group shows a wider range in stratabound metal associations including Zn, Cu and Mn; however, more information is needed from this area before its precious metal potential can be evaluated.

In summary, the most promising stratabound precious metal target appears at present to be the acid (and basic) volcanics of the Rjukan Group, especially in the area around Tuddal where indications of a caldera setting are present.

- H. Vein-type mineralization is interpreted as having been controlled by late fracturing and the action of hydrothermal cells set up by a late heating event produced by post kinematic granites and a concurrent anatexis of the basement. The metals originated from various sources. Cu and Ag primarily from the basic volcanics of the Bandak Group; Mo, Sn, W, F, Bi, Li, Be and REE from the basement gneisses and granitoids; and Au, Pb, Zn and As from the basement and from the acid volcanics of the Rjukan Group.

Moberg-Mosnap-type Cu-veins appear to represent the largest veins with a significant Ag content and minor Au content occurring in the district; however, taken individually these veins are without significance and their potential depends on either the presence of a large number of veins inside a small area or disseminated Cu-Ag(-Au) mineralization in the mother granite stock. The Klovereid Cu-Bi(-Au) veins and disseminations may represent an example of the latter type and should be checked.

- I. Stream sediment sampling is a suitable regional exploration tool; a preliminary survey has shown the presence of significant anomalies in the area surrounding Bleka, and two areas in the Rjukan Group stand out including the newly discovered gold-bearing acid tuff at Tuddal. However, some work is required with the fine tuning of this method.

6.

RECOMMENDATIONS

- A. Based on the occurrence of low grade Au-mineralization in the acid tuffs at Bonsvatn, high background values of (Au), Ag and As in acid volcanics of the same general area and scattered stream sediment anomalies on Au and As (Cu, Pb, Zn), it is recommended that the precious metal potential of the acid and basic volcanics of the Rjukan Group is tested in 1984. This should be done by geological mapping and lithogeochemical sampling (blasting) centered upon the Au-bearing tuffs at Bonsvatnet and aided by a Landsat imagery and an airport structural interpretation of a wider area in order to delineate highly fractured areas. The extent of this mapping and sampling programme should be determined by the geological and geochemical results, necessitating a quick response from the analytical lab. Further, a stream sediment survey is recommended. This should be divided into two parts: a detailed survey in the area Breidvatnet- Tuddal - Tinnsjø - Rjukan and a regional survey in the Rjukan Group volcanics to the north from Rjukan.
- B. The high Au-values reported from the Bleka vein, the large number of (gold-bearing) veins in this area, the favorable host rock/structural trap situation, and the chance of defining bulk tonnage mineralization in structurally complex areas motivate further work around Bleka. This should focus on detailed mapping and sampling of a major part of the amphibolites in the area emphasizing alteration and aided by an airphoto - and ground interpretation of structures and associated mineralization; furthermore some microscopy of the mineralized veins and alteration zones and a minor study of the fluid inclusions of the veins should be carried out in order to determine zoning patterns. Secondary methods including deep overburden sampling and VLF,

magnetometry and IP/resistivity measurements should be guided by the geological field work. The tenure situation is shown in Appendix 2 and to some extent in Fig. 57. ASPRO holds 6 claims (from 1982) in the Bleka mine area. NH has a 16-block claim over the same area and its surroundings, an 8 block claim to the northwest from this and a 16 block claim over Gjuv. It is felt that at present there is no reason to contact ASPRO with a view to establish a joint venture; NH holds most of the ground and Bleka itself need not turn out to be the most promising target.

- C. A small follow-up programme is suggested for the Moberg-, and Mosnap areas. At Mosnap the localities of the stream sediment anomalies must be examined by a geologist. At Moberg an IP/resistivity survey covering both the Moberg and the Grusen veins is recommended and further geological reconnaissance in the area to the west of the line: Moberg - Aslestad should be undertaken as it contains numerous small granite bodies and dykes. Contact should be maintained with Asheim at PF who registers all old mines in this area on a hobby basis.
- D. The geophysical anomalies at Guldnes should be explained; this is best done by blast-sampling. Some geological follow-up along the mineralized horizon should be undertaken.
- E. The follow-up on the Hovin deposit should proceed according to the guidelines set up by Schönwandt (report not available at the time of writing).
- F. Further sampling and geological reconnaissance is recommended in the following areas:
 - a. The Kløvereid Cu-Bi(-Au) veins and impregnations.
 - b. The Skolterberg-Graver lithological unit.

- c. The Hovden Mn-deposit
- d. The Sauda Zn-Cu mine

G. In the case of a shortage of funds or manpower items A, B and D should be given priority.

Oslo 16/1. 1984

Frank Pedersen

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APPENDIX 1

ESTIMATE OF THE TOTAL 1983 BUDGET FOR THE TELEMARKE PROJECT (20913):

N.kr.

External expenses:

Mercury, geochem. analysis	61 000,-
Shipping and preparation of samples	5 000,-
Car hire	6 400,-
Claims	30 000,-
Equipment, unspecified	10 000,-

Field work:

F. Pedersen, 9 weeks, inclusive of transport	45 000,-
H.K. Schönwandt, 4 weeks	25 100,-
P.M. Ihlen, 2 weeks	20 000,-
H. Elstad, 5 weeks	25 000,-
R. Elstad, 6 weeks	9 000,-
T. Vejsal, 4 weeks	14 000,-
K. Norup, 9 days, inclusive of transport	6 000,-
R. Thomsen, 9 days, inclusive of transport	6 500,-

Lab.work, PF:

Åsheim, Larsen, Jacobsen:	16 000,-
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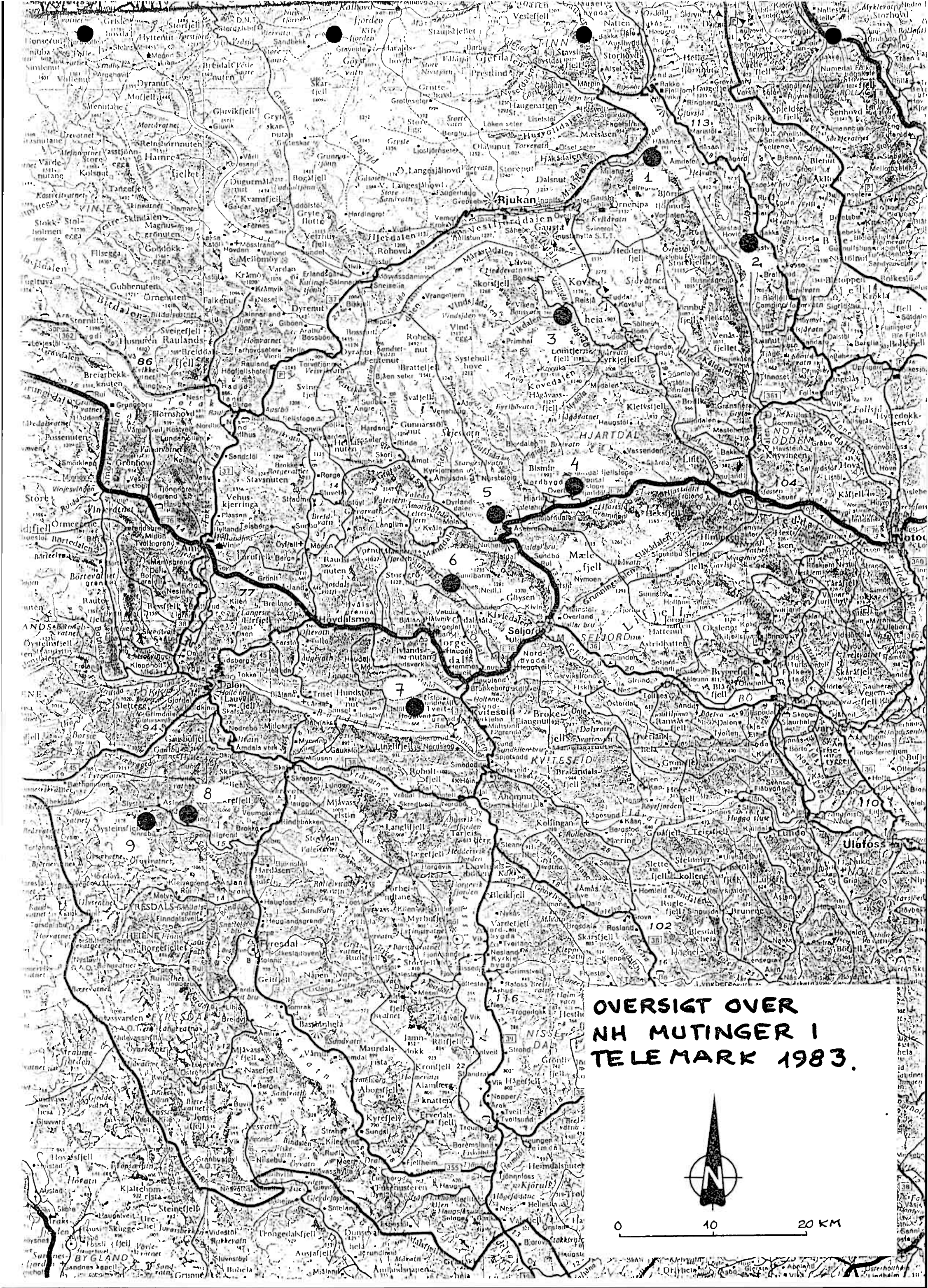
Hours, HK:

To Dec. 1, 1983:	
F. Pedersen	256 200,-
H. Elstad	130 200,-
T. Vrålstad	16 320,-
P.A. Lindberg	3 200,-
S. Parr	2 800,-
To Jan. 1, 1984:	
F. Pedersen	5 600,-
H. Elstad	7 000,-

T o t a l	N.kr. 700 320,-
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OVERSICHT OVER NORSK HYDRO MUTINGER I TELEMARK 1983

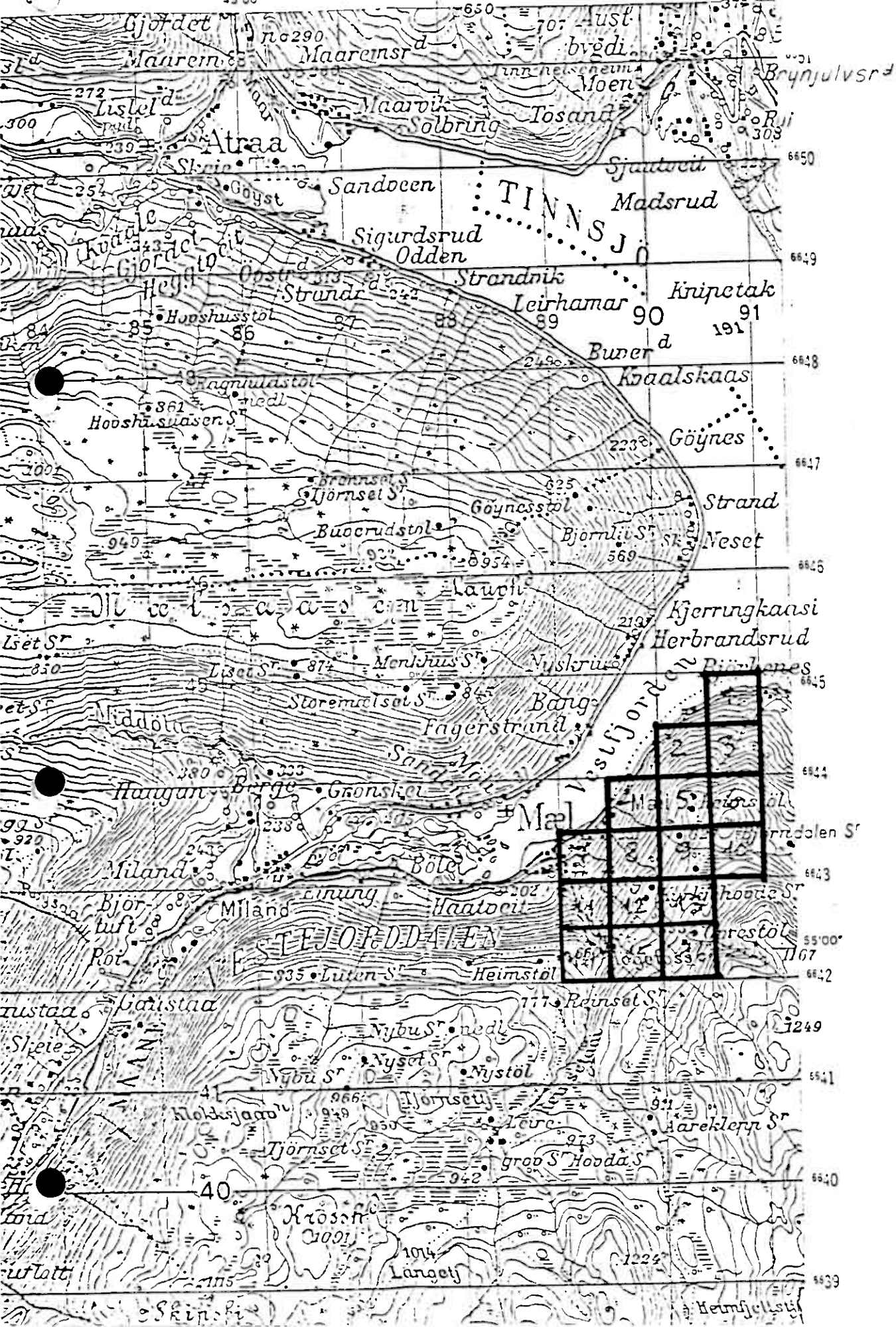
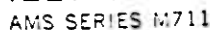
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2. Tinn	17	4.83	nej	1.8.84
3. Bonsvatn	8	6.83	nej	
4. Kvammen	16	2.83	nej	1.8.84
5. Bleka	8	12.82	ja	
5. Åkre	8	2.83	nej	1.8.84
5. Svartdal	8	2.83	nej	1.8.84
6. Sundsbarm	8	12.82	ja	
6. Sundsbarm	2	8.83	nej	
7. Listøl	8	12.82	ja	
8. Slystøl	56	9.83	nej	
8. Mosnap	29	9.83	nej	
TOTALT	184			



**OVERSIGT OVER
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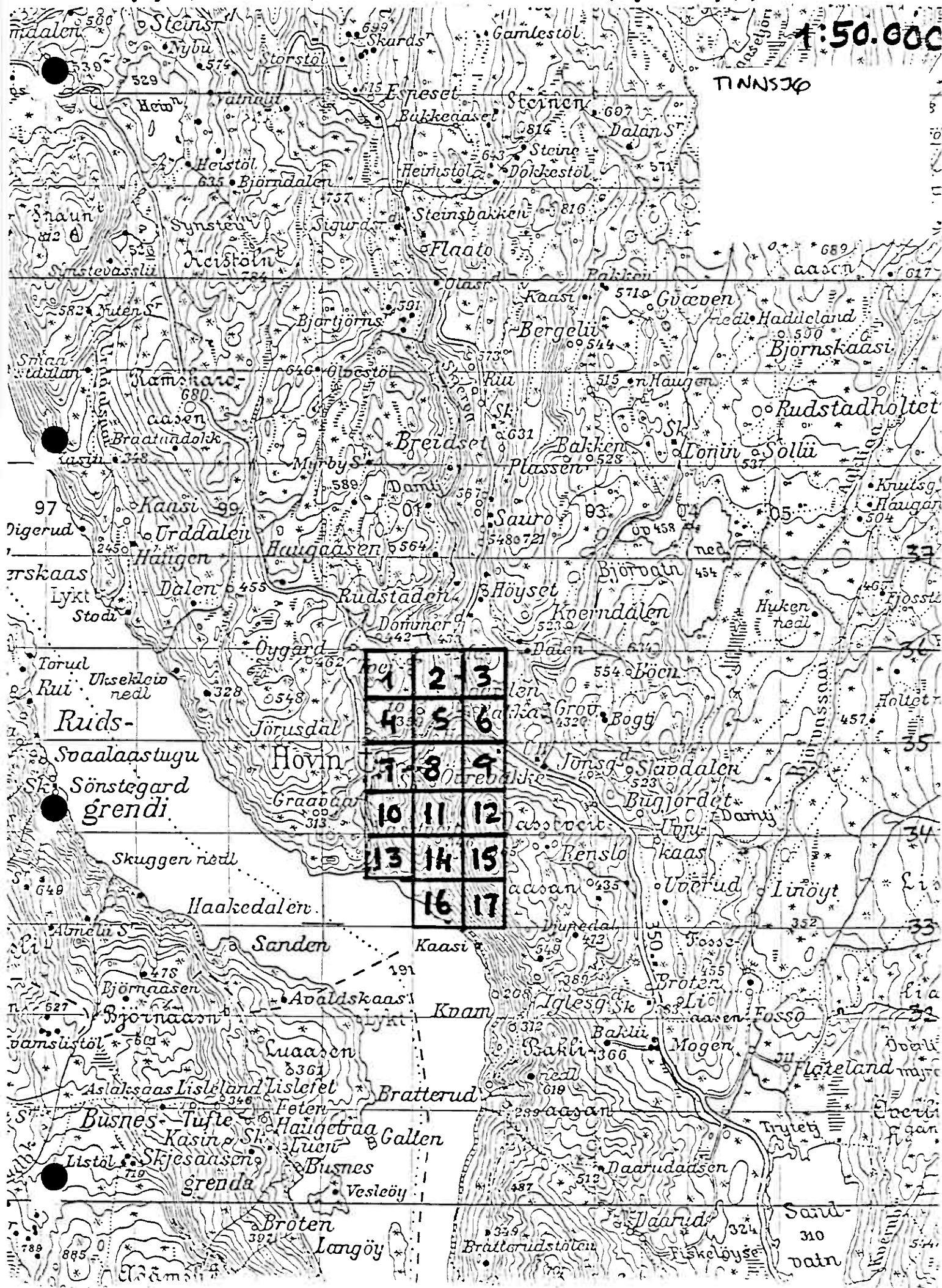


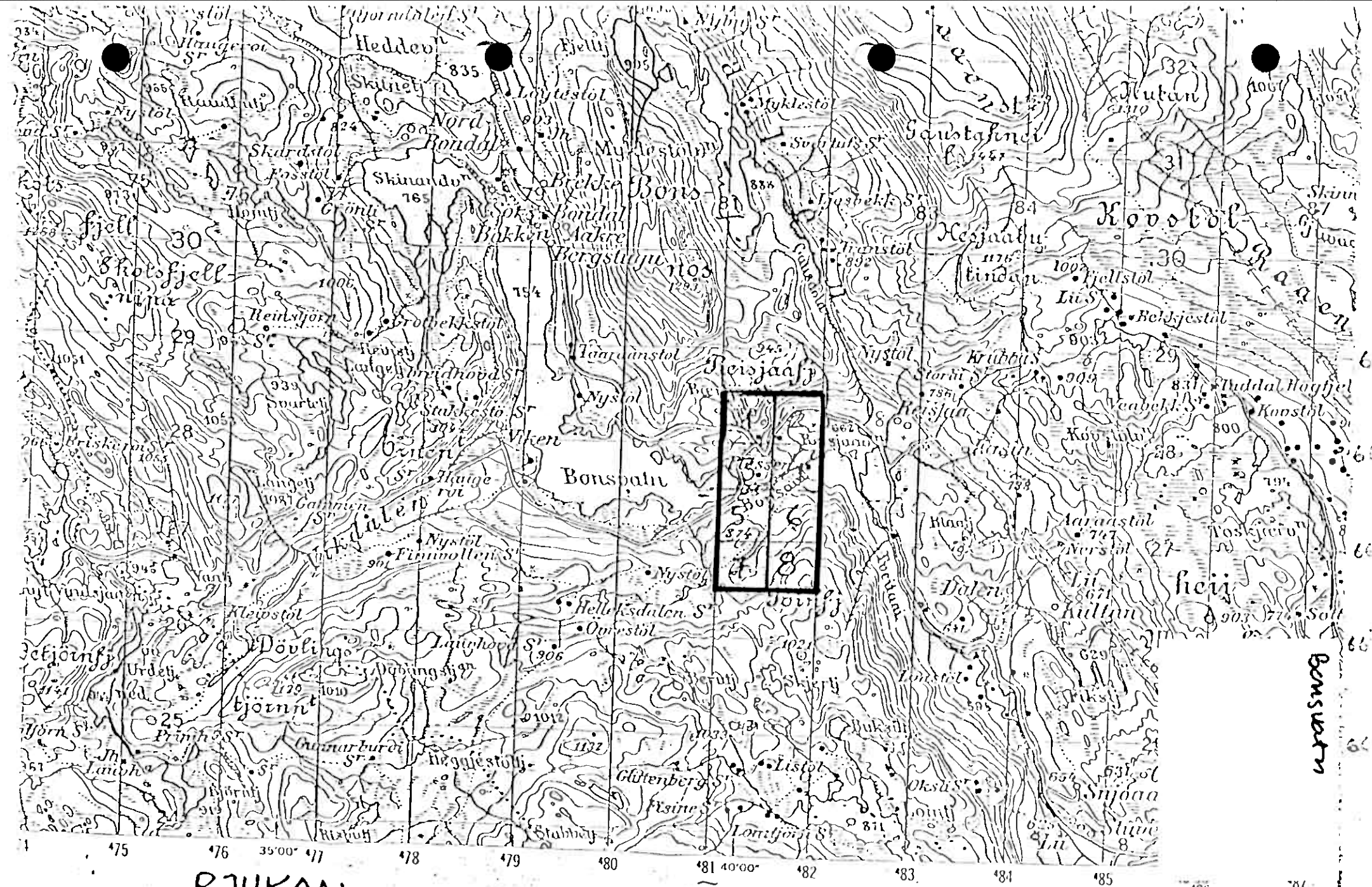
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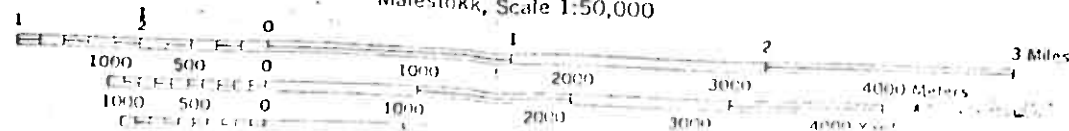
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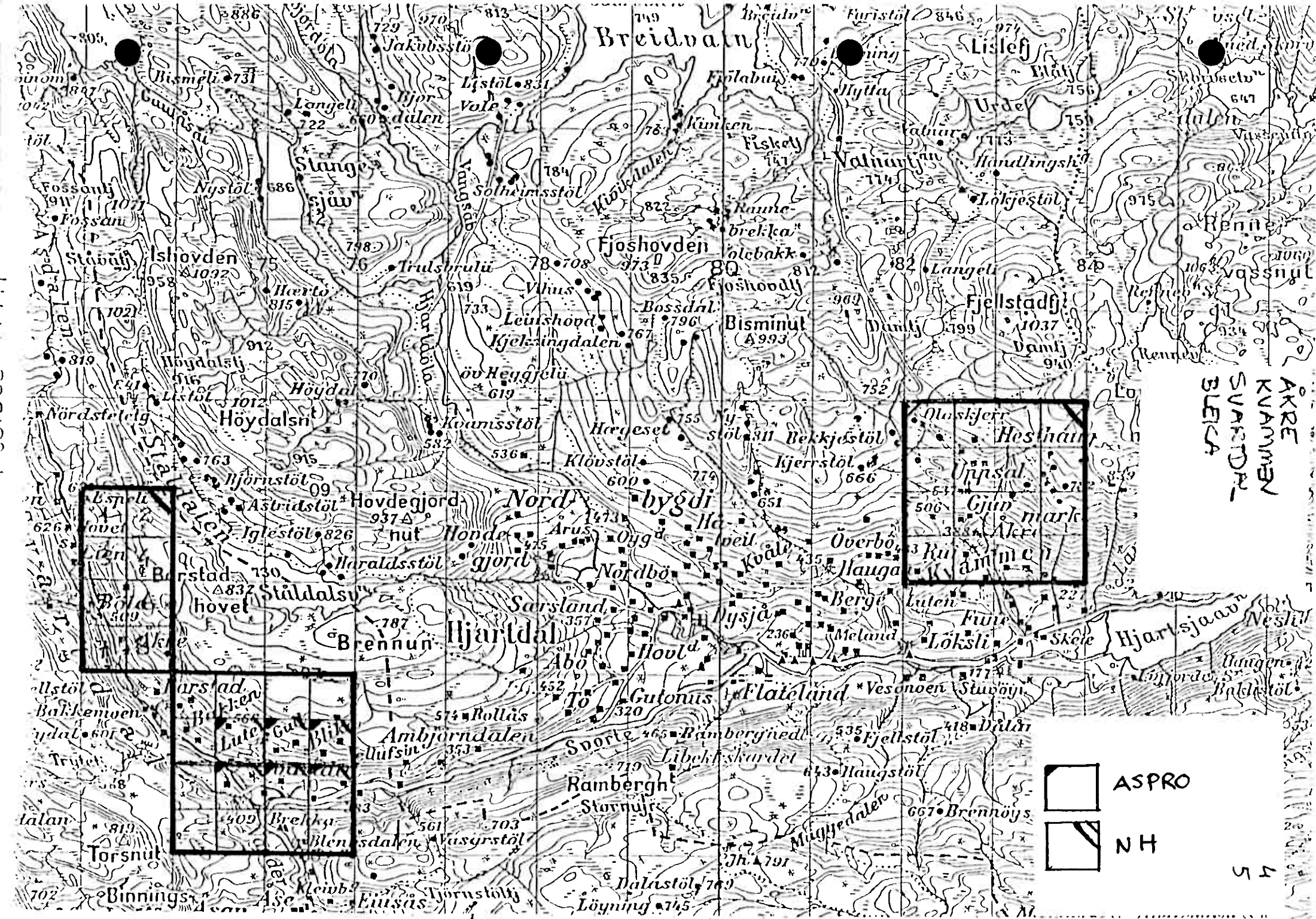


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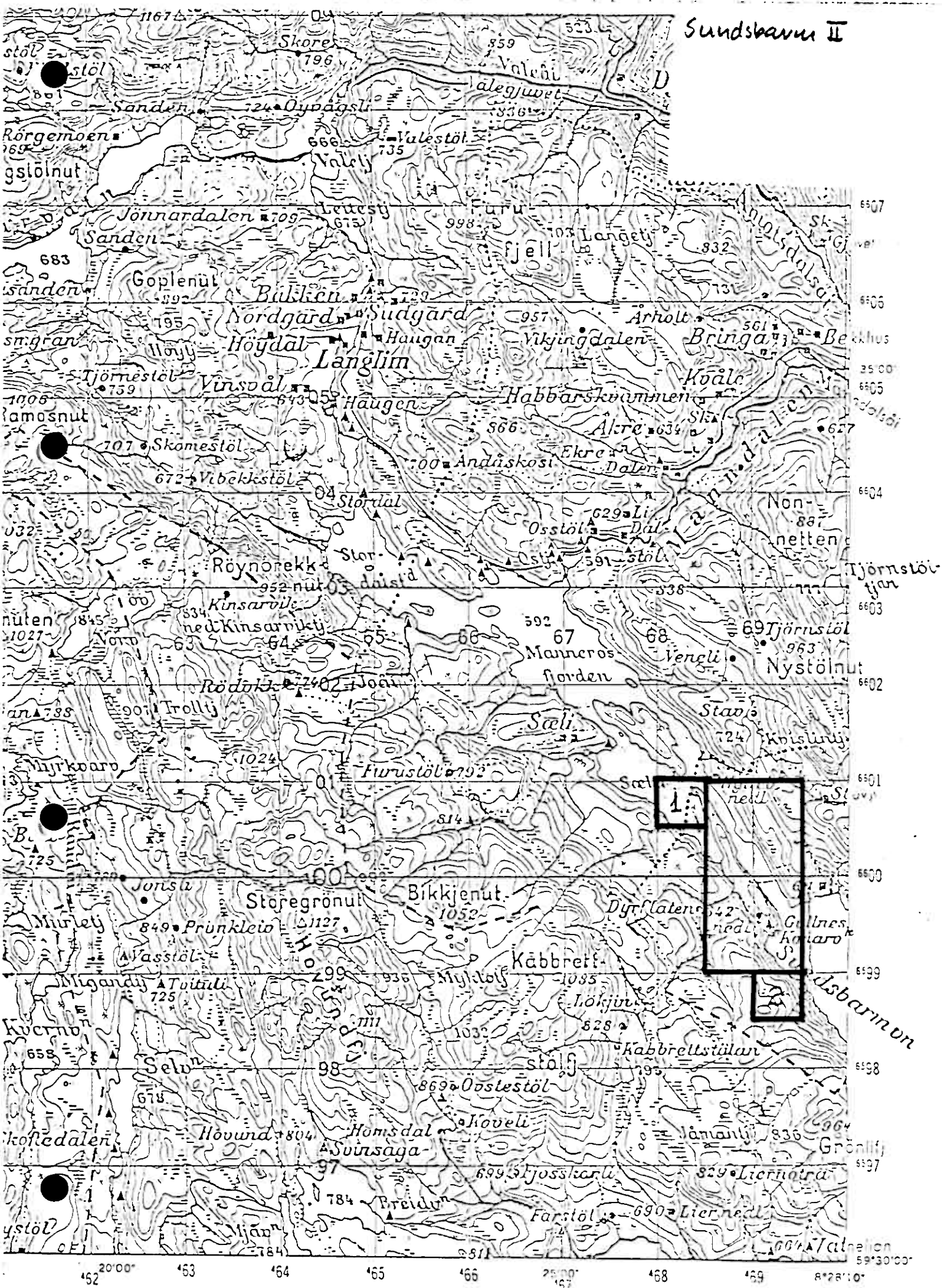
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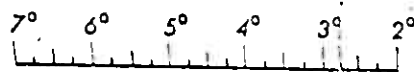
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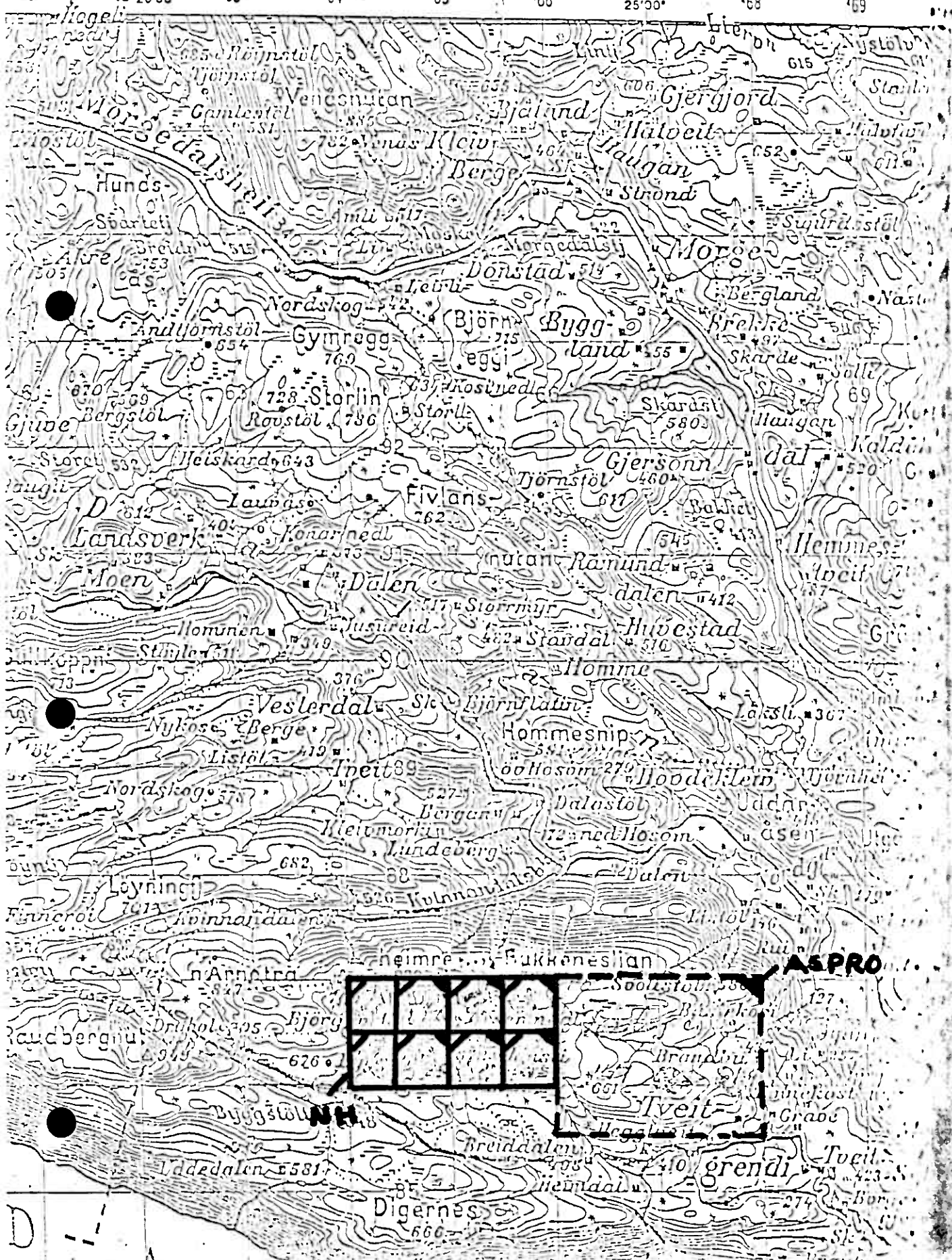
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Norsk Hydro

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☒ Rapport	☐ Notat	☐ Referat	☐ PM	Polydoc nr. (NR)	Arkivnr. (BI)
Rapport nr.	Eksemplar nr.			Antall sider (BI)	Arkivsted (BI)
				5	
Situasjon	Foresing			Tittel (TI)	
	1. T.Vrålstad 2. F.D.Pedersen 3. H.Elstad 4. arkiv (rød) 5. " (grønn)			Geofysikk over Guldneshalvøya, Seljord. 1983	
				Divisjon	
				T&F	
				Avdeling/seksjon	Dato (BI)
				Prospektering	3.1.1984
				Forfattet av (FO)	Red. H&E/Skj
				H.Elstad	
				Godkjent av	
				Vedr. ordrenr. (FA)	Sted/land (FA)
				20913-021	Telemark
Emneord (EO)					
Geofysikk				Magnetiske målinger	
IP-RP-målinger				Elektromagnetiske målinger (VLF)	

Resymé/konklusjon (RE)

Bakgrunnen for målingene var å undersøke den mineraliserte sone hvor Guldnes gruve ligger. Likedan var det av interesse å se hvor anvendbare de forskjellige metoder er på denne forekomst-type.

Det fremkom tydelige og klare anomalier med mag. og IP. Innenfor det undersøkte området ser forekomsten ut til å være for liten til å ha økonomisk interesse. Men det er ikke klarlagt noen begrensning i strømkretningen.

Anbefaling, videre arbeid

Det anbefales mag.målinger på isen over Sundsbarmvann inneværende vinter. Likedan bør det tas jordprøver og fastfjellsprøver i stikningsnettet.

En geofysisk undersøkelse med helikopter bør også vurderes for en større del av området.

INNHALDSFORTEGNELSE

Innledning	side 1
Målemetoder - utstyr	" 1
Målingenes utførelse	" 3
Resultater	" 3
Konklusjon	" 5
Anbefaling til videre arbeid	" 5

BILAGSOVERSIKT

Bilag 01:	Oversiktskart	M 1:50.000
" 02:	Isolinjekart magn. totalfelt	M 1:1000
" 03:	Isolinjekart FE-%	M 1:1000

INNLEDNING

I tidsrommet 3.10. - 22.10.1983 ble det utført IP-RP målinger, magnetiske målinger og VLF-målinger over Guldnes-halvøya ved Sundsbarmvannet i Seljord kommune, Telemark.

Hensikten med målingene var å kartlegge den mineraliserte sonen hvor gamle Guldnes gruver ligger. Samtidig var det også av interesse å se hvordan metodene - da i første rekke IP-metoden - er egnet til å kartlegge denne type mineraliseringer.

Guldnes-forekomsten har ifølge P.M.Ihlen to typer mineraliseringer:

Den ene er en lavgehaltig disseminasjon av kobberkis og pyritt i vulkanitter.

Den andre typen består av magnetitt, kobberkis, bornitt og kobberglans, og finnes bare innenfor breksjer og metadoleritter. Det er den siste mineraliseringstypen det har vært drevet på.

MÅLEMETODER - UTSTYR

IP - RP

Målingene ble utført med følgende utstyr utlånt fra A/S Folldal Verk:

Sender: McPhar HPIPTx o-690 V, o - 5A.

Mottaker: McPhar P 660

Strømforsyning: ILO, totaktsgenerator utstyrt av McPahr.

Effekt: 2.5 kVA

Utgangsfrekvens: 500 Hz

Utgangsspenning: ca. 110 V.

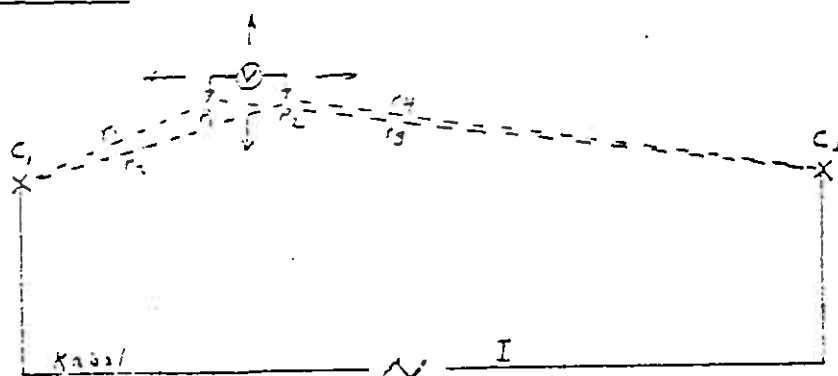
Til strømkabel ble benyttet 1.0 mm² kabel med kobberkjerne.

Som strømelektroder ble benyttet kobbertråd.

Benyttet elektrodekonfigurasjon: Gradient.

Motstanden (RP) ble målt ved 5.0 Hz, og frekvenseffekten (FE) mellom 5.0 og 0.3125 Hz med førstnevnte som referanse.

Gradient.



Beregning:

$$\text{Motstand: } \rho_a = \frac{\Delta V \cdot \rho_1 \cdot \rho_2}{I} \cdot 2 \pi \left(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4} \right)^{-1}$$

$$\text{Fremtenseffekt: } P = \frac{2 \pi \cdot \rho_a \cdot I^2 \cdot \left(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4} \right)}{\rho_a \cdot I}$$

Mag.målingene

Målingene ble utført med protonmagnetometer av type Scintrex MP 2, som måler det magnetiske totalfelt med en nøyaktighet på 1 gamma.

Ett basispunkt ble målt 5 ganger daglig. Dette viste en daglig variasjon mindre enn 20 gamma, noe man ikke fant grunn til å korrigere for.

Instrumentene ble hver dag etter endt måling testet med en magnetometertester av S.Paulsen type. Evt. tekniske feil ved instrumentet vil avsløres med denne test.

VLF-målingene

Det ble benyttet et instrument av S.Paulsen type.

Det ble gjort dip-vinkelmålinger på feltet fra den amerikanske sender NAA, som sender på 17.3 kHz.

For at det skal fremkomme anomalier med VLF er man avhengig av en viss ledningsevne og en strøkutstrekning mot senderen på minst 200 m.

UTFØRELSE

Med utgangspunkt i et trig.punkt like ved gruva, ble det stukket en basislinje i retning 150° langs hele halvøya. Det ble satt ned en stikke for hver 20. m. Ut fra denne ble det stukket profiler med avstand 40 m.

Stikning av basislinjen foregikk med siktetrommel, kompass og målebånd. Stikningen av profilene ble gjort med kompass og målesnor.

Basislinje og profiler fremgår ellers av bilag 2 og 3.

Hele halvøya ble målt med mag. Området øst for 1000 NV ble målt med VLF, og området øst for 1320 NV ble målt med IP-RP.

IP-målingene ble gjort med 2 kabelutlegg. For begge utleggs vedkommende ble den ene av strømelektrodene senket ned på bunnen av Sundsbarmvann.

Elektrodenes plassering fremgår også av bilag 2 og 3.

Man fikk en forholdsvis lav strømstyrke på utleggene - 0.5 - 0.6A - men det viste seg å være tilstrekkelig med den korte avstand mellom strømelektrodene som ble benyttet (ca. 400 meter).

Over anomale områder ble det, både med mag. og IP, målt mellom de stukne profiler, slik av profilavstanden der ble 20 meter.

Langs profilene var målepunktavstanden 10-20 m.

Instrumentene fungerte perfekt etter en noe uheldig start med IP-utstyret.

I forbindelse med en justering av mottakeren som Follidial Verk hadde fått utført for en tid tilbake, var det glemt å løse opp en kortslutning av forsterkeren. Dette medførte en dags forsinkelse, men programmet lot seg likevel gjennomføre innen det planlagte tidsrom.

RESULTATER

VLF-målingene ga ingen tolkbare anomalier, noe som heller ikke var ventet på denne mineraliseringstypen. En fant derfor ikke grunn til å måle ferdig området med denne metoden.

Både mag. og IP ga derimot klare og veldefinerte anomalier. RP-delen av målingene (motstand) ga derimot ingen anomalier som kunne tilskrives den aktuelle mineralisering, eller forhold i forbindelse med denne.

I presentasjonen er det derfor valgt å sløyfe VLF- og RP-målingene.

De magnetiske målingene

Resultatene er presentert i bilag 2.

Det fremkom tildels kraftige anomalier med styrke opp mot 3500 gamma over normalfeltet, som i dette området ligger på ca. 50.000 gamma.

Selve malmsonen som det tidligere har vært drift på, ga ingen magnetiske anomalier.

Like nord for det nordligste dagbruddet er en forholdsvis kraftig anomali. Det finnes flere røsker innenfor anomalien, og ifølge P.M.Ihlens geologiske kart, ligger det en breksje med magnetitt i matriks, og det er høyst sannsynlig denne som kommer frem.

Den største mag.anomalien ser vi noe lenger vest - bilag 2. Det finnes noen meget gamle røsker langs anomalien, men ellers er området forholdsvis mye overdekket.

Anomalien ser ut til å dreie vestover, og den blir muligens brutt av en forkastning, men dette kan ikke sies sikkert før det er foretatt ytterligere målinger. Bredden på det anomale området er ca. 100 meter. Hvorvidt denne anomalien også skyldes en breksje er usikkert, slik at dette må klargjøres med en geologisk undersøkelse.

IP-målingene

Resultatene er presentert i bilag 3. Anomaliens størrelse når opp til maks. 5% FE. Med et bakgrunnsnivå på 1.5% vil dette gi en anomalistyrke på maks. 3.5%. Dette er forholdsvis beskjedne anomalier, men med det rolige bakgrunnsnivå er anomaliene likevel klare og entydige.

Det anses som sikkert at det er sulfidmineraliseringen som gir IP-effekten. Bidraget fra magnetitt anses for minimalt, da anomaliene fra mag. og IP ikke faller sammen.

Den sterkeste IP-effekt ser vi ca. 100 m nordvest for dagbruddet, og med en tydelig sammenheng ned til dagbruddet og videre til gruva.

Det finnes få blotninger akkurat der hvor vi har sterkest IP, men trolig har vi en sterkere sulfidmineralisering i dette området.

De tildels store berghallene mellom gruva og dagbruddet vanskeliggjorde målingene noe, da det var vanskelig å få elektrisk kontakt med berggrunnen akkurat i dette området.

KONKLUSJON

Både IP og mag. synes godt egnet for kartlegging av denne type forekomster. Kombinasjon av de to metoder synes nødvendig, da det ikke er de samme mineraliseringstyper som gir anomalier ved de forskjellige metoder.

Magnetitt er et mineral som normalt gir en viss IP-effekt, og i dette tilfellet med ganske små IP-anomalier, burde man forvente et bidrag fra dette mineral hvis det forekommer disseminert.

Man kan derfor konkludere med at magnetitten forekommer i en form som ikke gir anledning til polarisasjon, f.eks. sprekkefyllinger.

Innenfor det målte området ser forekomsten ut til å være for liten til å ha noen økonomisk interesse, men man skal ikke se bort fra at det kan finnes liknende mineraliseringstyper langs det samme strøket.

Noen begrensning av anomaliene i strøkretningen er ikke klarlagt med denne undersøkelsen.

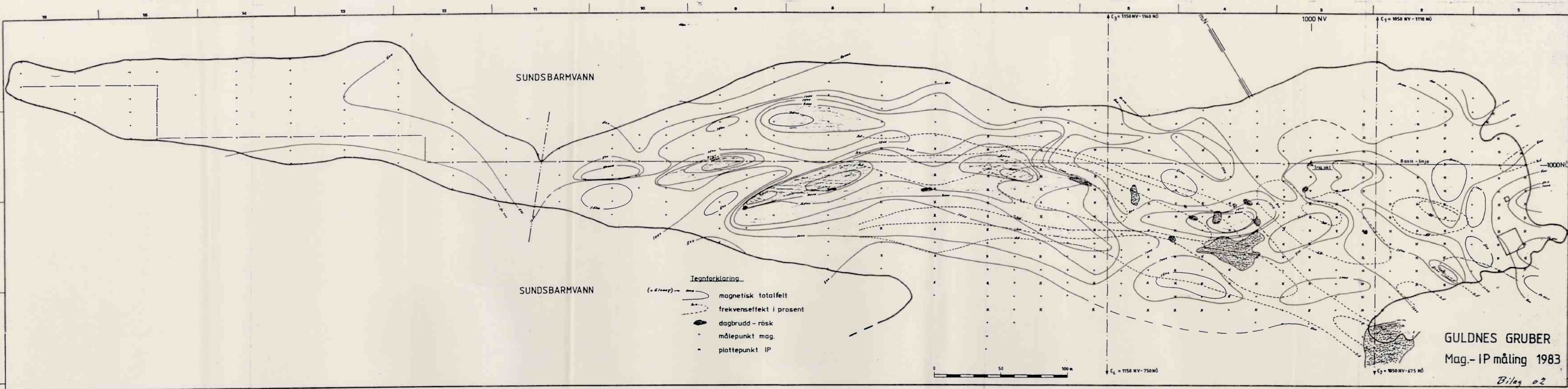
ANBEFALING TIL VIDERE ARBEID

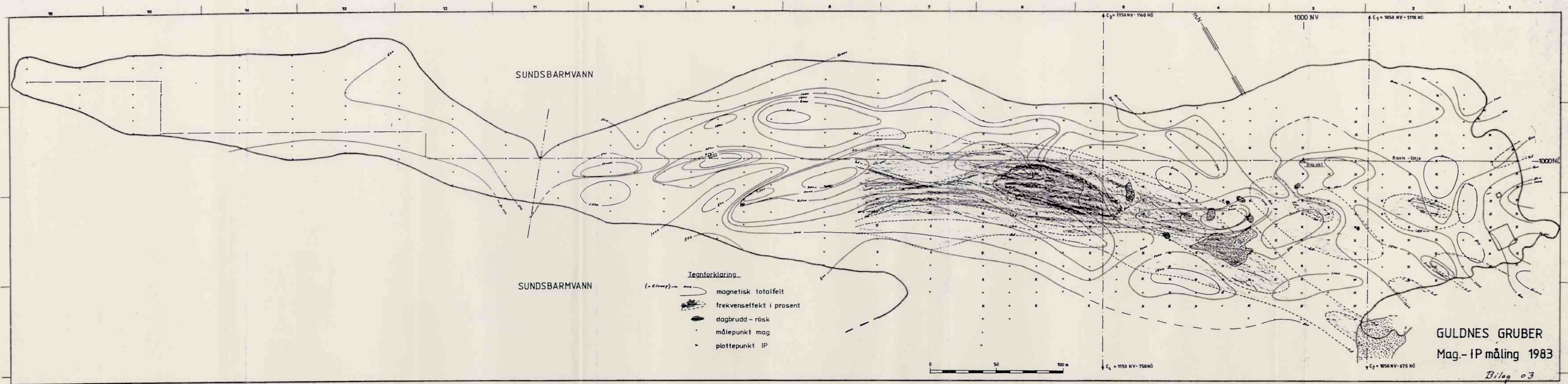
Det anbefales en begrenset vinteraksjon med magnetiske målinger på isen, for å klarlegge sonens videre forløp, og for å få et noe større bakgrunnsbilde.

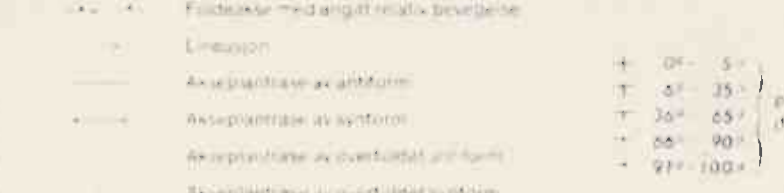
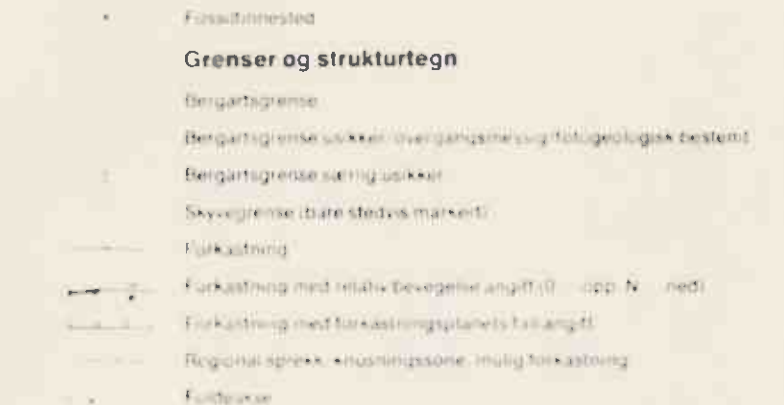
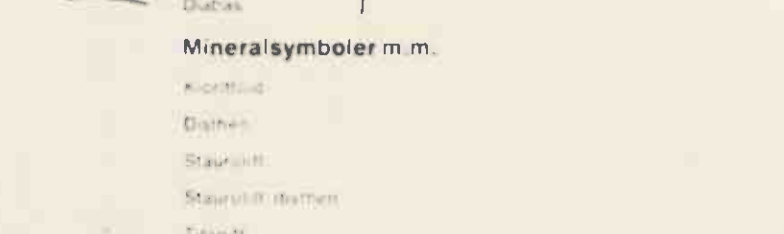
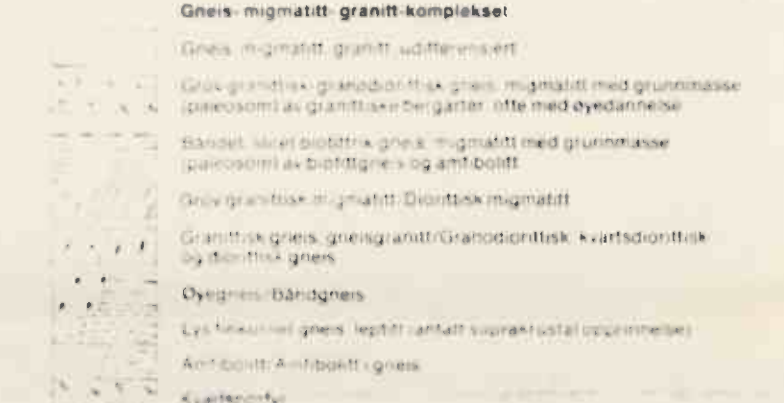
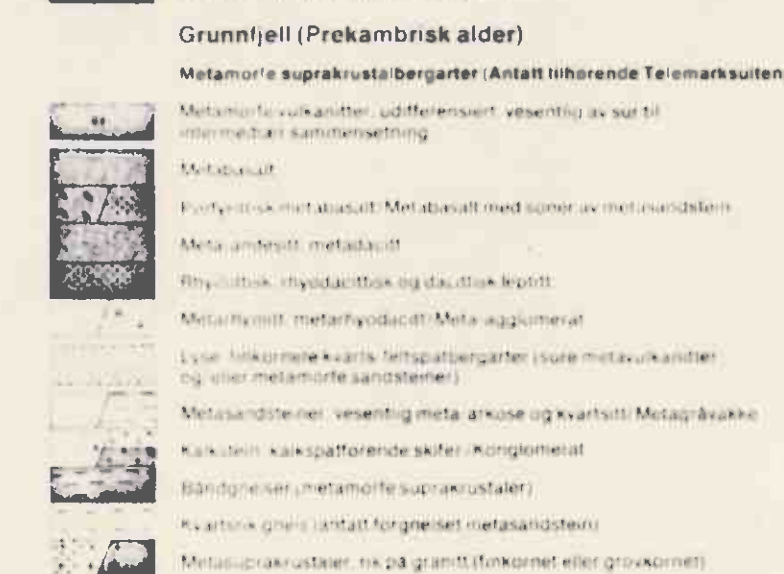
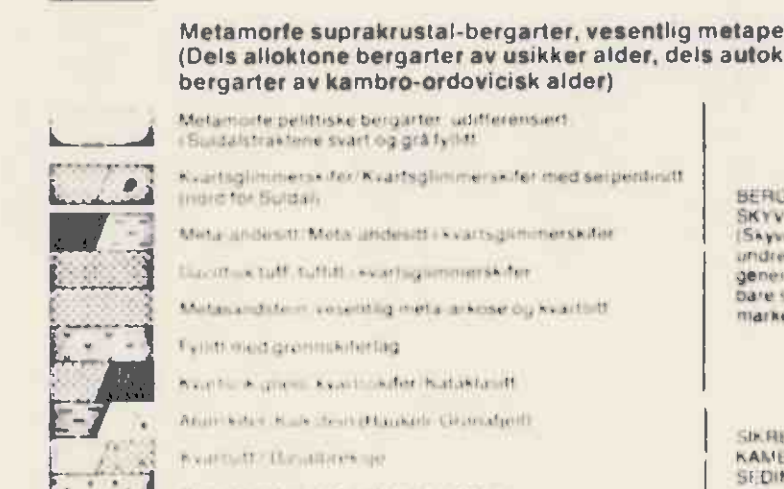
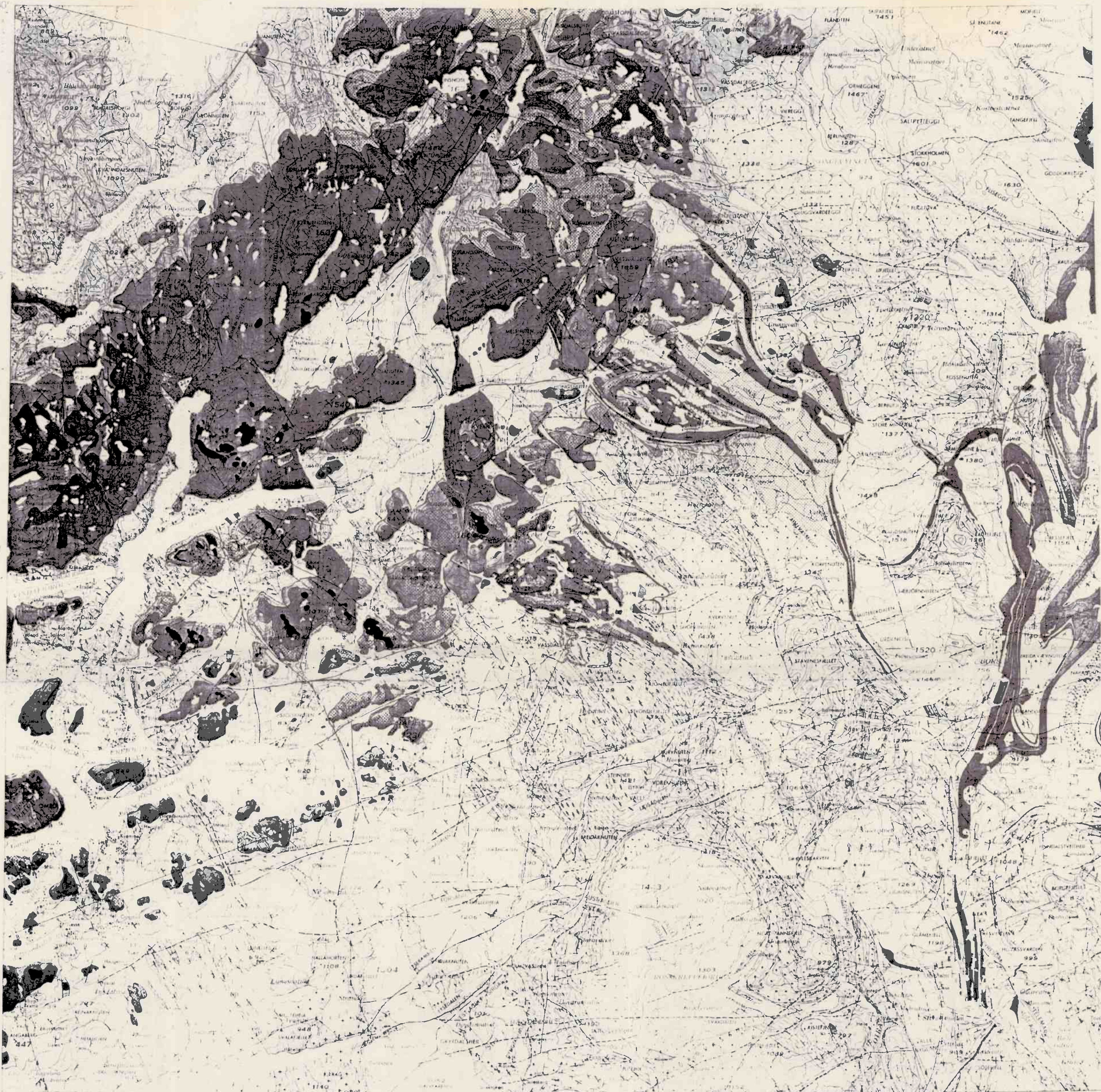
Kommende sesong bør det også tas jordprøver i stikningsnettet, evt. også fastfjellsprøver der dette er mulig.

Hvis forekomst-typen anses for lovende, bør det vurderes en geofysisk undersøkelse med helikopter over en større del av området så tidlig som mulig i sesongen, slik at en stor del av oppfølgingen kan skje samme høst.

Oslo, 3.1.1984







Oslo 1961

KVTEID

Plate 3

Løse avleiringer

Quartz, mica & deposits

Bregus, elveavsetninger, myrer og marine sedimenter +
Moraine drift, river deposits, bogs and marine sediments = 6

Berggrunn

Rev. A.

	Stor grønnitt-pegmatitt gang
	Larve granitt pegmatitt dykke
	Granittisert porfyr
	Granitt
	Gneis og granitt
	Gneis og granitt
	Røde arkose bergarter, vesentlig lagertegnet
	Røde arkose bergarter, vesentlig lagertegnet

Telemarksuiten

The Telemark suite

Bandakgruppen

Bandak group

E	Flötberg kvartsskaifer med flere konglomeratbenker	
g	Flötberg quartz schists with several beds of conglomerate	
K	Ørnrebrekk marmor	
k	Ørnrebrekk marble	
G	Gjåve lava, basisk, med Hauge skifer (fossiliferøs)	
g	Gjåve lava, basic, with Hauge schists (fossiliferous)	
d	Dalen porfyr, rød lava	
d	Dalen porphyry, red lava	
B	Bergstøl konglomerat, polymikt	
B	Bergstøl conglomerate, polymict	
M	Morgedal lava, basisk med 1-4 lag	Morg. 1-4
M	Morgedal sandstein, til dels konglomeratisk	Morg. 1-4
M	Morgedal lava, basic, with 1-4 beds of	Morg. 1-4
m	Morgedal sandstone, partly conglomeratic	Morg. 1-4
R	Røynestrand kvartsitt med konglomerat	
R	Røynestrand quartzite with conglomerate	
O	Øfte porfyr, rød lava, lokalt trøndel med kvartsitt inddelt i	
O	Øfte porphyry, red lava, locally divided into quartzite and	

Seljordgruppen

Seljord group

L Seljord kvartsitt med basiske intrusivt gæriger, konglomerat nær basis
Seljord quartzite with basic sills and dykes; conglomerate near base

Basiske bergarter, omfattende kvartær tilvs stratigrafisk tilhørende
er usikre) og instruksiv
Basis rocks, including list of uncertain stratigraphic position
and instruxes
Kvartstift i nordvest, sydost og syd. Stratigrafisk tilhørende
Quartzite in NW, SE and S. Stratigraphic position a

Rjukangruppen

Ryukyu group

v	Basiske lavener og tuffar i nordvest	1	Vennock (basalt)
	<i>Basic lavas and tuffs (in NW)</i>	1	Vennock (basalt)
p	Sure lavener (og tuffar) med agglomerat, omfatter også kvartssandemner i syd	2	Tuallik (basalt) og Vennock (basalt)
	<i>Acid lavas (and tuffs) with agglomerate, comprises also quartz sediments in SE</i>	2	Tuallik (basalt) og Vennock (basalt)

----- Forklættninger
Faults

Gyldenr. skjerp $\frac{1}{2}$ 1 2 3 4 5 6 7 8

Mings. cassin.

* Føddingskæder
Foll axes

1 1 1 Stræk og fall
1 1 1 Strike and dip



*Frarbejdet er grundlag for grundlovsrat Kjøbenhavn
Litografert og trykt i Norges geografiske oppmåling 1961*

Geologisch kartiert av Hovork Næsmund og Johannes A. Dons, 1941—59
Geology by Horvok Næsmund and Johannes A. Dons, 1941—59.

Multi-Cell FPGAR

NORGES GEOLOGISKE UNDERSØKELSE

Geologisk kart

RJUKAN

Oslo 1961

Plate 4

Løse avleiringer

Quaternary deposits

Berggrunn

Rock

Granittisk porfyr
Granitoid porphyry

Granitt
Granite

Gneis og granitt
Gneiss and granite

Basiske intrusiv bergarter, vesentlig rhyolitt
Basic intrusive rocks, mainly rhyolite

Telemarksuiten

The Telemark suite

Bandakgruppen

Bandak group

Rubekkeporfyr
Rubekke porphyry

Kvartskonglomerat
Quartz conglomerate

Seljordgruppen

Seljord group

Brattfjellkvartsitt, lokalt med brattfjellkvartsitt
Brattfjell quartzite, locally interbedded with brattfjell quartzite

Vindspiskifer, i vest med krakkekvartsitt og kalkkvikke
Vindspis schist, in west containing the krakke quartzite and kalkkvikke

Skottfjellkvartsitt, lokalt med skottfjellkvartsitt
Skottfjell quartzite, locally containing skottfjell quartzite

Lauvhaugkvartsitt, kalkholdig
Lauvhaug quartzite, calcareous

Bandakskifer
Bandak schist

Gaustakvartsitt, lokalt med gaustakvartsitt
Gaustak quartzite, locally containing gaustak quartzite

Rjukangruppen

Rjukan group

Basiske lavaer og tuffer samt kalkkvikke og konglomerater, i nordvest lokalt
sitt med konglomerat.
Basic lavas and tuffs, calcareous and conglomeratic, in the north-west locally
sitt with conglomerate.

Rhyolitt med flytstruktur
Rhyolite with flow structure

Mariniskonglomerat (agglomerat)
Marine conglomerate (agglomerate)

Sure lavaer og tuffer
And lavas and tuffs

Forkastninger
Faults

Andre markerte sprøkkelinjer
Other prominent fracture lines

Gryper, skjær
Mines, chert

Skaringsstriper
Glacial striae

Foldingsaker
Fold axes

Strøk og fall
Strike and dip



GOTHIAN SCENARIO OF SOUTHERN SCANDINAVIA

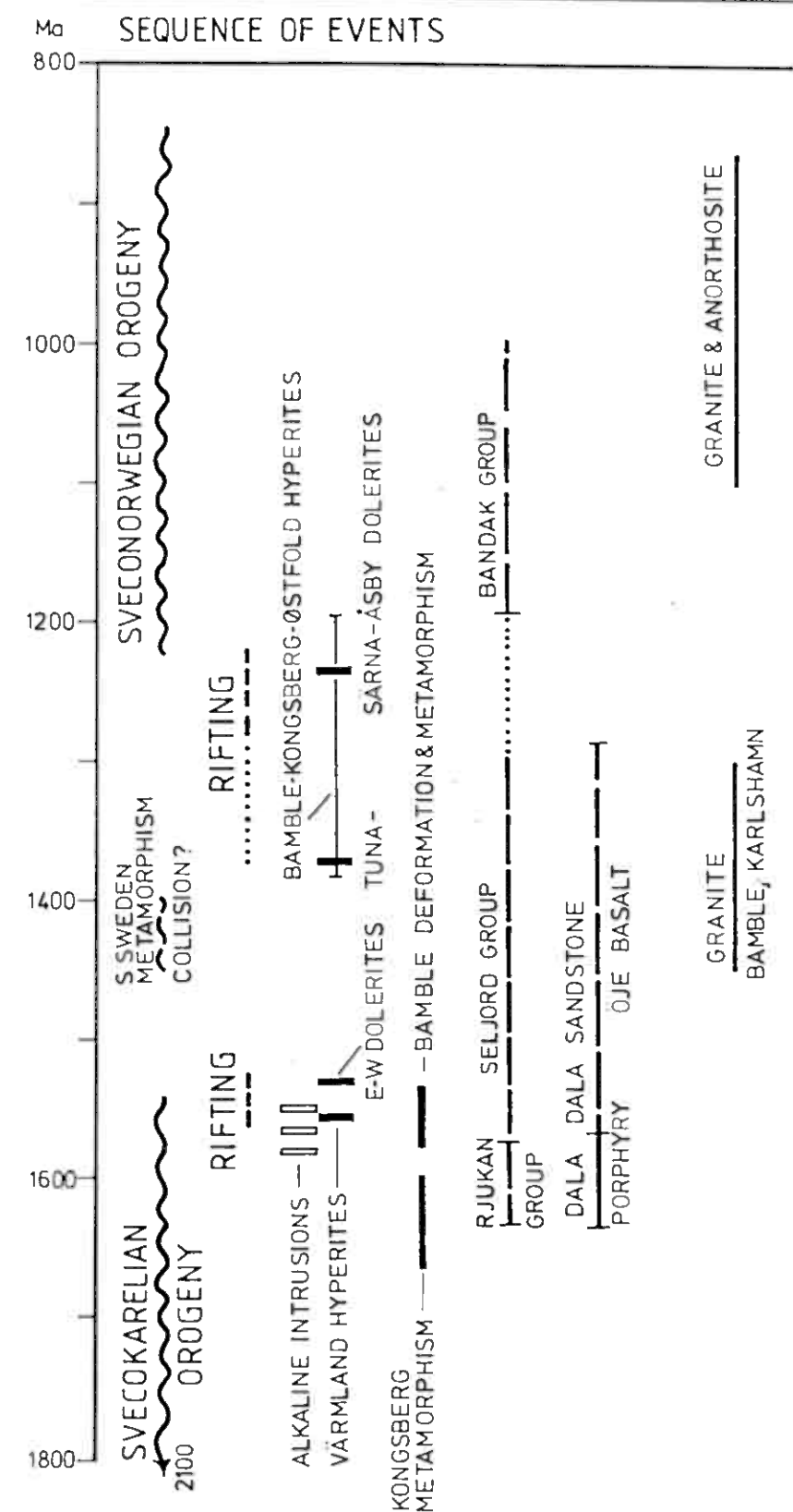
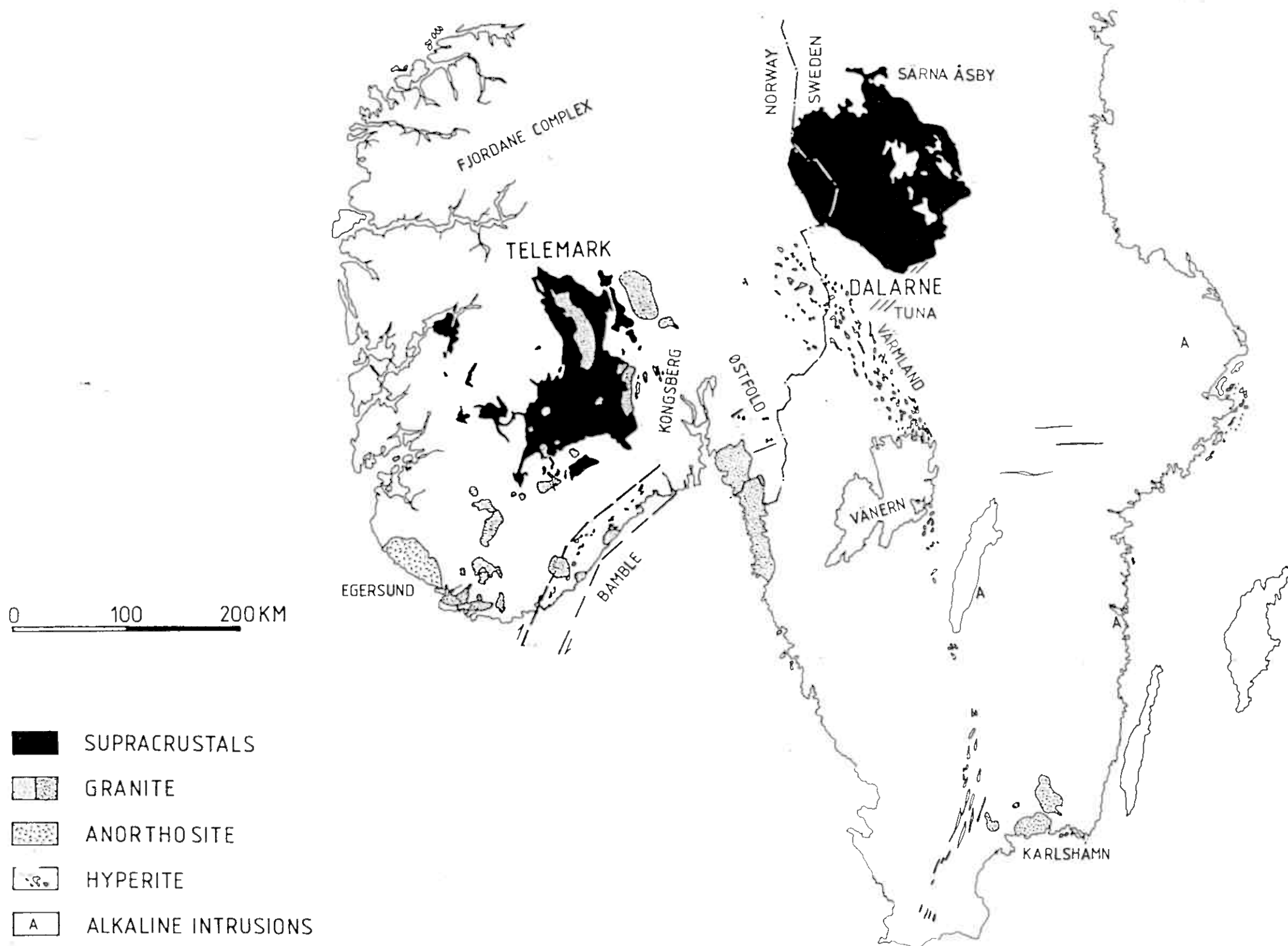
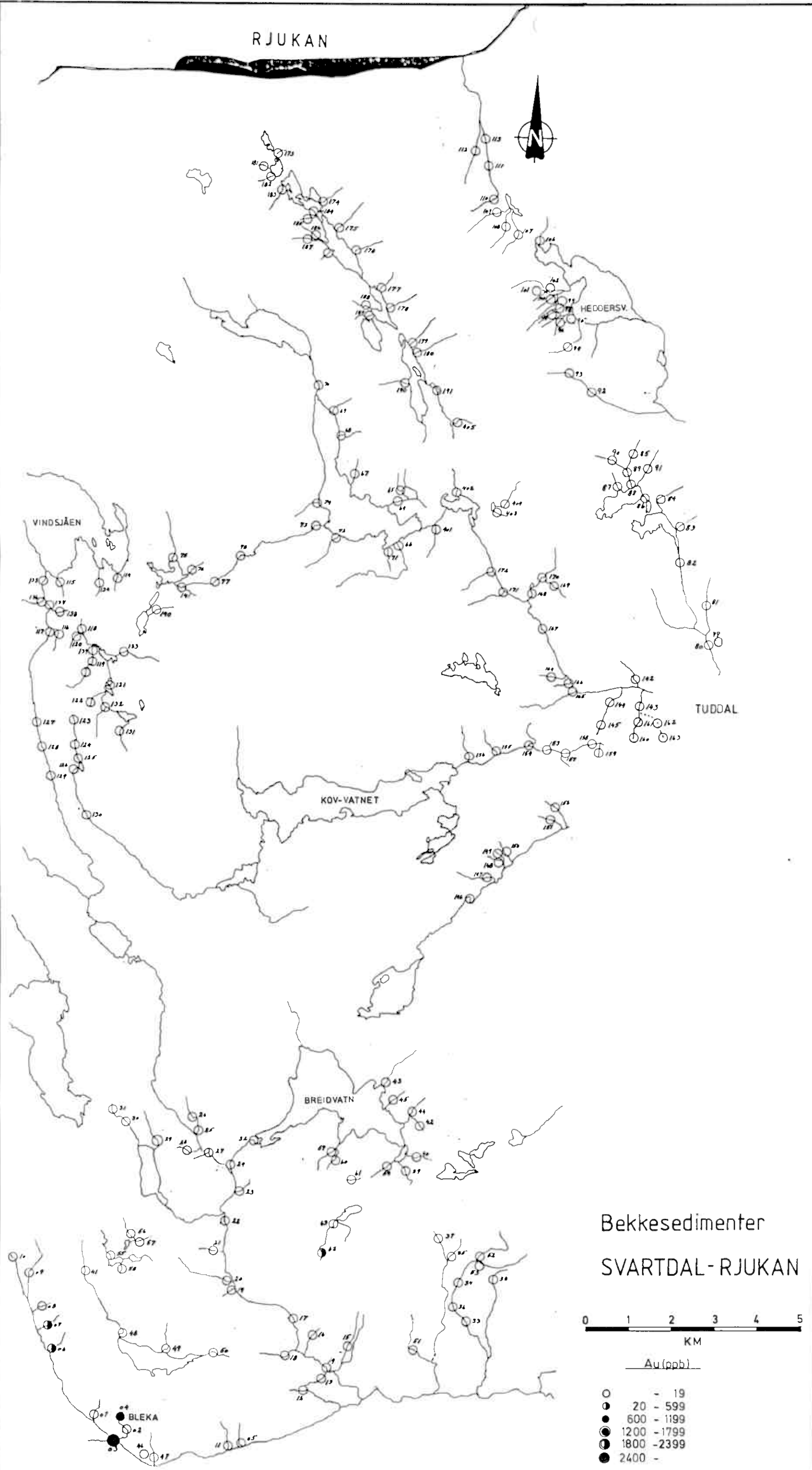
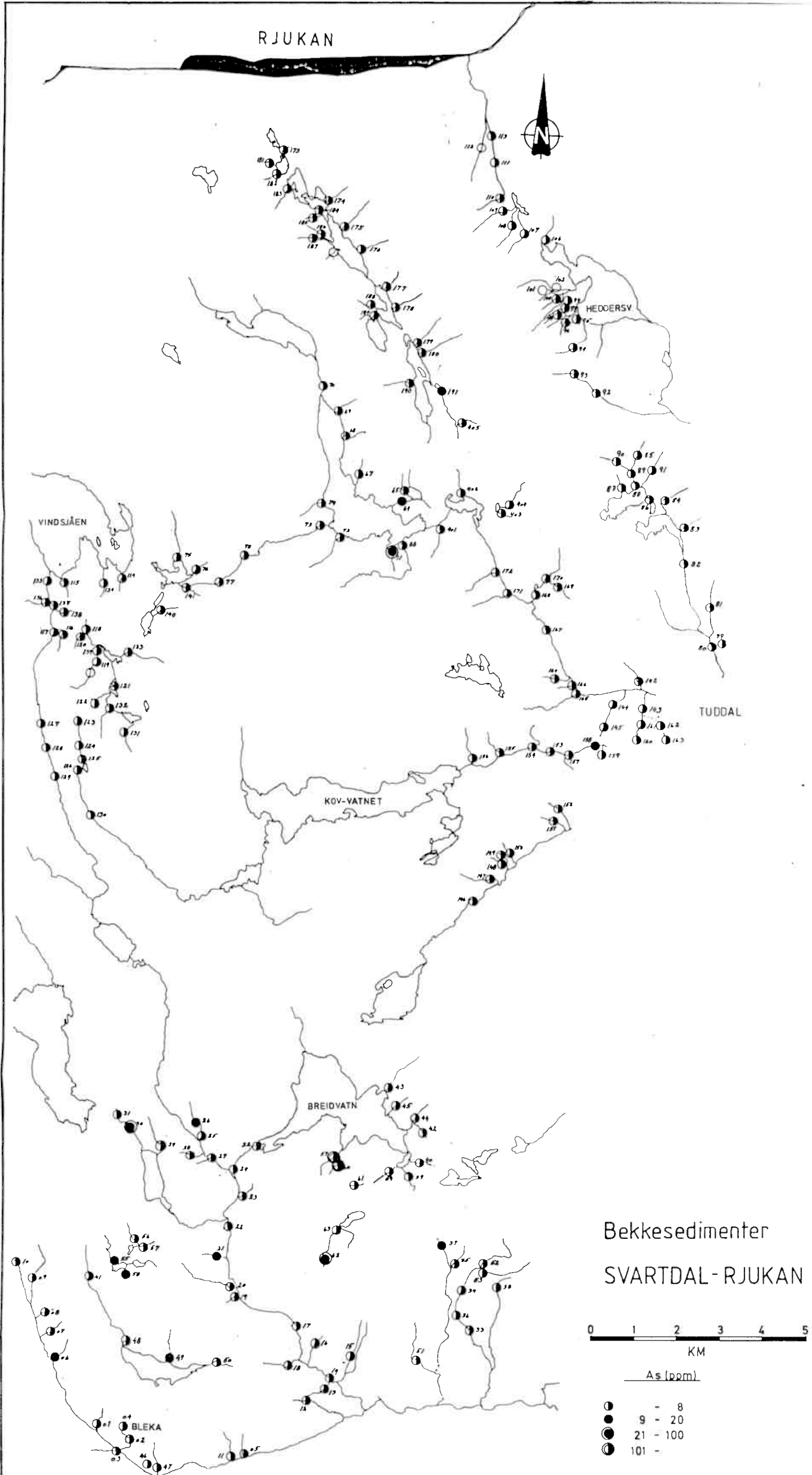


PLATE 5

Order No.		Qty	Item No.	Name, type, etc.	Drawing Standard	Material spec.	Mat. wt. & dim.	N.H.S. Standard No.
Design	Tolerance unless otherwise specified		Remarks		Material specification according to DIN 17006, 17106, 17440 unless otherwise specified		The drawing is the property of Norsk Hydro A.S. and shall not be copied or reproduced in any other form without permission	
	N5 1430 N5 1432							
Revision	Date	Drawn by	Checked by	Scale		Norsk Hydro a.s. Head Office		
	Approved	1:2	1:2	1:1	Price mark		Replacement for	Replaced by
Access					1 F.			
	Author's		Coll. no. Serial no.					
Use	Grading No.					Drawn by	Size A 1	



124715-6



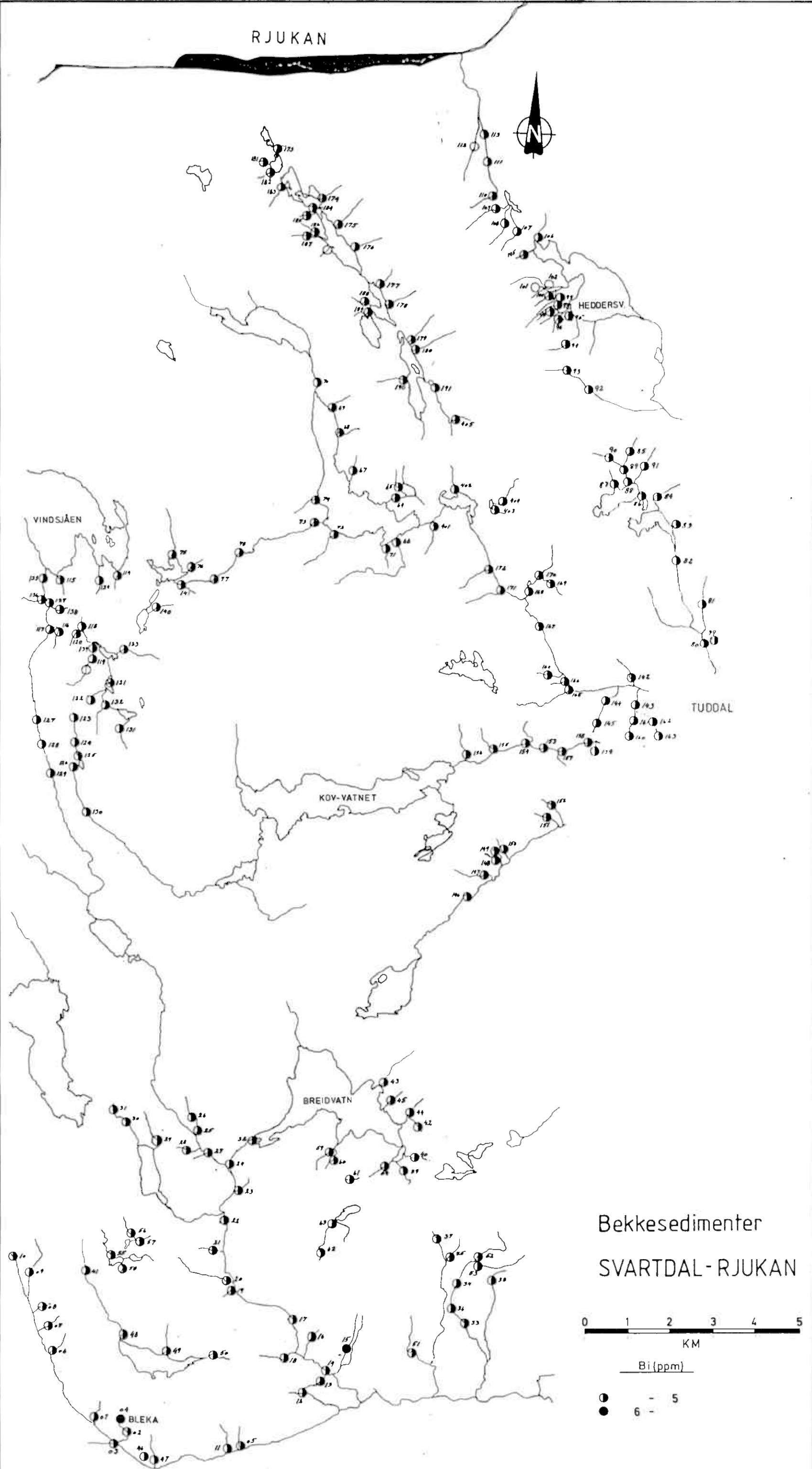
Bekkesedimenter
SVARTDAL-RJUKAN

0 1 2 3 4 5
KM

As (ppm)

- - 8
- 9 - 20
- 21 - 100
- 101 -

PLATE 7



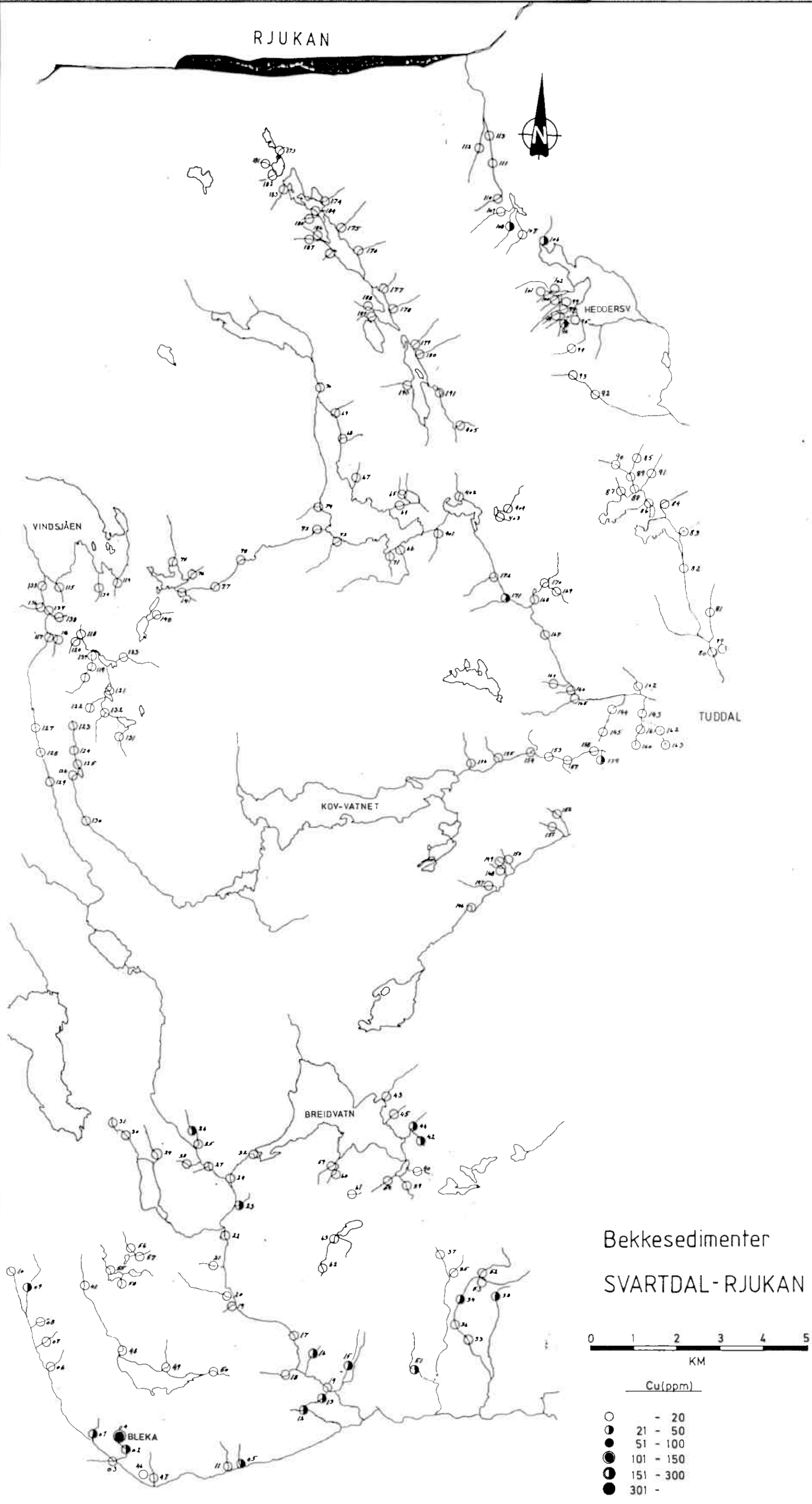


PLATE 9

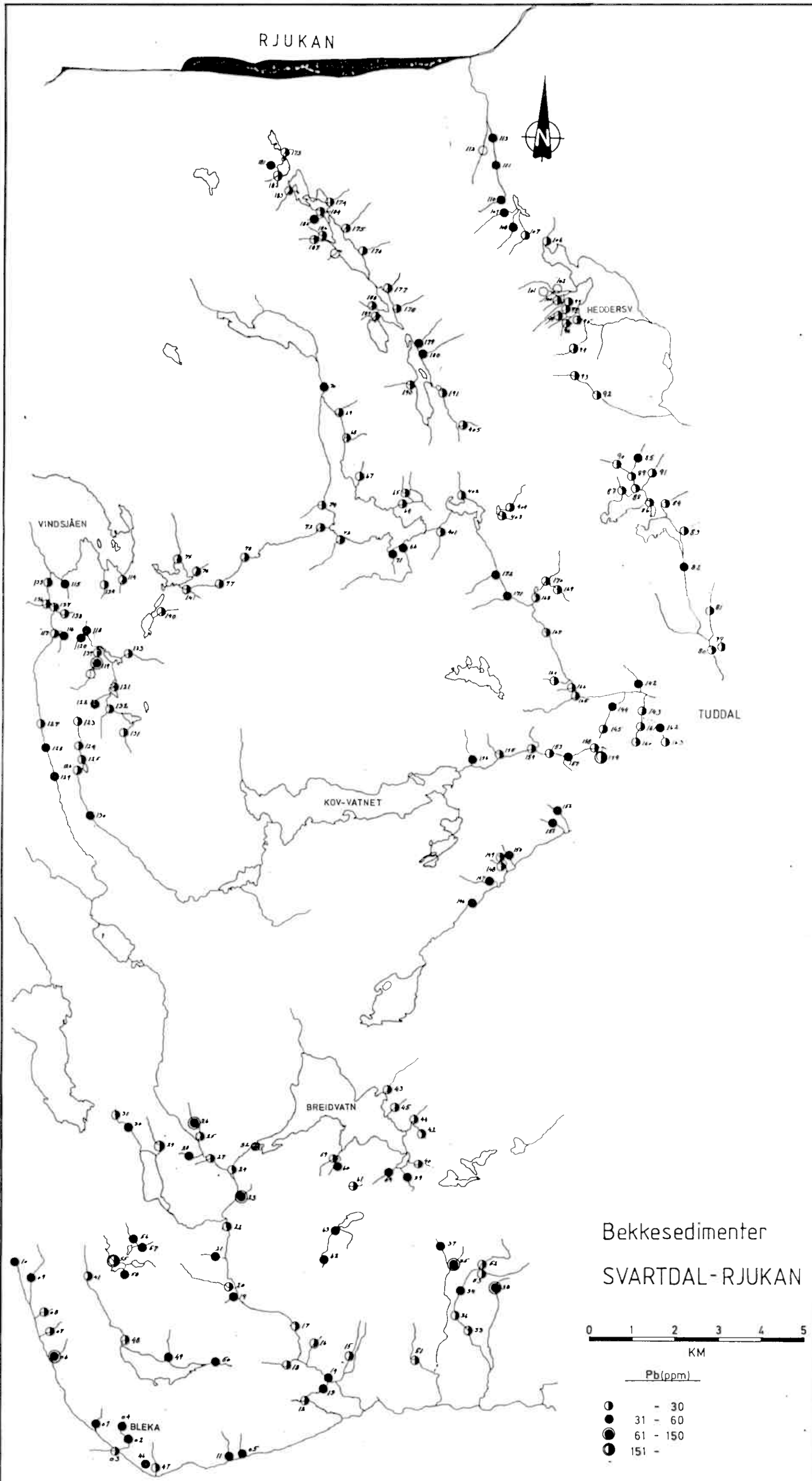


PLATE 10

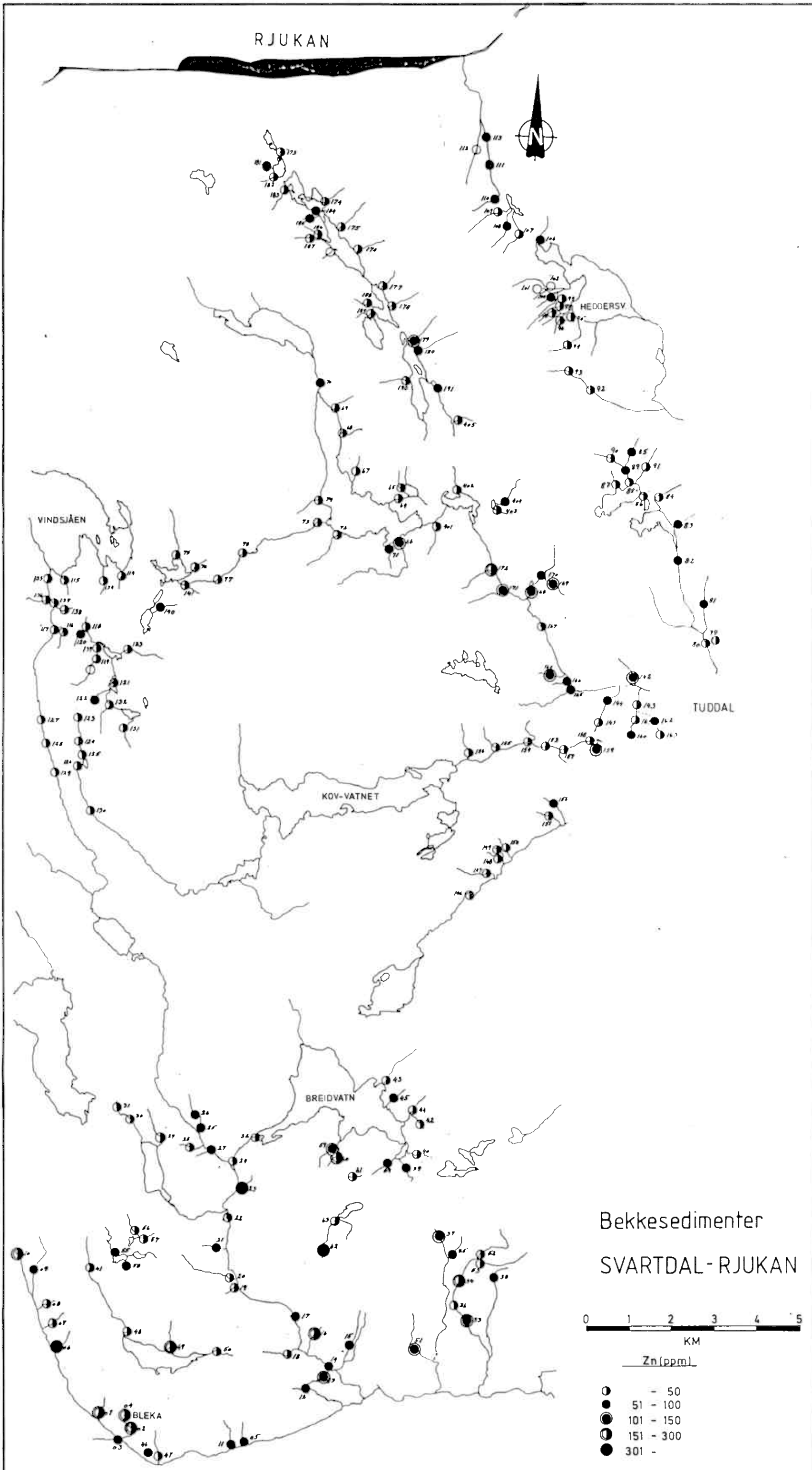


PLATE 11

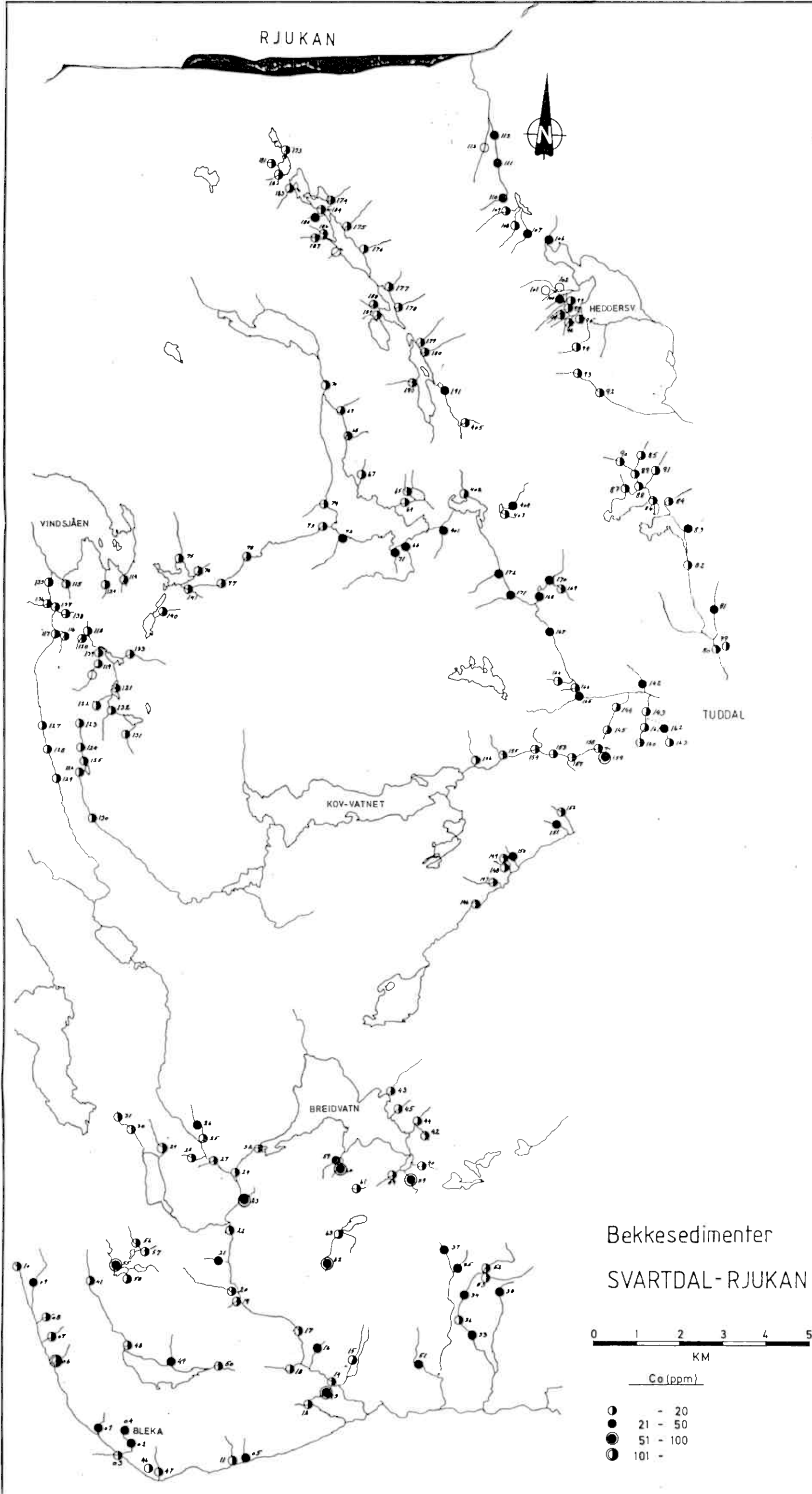


PLATE 12

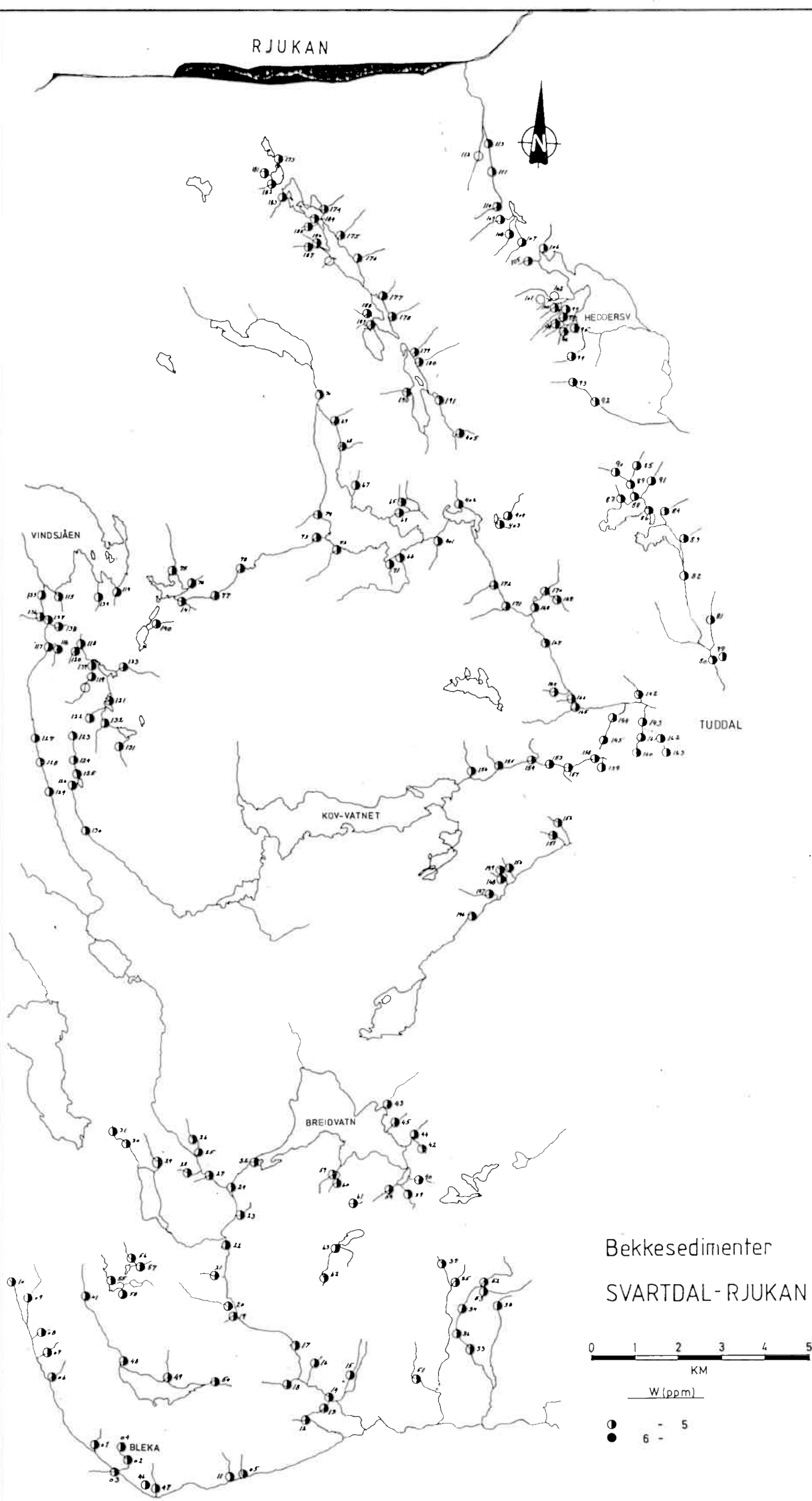
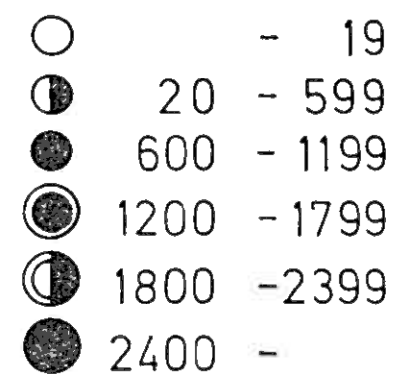


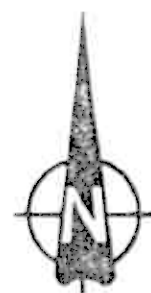
PLATE 13

Bekkesedimenter Aslestad

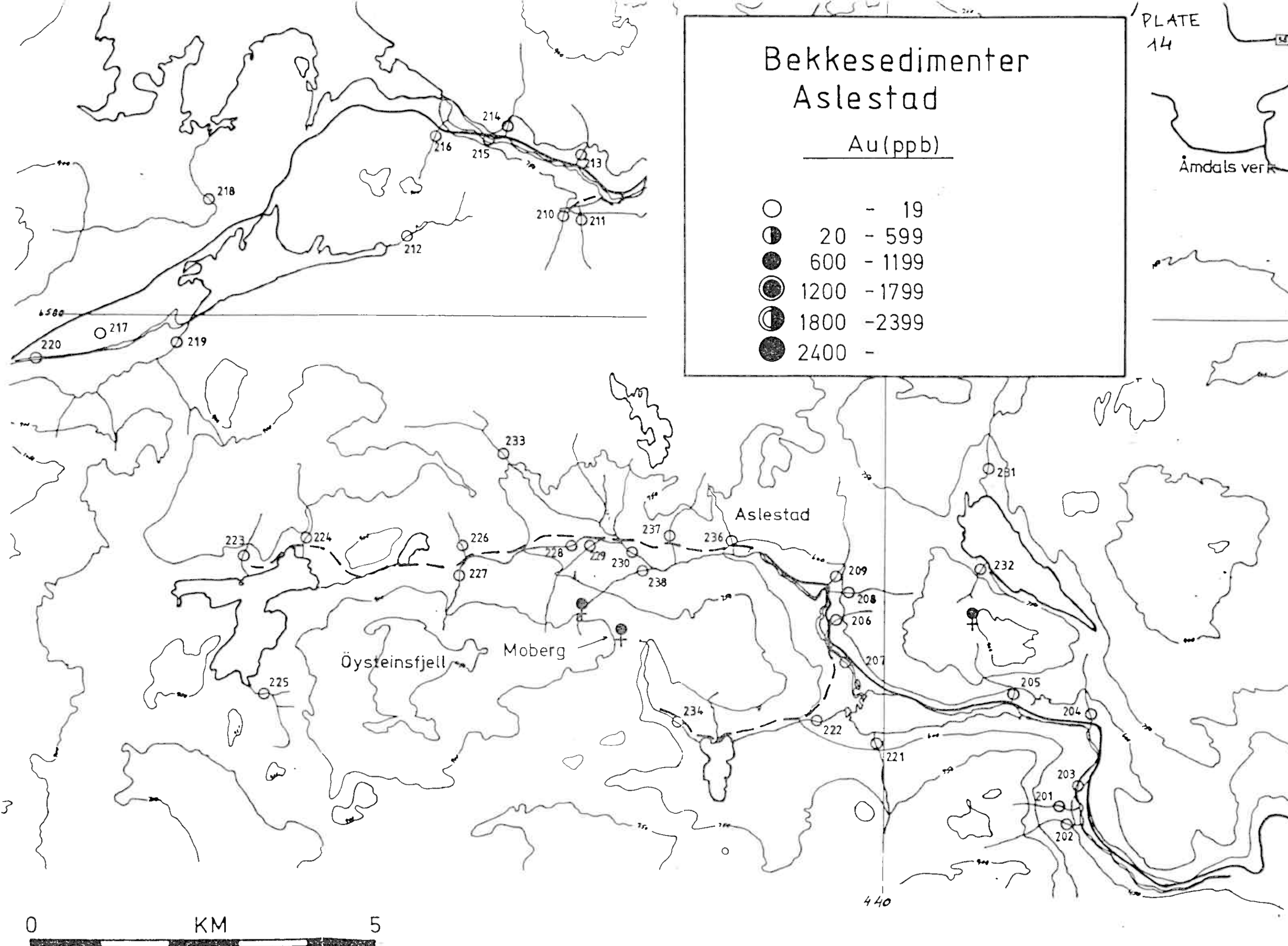
Au (ppb)



Åmdals verk

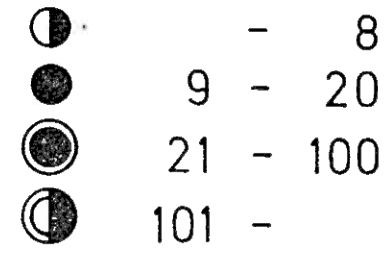


0 KM 5

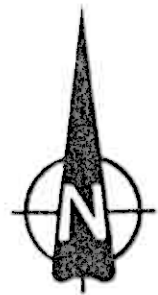


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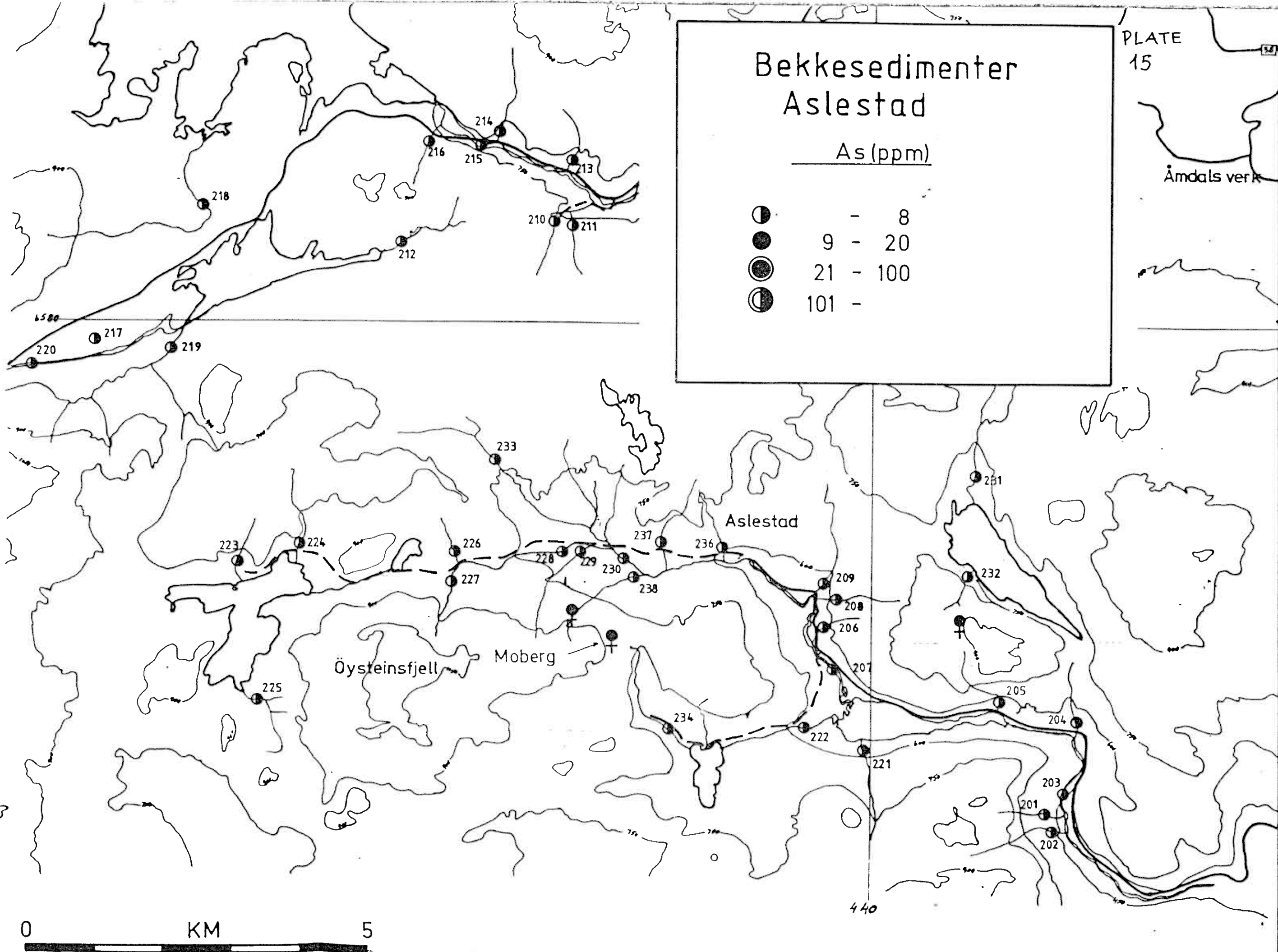
As (ppm)



Åmdals verk

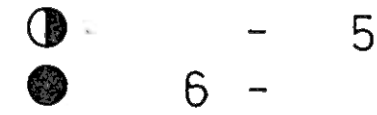


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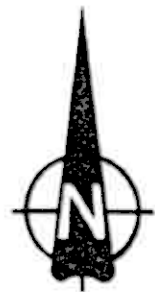


Bekkesedimenter Aslestad

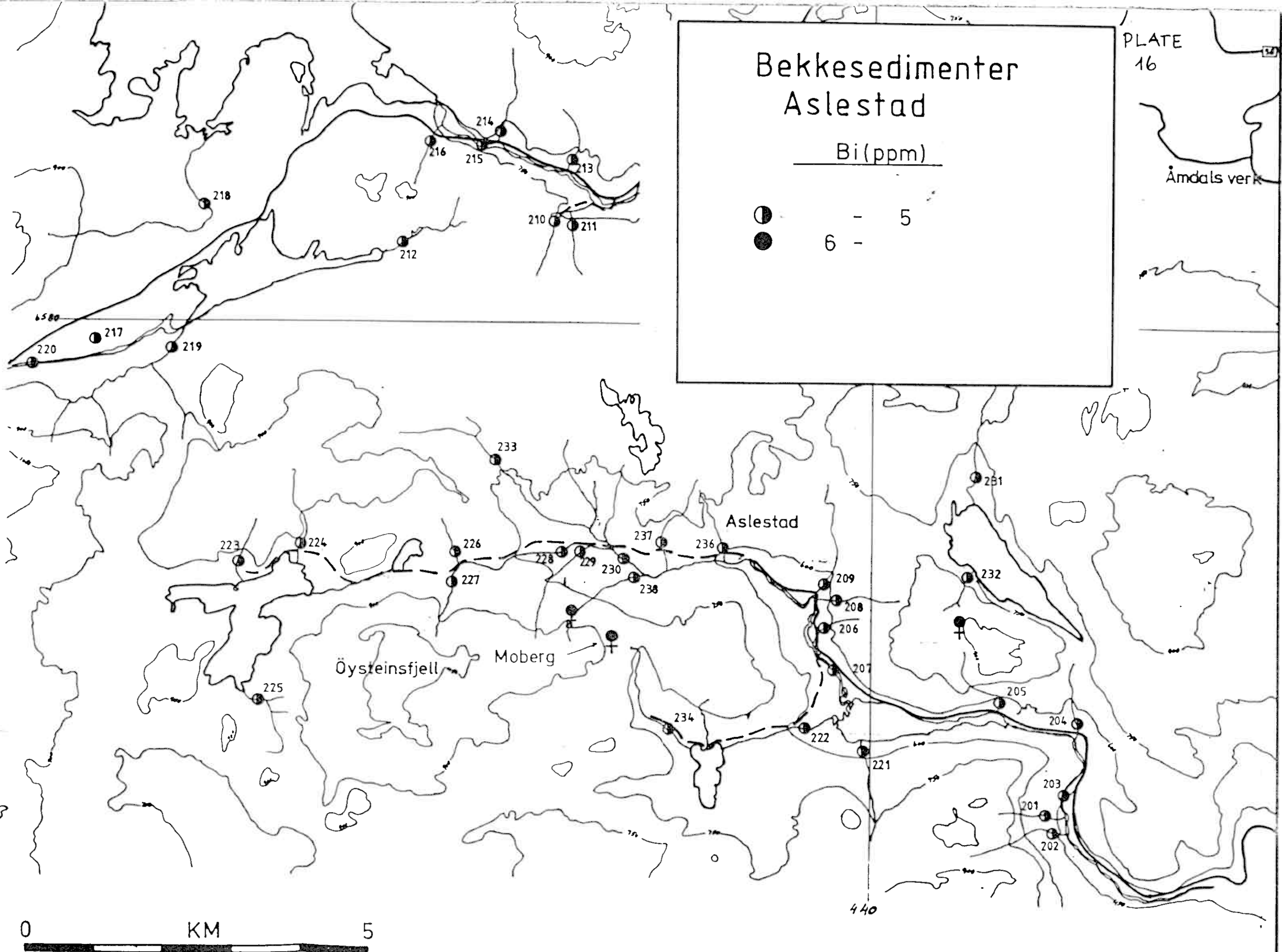
Bi (ppm)



Åndals verk



0 KM 5



Bekkesedimenter Aslestad

Cu (ppm)

○	- 20
◐	21 - 50
●	51 - 100
◉	101 - 150
◑	151 - 300
●	301 -

Åmdals verk

Öysteinsfjell

Moberg

Aslestad

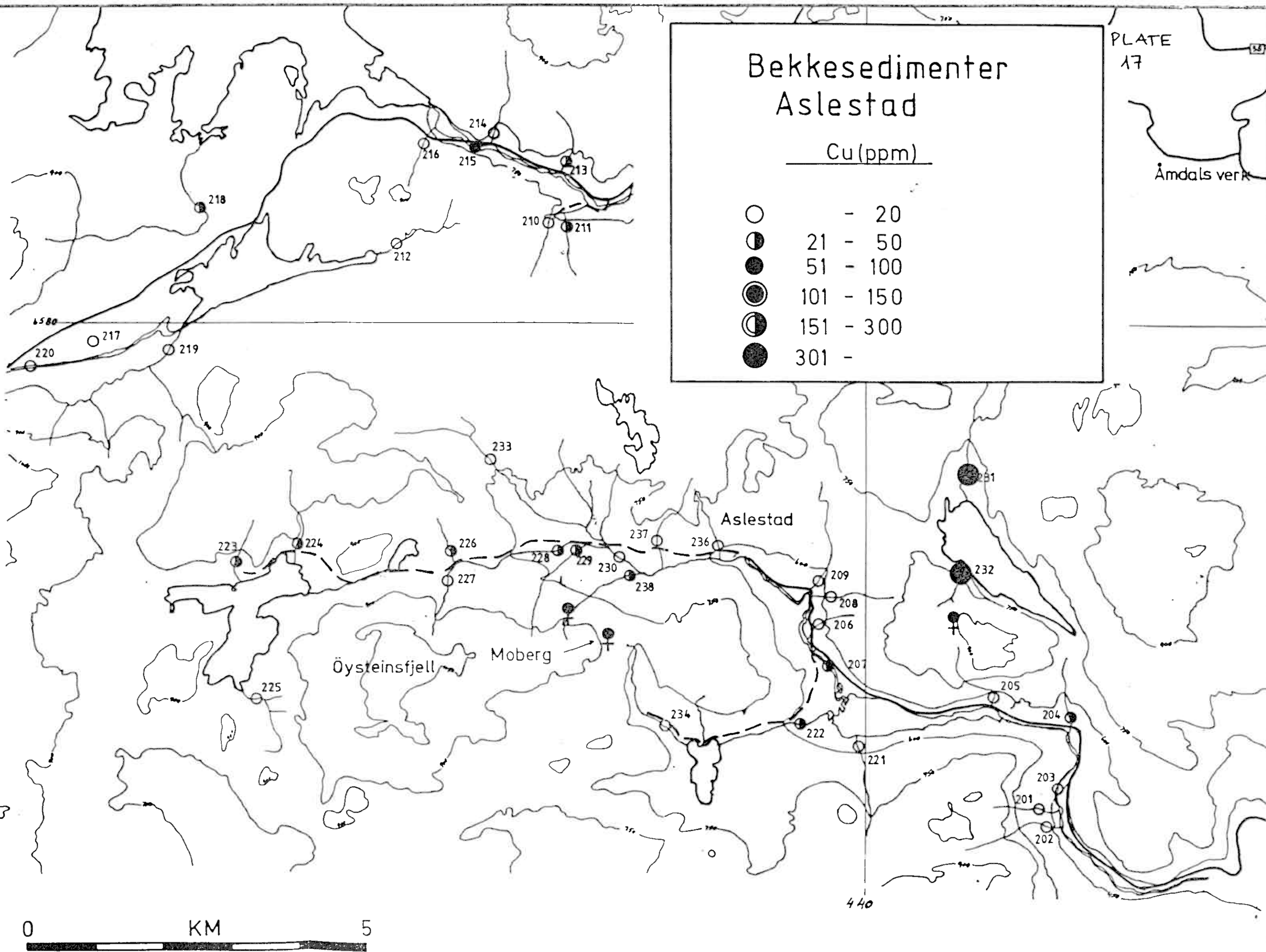


0

KM

5

440

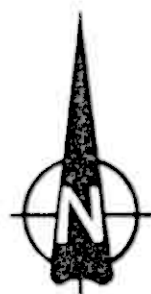


Bekkesedimenter Aslestad

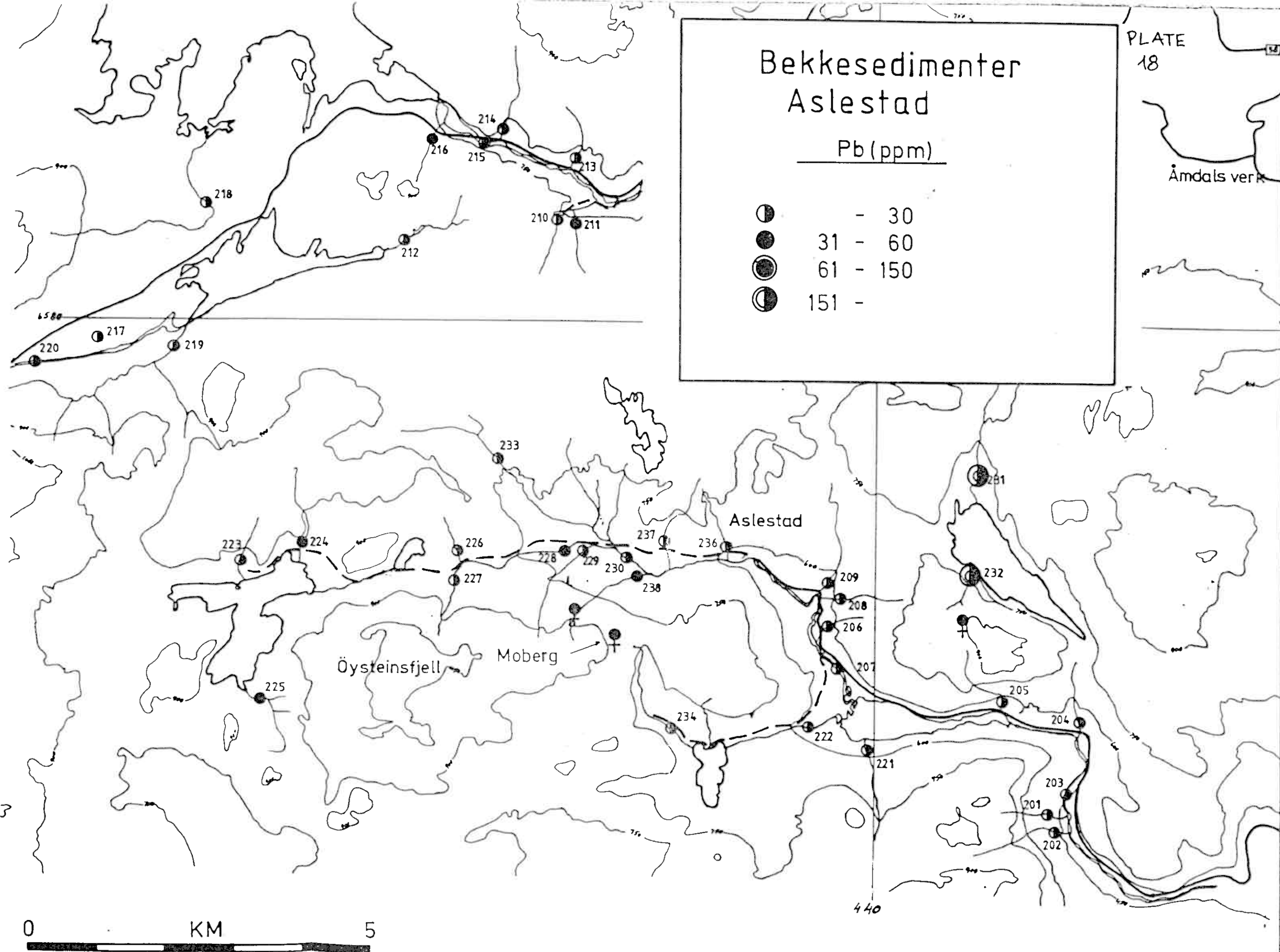
Pb (ppm)



Åmdals verk

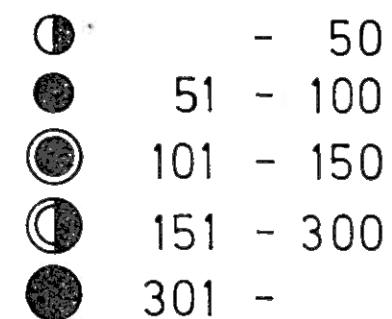


0 KM 5



Bekkesedimenter Aslestad

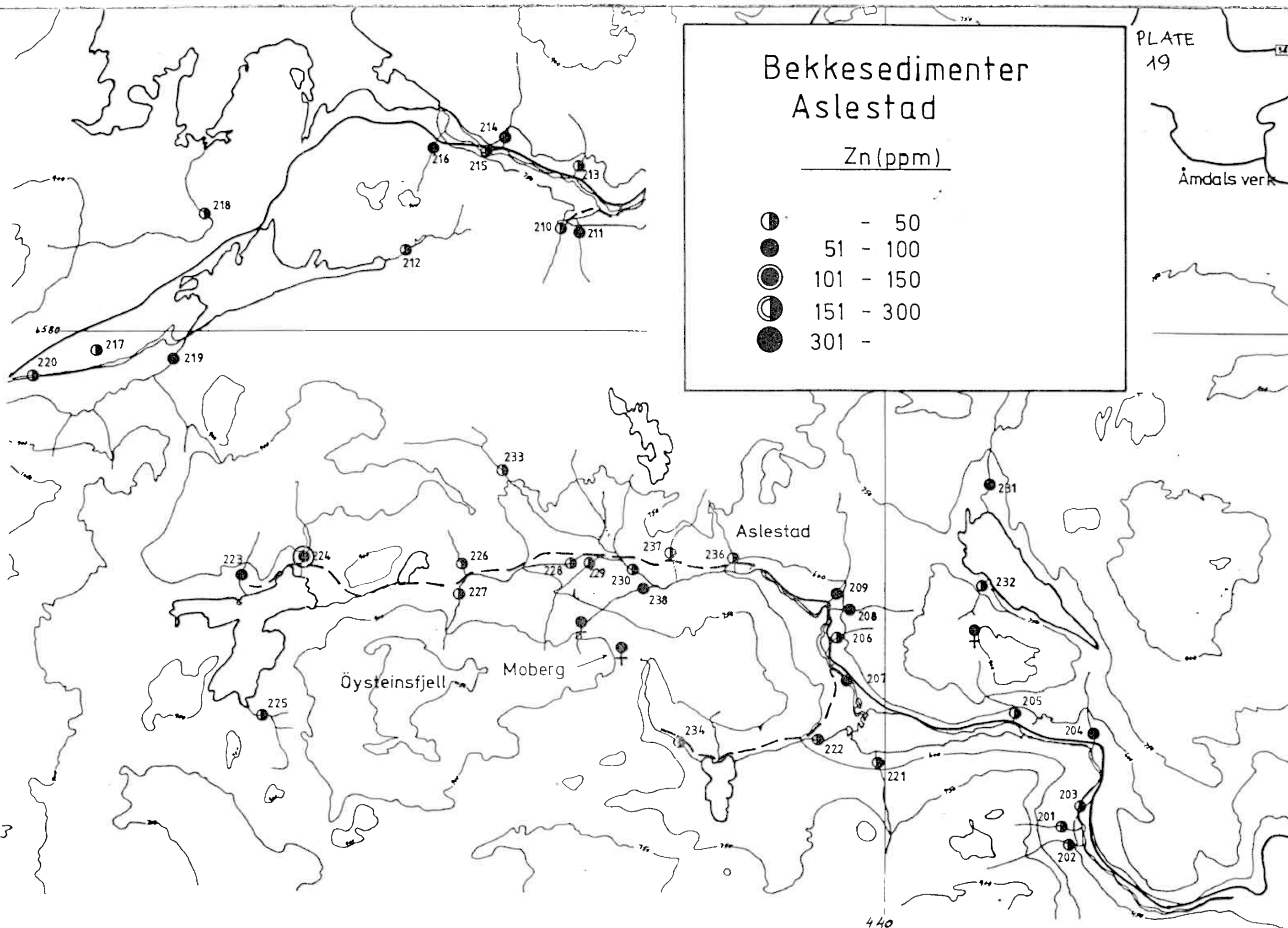
Zn (ppm)



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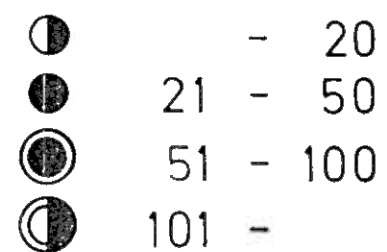


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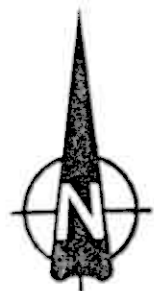


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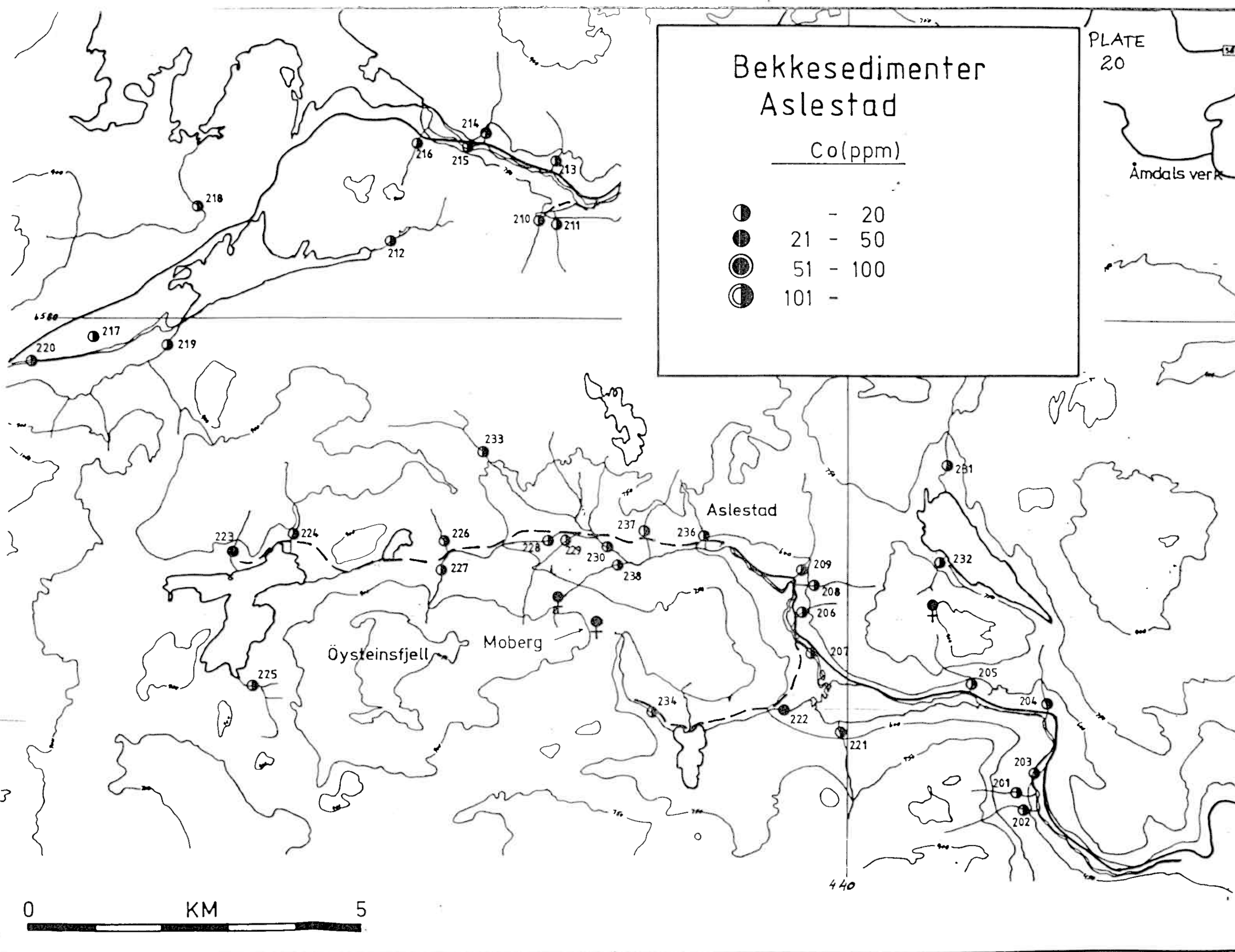
Co(ppm)



Åmdals verk

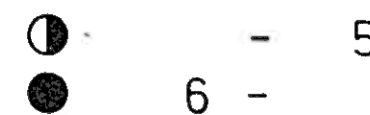


0 KM 5

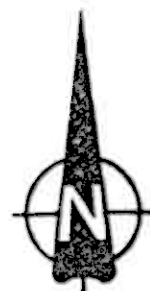


Bekkesedimenter Aslestad

W (ppm)



Åmdals verk



0 KM 5

