NGU
Feb 11/74

Dear Arne,

Enclosed is a copy of my Sanddøla effort from 1972. The overall interpretation withstood the test of the 1973 fieldwork but some of the details - such as relative ages of the late minor folds will have to be modified ~~somewhat~~ when the past season's work is sorted out.

I am still interested in receiving a copy of the Imperial College students' 1972 reports whenever you can spare them.

The maps from 1973 are nearing completion. Four of them are ready now and the Gaziesvann sheet needs only to be checked out for errors and omissions. We shall send you foil copies when completed later this week or next. (I hope).

Best regards,
George.

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GRONGPROSJEKTET - NGU rapport nr. 1189.

./. Vedlagt oversendes ett eksemplar av George H. Gales rapport om geologien i Sanddøla-Blåmurenområdet.

Med hilsen
Geologisk avdeling

Sigrid Petersen
S. Petersen
sekretær

Oppdrag:

GRONGPROSJEKTET

NGU Rapport nr. 1122 A

Foreløpig rapport over geologisk feltarbeide i Sanddøla-området. Grong, Nord-Trøndelag

15. mai - 15. september 1972

Utført ved dr. G.H. Gale

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Plates:

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Preliminary report on fieldwork, Grong 1972.

1. Introduction.

Remapping of the south-western extremity of the Grong Concession area, lying between the Sanddøla and Namsen river, was conducted during the period mid-may to mid-september. The area under consideration in this report lies within the northern part of Grong (1823 IV) and the southern part of Harran (1824 III) 1:50 000 map sheets. Metasedimentary, metavolcanic and igneous rocks of the Sanddøla area are separated from the Palaeozoic rocks of the Trondheim region and those of the Snåsa area (Roberts 1968) immediately to the south by the gneissic terrain of the 'Grong culmination' (Oftedahl, 1955). Lithologies are comparable with those reported from the Snåsa area (Roberts, 1968) and thus the nonfossiliferous metasediments and metavolcanics are probably the same age as the lower Ordovician (?) rocks in the Snåsa area (Carstens, H. 1960). Geological investigations have been largely confined to (1) establishing the structural geology of the area, (2) determining whether the sulphide occurrences, of which the Rosset and Godejorde occurrences are the most promising, in the area were stratigraphically controlled.

Roberts, D. 1968: Geological investigations in the Snåsa - Lurendal area, Nord-Trøndelag, NGU 247 18 - 38.

Oftedahl, Chr. 1955: Om Grongkulminasjonen og Grongfeltets skyvedekker, NGU 195.

In addition a one week excursion was made to the Gjersvik - Joma area in order to collect samples of volcanic rocks for geochemical studies and to reconnoiter the area for regional structures to facilitate the planning of detailed study areas for the 1973 field season.

The eastern part of the area under consideration is covered by the 1:100 000 map sheet Sanddøla (Foslie 1958). The remainder of the area was mapped by statsgeolog Foslie in the scale 1:50 000 (NGU archives), but has remained unpublished to date. It is noted here that although new stratigraphic and structural data were obtained which throw new light on the tectonics of the area, and are probably of considerable importance in interpretations of the whole Grong field, detailed mapping on the scale 1:20 000 have required only minor local adjustments of Foslie's lithological boundaries.

Lithological boundaries in the vicinity of the Rosset sulphide occurrence are based on detailed (1:5000) mapping by R. Kvien in 1972.

2. General Geology.

The area is underlain by gneisses and granitic gneisses of probable Precambrian age, that have been deformed during the Caledonian orogen. These rocks are overlain by, or grade upwards into, a thick sequence of paragneisses which include quartzites, possible leptites layered porphyroblastic gneisses and minor mica schist. These rocks are collectively referred to here as 'basement' although the paragneisses probably grade upwards into, and are of approximately the same age as, the overlying quartz-biotite schist. [This relationship will be discussed in more detail later].

The rocks of primary interest during the 1972 field season were the younger 'Caledonian rocks' which overlie the basement complex. These include basal quartz - biotite schists, limestone, amphibolite, psammitic and semi-pelitic sediments, conglomerate and a mafic to silicic igneous plutonic sequence of Caledonian age.

The area has undergone intense deformation and metamorphism so that all of the extrusive volcanic rocks and the sedimentary sequences have developed a strong schistosity which has destroyed many of the original bedding features. The widespread presence of garnets, hornblende and kyanite in favourable lithologies attest to the attainment of a least amphibolite facies metamorphism. Early pre-schistosity and several post-schistosity minor folds are indicative of polyphase deformation. Although not all of the major folds have been satisfactorily delineated during the past season's field work, it can now be shown that an early major recumbent tight to isoclinal fold has been refolded by later N/S, NW/SE and NE/SW fold systems.

3. Description of lithologies.

3.1. The basement rocks are tenatively separated into a 'granitic gneiss' unit and a 'layered gneiss' unit. The granitic gneiss consists mainly of medium to coarse grained reddish - and grayish - coloured gneisses in which porphyroblastic albite and k-feldspar are usually developed. Locally the feldspar porphyroblasts are 2 - 3 cm in length, and the rock is a typical 'øye-gneiss'. Bands of basic gneiss, consisting mainly of medium grained hornblende and plagioclase, are scattered throughout the granitic gneisses and may have been pretectonic basic dikes. The thickness of the basic gneisses rarely exceed ten meters, and they are usually only one to two meters thick. The main constituents of the granitic gneisses are k-feldspar, albite, biotite, muscovite and quartz. The feldspars and micas are often lineated. Garnets were not observed in hand specimens but have been noted in one thin section. Those rocks are generally massive and layering when present is generally on a scale of 10 - 20 meters in thickness.

The 'layered gneisses' overlie the 'granitic gneisses' and form the upper 200 - 300 meters of the 'basement'. Although their exact relationship to the underlying granitic gneisses is still in doubt, since no uninterrupted section was observed, and the layered gneisses could be gradational downwards into the granitic gneisses since several exceptionally thick layers (10 - 15 m) resemble the porphyroblastic granitic gneisses, it is possible that they are unconformably overlying granitic gneisses. The layered gneisses are distinct compositionally banded, $<$ 1 dm to several tens of meters thick with the majority $<$ 1 m thick, quartz-feldspar rocks which include greyish-white quartzites, micaceous quartzites, reddish fine-grained quartzites/leptites, often with 5 - 10% reddish feldspar porphyroblasts, minor fine to medium grained quartz-feldspar gneisses with 5 - 20% feldspar porphyroblasts, and (near the contact with the 'quartz-mica schist') thin horizons of semipelitic rocks which are rarely more than 0,25 m in thickness. Several amphibolite units, 1 - 2 m thick, are scattered throughout those rocks; the amphibolite layers parallel the layering in the surrounding gneisses.

The original nature of the layered gneisses is still problematical, however, the well devoloped layering at some localities, the quartz rich character of the upper levels and the marked increase in the mica content as the 'quartz-mica schist' unit is approached suggests that these rocks are of sedimentary origin and grade upwards into the overlying 'quartz-mica schists'. If a sedimentary origin is accepted for these layered gneisses, then they can be correlated with the sparagmitic successions of Southeast Norway and the sparagmites exposed west of the main Caledonian sequences in the Trondheim region (Holtedahl and Dons 1960: Geological map of Norway).

3.2. The quartz-mica schist (Garnetiferous mica schist) overlies the layered basement gneisses and probably grades downwards into them (see also Oftedahl 1955). They appear to form the base of the Caledonian sequence in the Grong and adjacent areas in that they always separate basement gneisses from the Cambro-silurian volcanics and sediments (cf. Roberts 1968, Birkeland 1958).

The reddish brown quartz-mica schist unit is variable in that it consists mainly of interbanded quartz-rich biotite schists (75% quartz, 25% biotite) and quartz-poor biotite schists (25% quartz, 75% biotite). Impure quartzite horizons are present in exposures along the Namsen river north of Grong station. Amphibolite horizons, up to one meter thick, are present near the contact with the overlying amphibolite and amphibolite porphyroblasts are also common near this contact.

Quartz and biotite are the main minerals present and together constitute more than 95% of the rock. Garnet, kyanite and hornblende porphyroblasts are present at a number of localities, in general the garnet and kyanite porphyroblasts occur mainly in the lower parts of the unit while hornblende which is most abundant adjacent to the amphibolite contact occurs throughout the unit. The garnets are usually 2 - 3 mm in diameter, but crystals greater than 1 cm are also common. Kyanite crystals are commonly tabular (0,1 x 1 x 5 cm) and exhibit radiating star-like crystal forms nucleated on earlier garnet prophyroblasts. Hornblende porphyroblasts, 2 - 3 cm in length, overgrow the schistosity.

Quartz segregations and boudins are common throughout the quartz-mica schist unit, but are most profuse in the lower part of the unit north of Grong Station. They are contained within the regional schistosity and have a preferred easterly plunge.

East of the road to Stamtjern the quartz-mica schist unit becomes more phyllitic, the garnet content decreases rapidly eastwards and chlorite and muscovite are the dominant micaceous minerals. In this area the main schistosity is parallel to the compositional layering (bedding) and can be traced uninterrupted within individual outcrops.

The change in character of the quartz-mica schist from that of a garnetiferous quartz-biotite schist to a phyllite is considered to be largely due to decreasing metamorphic grade eastwards along the Sanddøla river, and a facies change (cf. Roberts 1964).

3.3. The amphibolite is a dark green, schistose rock which often has a poorly defined layering. Although the amphibolite resembles metamorphosed lavas undoubted volcanic structures are rare and in many places continuous layering suggest a sedimentary or at least a volcanic-sedimentary origin for parts of this unit. Above Tømmerås setter and west of Rossettjern several thin units of quartz keratophyre (0,1 to 1 m thick) parallel the banding in the amphibolite, however, it is not clear whether these are intrusive or extrusive.

The amphibolite appears to be gradational over 10 - 15 meters with the underlying quartz-mica schist since quartz mica schist with hornblende porphyroblasts are interbanded with amphibolitic layers up to 1 meter thick in the brook section above Trangen (0231 0453). Volcanic textures include pillow lava at Hotjern and agglomerate (0681 0413). In several places massive amphibolitic units 2 - 3 meters thick have been interpreted as lavas. Since volcanic structures have not been recognized in these lava-like units it should be remembered that they may represent poorly stratified basic tuffaceous sediments especially in view of the abundance of well-layered amphibolites in other places. The layered amphibolites are often quartz-rich and exhibit rythmic layering which suggest an original sedimentary rather than a tectonic origin for the layering.

In the section along the Namsen river the top of the amphibolite unit is marked by an impure grayish quartzite containing garnet and hornblende porphyroblasts. A similar quartzite occurs near the top of the amphibolite unit southwest of Renslitjern (0478 0305). A green coloured 'basic' quartzite occurs at the bottom of the amphibole mass immediately north of Hotjern and in the deeper levels of this amphibolite mass (exposed in the valleys) west of Hotjern (see Geol. Map). [A similar rock type occurs in stream sections above Trangen and west of Rosset tjern]. The maximum thickness of the grayish quartzite unit is estimated to be about 20 m while that of the 'basic' quartzite is 10 m or less.

Approximately 4 km east of Trangen the basic rocks are best described as a greenstone or greenschist since the main mafic constituents are actinolite and chlorite instead of hornblende. The rocks are well banded, schistose and are mostly basic sediments/tuffaceous sediments. (This area has not been studied in detail, and a description of the basic rocks must await more detailed field studies).

A 'garben schifer' zone occurs in areas between the Godejorde mineral occurrences and the limestone units. Hornblende porphyroblasts 2 - 3 cm in length are common in this unit which is more calcareous than the greenstone north of the Godejorde occurrences.

3.4. Limestone.

An impure limestone (marble) occurs at the contact between the quartz-mica schist and the amphibolite but is separated from the quartz-mica schist by several meters of amphibolite/greenschist. West of Trangen the limestone exposures are discontinous (boudinaged) but can be followed continuously from the forestry road to Stamtjern eastwards to just beyond Finnbutjern. The limestone which is rarely more than 5 meters thick is a grayish white colour and has a foliation defined by quartz and mica layers 1 - 2 mm thick.

3.5. Acidic lavas, quartz keratophyric, occur in several small exposures immediately north east of Elstad farm and adjacent to the Trondhjemite body east of Elstad river. The rock is a buff coloured very fine grained silicic volcanic with flow-banding and phenocrysts of quartz and feldspar (0781 0473) and along the gabbro contact (0816 0479) are strongly schistose and overlie basic volcanic rocks.

3.6. Psammitic rocks.

Psammite, conglomeratic psammite, calcareous psammite and semipelite constitute a sedimentary unit which crops out over a large part of the map area and forms the core of a large recumbent fold in the western part of the map area.

The psammite is a medium granied well banded (2 - 10 cm) quartz rich rock with 5 - 15% mica (biotite and muscovite). Locally it is conglomeratic with boulders of a fine to medium grained igneous rock (trondhjemitic or keratophyritic) and rare epidotized basic fragments. In places boudinaged psammite layers have a conglomeratic appearance,but these are easily distinguishable from the true conglomerate fragments on the basis of textural differences. The calcareous psammite are more finely banded and intensly deformed than the psammites (cf. plates 6A and 6C). They contain 10 - 20% carbonate, 5 - 25% biotite, minor muscovite and quartz (50 - 70%). The calcareous psammite occurs in the core of the major fold between the conglomeratic psammite and probably represent a younger and more calcareous depositional phase than that producing the psammites, although sedimentary criteria to support this have not been found. In the area north of Bryntjern the psammites and calcareous psammites appear to be interbanded on a megascopic scale, however, it cannot be stated at this time if this is a sedimentary of tectonic feature as the detailed structures in this area have not yet been determined .

Semipelites, comparable to Foslies 'Highly calcareous phyllite' unit (Foslie 1958), occur in several places in the bed of Elstad river and in road cuts along the E6 east of Gartland (adjacent to the gabbro mass). These have not been delineated on the geological map since it is not yet clear whether they are part of the calcareous psammite unit or form a separate unit.

3.7. Intrusive.

Igneous rocks in the Sanddøla area include meta-gabbro, meta-trondhjemite and meta-dolerite. The meta-dolerite is a fine grained hornblende plagioclase rock with relict ophitic textures and is probably the fine grained equivalent of the medium grained meta-gabbro mass. The meta-gabbro intrudes basic volcanic rocks northeast of Elstad farm. The contact zone of the meta-gabbro and volcanics along the E6 east of Gartland is a steep near vertical scarp approximately 50 m high, but the actual contact has not been observed. Lenses of medium grained meta-gabbro can be seen to intrude basic volcanics about 50 meters from the contact at this locality.

Contact relationships between the medium grained trondhjemite and the amphibolites have not been observed. A small body of fine-medium grained trondhjemite near Stamtjern does however intrude basic volcanic rocks , and the medium grained trondhjemite intrudes meta-dolerite in the vicinity of Bryntjern. The meta-gabbro, meta-trondhjemite and metadolerite have a weak regional foliation and therefore were emplaced prior to the first deformation.

4. Structure.

Minor structures, folds and lineations are abundant in the Sanddøla area. Primary sedimentary structures are rare and thus it has not been possible to establish with any certainity the relative ages of the various rocks units beyond their present superposition configurations. The direct correlateability of the rocks sequences with those of the Snåsa area (Roberts 1964, 1968) suggests that the sequence from basement to amphibolite in the Namsen river section is probably right way up.

A quick glance at the geological and structural maps can immediately reveal the discordance in structures across the Trangen antiform - to the east of this structure the bedding-foliations have E/W strikes whereas west of the structure they are roughly N/S. To avoid confusing references the structures to the east of the Trangen antiform are described separately.

4.1. Minor structures.

The earliest structures recognized in the area are isoclinal folds, F_1, which have the regional schistosity, S_1, parallel to their axial planes (Plate 1). Particle and mineral lineations parallel to the axes of the F_1 folds include lineated hornblende, quartz boudins and boudinage structures.

These first deformations, D_1, structures have been deformed by later F_2 (?) minor folds. In favourable lithologies these folds have an axial planer cleavage/schistosity (S_2). Quartz rodding in the Trangen area is considered to be of D_2 age.

Third deformational structures, D_3, are recognized as open folds with a NE/SW plunge and usually have a well developed axial plane cleavage. A number of later 'gravity type' fold structures on the limbs of the F_3 Major folds are considered to be of the same age.

D_4 structures are open to close structures with vertical axial planes and a vertical cleavage D_4 in favourable lithologies, and NW/SE axial directions. These folds are best developed at Renslitjern and near the amphibolite sediment contact at (0610 0283).

Exact age relationships of D_4 and D_3 structures are not clear.

Interference folds in quartzites at (0608 0285) and at (0544 0235) Grong station suggest that the D_4 structure is earlier than D_3. (i.e. $D_3 = D_4$). On the other hand F_3 & F_4 could be both related to Deformation D_3.

A later brittle deformation episode, D_5, is recognized by the presence of kink bands.

4.2. Minor structures of probable D_2 age.

At Renslitjern, top of Tømmeråsfjellet, there are two local fold styles which are difficult to fit into the deformational scheme established here. These folds are shown in Plate 6. The open recumbent folds of Plate 6A commonly have an associated nearly flatlying schistosity which deform the long limbs of the folds of the type shown in Plate 6C. At this time their relationships to each other are not clear, and further field observations are necessary to establish their true age relationships. Some possible interpretations are: (1) The open recumbent structures of Plate 6A are late gravity folds. (2) Both folds are related to one local deformational phase. (3) The folds (Plate 6C) are related to the D_3 deformation and represent folding of a non-planer surface. (4) Both or one of these folds are related to a major F_2 closure.

Suggestion 1 - is certainly possible since similar folds have been observed in psammites immediately west of Rossettjern and open 'warps' with a similar trend are present in the amphibolites east of Renslitjern. Proposal No. 2 is highly unlikely due to the presence of the schistosity associated with folds of Plate 6C and the strong cleavage associated with those in Plate 6A. (3) Cleavages associated with these folds are at a high angle to the vertical AP cleavages of the open D_3/D_4 folds. In addition the fold styles are quite different.

Folds of type 6A are not uncommon in the area since they are the common structure in the hinges of small scale D_2 folds. Folds of type 6C are however difficult to correlate with any of the other minor fold styles yet the cleavage associated with them is roughly coplaner with D_2 axial planes. The trend of these minor angular folds is also parallel to the D_2 structures, but this could be merely coaxial folding instead of a single fold phase. The strongest factor against these folds being F_2 structures are their angular style verses symmetrical F_2 minor structures and their steep (Av. 50°E). axial planes in cont~~ast~~rast to gentler AP's for the F_2's. Each of these features could possibly have been produced by post D_2 deformations.

4.3. Interference folds.

Some of the interference patterns observed are shown in Plate 8 with descriptions.

4.4. Major structures.

Several major fold structures are observable from the geological and the structural maps. The Trangen synform/antiform pair of D_2 age are the most obvious structural features. The axial trace of these structures is still uncertain due to the sparcity of exposure, however the existence of these structures can be concluded not only from the variation of S_1, but also by an abundance of minor folds and minor structures (quartz rodding and mineral lineations).

The antiform - synform pair (Killingberget) is delineated by S_1 attitudes, NE trending minor folds and a schistosity (S_3). The antiformal structure at (0660 0330) is also probably of D_3 age, however, confirmation of this must await further field studies on the exact nature of the fold closure. The major F_4 structures at Fosland and Renslitjern are established on the basis of minor folds with SE/NW trends. A large F_4 structure is clear from the attitudes of S_1 along the forestry road at (0555 0260).

The existence of a major recumbent isoclinal F_1 fold must be based entirely on interpretation of lithology and minor structures in the absence of primary sedimentary structures. The observations to-date which support the existence of this major fold are:

(1) Tight to isoclinal pre-S_1/syn S_1 minor folds have easterly or westerly striking axes with S_1, the regional foliations, as on axial plane (see plate 1).

(2) Hornblende mineral lineations, except where modified by F_2 folds, have an E/W trend and locally parallel F_1 minor fold axes when both structures are observed together.

(3) D_1 quartz rods and boudins have an overall easterly strike.

(4) The conglomerate horizon at Renslitjern underlies the calcaous psammite but overlies this unit elsewhere.

(5) If the quartzites overlying amphibolite northeast of Grong station are correlated with quartzitic amphibolite underlying the amphibolites at Hotjern, then the sequence is certainly overturned and a major recumbent structure is obviously present.

(6) A reasonably well preserved graded bedding at (0531 0449) indicates overturning of psammites at this locality.

(7) The psammites and calc-psammites west of Rosset are difficult to explain except as antiformal since they dip under the amphibolites in the east and north and appear to form a tight to isoclinal fold closure immediately west of Rosset-tjern (this closure has not yet been conclusively delineated).

(8) The outcrop patterns of the psammites calcareous psammite and conglomerates above Tømmerås setter and west of Rosset-tjern are consistent with the interpretation as a refolded major F_1 tight to isoclinal fold, the axis of which can be defined by a line drawn between the southern extremities of the two areas of psammite. The boudinage structures are considered to be B-lineations to the major F_1 structure since they and the D_1 hornblende lineations are parallel to the B-axes of F_1 minor folds.

4.5. Structural geology of the Eastern Part of the Sanddøla area.

In the eastern part of the Sanddøla area, i.e. east of the Trangen antiform, the structural style is somewhat different from that to the west. The area has not been remapped in detail, but some preliminary observations can be presented for comparisons with the western subarea.

The most conspicously discordant feature of the eastern subarea is the dominantly westerly strikes, with steep to moderate northerly depths, which parallel the 'basement' gneisses along the Sanddøla valley. An exception to these westerly dips is the fold structure southeast of Møklevann delineated by R. Kvien (cf. Foslie 1958). Delineation of early major structures in this area is difficult due to the absence of distinctive marker horizons in the amphibolite/greenstone pile.

It is now clear that the rocks west of the forestry road to Stamtjern are dipping steeply southwards rather than northwards. This indicates that a major antiformal structure exists here since dips on Lillefjeldet are mostly vertical while those farther north, near Eldstadelven are northwards dipping. (The axial trace of this fold has not yet been delineated). Minor folds thought to be related to this major structure can be seen in phyllites on the road to Stamtjern.

The minor folds are close to tight with a well-developed axial plane schistosity (S_2). Locally this schistosity is seen to completely transpose the regional foliation, S_1, and since the S_2 is locally parallel to S_1 it is sometimes uncertain which fabric is being measured in areas where the S_1 (?) has steep to vertical dips.

East of the Stamtjern road southward dipping S_1 bedding-foliations have not been observed. The dominant minor structure in this poorly exposed area is minor Z-folds with S_2 as axial plane. These are well exposed in the Godejorde occurrence at (0283 0638).

Other minor structures include a late crenulation cleavage, kink folds, and brittle deformation conjugate folds. In addition quartz rods are present, especially in the quartz mica schist and a late, post S_2, near horizontal crenulation folding of the limestone bands with an associated horizontal cleavage. Tight to isoclinal F_2 (?) folds are present in the limestone unit.

In several small exposures of quartz-mica schist there is either an early Pre S_1 schistosity or S_2 is strongly developed parallel to the regional S_1, because the regional fabric crenulates an earlier 'mica fabric'.

5. Metamorphism.

5.1. Metamorphism west of the Trangen antiform.

The following notes are based largely on field observations, supplemented by a small number of thin sections.

Pre S_1 on syn S_1, garnet growth has been noted in micaceous gneisses near the basement quartz-mica schist contact north of Grong station. It is possible that this represents a pre D_1 metamorphism, but supporting data elsewhere has not yet been observed.

The first deformation, D_1, was accompanied by a regional dynamothermal metamorphic event, M_1, which brought about a recrystallization of most of the rocks in the area and the development of the regional schistosity, S_1. During the M_1 event biotite, hornblende, muscovite and quartz recrystallized + (requilibrium of feldspars in the amphibolite and growth of feldspar porphyroblasts in the gneisses). Some garnet growth in the quartz-mica schists may have taken place near the end of the D_1 event since they grow across the M_1 biotite fabric.

The metamorphic event, M_2, accompanying D_2, was of relatively lower grade since it is only expressed in the weak schistosity resulting from muscovite/biotite recrystallization in the cores of F_2.

A metamorphic event, M_3, accompanied the D_3 deformation since chlorite + biotite grow along S_3 schistosity in the micaceous layers of F_3 folds.

Garnet + kyanite growth in the quartz-mica schist may have occurred during M_1. Rosettes of tabular kyanite, nucleating on garnet prophyroblasts, appear to be post-D_1 age (?) but have not been observed to overgrow S_3 og S_2. The kyanite is slightly strained with undulatory extinction and is a late metamorphic mineral since it shows a totally random orientation. A post kinematic D_1 age for this mineral is preferred.

5.2. Metamorphism in the Eastern area.

Metamorphic grade decreases progressively eastwards. Garnets are common in the quartz - mica schist near Trangen but become increasingly smaller and rarer to the east and are rarely seen east of Nyneset. In addition, chlorite takes the place of biotite in the quartz-mica schist and actinolite occurs instead of hornblende in the greenstones so that in the vicinity of Finnbu one is dealing with a greenschist grade instead of an amphibolite grade metamorphism.

6. Mineralization.

A sulphide occurrence at (0541 0260) in a road cut on the forestry road behind the Grong Folkehøgskole (Folkehøgskoleveien) occurs at the contact between underlying amphibolites and the overlying quartzites. The ore horizon is 5 - 10 cm thick and is broadly conformable to the lithological contact. The sulphide occurs as massive lenses up to 10 cm thick and 0,5 m in length, and also in irregular veinlet and stringers as a result of mobilization during deformation. In the road cutting at

(0541 0260) the sulphide occurs along the whole of the exposed amphibolite/quartzite contact - a distance of approximately five meters. Minor concentrations of sulphide have occurred in the hinges of small folds. The chief sulphide mineral is pyrite with chalcopyrite occurring in only trace quantities. Locally leaching of the sulphide by groundwater has occurred since the ore horizon is friable and contains considerable limonite.

Although the amphibolite/quartzite contact has not been traced in detail, traces of sulphide have been observed whereever the contact is exposed in road cuts along the Folkehøgskoleveien and also along the E6 northeast of Fosland.

Lenses of pyrite, maximum thickness 5 cm, occur in amphibolites at the sediment/amphibolite contact south of Kultjern (north of Tømmerås setter). (0432 0344; 0433 0355; 0413 0350). The pyrite lenses parallel the foliation in the amphibolites, but it is not possible to state with any certainity if they are of a sedimentary or remobilization origin.

Irregular veinlets and thin lenses of compact pyrite with traces of chalcopyrite occur in the bed of Miganbækken just below the top of the cliff on the south side of the Namsen river (0651 0310). The sulphides occur in amphibolites near the amphibolite/sediment contact. This would appear to be a previously unknown occurrence since it is not shown on Foslie's map sheets (unpublished).

The sulphide occurrence at Hotjern (0720 0372) occurs at the contact between amphibolites (above) and sediments (below). The deposit appears to be of the stratiform type.

The Rosset mine (0490 0478) occurs in metasediments which underlie amphibolites. The main ore occurrence is a massive 'dike'-like body which is capped (?) by a 10 - 20 cm massive sulphide unit which is conformable to the enclosing rocks. The exact relationships between the vertical ore 'dike' and the horizontal ore layer have not yet been satisfactorily delineated. The western Rosset occurrence (0490 0443) also appears to lie at the lower contact of the amphibolite unit near the amphibolite/sediment contact (R. Kvien, personal communication).

The Godejorde mineralization occurs in a pyritized zone which appears to follow stratigraphic layering from (0276 0641) in the west to at least (0293 0711) and may belong to the mineralized horizon which can be followed intermittently to the east beyond Finnbu.

The Godejorde horizon occurs mainly in a small valley and is covered with overburden over most of its length except where exposed by trenching. The horizon is mainly a pyritized quartz-sericite schist (except in the vicinity of the Godejorde deposit (0293 0711) and is conformable to bedding/foliation in the host rocks. The mineralized horizon dips steeply (50 - 75 degrees) northwards and is bounded on the north by layered amphibolites which resemble strongly deformed fragmental rocks in several places. 'Garben schifer' is common south of the mineralized zone although amphibolites and greenschists (layered basic sediments/tuffs) are the dominant rock types. Although layered sediments/tuffs occur immediately adjacent to the mineralized horizon at (0276 0641) more detailed mapping is required before the conditions of deposition can be deduced with certainity, i.e. whether the mineralization is stratiform sedimentary or stratiform replacement.

Except for the high grade heavy metal occurrence at the Godejorde deposit (0293 0711) the exposed portions of the mineralized horizon are relatively low in economic metals. In the section at (0278 0674) selected hand specimens contain 0,5 to 1% Cu (estimated).

With the exception of the Godejorde occurrence where the stratigraphic and tectonic relationships are not known in detail, the other mineral occurrences mentioned here occur at a sediment/amphibolite contact. If the interpretation of the area in terms of an early major recumbent fold structure is correct, then all of these occurrenced occupy the same stratigraphic horizon. The question of the age of the mineralization, i.e. initial (early) or end (late) in the volcanic cycle must await the establishment of stratigraphic age relationships. In terms of the relative stratigraphic established, the mineralization event would have occurred at the end of a volcanic cycle.

George H. Gale 4/2/74

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Plate 1.

D_1 Minor structures.

A. F_1 isoclinal fold in layered gneisses (02090450).

B. F_1 Z-fold in psammite, near Renslitjern. (04970359). Refolded by open D_3 structures with vertical crenulation cleavage.

C. Tight to isoclinal F_1 fold in psammites (04740339). Cf. Plate 1 -

D. F_1 isoclinal fold in psammite, near Renslitjern (04980359).

E. Tight to isoclinal F_1 folds in psammites south of Renslitjern (04910350). Note differential weathering of calcareous layers.

F. F_1 isocline in psammite (05140363).

G. Tight F_1 folds in psammite above Tømmerås setter. (02960357). Looking east.

H. Tight F_1 fold in amphibolite (05040285).

I. D_1 Boudin in layered amphibolite (04100395).

J., K. 2 photos showing progressive boudinage. Early boudins, coins mark necking sites of small early boudins inside larger boudin.

L. Large Boudin structure with necks in the foreground and where the exhuberant geologist stands. S_1 closures of smaller boudins (some are marked by objects) were noted within the larger boudin. (04100395).

A

B

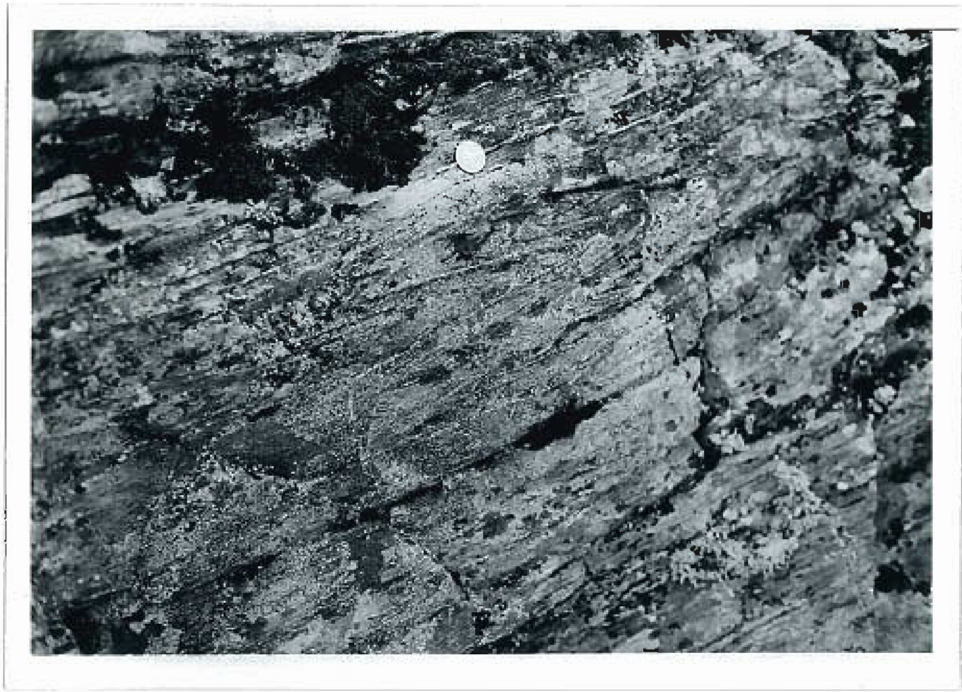
C

D

E

F

G

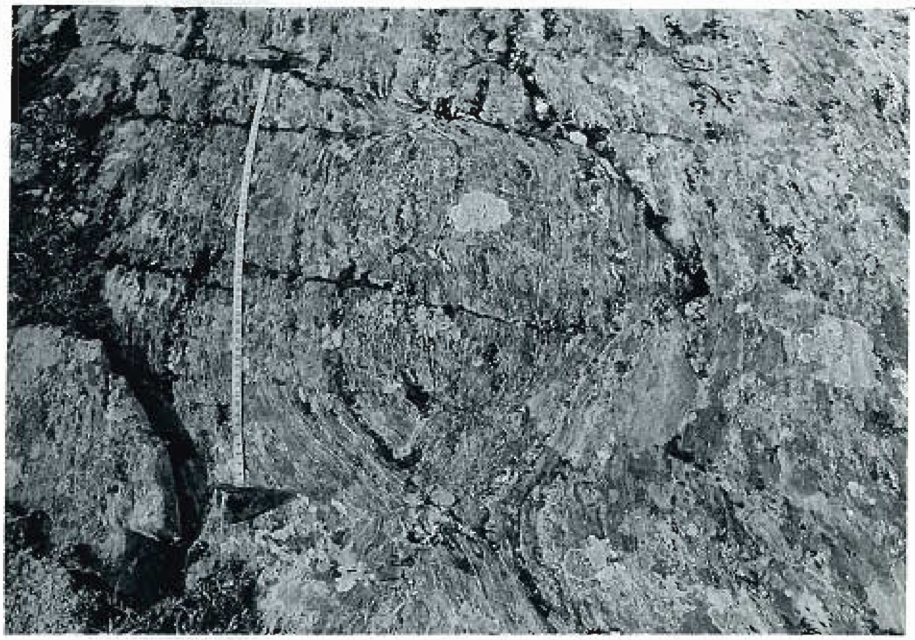


H

I

PLATE 1.

j



K

L

Plate 2.

D_2 minor structures.

A. F_2 S-fold in amphibolite. (0263 0462).

B. F_2 S-fold in amphibolite. (0460 0335).

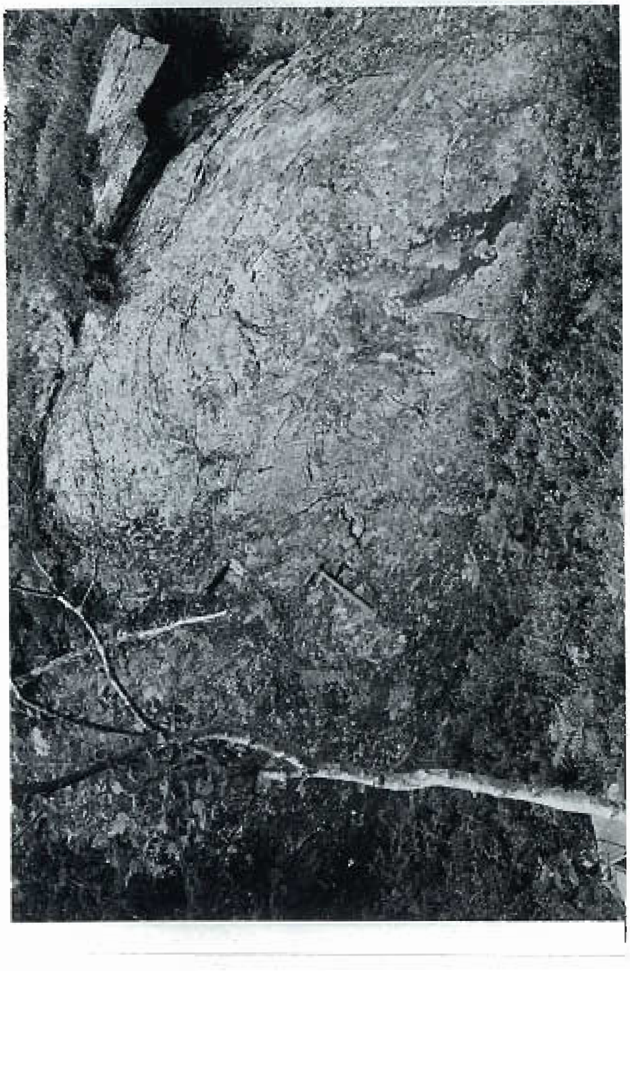
C. F_2 S-folds in clacareous psammite. (0560 0335).

D. F_2 S-fold in conglomeratic psammite at contact with amphibolite (top of picture). (0565 0312).

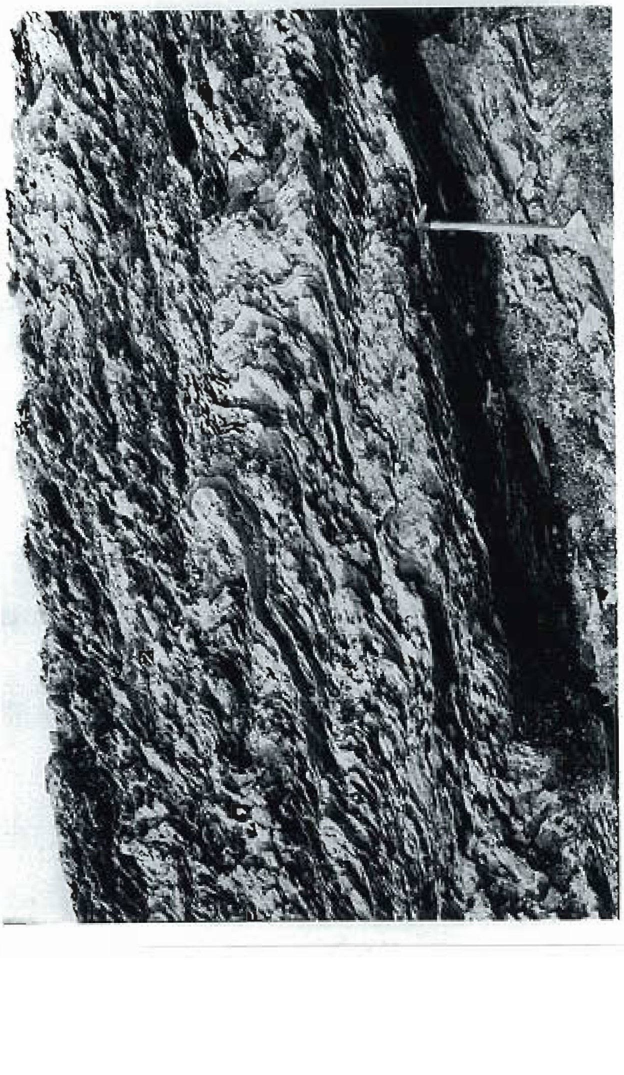
PLATE 2.

B

D



A



C

Plate 3.

A. Boudinaged and folded quartz veins of D_2 age in quartz biotite schist. (0234 0465).

B. Large F_2 S-fold in psammite. (0530 0376).

C. Open F_4 folds in quartzites. F_4 antiform on the right. (0543 0265).

PLATE 3.

A

B

C

Plate 4.

A. F_4 minor folds in amphibolite. (0373 0357).

B. F_4 minor folds on limb of F_4 synform to the left. (0500 0359).

C. F_4 (?) folds in amphibolite. Looking south. Note that axial planes are westward dipping here. (0510 0428).

D. Tight (?) minor folds in psammite. Locally the primary foliation (S_1) is completely transposed into a later schistosity S_2/S_4 (?). (0427 0347).

PLATE 4.

A

B

C

D

Plate 5.

A. Tight to isoclinally folded amphibolite probably of D_2 age. (0300 0395).

B. Minor Z-fold (D_2?) in amphibolite. (0380 0373).

C. Tightly folded psammites in which S_1 parallels S_2 (?) on fold limbs. (0437 0345).

D. Axial plane schistosity (S_2) and layering in amphibolites. Note the nearly parallel alignment of S_1 and S_2 on the far right and left of the fold core (center). (0510 0380).

PLATE 5.

B

A

C

Plate 6.

Folds styles of uncertain age.

A. Tight to open recumbent folds in psammites (axial planes near horizontal). (SW of Renslitjern).

B. Crenulation cleavage associated with folds shown in A.

C. Folded clacareous psammite and psammite cf. Plate 2-C. NW of Renslitjern.

D. Minor fold in psammite. A crenulation cleavage with a near horizontal attitude occurs in the fold hinge. N of Renslitjern.

NB! It is possible that the crenulation cleavage of the folds in A, C and D are of D_2 age but has been rotated by later folding, however no systematic variation of the cleavage in C has been observed, and the style is different from that of the F_2 folds (cf. Plate 2).

PLATE 6.

B

D

A

C

Plate 7.

Minor folds in the Rosset area.

A. F_1 recumbent fold in psammite (greyish white) and clacareous psammite (dark grey). S_1 (schistosity is nearly flat lying. Fold axes, strikes 070 and plunges away from the observer at about 20 degrees. (2800 x 6200 y). Rosset grid.

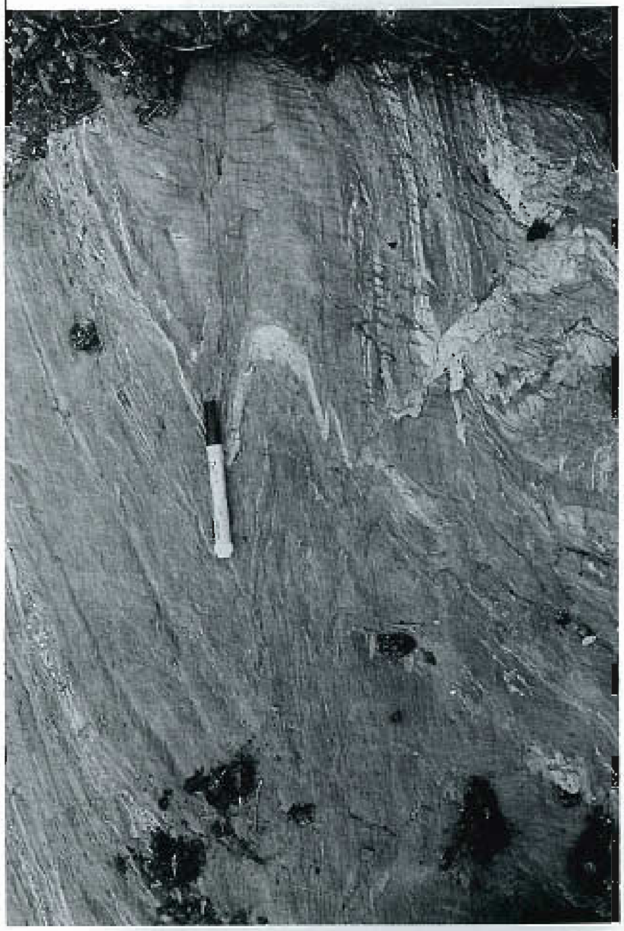
B. F_2 type fold in conglomeratic psammite below amphibolite ~~(5050 y~~ (0500 0473) Looking north.

C. F_4 (?) open folds in amphibolite. Looking northwest.

D. Tight F_3 folds with vertical axial plane cleavage (parallel to pen). Pen oriented NE/SW. (5200 y 2420 x). Rosset grid.

PLATE 7.

B



D

A

C

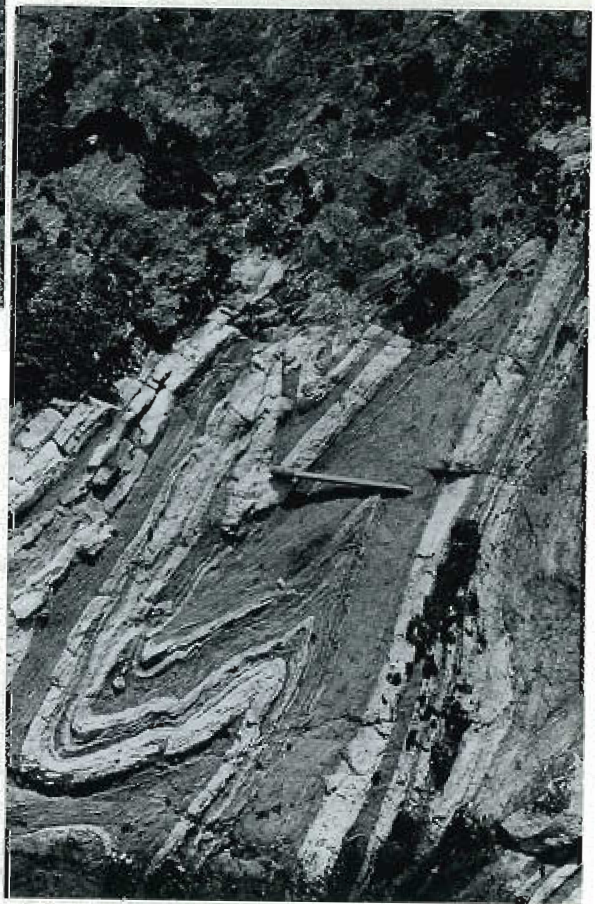
Plate 8.

Interference folds.

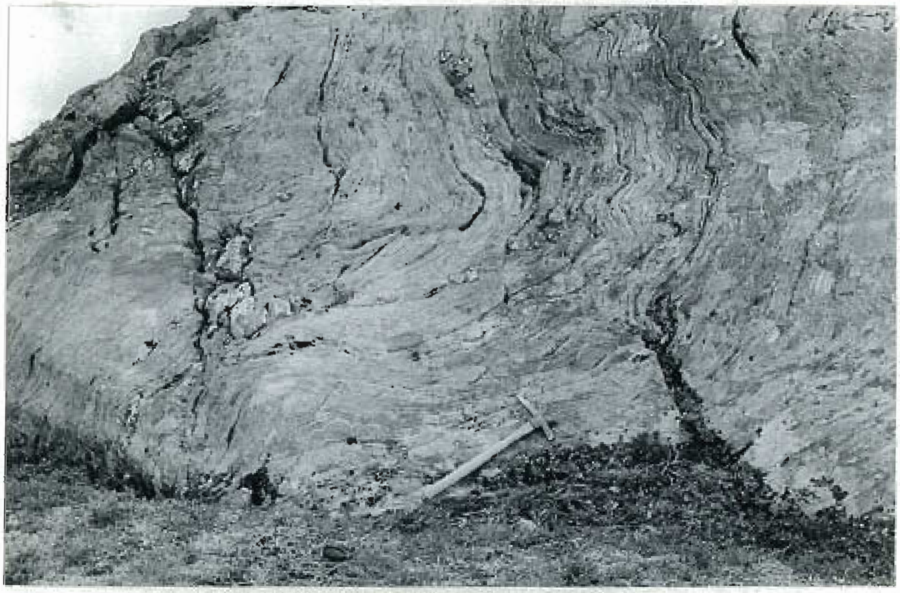
A.	F_4 and F_1	(0505	0347)
B.	F_2 and F_1	(0286	0409)
C.	F_2(?) and F_1	(0485	0345)
D.	F_2 and F_1	(0241	0471)

PLATE 8.

A

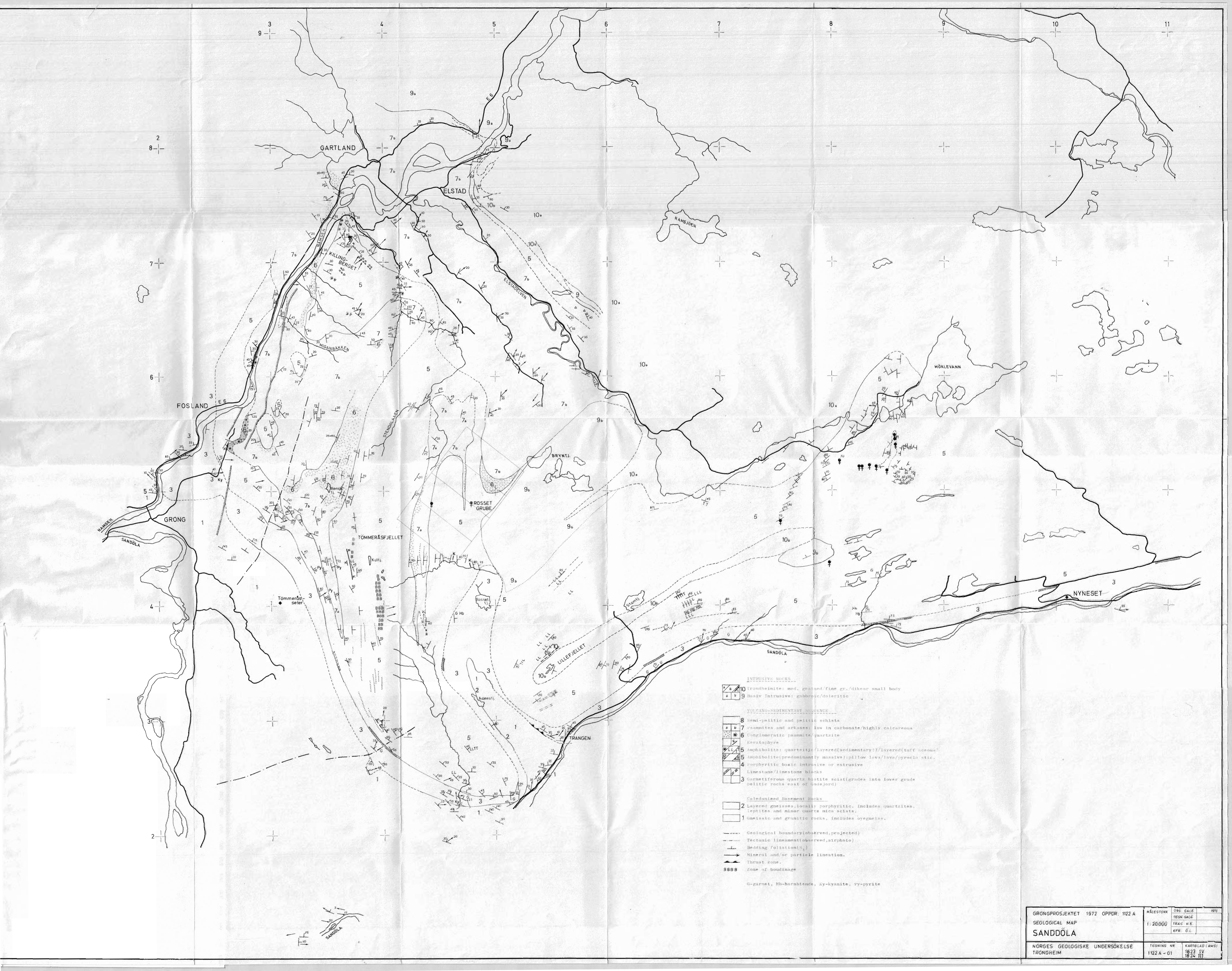


B

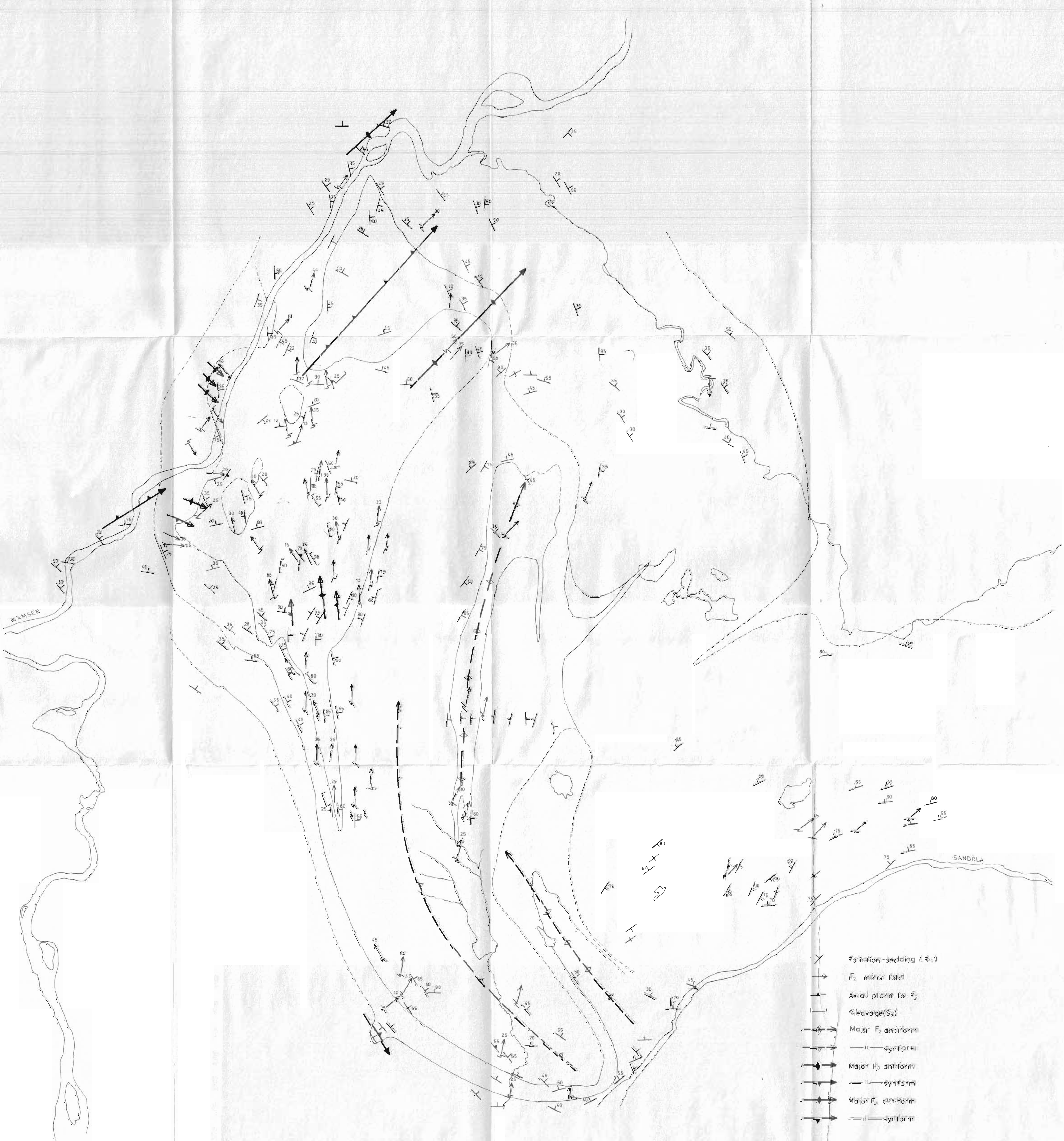


C

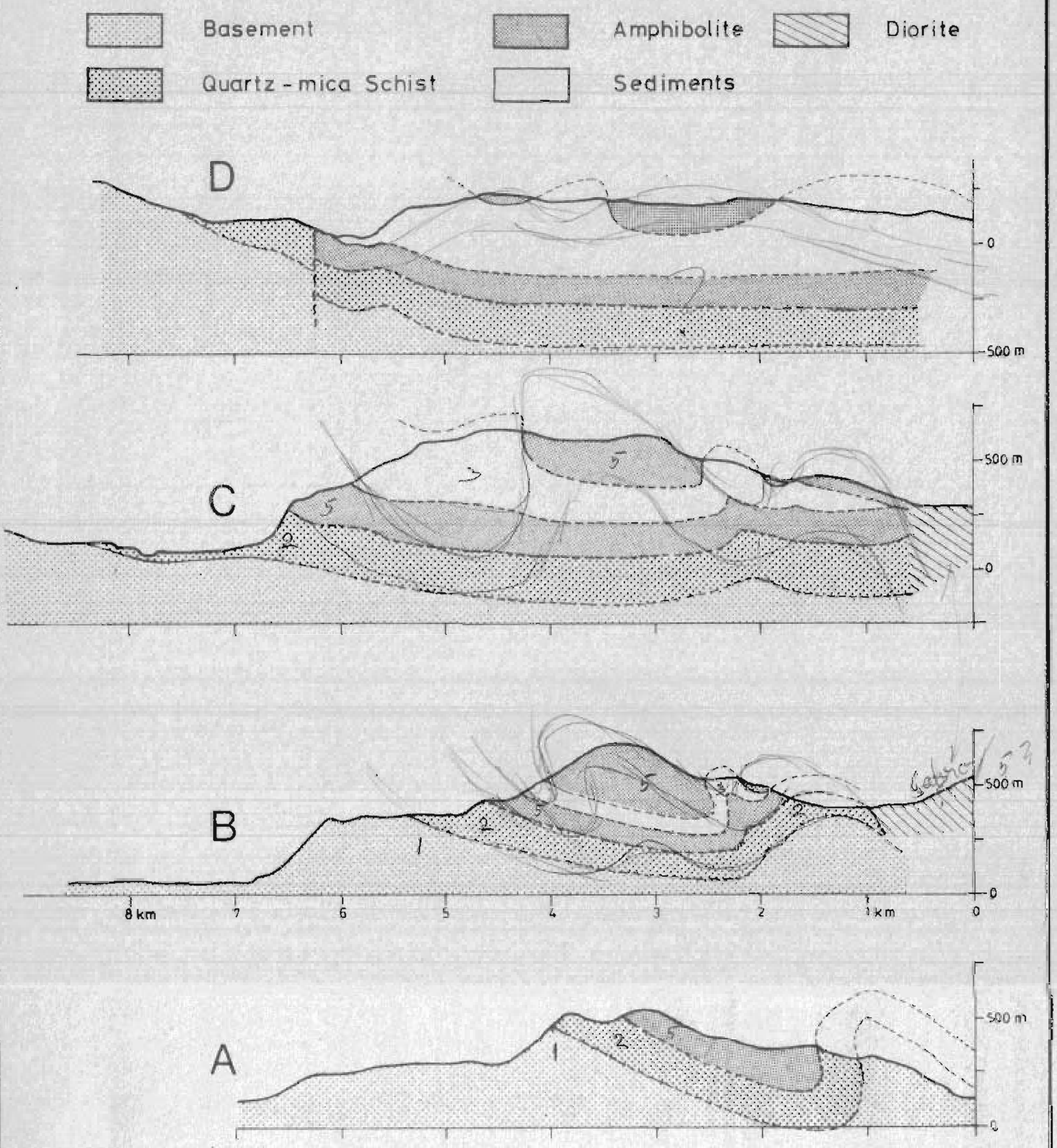
D



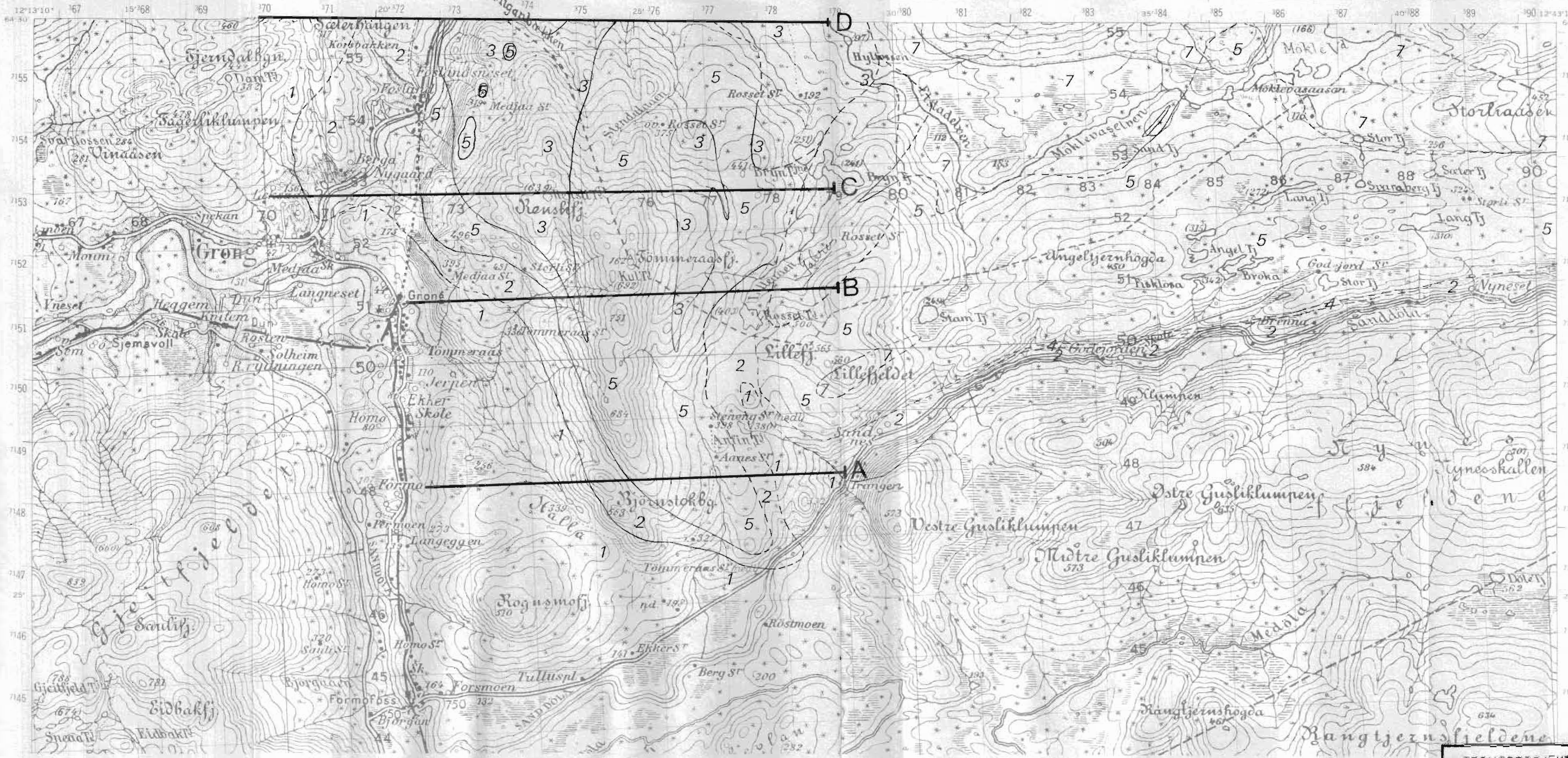
GARTLAND
ELSTAD
KILLINGBERGET
FOSLAND
GRONG
NAMSEN
SANDÖLA
TOMMERÅSFJELLET
Tommeråsseter
ROSSET GRUBE
BRYNTJ.
RAMSJOEN
ELSTADELVEN
MÖKLEVANN
LILLEFJELLET
TRANGEN
NYNESET
E 6
INTRUSIVE ROCKS
10 Trondheimite: med. grained/fine gr./dikeor small body
9 Basiv Intrusive: gabbroic/doleritic
VOLCANO-SEDIMENTARY SEQUENCE
8 Semi-pelitic and pelitic schists
7 Psammites and arkoses: low in carbonate/highly calcareous
6 Conglomeratic psammite/quartzite
Keratophyre
5 Amphibolite: quartsitic/layered(sedimentary?)/layered(tuff aceous)
5 Amphibolite(predominantly massive):pillow lava/lava/pyrocla stic.
4 Porphyritic basic intrusive or extrusive
Limestone/limestone blocks
3 Garnetiferous quartz biotite scist(grades into lower grade pelitic rocks east of Godejord)
Caledonized Basement Rocks
2 Layered gneisses,locally porphyritic. Includes quartzites, leptites and minor quarts mica scists.
1 Gneissic and granitic rocks, includes oyegneiss.
Geological boundary(observed,projected)
Tectonic lineament(observed,airphoto)
Bedding foliation(S1)
Mineral and/or particle lineation.
Thrust zone.
Zone of boudinage
G-garnet, Hb-hornblende, Ky-kyanite, Py-pyrite
GRONGPROSJEKTET 1972 OPPDR: 1122 A
GEOLOGICAL MAP
SANDDÖLA
MÅLESTOKK
1:20.000
OBS. GALE 1972
TEGN. GALE
TRAC. H.E.
KFR. Ö.L.
NORGES GEOLOGISKE UNDERSÖKELSE
TRONDHEIM
TEGNING NR
1122 A - 01
KARTBLAD (AMS)
1823 IV
1824 III



GRONGPROSJEKTET 1972 OPPDR.: 1122 A STRUCTURAL GEOLOGY **SANDÖLA**	MÅLESTOKK 1 : 20 000	OBS. G.A. TEGN. G.G. TRAC. H.E. KFR.	1972
NORGES GEOLOGISKE UNDERSÖKELSE TRONDHEIM	TEGNING NR. 1122 A - 02	KARTBLAD (AMS) 1823 IV 1824 III	

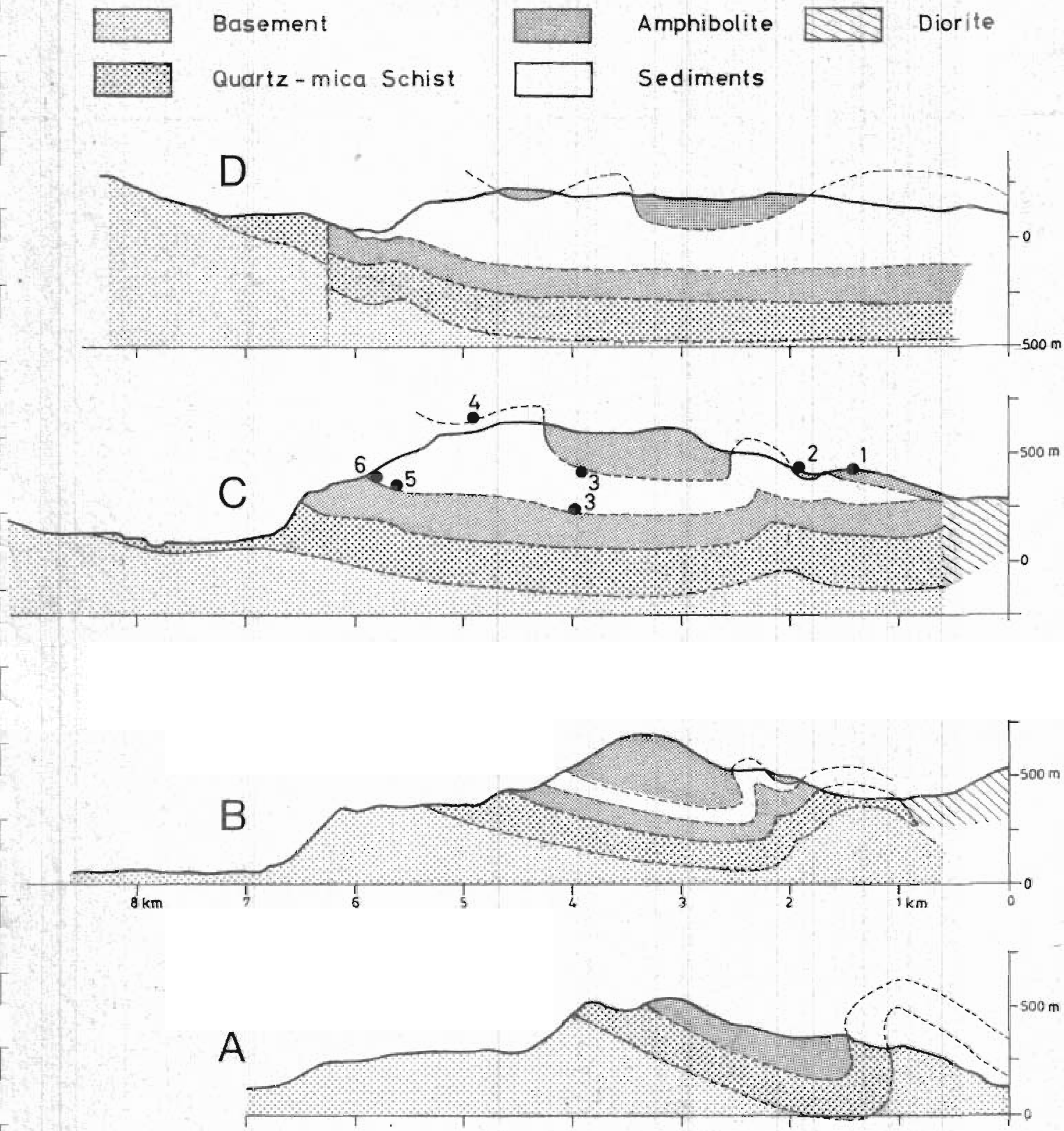


GRONGPROSJEKTET 1972 OPPDRAG 1122A	MÅLESTOKK	OBS. GALE	1972
SANDDÖLA		TEGN. GALE	
GEOLOGICAL CROSS SECTIONS	Vertical 1:25000	TRAC H.E.	MAI 1973
	Horizont 1:50000	KFR.	
NORGES GEOLOGISKE UNDERSÖKELSE TRONDHEIM	TEGNING NR 1122 A - 03	KARTBLAD (AMS) 1823 IV	



7	TRONDHEIMITE
6	DIORITE
5	AMPHIBOLITE
4	LIMESTONE
3	SEDIMENTS
2	QUARTZ-MICA SCHIST
1	BASEMENT

GRONGPROSJEKTET 1972 OPPDRAG 1122 A SANDDÖLA SIMPLIFIED GEOLOGICAL MAP SHOWING LINES OF SECTION	MÅLESTOKK 1:50.000	OBS. G. GALE TEGN. TRAC. H.E. KFR	1972 MAI 1973
NORGES GEOLOGISKE UNDERSÖKELSE TRONDHEIM	TEGNING NR	KARTBLAD (AMS)	



1 – ROSSET MINE
2 – WEST ROSSET OCCURRENCE
3 – TÖMMERÅS-SETER OCCURRENCE
4 – HOTJERN OCCURRENCE
5 – MIGANBEKKEN OCCURRENCE
6 – FOLKEHÖYSKOLEVEIEN OCCURRENCE

GRONGPROSJEKTET 1972 OPPDRAG 1122 A SANDDÖLA Projection of mineral occurrences onto GEOLOGICAL CROSS SECTIONS	MÅLESTOKK Vertical: 1:25000 Horizont: 1:50000	OBS G. GALE TEGN. GALE TRAC. H.E. KFR.	1972 MAI 1973
NORGES GEOLOGISKE UNDERSÖKELSE TRONDHEIM	TEGNING NR 1122A-05	KARTBLAD (AMS) 1823 IV	