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Sammendrag

THE GEOLOGY OF THE HOGKNIPPEN AREA, MELDAL, SØR TRONDELAG

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Brief report of findings to:-

ORKLA GRUBE, LØKKEN VERK.

April 1982

C O N T E N T S

SECTION 1.

Introduction

The area discussed is about 35 square kilometres and is centred on Hogknippen mountain (2 kilometres east of Meldal), Sør Trondelag. A brief account of the geology of this area is presented. Only preliminary results are available as most of the thin section work and geochemistry is still in progress.

This area is important in the context of Trondheim geology. It lies about 10 kilometres west of the Holonda-Horg area which has been regarded as the type area for Norwegian Caledonian geology since the beginning of the century. Vogts (1945) work in that area and Chaloupsky's (1969) treatment of the geology between Holonda and Hogknippen, are the more recent contributions, and they will occasionally be referred to in this text.

For a good description of the geology of the north of Hogknippen and a brief account of the succession in this area, the reader is referred to Ryan et al. (1980).

SECTION 2: STRATIGRAPHY

2.1 INTRODUCTION

The structural revision proposed (Sect. 4) necessitates the construction of a new stratigraphy. This stratigraphy (in agreement with Ryan et al. 1980) invokes the absence of the Lower Ordovician Nyplassen directly to the south of the Grefstadfjell complex, and the presence of an apparently continuous Upper Ordovician (Silurian?) succession which lies unconformably on the basic volcanics to the north.

The Kałstad limestone formation is overlain by the Ryanda Formation comprising grey green volcanic sandstones, pebbly sandstones, conglomerates, dark laminated shales and possible limestone. A transitional boundary into the Hogknippen Formation follows. This comprises three sequences of rhyolite tuff and volcanic sandstones, three extensive conglomeratic horizons, a major debris flow and a sequence of interbedded shales and tuff/sandstones. This Formation has been subdivided into members (described later: Fig. 2.1).

2.2 RYANDA FORMATION

This Formation has not been studied in detail, however, preliminary observations will be presented.

To the west this sequence overlies the Kalstad limestone, but may also be equivalent to it further to the east. In fact, a limestone containing similar fauna to that of the Kalstad occurs within the Ryanda to the east, however, no younging evidence was observed to obviate the possibility of infolding.

Rock types include, interbedded black shales and sandstones (dark laminated shales), grey green volcanic sandstones and shales, pebble sandstones, conglomerates and, locally towards the top of the sequence, volcanic tuffs.

The grey green sandstones are very felspathic and contain shale and dark laminated shale (D.L.S.) clasts up to 10 cm. long. Their importance increases upwards while the black shales are more common towards the base with occasional yellow volcanic sandstones and grey green greywackes. The sandstones display characters of the A and E divisions of the Bouma sequence (extremely rare C divisions were also observed). Soft sediment deformation in the form of disrupted beds is common. In the north, dark laminated shales of the same character as within the Sanda member (of the Hogknippen Formation) increase in importance towards the top of the succession. However, volcanic sandstones and tuffs usually occur at the transition with the overlying Hogknippen Formation. To the south the upper part of the Ryanda comprises sediments of a more distal character with up to 100 metres of dark shales.

The Ryanda conglomerates contain quartz (about 30%), limestone (about 20%), Rhyolite-andesite (5 - 10%), shale (about 2%) and other sedimentary clasts (5 - 10%). These are usually rounded, close packed, have a mean size of 4 - 5 cm. (less than ½ metre) and are set in a volcanic sandstone matrix. They are a minimum of about 3 metres wide. At least two conglomeratic horizons are present.

Pebbly sandstones are only locally developed. They have subangular - rounded clasts (less than 2 cm.), quartz being the most common and conspicuous clast type. To the north, the upper 300 metres of the Ryanda is usually marked by the presence of volcanic sandstones and occasional dacitic tuffs (amphibole bearing). The former are coarse to fine calcareous volcanic sandstones. They are occasionally thick (greater than 3 metres) and massive, but thinner beds (less than 2 metres) are often normally graded and have well developed load structures at their base. The complementary E division of these A type beds are also seen in the form of black shales. D.L.S. are a common associated rock type. In one well exposed river section (the Messa river in the N. Western part of the area) no bedding is visible for 30 metres. The volcanic sandstones are very homogenous and at the base very large (3 metres x 30 metres) D.L.S. clasts occur.

In the main, the character of the Ryanda formation sequence indicates that it is of proximal nature. Features indicative of an inner-mid fan depositional environment are common with AE divisions, conglomerates, pebbly sandstones, soft sediment deformation and possible grain flows (i.e. thick sequences locally developed in the Messa volcanic sandstones). The lateral variation from the proximal Messa volcanic sandstones in the north to the dark shales in the south is notable. It suggests basic deepening to the south. The observation that the Kalstad lies unconformably on the Grefstadfjell complex while the Grut limestone (a probable equivalent of the Kalstad, Kiaer 1932) to the south overlies a thick sequence of the lower-middle Ordovician Nyaplassen formation, lends weight to the above conclusion.

Therefore a sediment source to the north and a southward lying basin is invoked. Further, the transition from the Kalstad limestone to the Ryanda formation attests a significant basin-deepening episode at the beginning of the Ashgill.

2.3 THE HOGKNIPPEN FORMATION

This formation is sub-divided into four members (Fig. 2.1)

(1) The Klemfjellet member.

(2) The Sanda shale member.

(3) The Hogasen massive tuff member.

(4) The Hoyluenget member.

The upper and lower boundaries of each member are defined by very distinctive marker horizons (Plate 1). These and the intervening members will be described in chronological order.

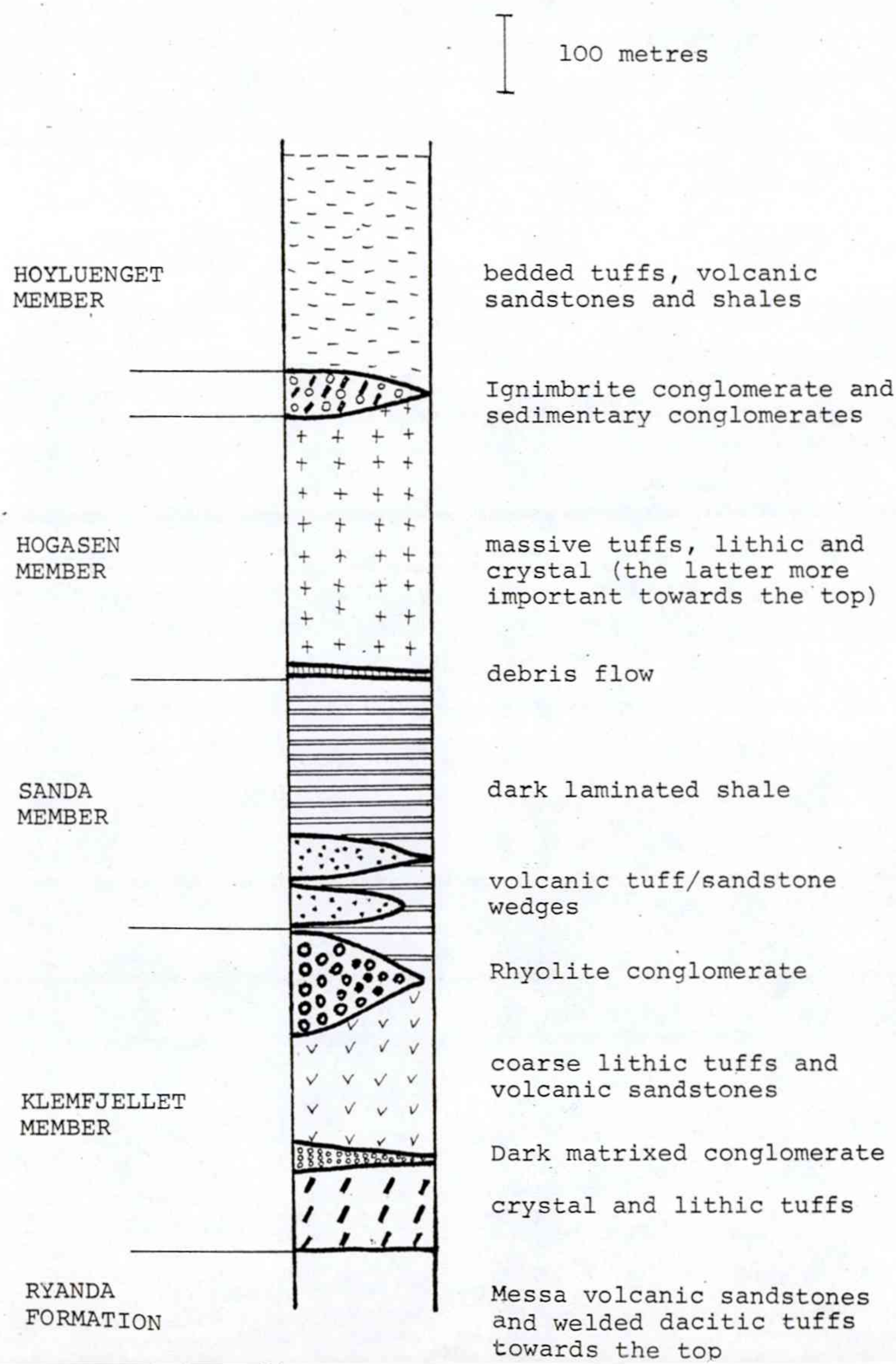
(1) The Klemfjellet member.

Yellow lithic and crystal tuffs, with sandstone and siltstone grain sizes, occur at the base. The conglomerate that follows is up to 10 - 15 metres thick in the north, where it has a wedge shaped outcrop pattern, but thins and becomes more extensive to the south. D.L.S. (less than 1 metre), rhyolite and limestone (up to 1/3 metre) clasts are common and are often rounded. The clasts are framework supported. In one area (north of Klemfjellet mountain) a very large limestone "boulder" occurs which is certainly a few hundred cubic metres in volume. The matrix of the conglomerate is heterogenous with varying amounts of white felspathic sandstone and dark tuff (the latter sometimes occurs in large wisp like forms within the former).

Coarser tuff/sandstone beds follow in thick bedded units (about 2 - 3 metres or more). Occasional shale interbeds occur throughout this member.

FIG. 2.1

HOGKNIPPEN FORMATION (approx. 1400 metres thick)



The top of the member is marked by the Rhyolite conglomerate. This conglomerate also thins to the south but to the west of the area it is not present. Indeed, to the west, its wedge shaped form mimics that of the Klemfjellet unit as a whole. A decrease in grain size is accompanied by bed thinning and it would appear that the main channel is in the north central part of the area while the southern exposures correspond to a more distal facies. Clasts are rounded and up to 1 metre in the north decreasing to less than ½ metre in the south. Clast types include rhyolite-dacite (80%), grey-yellow shale/tuff and very rare small quartzs (about 1 cm.). The matrix is a white volcanic sandstone. The conglomerate is demonstrably composite to the north but appears to be one unit to the south. It is occasionally orthoconglomeratic but normally paraconglomeratic.

(2) The Sanda member.

This usually follows the conglomerate immediately, particularly to the south and west. However, above the thickest development of the conglomeratic horizon a wedge of volcanic sandstone/tuff occurs (Plate 11).

This member is equivalent to Vogts (1945) and Chaloupsky's (1969) dark laminated shales. As is evident from the Ryanda formation this lithology is by no means restricted to one level of the Upper Ordovician stratigraphy. It is, however, typical of sediments above the Kalstad limestone formation, the lower Hovin group having shales with a distinct green colour. The member consists of dark shales with interbedded fine grained tuff/sandstones (the distinction between the two may be resolved by ongoing petrographic studies). The yellow tuff/sandstones are sometimes normally graded and have loaded bases, flame structures and diffuse tops. The shales are often very flinty and grey (particularly in the north and west) and may in some cases represent very fine grained ash fall tuffs. A notable feature is the decrease in yellow tuff/ sandstone beds in the southern part of this member.

(3) The Hogasen member.

The character of this member is markedly different from that of the Sanda member. A sharp transition into these coarse (- fine) grained volcanic tuffs is preceeded by D.L.S. which have suffered significant soft sediment deformation (folds, ball and pillow structures, chaotic bedding etc.). Indeed, for this reason, it is often very difficult to establish good way-up evidence.

At the base of the member a thick (up to 15 metres) debris flow occurs to the north and is only locally missing in the central part of the area to the south. Otherwise it is remarkably extensive and provides a very distinctive marker horizon. Its main characteristic is the abundance of very large limestone clasts up to 200 cubic metres in volume. Disrupted and chaotically bedded D.L.S. are very common while virtually no rhyolite boulders are present. The matrix is often a dark volcanic sandstone, with angular fragments of rhyolite, but can also be a white volcanic sandstone. As in the case of the dark matrixed conglomerate the matrix is often heterogenous.

The transition into massive tuffs is often sharp but to the east and south up to 20 - 30 metres of D.L.S. can occur. Once into the tuff no shale interbeds are present. The tuffs consist of thick massive tuffs (up to 4 metres) with interbedded fine grained varieties (particularly at the base of the member) in the central part of the area. To the west, however, bedding is sometimes thinner and discrete channels, with loads and sand dykes, occur. Welding is occasionally seen in the field and crystal tuffs are not uncommon, particularly at the top. A feature of this member is the presence of up to 75 metres of tuff which contains needles (and flakes) of biotite. This mineral sometimes gives the rock an appearance similar to that of a microgranite (but fragments are clearly visible on weathered surfaces). A deep yellow crystal tuff is a conspicuous component of these volcanics particularly towards the top where it is associated with the ignimbrite conglomerate. The latter contains piped ignimbrite clasts in a volcanic matrix which is clearly welded. More rarely, no large rounded clasts are present and the ignimbrite looks almost like a quartz porphyry. The sedimentary conglomerates have a green tuffitic matrix, a large proportion of volcanic sandstone/tuff clasts and significant amounts of clasts similar to the ignimbrites. These conglomerates occur both above and below (more commonly) their volcanic equivalent. It is apparent, therefore, that this important ignimbritic phase of eruption may have produced the instabilities required to deposit concomitant sedimentary conglomerates.

(4) The Hoyluenget member.

The occurrence of significant orthoclase within tuffs and the appearance of interbedded shales are important features of this member. The proportion of tuff decreases upwards where the presence of small shale fragments and the lack of crystals and rounded volcanic quartzs suggests that they may be volcanic sandstones. Bed thickness also shows a broad decrease upwards.

Hogknippen formation: volcanic or sedimentary?

The decision as to whether this formation is primary volcanic or resedimented volcanic material is both important and difficult. Limited petrography and field observations, however, enable one to make some tentative conclusions.

The sequence, particularly in the central part of the area, is massive tuff with no interbedded shales. The highly, and apparently exclusive, volcanic composition of the strata suggest that they are at least derived from a source area extremely rich in volcanic material. The extreme angularity of many of the clasts suggest a proximal depositional environment while the presence of crystal tuffs, occassionally welded, and ubiquitous shard rich fine grained tuffs indicates contemporaneous volcanic activity. The question is, therefore, are the remaining beds the products of the rapid erosion of broadly contemporaneous tuffs, ignimbrites and flows or are they in fact subaqueous pyroclastic flows.

The bed thickness, lack of sole features and cross bedding are not compatible with the classic turbidite sequence (Bouma 1963). In fact, their features are similar to those of grain flows, mass flows and submarine pyroclastic flows (Lajoie 1979). One of the main difficulties with resolving what origins some of these rocks had, is that recrystallisation and replacement may have destroyed or masked many of the primary textures. At present, however, the above bedding characteristics, the exclusively volcanic composition and an association with crystal tuffs and well developed air fall tuffs is considered sufficient evidence to conclude that a bed probably represents a subaqueous pyroclastic flow.

These criteria enable one to conclude that the following represent primary volcanic sequences:
(a) The base of the Klemfjellet member. (b) The Hogasen member. (c) The base of the Hoyluenget member. In each case lateral thinning, the presence of thinner beds and more interbedded shale and small scale sedimentary features, to the west indicate that the main depositional channels were towards the centre of the area and that the production of more typical sedimentary characters was restricted to environments marginal to those channels.

Hogknippen formation: depositional environment.

The features of the Hogknippen formation are indicative of a proximal environment in a submarine fan. Marked lateral variation, thick bedded sequences, extensive conglomerates and a thick debris flow are just a few of the components typical of this depositional regime.

The channelised nature of the conglomerates to the north and the decrease in grain size and thickness to the south, suggest a northerly source area. The thickness of the debris flow to the north and the very large boulders within it; the lack of sandstone and volcanic tuff/sandstones wedges to the south; also indicate derivation from the same direction. As previously noted a northerly source area is likely for the sediments of the Ryanda formation.

The thickness of the Rhyolite conglomerate implies either a more proximal environment or a period of rapid sediment influx, possibly due to volcanic activity and/or uplift to the north. This phase was followed by one of relative quiescence and/or transgression (thereby leading to the deposition of the more distal type Sanda member). An extensive debris flow, containing large limestone boulders, marked the beginning of a period of rapid influx of volcanic material. The fact that the limestone clasts provide the youngest age for rocks of this succession, may suggest that a carbonate shelf had developed concomitant to the deposition of the more distal Sanda member.

Rapid deposition of the Hogasen massive tuff ensued contemporaneous with dacitic and rhyolitic vulcanism to the north. Gradual coarsening of the rock types and the deposition of a thick ignimbrite and associated sedimentary conglomerates, provide good evidence for an increase in instability and volcanic activity contemporaneous with basin shallowing.

The return to tuff and sandstone deposition with interbedded shales indicates a waning of sediment influx. Their thick bedded nature still, however, suggests a proximal regime. The possibility that these deposits are to a significant extent volcanic sandstones may suggest that volcanic activity was minimal.

Finally, because of their distinctive character and as they mark important changes in depositional phases the various markers described may be useful in sediments of the same age to the east within the Horg syncline.

SECTION 3.

Established ages

The Kalstad formation contains a brachiopod, crinoidal and coral fauna which has been dated as Ashgillian. The Grut limestone to the south is probably of the same age (Kiaer 1932; B. Neumann pers comm.) and its spatial position suggests that it is on the southern limit of the Hogknippen syncline.

The Grimsas rhyolite boulder which was found to the west of this area in the early part of the century is of Ashgillian age. A similar rock type has recently been discovered as outcrop (B. Neumann pers comm.) and its brachiopod fauna also revealed an Ashgillian age. As the volcanic sandstones at the top of the Ryanda formation bear a marked similarity, both in appearance and structural level, to the aforementioned rocks an Ashgillian age may be inferred.

The youngest age has recently been recorded for corals within a limestone boulder from the Hogasen debris flow (P. Ryan pers comm.). These fossils have an established age of uppermost Ordovician - lower Silurian.

The Hogasen and Hoyluenget members of the Hogknippen formation, particularly the former, do not hold too much hope for future palaeontological finds! Geochemical dating, as the remaining possibility, is therefore being undertaken using the boulders and matrix of the ignimbrite conglomerate.

SECTION 4.

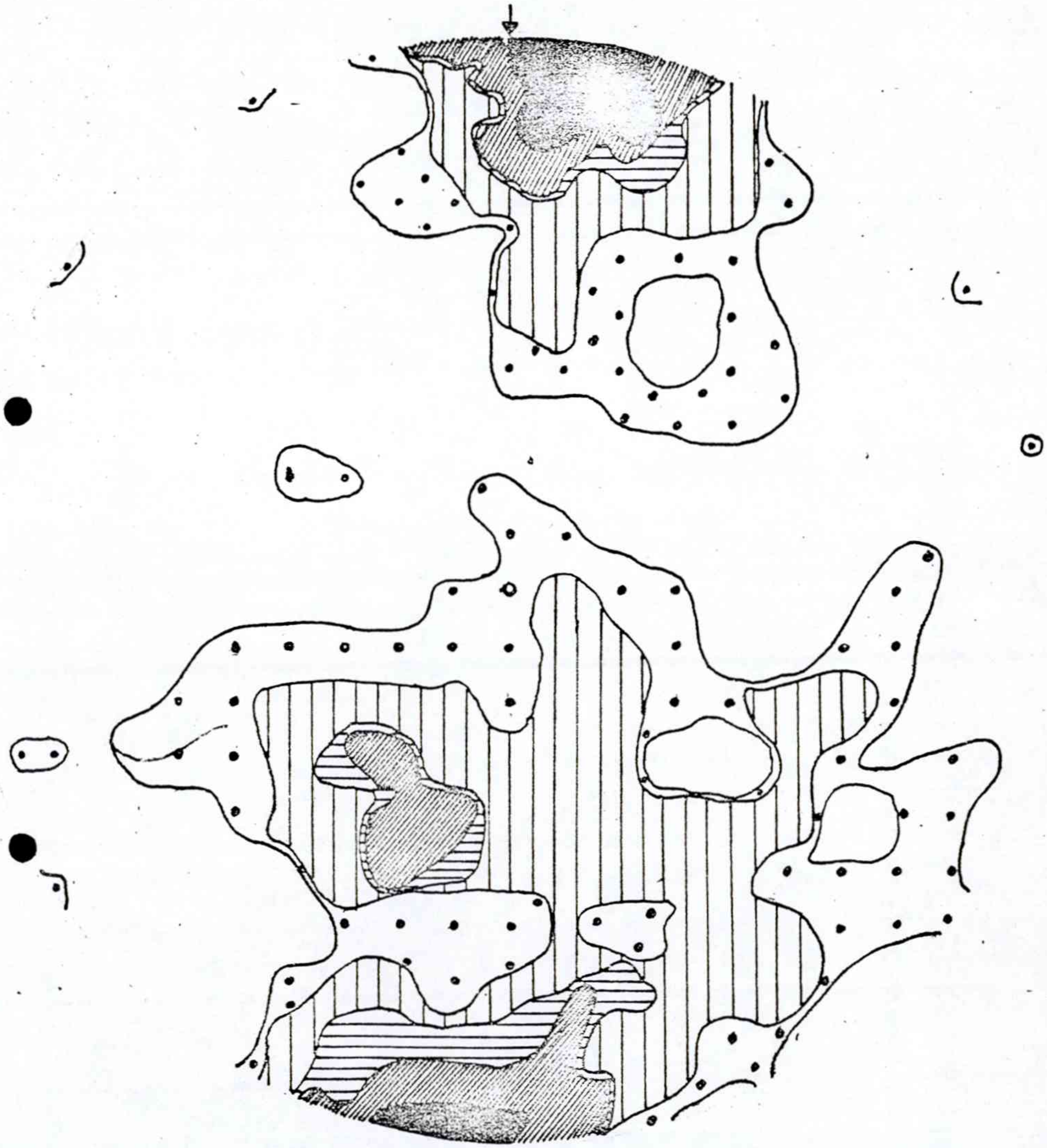
Structure

Three main phases of deformation were observed in this area (a minor phase of kink band formation is also evident).

The first produced a large scale (wavelength greater than 2.3 km.) E - W syncline, with a steep to overturned northern limit and a moderately dipping southern limb (Plate I; Fig 4.1). An associated axial planar cleavage, normally restricted to fine grained tuffs and shales, is often well developed (Fig 4:2 and 4:3). Fabrics in the fine grained tuffs are demonstrably shallower than those within the more pelitic beds. Although usually dipping moderately to the north, the cleavage steepens within the pelites of the Grydalen valley due to constriction between the more compotent strata. A minor fold plunging to the east occurs in the north-eastern part of the area. There is good evidence for the existence of a fault to the south and east of this. Although it is never seen in outcrop (due to lack of exposure) on gross structural grounds its presence is inferred.

Major NNWesterly upright folds comprise the second main phase of deformation. A large scale fold interference (Ryan et al 1980) was produced, symmetrically disposed relative to the Orkla river. To the east only the southern limb (and cleavage) of the Hogknippen syncline has been

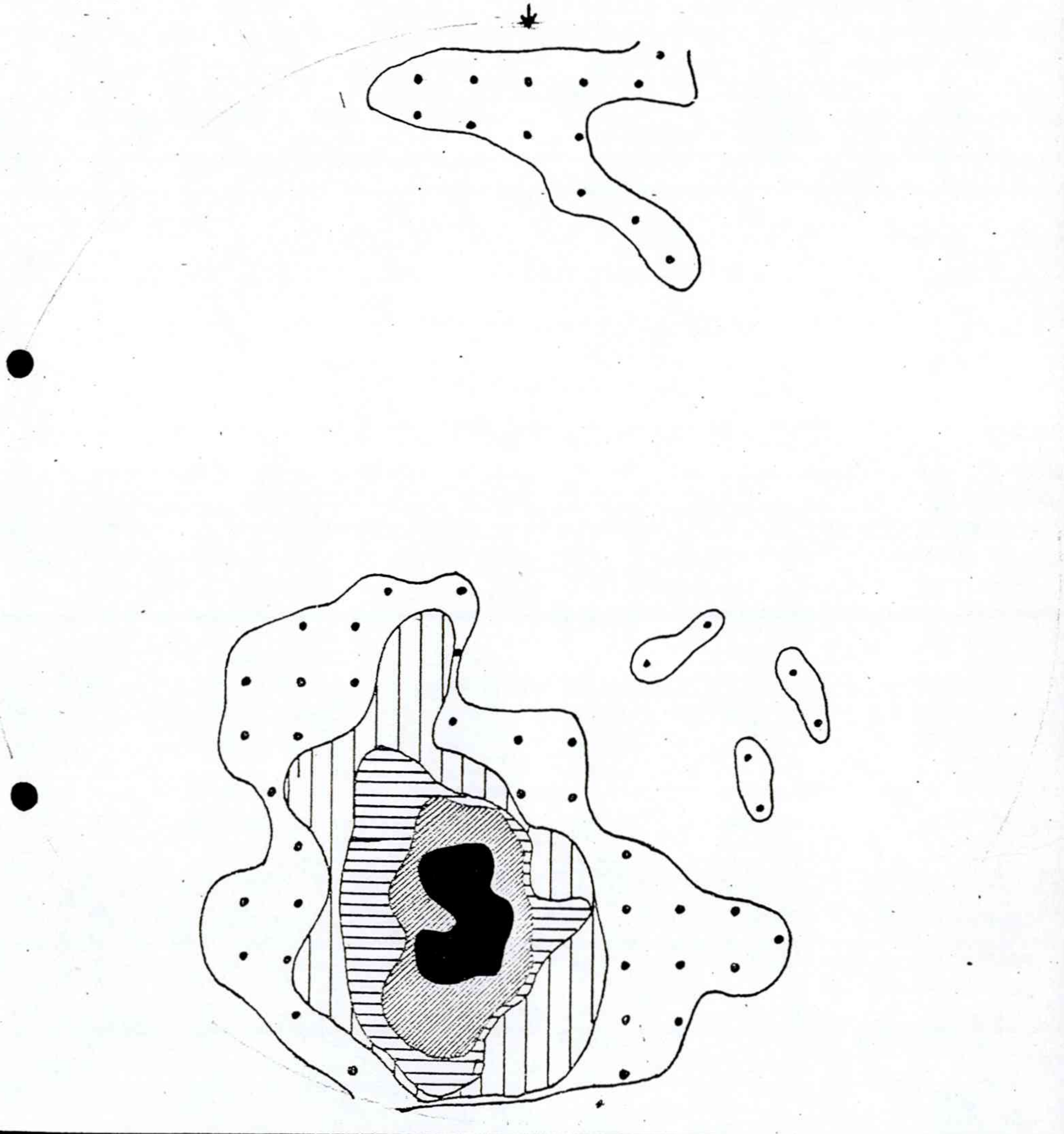
FIG. 4.1



BEDDING; 416 readings

CONTOUR INTERVALS (%); O; 1/4 - 1; 1 - 3; 3 - 4; 4 - 8; 8 - 11.5.

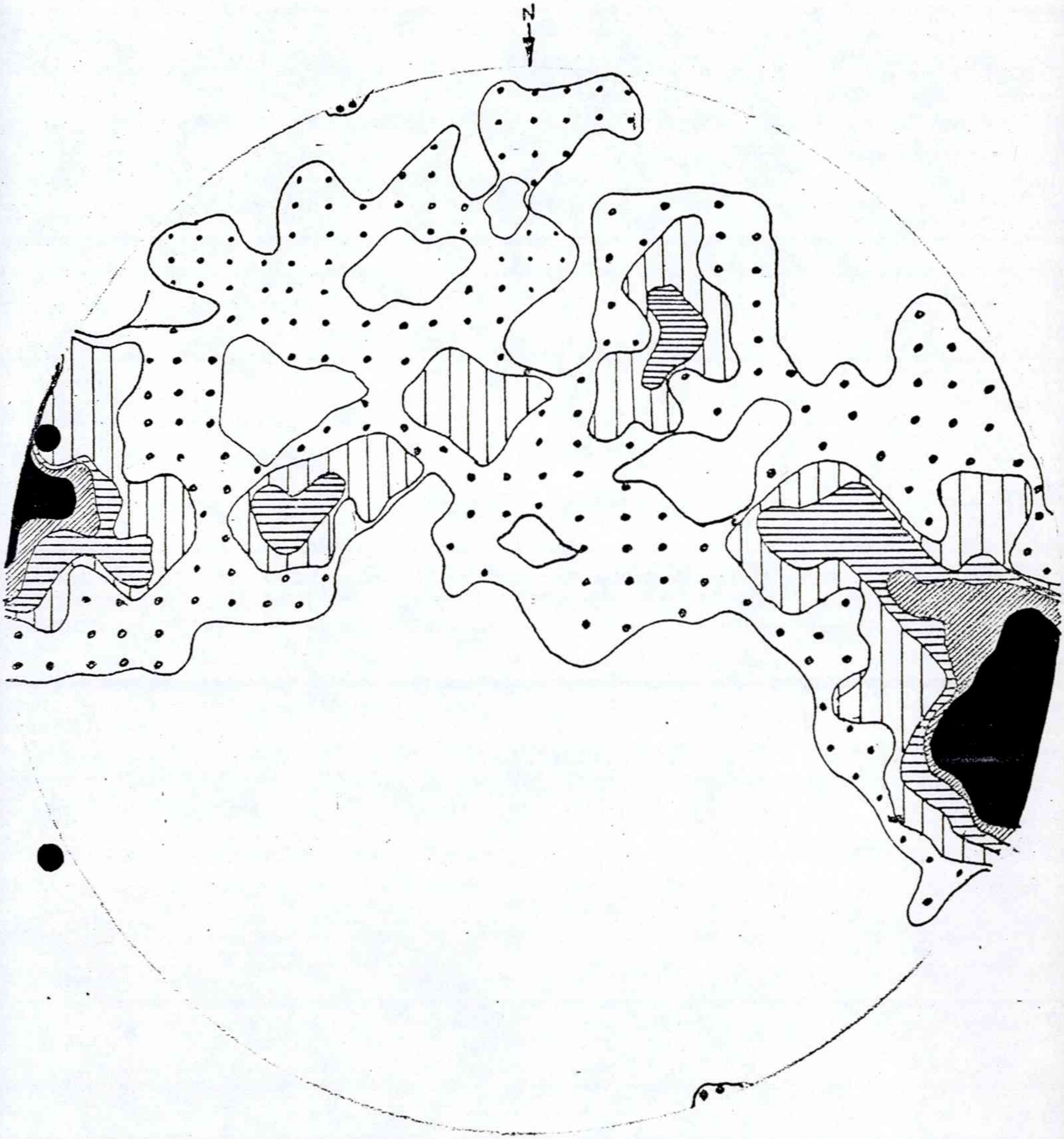
FIG. 4.2



CLEAVAGE; 230 readings

CONTOUR INTERVALS (%); 0; 0 - 2; 2 - 5; 5 - 10; 10 - 13; 13 - 15.

FIG. 4.3



CLEAVAGE/BEDDING; 119 readings

CONTOUR INTERVALS (%); 1 - 2; 2 - 4; 4 - 6; 6 - 8; 8+.

refolded while the northern limb has not probably due to its proximity with the extensive Grefstadfjell basic complex to the north. Minor associated folds (wavelength about 2 metres; amplitude about 20 cm.) are seen in the southern parts of the Sanda member and Ryanda shales.

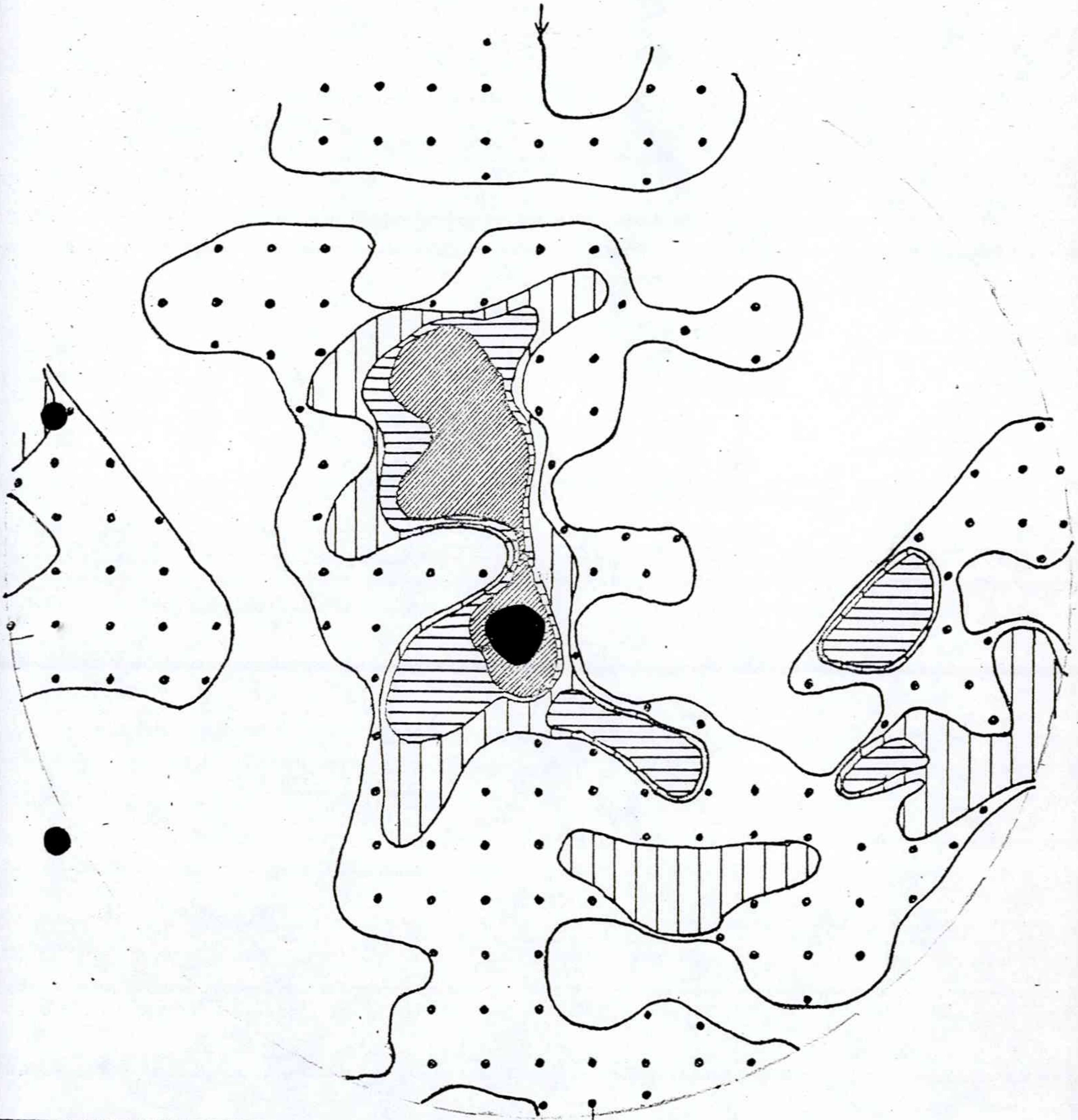
Kinks are very rare and only occur in pelitic beds. They constitute the minor phase of deformation and are either D_2 or D_3. To the north a localised development of kinks show distinct assymetry, overturning down dip on cleavage (wavelength about 1 - 2 mm.). In other areas they are larger (less than 3 cm.) and show no clear pattern of development. More readings are required before an attempt can be made to understand these structures.

The last main phase encompasses all brittle deformation structures quartz (and feldspar) veins, joints and the emplacement of basic dykes.

Quartz veins (less than 2 cm. thick) are common while multiple quartz and feldspar veins (less than 1 cm. thick) also occur. They are usually sub-horizontal or shallow dipping although one set of E - W vertical veins also occur (Fig 4:4). Inconsistent shearing parallel to these veins has occassionally produced sigmoidal quartz beins (particularly in the south).

Although basic dykes are discussed later it should be noted that they have orientations similar to most quartz veins and are cut by them, as well as joints.

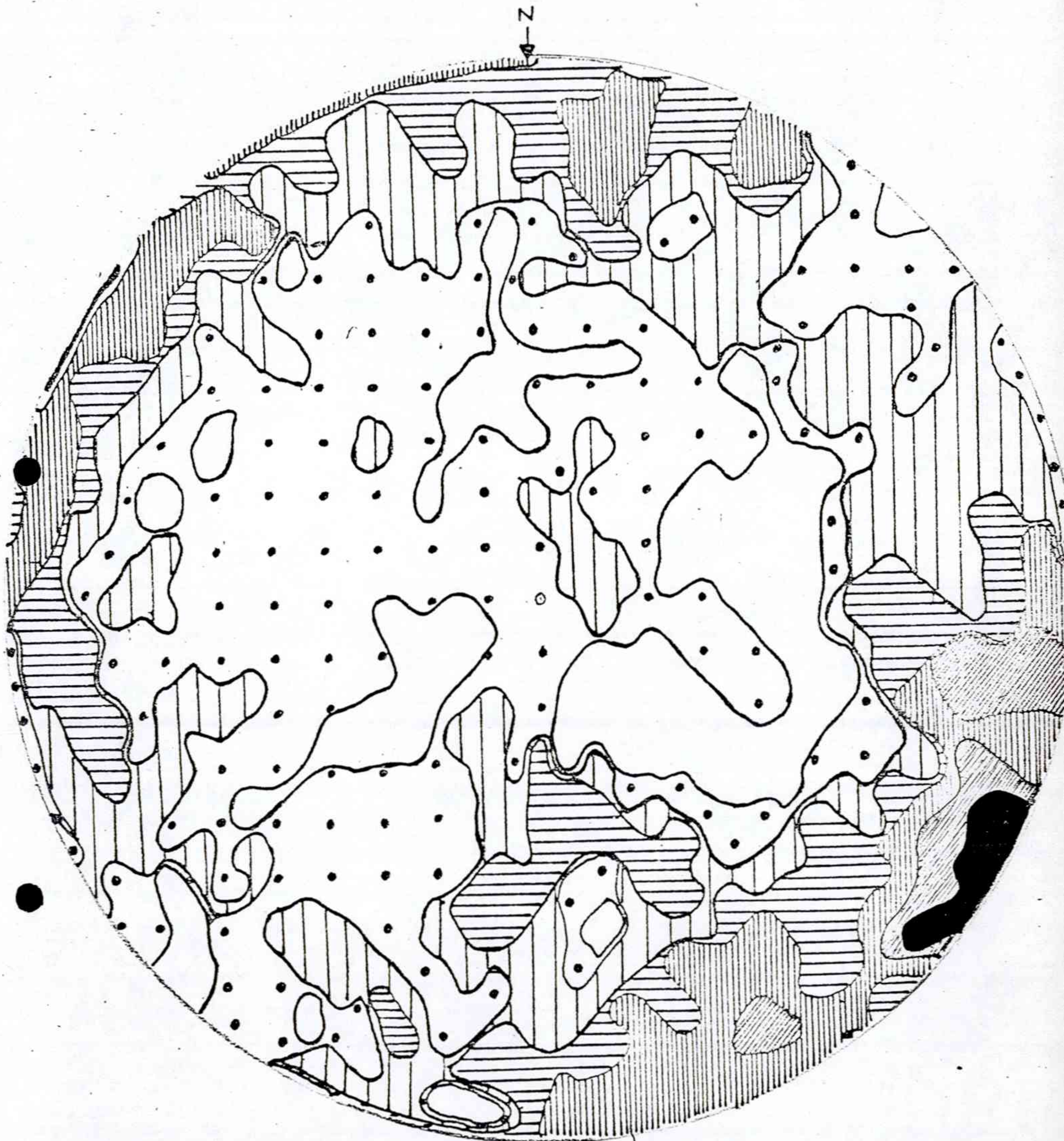
FIG. 4.4



QUARTZ VEINS; 142 readings

CONTOUR INTERVALS (%); 1 - 2; 2 - 3; 3 - 4; 4 - 6; 6 - 9.

FIG. 4.5



JOINTS; 394 readings

CONTOUR INTERVALS (%); 0 - 1/4; 1/4 - 1/2; 1/2 - 1; 1 - 2; 2 - 3; 3 - 4; 4 - 6.

Although the distribution of poles to joint surfaces is scattered (Fig 4:5) two main sets (NNE - NE and E - W) are observed. These may represent typical ac and bc joints of the main E - W syncline (Plate 1).

It is notable that within the lower (- middle) Ordovician succession to the south of Hogknippen, folding and minor deformation structures are much better developed. Therefore, at the moment it would appear that deformation increases in complexity down the stratigraphic. The nature of this transition is not known, however, field work this coming field season may provide a solution.

SECTION 5.

Geochemistry

The rocks analysed to date, are either air-fall fine grained tuffs or coarser grained welded tuffs (from the top of the Ryanda formation and from the ignimbrite conglomerate). Although the geochemical data compiled so far is minimal, a few preliminary observations may be made.

The volcanics represent part of a calc-alkaline suite of rocks with dacitic-rhyolitic composition. Variation diagrams for CaO, K_2O and Na_2O show a large scatter while FeO*, MgO, TiO_2 and Al_2O_3 have broad linear relationships with SiO_2. As yet no clear stratigraphic variation is apparent, however, maybe microprobe studies on pumice fragments will provide a clearer pattern. It is notable, however, that the ignimbrite conglomerate is the most rhyolitic, while the welded tuff at the top of the Ryanda formation is the only tuff (studied to date) with large amounts of modal hornblende.

The chemistries of these rocks compare very well with their correlatives in the Holonda-Horg area (Vogt 1945).

Unfortunately, the lack of trace element data and the paucity of geochemistry at hand renders a more detailed geochemical account impossible.

SECTION 6.

Basic intrusions

These dykes are usually 30 cm. to 1 metre in thickness but a composite dyke about 7 metres in thickness also occurs. Spatially these dykes appear to be related to the core of the syncline and in the case of the composited dyke it is associated with a brecciation zone close to the fold closure. They show no definate preferred orientation although they tend to be shallow dipping. Their spatial association with the syncline core and their non-foliated texture suggest that they just post-date folding.

Microprobe and petrographic studies show that the one dyke studied, to date, contains Kaersutite, K-feldspar, augite, quartz, muscovite and calcite. The Kaersutite is often fresh and zoned while the muscovite is a secondary deuteric alteration product of K-feldspar.

With high K/Na ratios (3.75) and an SiO_2 content of 51% the rock has shoshonitic-lamprophyric affinities. The importance of deuteric alteration and the high proportion of amphibole (about 15%) suggest high H_2O contents similar to lamprophyres. Mineralogically it is similar to a vogesite (apart from the presence of Kaersutite in lieu of common hornblende NB. this is due to the K:Na ratio of 1 for vogesite). However, if as suggested above these dykes are just post-tectonic, they may have an origin in common with normal shoshonites rather than an association with granites (as vogesites often are).

Clearly much more geochemical and petrographic study is required to resolve this problem and until then many possibilities, including the two outlined above remain open. It is notable, however, that rocks with similar mineralogies and geochemistries have not been previously described in the Trondheim area.

SECTION 7.

Summary

Main conclusions

A. The revision of the structure of this area is important with regard to the geology of the Horg "syncline". The structure of this "syncline" has been in debate for almost a century. The most recent proposals by Vogt (1945), Chaloupsky (1969) and Oftedahl (1980) respectively invoke a synclinal form, an anticlinorium and a sequence of nappes. The structure of the Hogknippen area, however, is only in agreement with Vogt's proposal. There, in common with his stratigraphy the rhyolite tuffs and sandstones assume a higher position in the sequence.

B. Caution should be taken when using conglomerates as marker horizons. That is, if only those with similar characteristics are correlated, a few conglomeratic horizons may be observed, thus removing, in some cases, the necessity of tightly infolding the strata (see Chaloupsky 1977). This observation also applies to the dark laminated shales which in this area occur throughout the succession and as clasts within many of the rocks of the Upper Hovin group.

C. Primary volcanics do occur within this area, and therefore the Horg syncline (see Oftedahl 1980). They were deposited in a subaqueous environment.

D. The sediments and volcanics of the Ryanda and Hogknippen formations were probably derived from the north-west indicated by their well developed facies variations.

Questions

A. If the simple synclinal structure is applicable to much of the surrounding area then the Storen Group (to the south) may well be correlative with the Grefstadfjell complex.

B. Where does the Hovin sandstone fit into this stratigraphy, is it part of the Silurian Horg group or is it just a facies variation of the Grut (and Kalstad) limestones.

C. What is the nature of the upper Ordovician unconformity to the south (is there any!) and was there an intra-ordovician folding episode.

D. Where is the exact source for the rhyolite volcanics of the Hogknippen formation.

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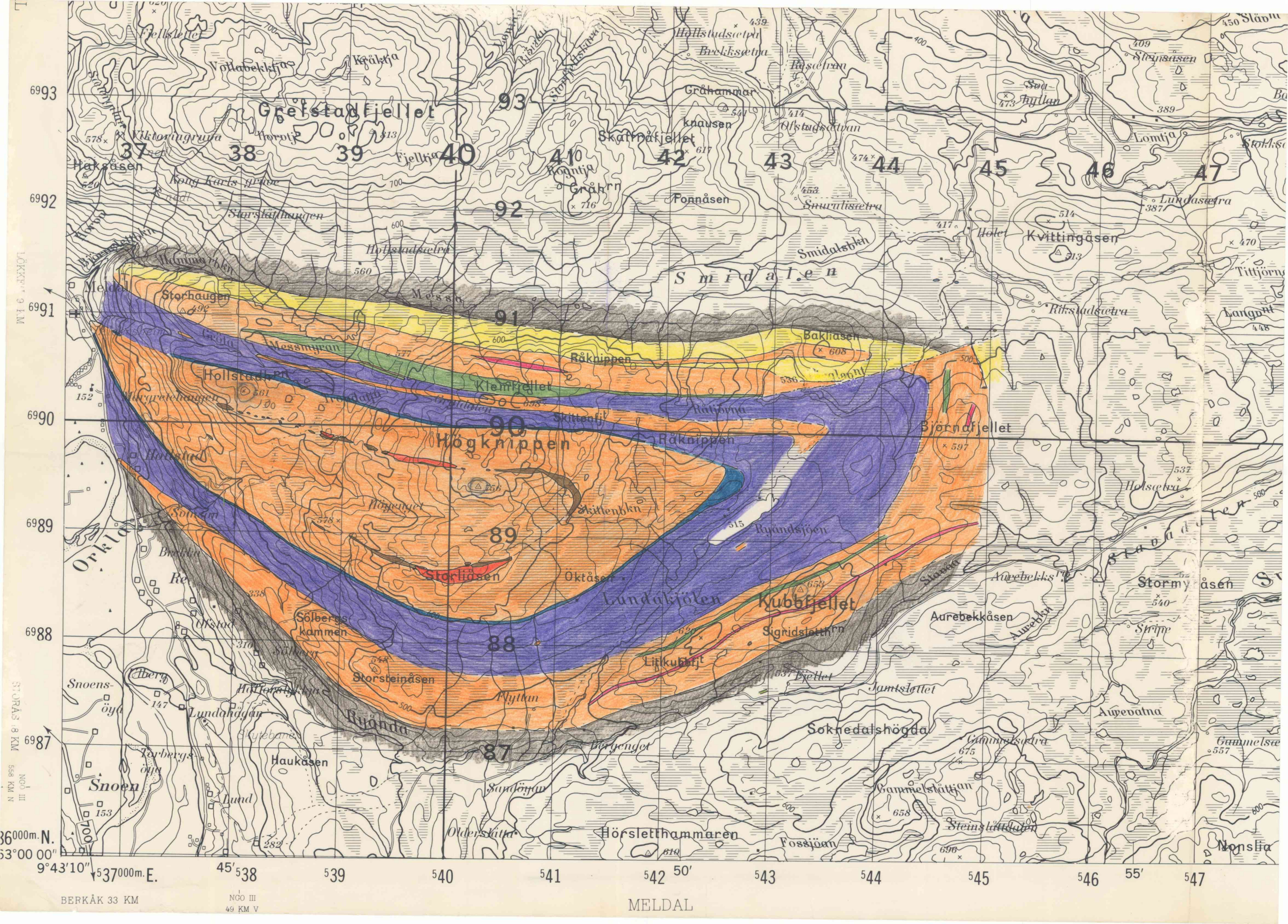

Grefstadfjellet
Vollabekktj.
Kråktj.
Haksåsen
Viktoriagruva
Kong Karls gruve
Storslåttaugen
Hollstadsætra
Hollstadsætra
Brekksætra
Gråhammar
Skaftnafjellet
Fonnåsen
Smidalen
Smidalsbkn
Rikstadsætra
Kvittingåsen
Steinsåsen
Lomtj.
Lundasætra
Tittjörn
Langtjt.
Meldal
Storhaugen
Messa
Messmyran
Hollstadh.
Margretehaugen
Klemfjellet
Råknippen
Bakliasen
Högknippen
Skittenfj.
Skittenbkn
Högenget
Storliåsen
Öktåsen
Lundakjölen
Ryåndsjöen
Bjørnafjellet
Holsætra
Kubbfjellet
Sigridslottk.
Litlkubbfj.
Aurebekkåsen
Stormyråsen
Sölbergskammen
Storsteinåsen
Flyttan
Ryånda
Orkla
Snoens-öya
Lundahagan
Haukåsen
Snoen
Bergenget
Sandåsen
Soknedalshögda
Jamtslottet
Aurevatna
Gammelsætra
Gammelslåttjan
Steinslåttdalen
Hörsletthammaren
Fossjöan
Oldersätta
Nonslia
BERKÅK 33 KM
NGO III 49 KM V
MELDAL
LÖKKEN 9 KM
STORÅS 18 KM
558 KM N NGO III