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Tittel

Mapping/Explortion for ZN, Pb sulphides in the calcareous phyllite group (L. Køli) Henriksvatn-Orrevatn 1979

Forfatter	Dato	År	Bedrift (Oppdragsgiver og/eller oppdragstaker)
Herrington, Richard		1979	Grong Gruber AS

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Geologi Analyser		Henriksvann Orrevann Grongfeltet
Råstoffgruppe	**Råstofftype**	
Malm/metall	Cu, Zn, Pb	

Sammendrag, innholdsfortegnelse eller innholdsbeskrivelse

Rapport med kart i 1:5000 som basist for B.sc. ved Royal School of Mines, London.
Geologisk karlegging av kalkfyllitt - gruppen (Blåsjøfyllitt) på grensen til Sverige. viders kulle kartlegges mulige mineralisereinger i området da en hadde håp om at Cu/Zn som var påvist ved Renselvannet også kunne finnes i dette området.
Det er markerte dekke - enheter i området. Mineralisering er knyttet til små opptredene i det øvre dekket, og til litt basemetall noen av de vulkanske enhetene en finner i den midtre enheten.
Det er foretatt røsking på tre lokaliteter langs samme sone. En finner opptil 1 % py og svært lite basemetaller i røskene.

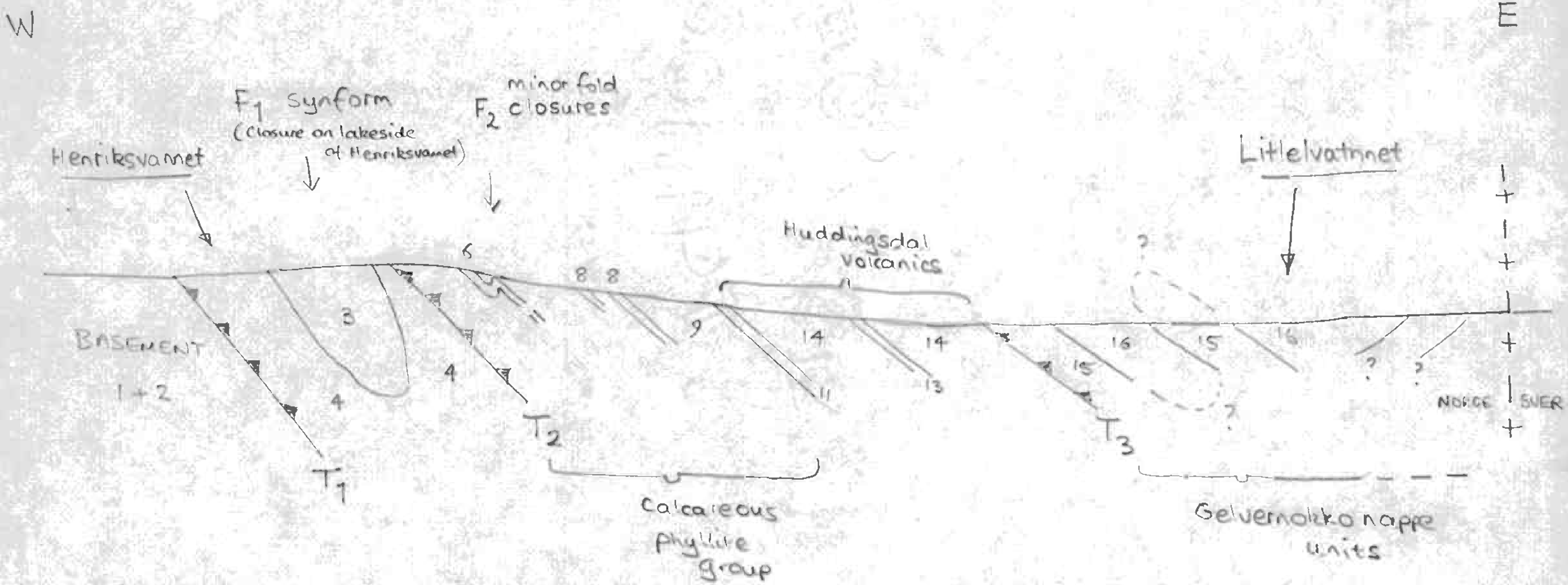
MAPPING/EXPLORATION FOR Zn, Pb SULPHIDES IN THE CALCAREOUS PHYLLITE GROUP (L.KOLI) HENRIKSVATN-ORREVATN 1979.

RICHARD HERRINGTON

ROYAL SCHOOL OF MINES, LONDON.

SKETCH SECTION

W — E



S. KOLLUNG		R. HERRINGTON
HUDDS. VOLCANICS ? { Meta tuff	—	Acid / basic tuffs
Rantserfyllit	—	Bituminous phyllite / Green chloritic phyllite
- - - - - -		- - - - - -
Yngre kvartsrik kalkfyllitt	—	Grey-green quartz rich calcareous phyllite
Metagabbro	—	Coarse chloritic schist
Meget kalkrik fyllitt	—	Carbonate rich calc. phyllite
Meget kalkrik båndet metasandstein/fyllit (Blåsjöskifer)	— }	Feldspathic psammite
(Nordligruppen ?)	— }	Feldspathic psammite
Mork fyllitt med kvartsskifer	— }	Feldspathic psammite
Eldre kvartsrik kalkfyllitt	—	Grey qtz. rich calc. phyllite
V V V V V		V V V V V
Dargafjell gruppen	—	Quartzites and micaceous psammites
Namsengruppen	—	Mica schists
V V V V		V V V V

BASEMENT


BV 6806
Henrikvatnet-Orrevatnet
R.J.HERRINGTON 1979
Scale 1:5000
0 100 200 300 400 500 metres
UPPER NAPPE (GELVERNOKKO)
16 Green chloritic phyllite
15 Bituminous phyllite
T3
MIDDLE NAPPE (L. KOLI)
14 Banded acid/basic meta volcanics
13 Qtz. chl ser schist /+pyrite/bituminous+py
12 Basic meta volcanics
HUDDINGSDAL VOLCANICS
11 Bituminous phyllite
9 Grey-green qtz rich calc phyllite
Coarse chloritic schist
7 Carbonate rich calcareous phyllite
6 Feldspathic psammite (intercalated schists and qtzites)
5 Grey qtz rich calc phyllite
CALCAREOUS PHYLLITE GROUP
T2
LOWER NAPPE
4 Mica schists
3 Quartzites and micaceous psammites
T1
2 Lower meta sediments (probably autocthonous)
1 Basement gneiss
Bedding
S2 schistosity (f2 plunge)
Lithological Boundary (/inferred)
S1 schistosity (f1 plunge)
S3 schist (f3 plunge)
Thrusted contact
HENRIKVATNET
LITLEELVATNET
ORREVATNET
N
T1
T2
T3
A
B
C
D
E

Personal Copy

(cont.)

ABSTRACT

Part A of the thesis is based on an exploration programme in an area of meta-sediments and meta-volcanics, of which the former was more extensive and was characterised by the so called calcareous phyllite group; aseries of metamorphosed siliceous marls,with a ubiquitous segregate banded texture of alternate quartz and phyllosilicate bands.

The volcanics were believed to be shallow sea extrusives and were often associated with a bituminous phyllite.

The uppermost calcareous phyllite unit often contained a very coarse chlorite schist which by its texture appeared to represent thin gabbroic intrusions, parallel to bedding. Some of the lower calcareous phyllite units appeared to pyroclastics and a further study of these was projected.

The area was recgnised to be dominated by major nappe units,part of the Caledonian series. Structural interpretation was thus very important and three deformation phases were recognised in the allocthons: the first responsible for tight isoclinal folds and the formation of the nappes, the second represented by large open folds with wavelengths of several 10s of kilometres. The third phase of deformation has caused only minor, low angle, kink folding.

Mineralisation was represented by a small, probably a cupreous pyrite body, seemigly associated with a chloritic schist and a bituminous phyllite; and there was evidence of possibly hydrothermal base-metal enrichment in some of the volcanics.

Part B is concerned with the study of the geochemistry of the petrographically mapped units in order to illuminate origins, especially of the volcanic units and some of the calcareous units which were considered pyroclastic.

These rocks were found to be similar in nature to the "true" volcanics, and are shown to represent a differentiated series of sodic spilites, which fits very well into the model

proposed of an immature ensimatic island arc environment, proposed by previous authors,during the Caledonian orogenic event.

Some of the volcanics were found to be potash enriched and soda depleted and these were considered to represent, in all probability, a non-spilitised intrusive.

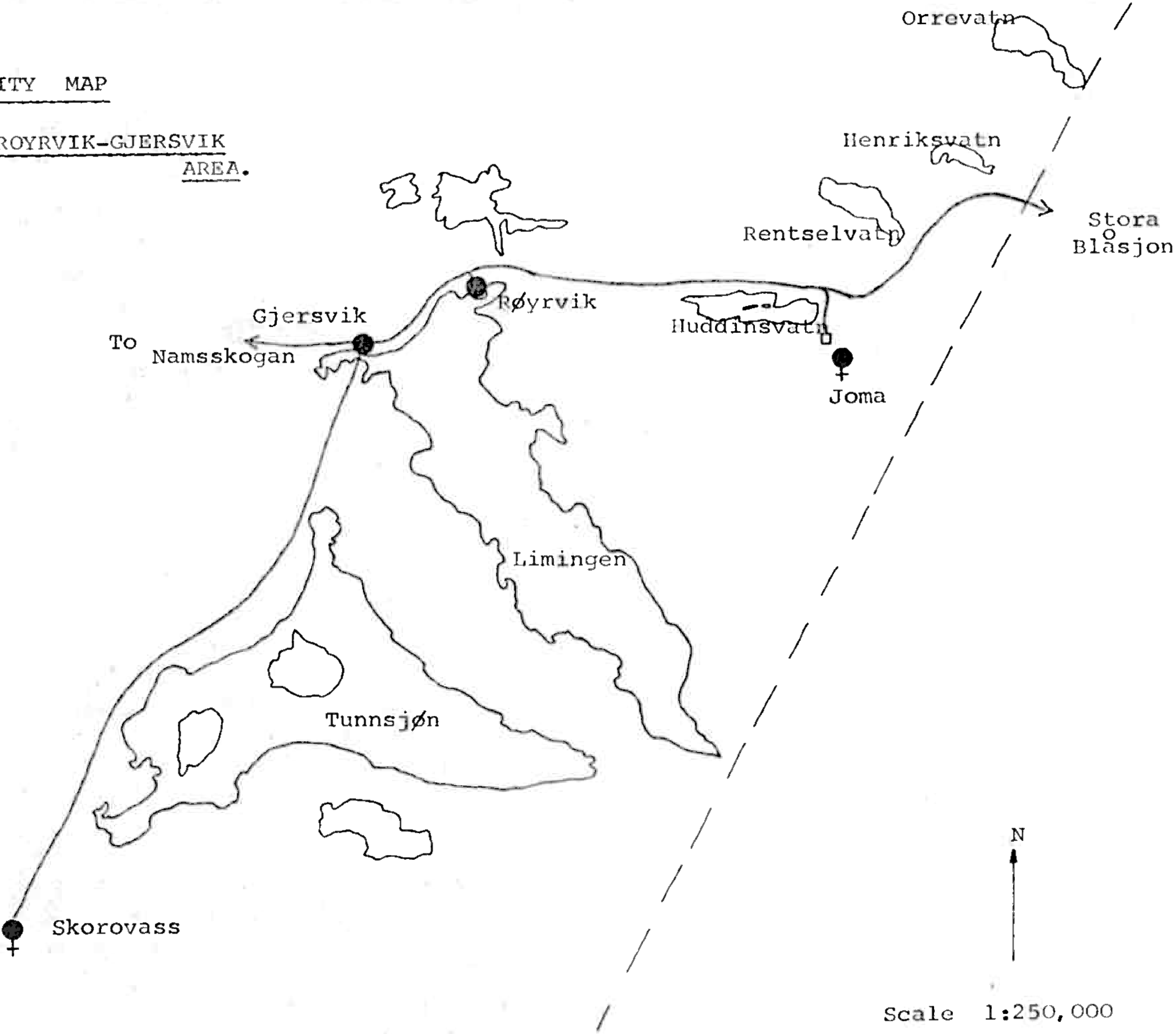
1: INTRODUCTION

The author spent a period of 10 weeks during the summer of 1979 employed as an exploration geologist with Grong Gruber A/S, operators of Joma mine in Nord Trøndelag, Norway; and was engaged in mapping the strike extension to a sequence of meta-sediments and volcanics in which some Cu,Zn sulphide showings had been found, assessing the potential mineralised zones within the area of study.

A map of the region is shown overleaf, indicating the mapping area

LOCALITY MAP

ROYRVIK-GJERSVIK AREA.



Retype?

Object of Work

The major part of the work involved mapping the so-called calcareous phyllite group (referred to as Blåsjøfyllitt by the Swedes) and differentiation of the group into separate units with the hope of extending the mapping done by Sigbjørn Kollung up to 1978 in the Renselvatn - Henriksvatn area.

Groups bordering the calcareous phyllite group were also to be considered, and location of the various nappe complexes reported by Zachrisson, Nilsson, Sjøstrand and earlier authors was important. To this end the rocks were mapped from the Børgefjell tectonic window (see text) towards the higher rock sequences located eastwards on the Norwegian/Swedish border.

The aim was to find mineralisation in the area. Previous work in the calcareous phyllite group[1] had located small orebodies of sphalerite and pyrrhotite disseminated ore in the Renselvatn area

and it was hoped similar mineralisation would be found. Some evidence of anomalous base metal concentrations in stream sediments was provided (see later text) and these were to be followed up.

[1]Personal communication from A. Haugen, Grong Gruber A/S

Organisation

Mapping was done on 1:5,000 air photographs of the area, together with a 1:50,000 topographic map for general location purposes. A set of stream sediment survey maps was available for the area shown in diagrams 1a-d and discussed later in the text.

Routine for the period of mapping was five days in the field per week; Saturday and Sunday being spent in a local village. Monday to Friday was spent in a tent in the mapping area accessed by road to

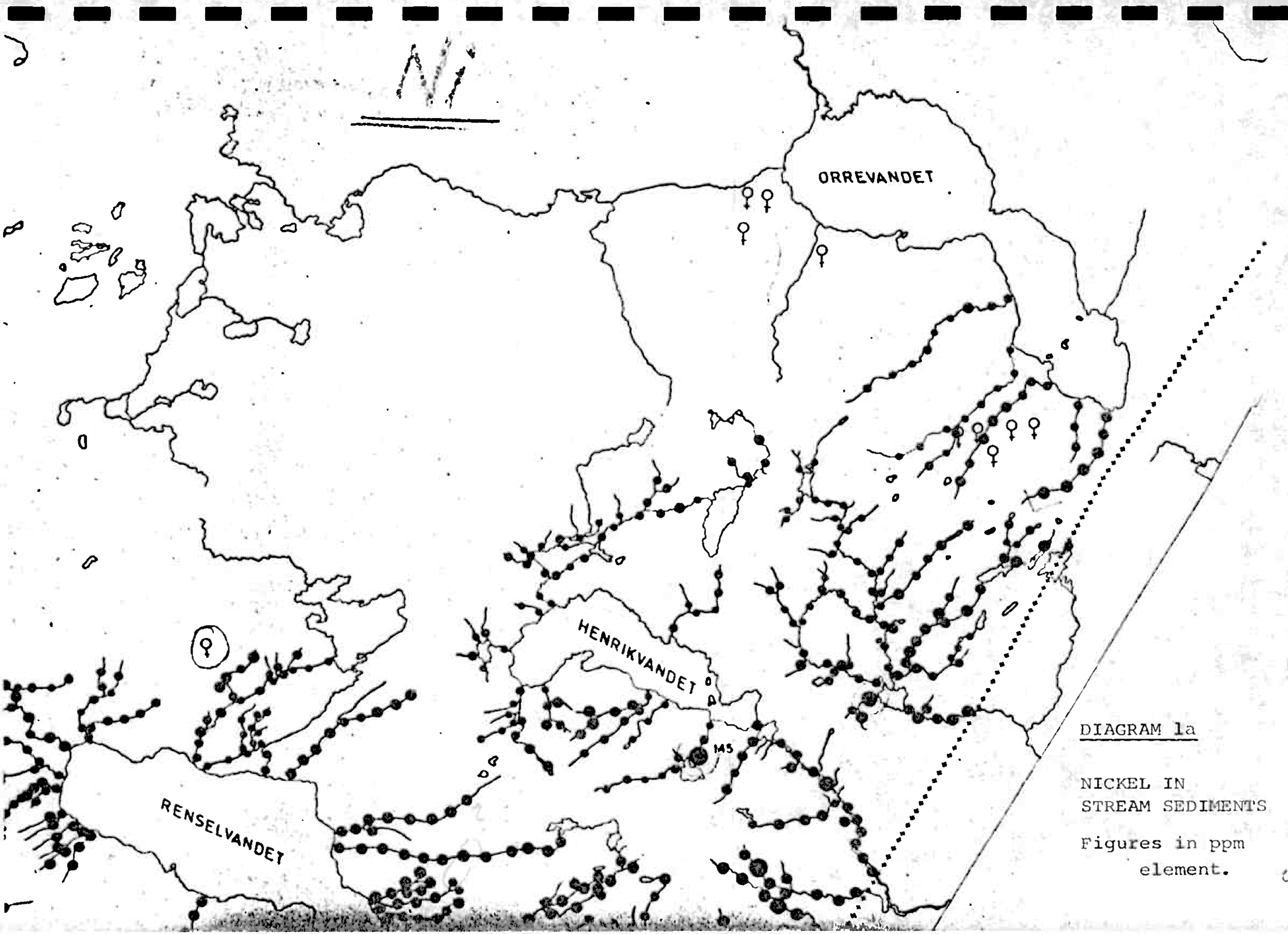


DIAGRAM 1a

NICKEL IN
STREAM SEDIMENTS

Figures in ppm
element.

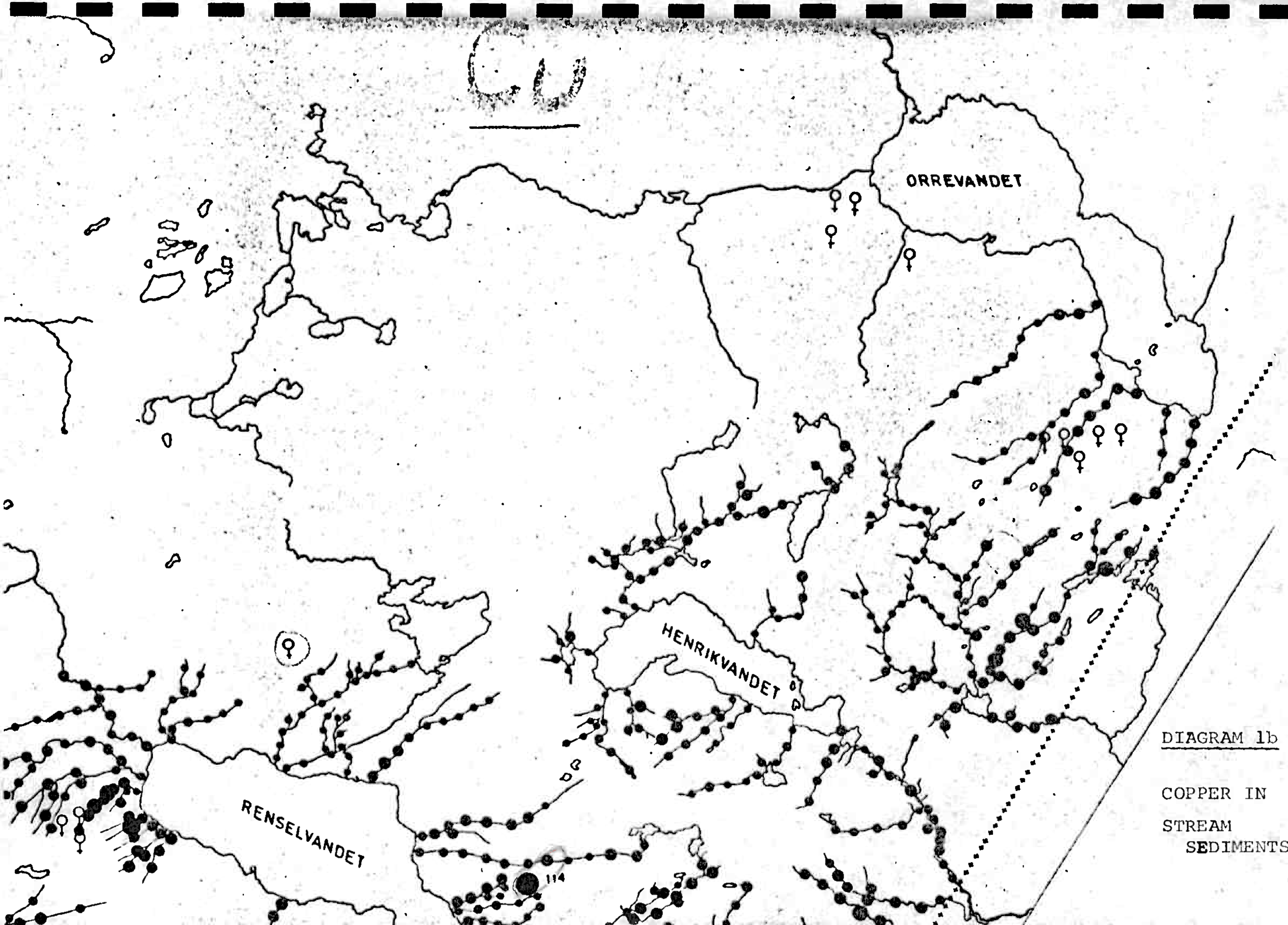


DIAGRAM 1b

COPPER IN STREAM SEDIMENTS

6

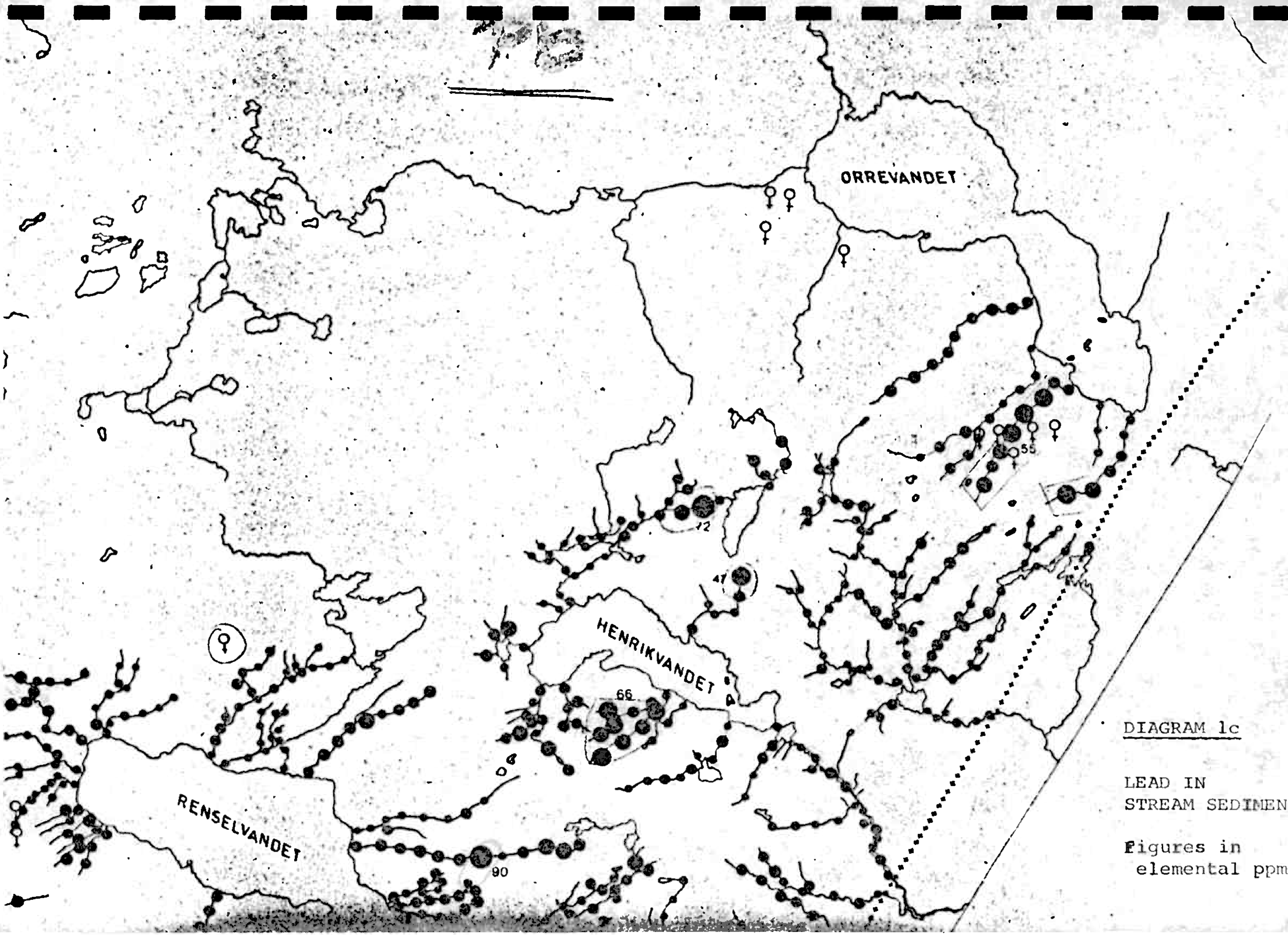


DIAGRAM 1c

LEAD IN
STREAM SEDIMENTS

Figures in
elemental ppm

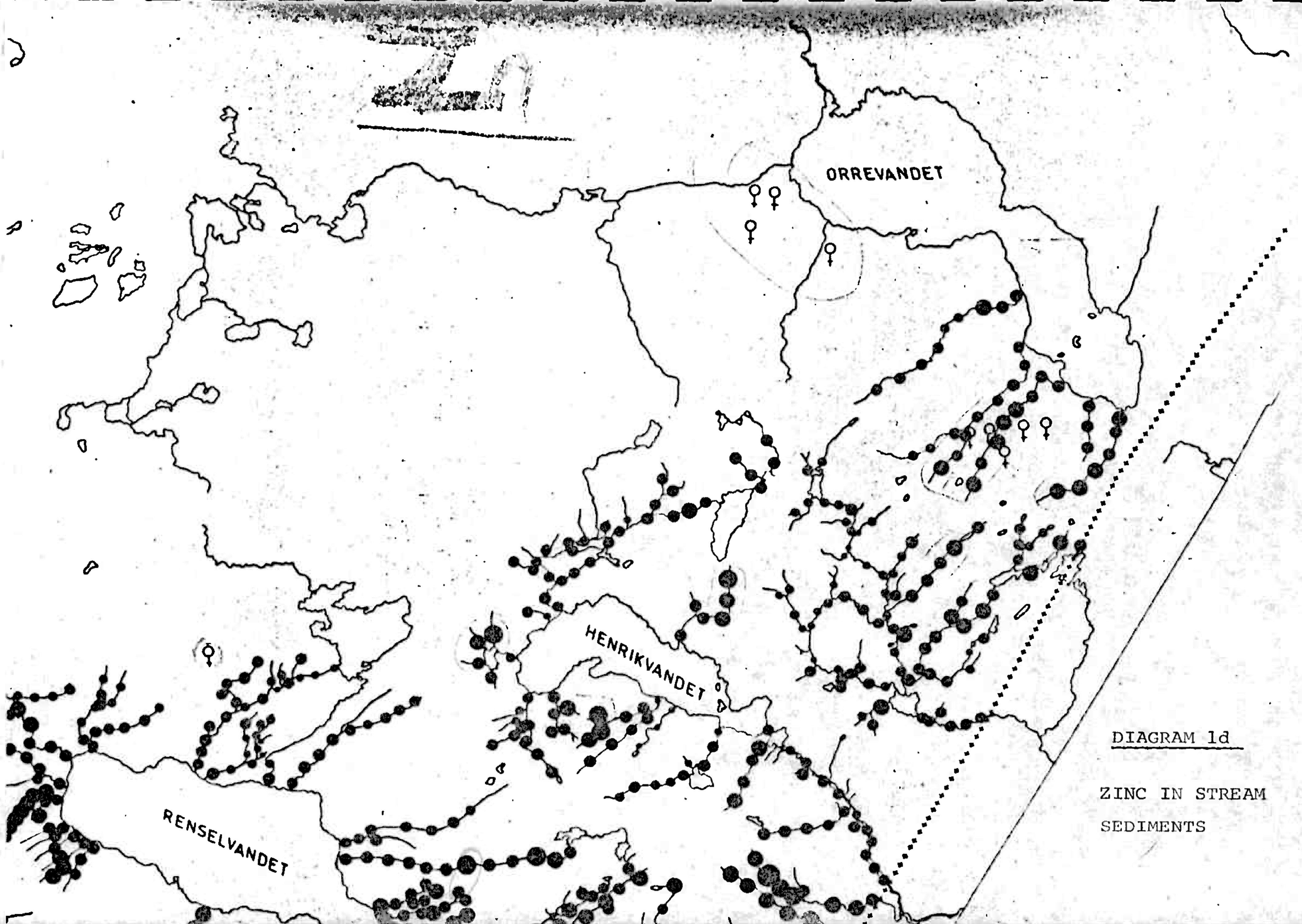


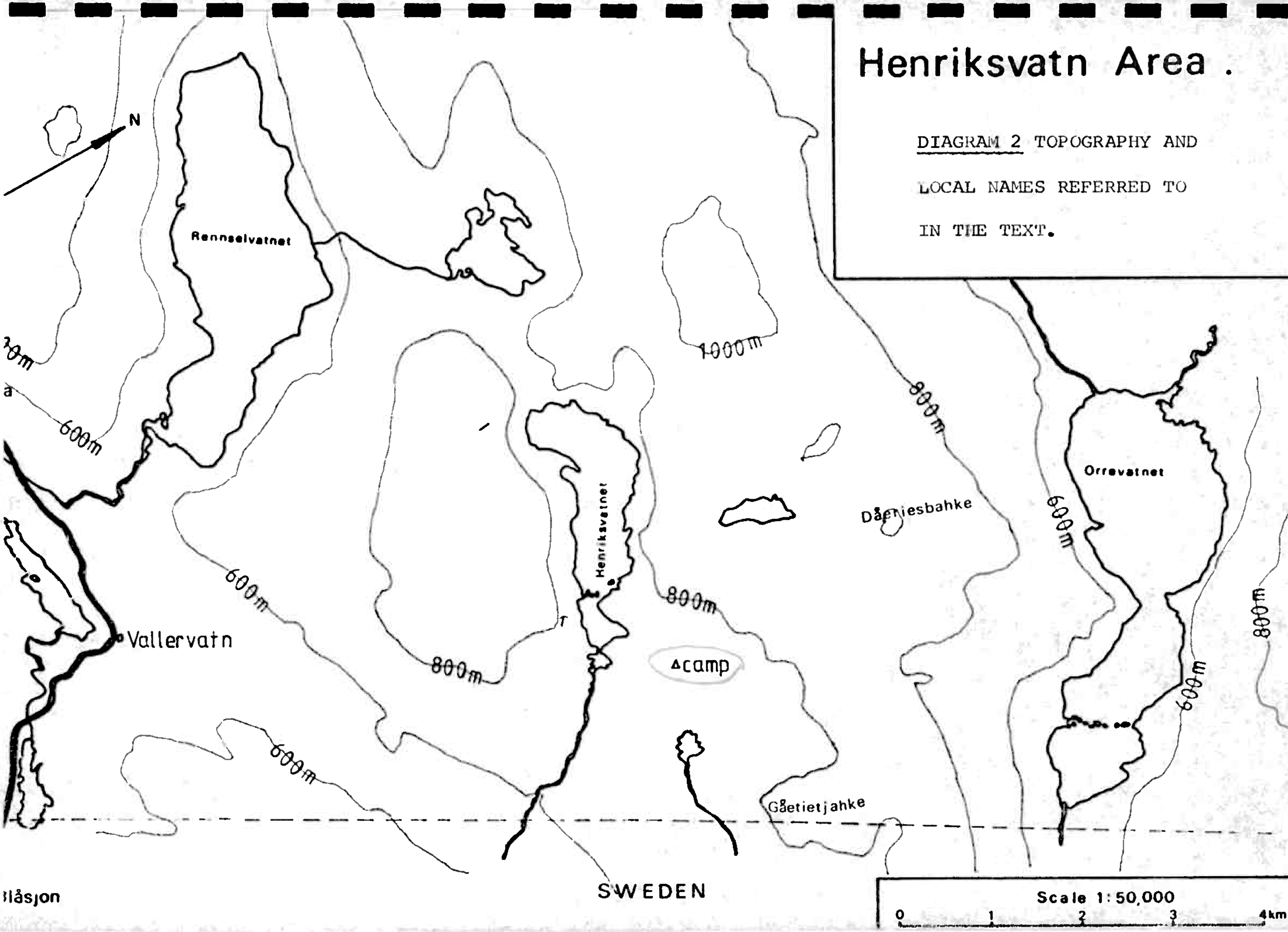
DIAGRAM 1d

ZINC IN STREAM SEDIMENTS

Vallervatn and by foot to the camp (see diagram 2). All supplies were brought up from the road.

For the last two weeks geologists Mellin and Hinde assisted in trenching and sampling of Skjerp[2] zones located during the mapping.

[2]Skjerp = Norwegian word meaning mineralised showing


Henriksvatn Area .
DIAGRAM 2 TOPOGRAPHY AND LOCAL NAMES REFERRED TO IN THE TEXT.
N
Rennselvatnet
600m
600m
600m
800m
1000m
800m
800m
800m
600m
600m
Henriksvatnet
Vallervatn
camp
Orrevatnet
Gåetietjahke
SWEDEN
Scale 1:50,000
0
1
2
3
4km

3: Regional geology

The area studied lies in a region of the Scandinavian Caledonides. The Caledonides are characterised as described by Kulling (1964), by allochthonous and parautochthonous units over-thrust on to the Pre-Cambrian Baltoscandian Shield rocks. Swedish authors, as indicated in Strand & Kulling (1972), generally classify the Caledonian complex into the tectonic classification as shown in diagram 3 , with later additions by Sjøstrand (1973).

The crystalline basement of Pre-Cambrian acid gneisses, porphyries and granites is exposed within the region in several places, notably the Børgefjell tectonic window, as shown on diagram 6 . Granites here have been dated to 16 70m.y. (Zachrisson 1969).

The rest of the region is covered by Late Pre-Cambrian to Ordivi-cian autochthonous sediments which occur stacked in a tectonic "pile".

The basement is overlain by a sequence of autochthonous sediments and lower nappes, which outcrop mainly in the Southern Jämtland-Västerbotten area, some of the lower nappes being missing from around the Børgefjell window. An east-west section showing the presumed style of the nappes is shown in diagram 4 .

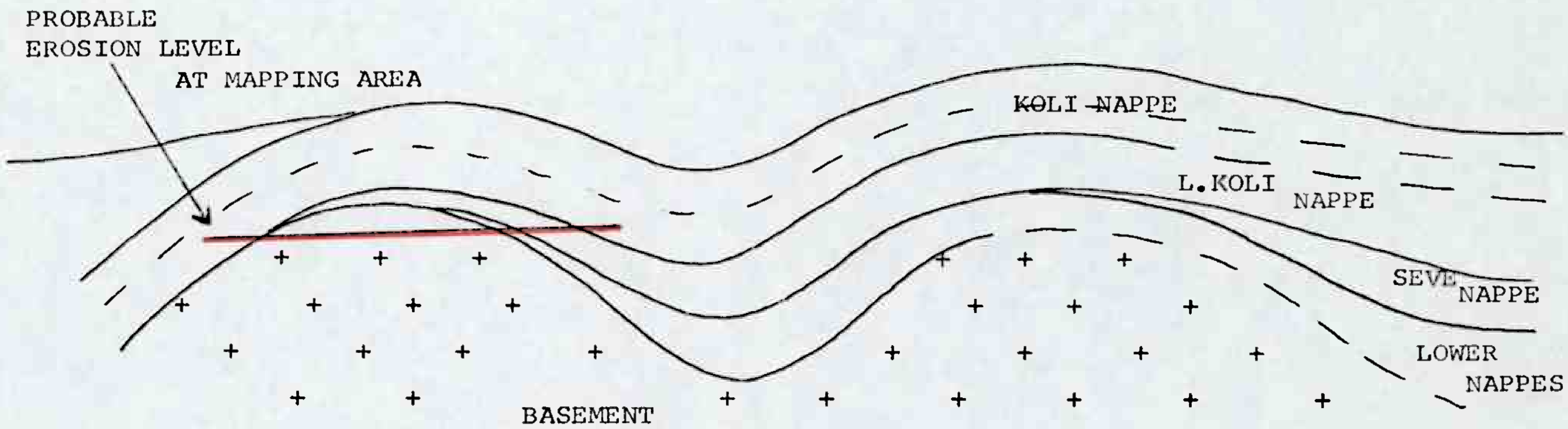
The rest of the area is within the Seve-Köli nappe complex, which is subdivided according to Zachrisson and other authors to the divisions shown in diagram 5 .

DIAGRAM 3

TECTONIC CLASSIFICATION
OF THE SCANDANAVIAN CALEDONIDES

Sjøstrand (1973)		Kulling (1972)
Helgeland Nappe Complex		Uppermost thrust rocks
Koli	Seve-Koli Nappe Complex	Upper thrust rocks
Seve		
Sarv Nappe		Middle thrust rocks
Offerdal Nappe, Stalon Nappe		
Jamtland Nappes , Blaik Nappe Complex		Lower thrust rocks
East Jamtland Nappes		Lowermost thrust rocks
Cover		Autochthonous sedimentary rocks
Basement		Pre-Cambrian basement

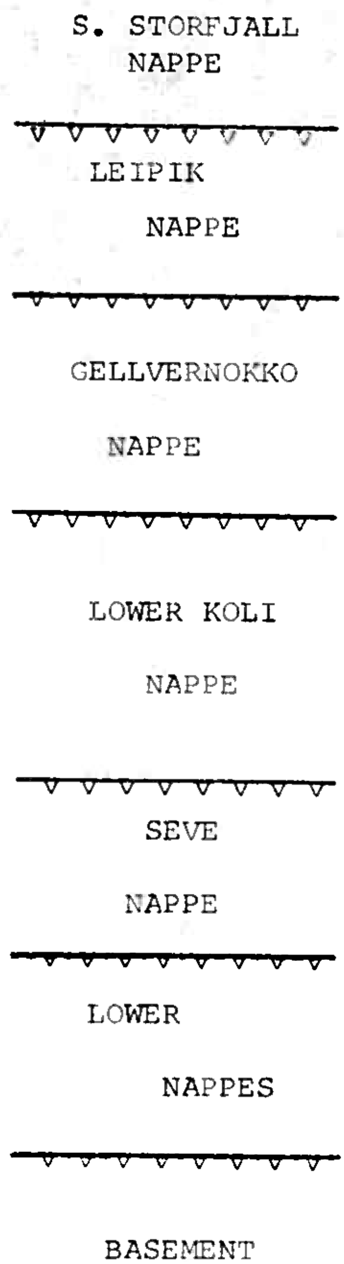
DIAGRAM 4: Section E-W showing presumed style of nappes



After Zachrisson (1969)

DIAGRAM 5

Nappe Succession in the Northern Jämtland-Southern Västerbotten area of Sweden



The Seve rocks as described by Zachrisson (1973) consist of amphibolites and micaceous to quartzo-feldspathic schists or gneisses. They are unfossiliferous but are structurally lower than the Koli rocks and hence are considered older. In Jämtland, Sweden, tectonic discontinuity is seen between the Seve and Koli rocks and hence separate nappes are defined.

The Köli rocks are characterised by phyllites and meta-greywackes, frequently calcareous or graphitic together with occasional thick basic or alternating acid/basic meta-volcanics. Also occurring in various horizons are thin limestones and conglomerates. Ultrabasic bodies are also found, concentrated in the Upper Seve and Lower Koli units. Move Seve and Köli units wedge out westwards towards the base of the allochthon especially around the Børgfjell window as described in Zachrisson (1973).

Metamorphism of the rocks in the area is distinctly different between units. The lowest rocks are very low grade metamorphics, either belonging to the greenschist facies or else apparently unmetamorphosed. The grade increases to amphibolite facies towards the centre of the Upper Seve rocks and then decreases further up structurally, to lower amphibolite and greenschist facies in the Upper Köli rocks. This has been attributed to inhomogeneous shear during thrusting by Zwart (1974).

A good regional geology compilation is shown on diagram 6 taken from Halls et al. (1977).

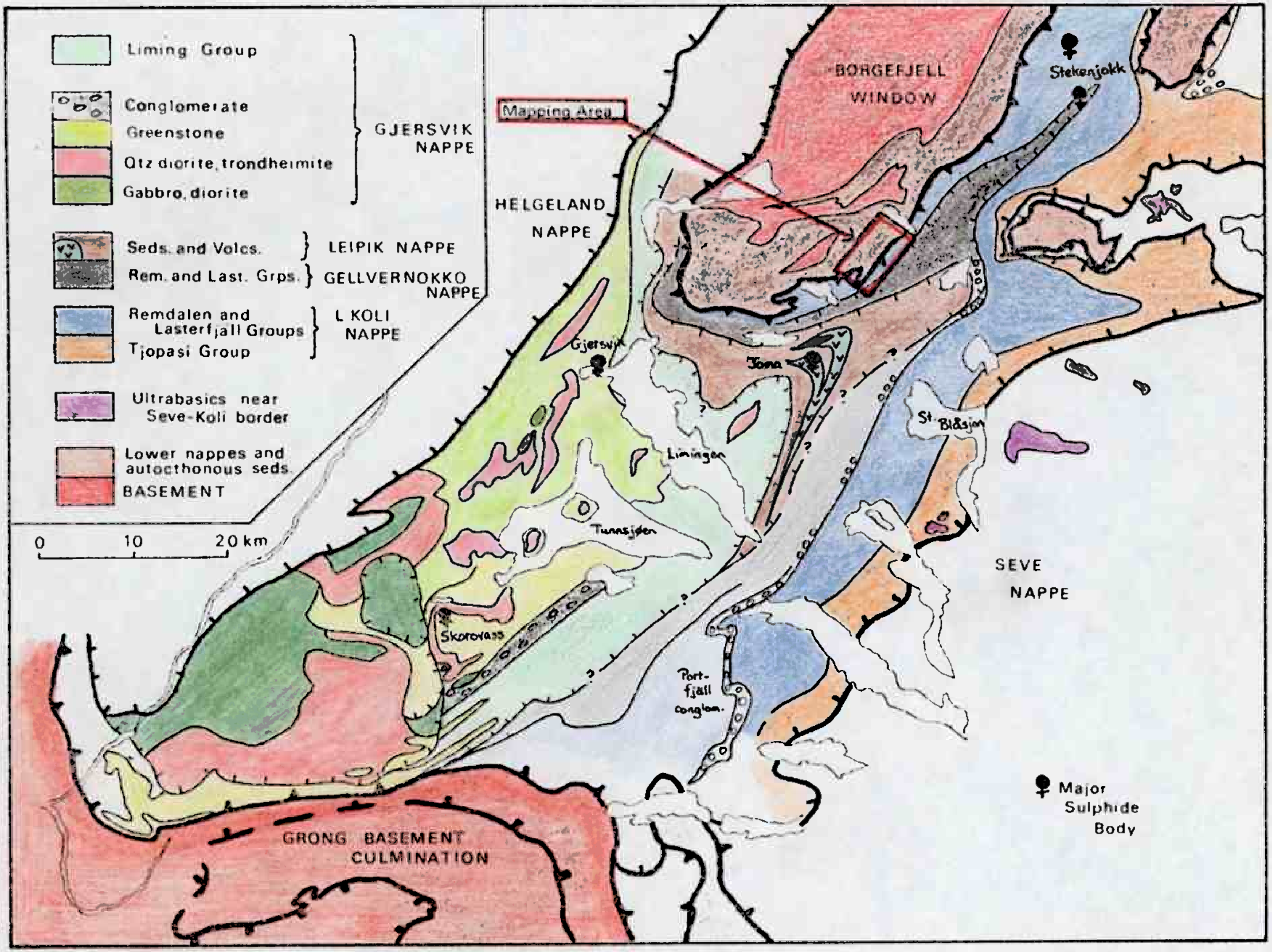


DIAGRAM 6

MAIN STRUCTURAL AND STRATIGRAPHICAL UNITS WITHIN THE SEVE-KOLI NAPPE COMPLEX.

(After Halls et al. 1977)

4: Previous Work

The first real map published of the area was by Foslie & Strand in their paper of 1956 and this was followed in 1958 by a paper of C. Ofterdahl describing mineralised areas within the area. Various Swedish authors have mapped the adjoining areas of Sweden, and it is indeed these authors who have done most to unravel the structural and stratigraphical problems in the area.

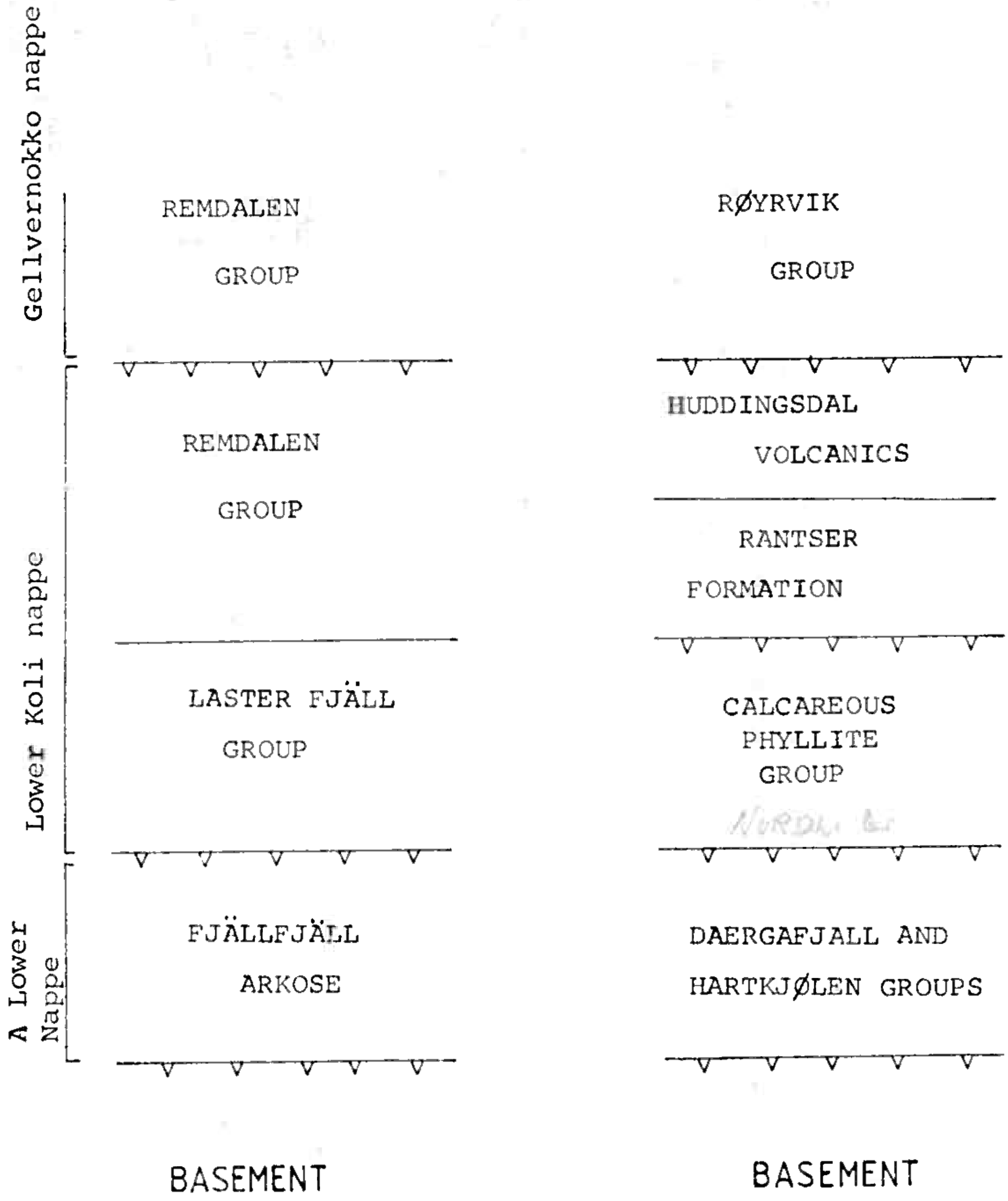
Kulling 1933 and 1958 was the first author to devise a stratigraphy and subsequently revised stratigraphies and correlations have been made by Nilsson (1964), Zachrisson (1964), Zachrisson (1969) and Sjøstrand (1973). Recent work by S. Køllung (up to 1976) has extended mapping and correlation of stratigraphy into Norway. A compiled stratigraphy is shown in diagram 7 .

Structure was acknowledged to be dominated by large tectonic discontinuities by Foslie & Strand (1956).

Zachrisson, (1964, 1969, 1973) has done much to unravel the structure and his ideas can be summarised by diagram 8 which is adapted from his 1969 paper. Mapping by these authors has shown the presence of the large thrusted contacts shown in the diagram and also the large open fold structures. Details from various authors differ, as will be discussed further on, but the general pattern is in agreement with Zachrisson's 1964 conclusions.

DIAGRAM 7

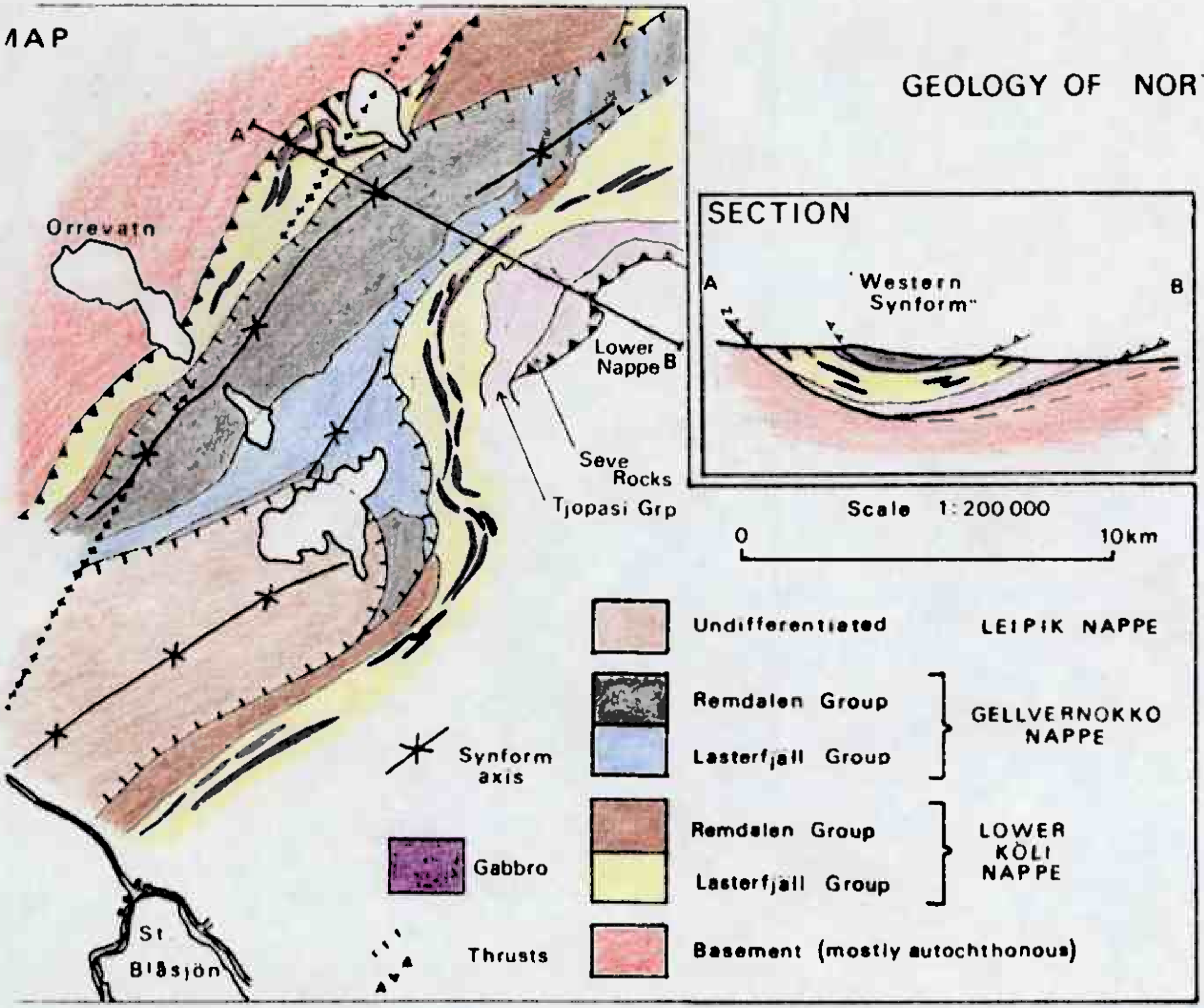
Structural succession mapped by previous authors



After Zachrisson (1969)

After Kollung (1978)

GEOLOGY OF NORTH JAMTLAND, SWEDEN



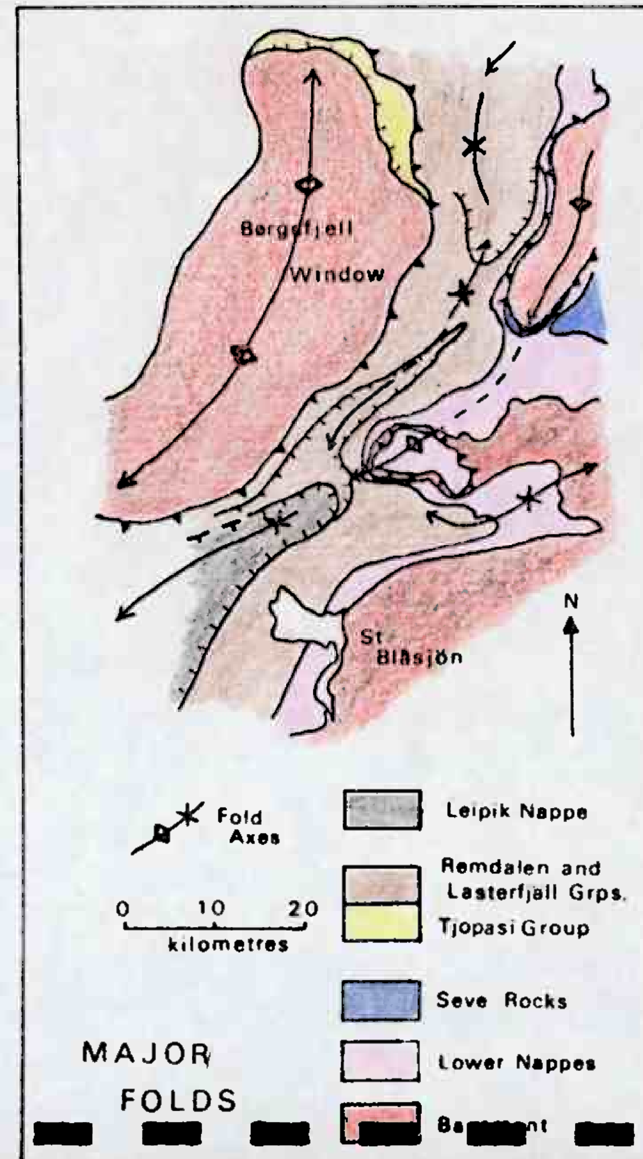


DIAGRAM 8 MAJOR STRUCTURAL FEATURES

adapted from ZACHRISSON (1969)

The present mapping area is situated on the Norwegian-Swedish State boundary on the eastern border of the Børgefjell massif.

Zachrisson has constructed a schematic section E-W from Børgefjell massif, shown in diagram 8 , where he considers the nappe complexes to wedge out west against the Børgefjell massif as well as to form the large open folds also shown. He considers the Seve rocks to have totally wedged out before the Børgefjell massif.

Zachrisson (1969) and Sjøstrand (1973) generally agree on the tectonic succession to be expected in the area, and by extrapolating their nappe contacts, we might expect the succession indicated in diagram 7 .

Brenna (1966) mapped the Gaetieçakke area, but concentrated on the lithologies along the Norway/Sweden border. Because of this he failed to recognise the presence of the meta-volcanic rocks and also did not recognise many of the major structural features of the area. He did, however, indicate the presence of mineralised zones. (See later text).

5: Lithologies and Stratigraphy

The rock sequences will be described in ascending structural order, the discussion will include any differences between this order and stratigraphic order. Detailed discussion of important units from specimens are dealt with in Appendix II.

a) The basement sequences

The basement sequences in the area mapped consist of two major types, i) Augen gneiss and ii) Autochtonous sediment cover.

i) Augen gneiss

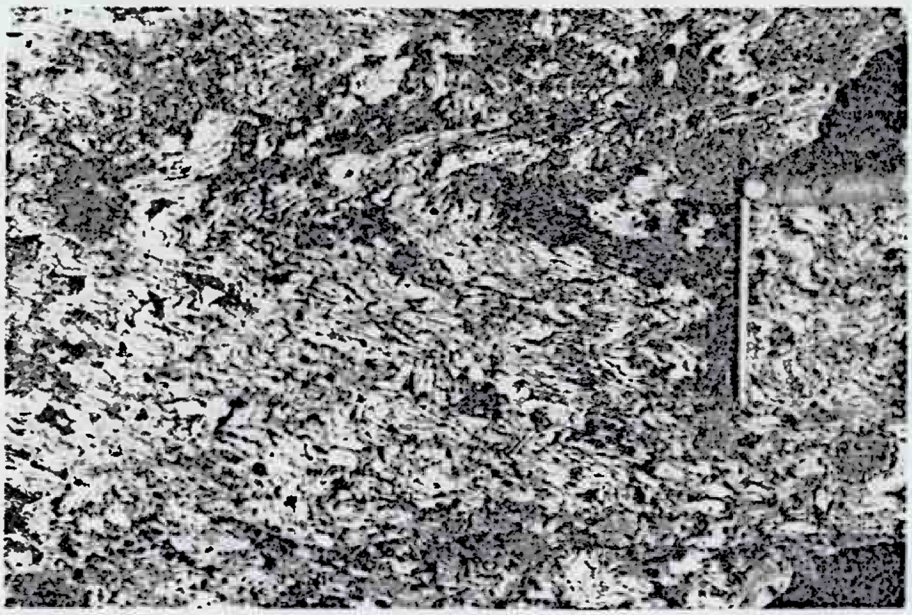
This is presumed to represent the oldest of the basement rocks. The gneiss is present as coarse porphyroblasts of quartz and feldspar in a biotite, muscovite groundmass. The porphyroblasts lend the rock both an L and a P tectonic fabric, occurring as augens:

The rock is partly schistose due to orientation of the phyllo-silicates, but this schistosity has suffered much post-schistosity folding.

The general appearance of the rock at outcrop is shown in photograph 1, and in hand specimen as photograph 2.

ii) Autochthonous sediment cover

These rocks comprise mainly feldspathic garnetiferous quartzites



Photograph 1: Augen Gneiss in outcrop.

Photograph 2: Slabbed specimen of Augen gneiss clearly showing the feldspar Augens.

and quartz, feldspar schists. Large feldspar clasts are very often present. Evidence for bedding or at least geochemical/petrological banding is present and indicated multiple deformation episodes.

Close to the thrust contact with the Lower nappe group, the sediments consist of a banded quartz, feldspar schist, sometimes alternating with amphibole, biotite and muscovite bands.

b The Lower nappe group

The two units of this lower group are i) the quartz mica schist and ii) the quartzite unit. From structural evidence, the mica schist appears to be structurally lower than the quartzite in this area.

Previous authors (including Kollung (1978)) have identified these rocks as the Hartkjølen schists and Daergafjell quartzite respectively and consider the latter to be the oldest, believing it to be EoCambrian. This could still possibly be the case if an overturned recumbent structure is considered.

The Hartkjølen schists

In hand specimen these schists are seen to grade from a mica-rich (muscovite and biotite) schist to a psammitic schist. The group is characterised by a generally large mica content (20%) and also by large biotite porphyroblasts on s1 schistosity. These rocks are often well crenulated with a cross cutting s2 schistosity (see photograph 3).

The Daergafjell quartzites and micaceous quartzites

The outcrop of this group is extensive in the area and is apparently several 100m thick. It forms the large bluffs which over look the Børgefjell massif, and which run NE-SW from Henriksvatn over Daeriesbahke to Orrevatn (see diagram 2).

In hand specimen the rocks vary from pure quartzite, which is limited in its extent, to micaceous psammites with 2-3mm layers of quartz and feldspar with thin partings of muscovite along schistosity. A feldspathic grit was found in parts, feldspar clasts were fairly common in the whole rock type, forming up to 20% of rock.

The typical micaceous psammite appears to be 75% quartz with approximately 20% phyllosilicate, being mostly muscovite with some chlorite, occasionally biotite together with isolated feldspar grains. In parts feldspar makes up to 20% of the rock, by volume.

Zachrisson (1964) in discussion of sediments bordering the Børgefjell further north, indicates that the Daergafjell group may be equivalent to the Fjallfjall arkose which, in Remdalen, is thrust against the basement series. Direct outcrop connection between these areas is lacking, however, and a detailed comparison needs to be made.

Photograph 3: Well crenulated Hartkjølen schist
(s2 parallel to pencil)

c) The Middle nappe group (Lower Koli nappe)

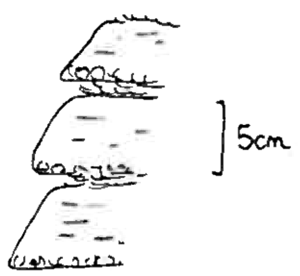
This group is characterised by 3 sub-groups, these are: i) calcareous phyllite group, ii) Bituminous phyllite and iii) Meta-volcanic group.

Kollung (1978) as stated, considers this nappe group to be part of 2 nappes, but the present author considers the rocks to be a single group.

The Calcareous phyllite group

Referred to as the Renselvann group by Kollung (1978) and previously as part of the Lasterfjall group by Swedish authors Zachrisson and others) and considered to be Ordivician/Silurian in age as shown from fossil evidence in equivalent groups. The group was found to be composed of main units. These units are (from oldest to youngest) 1) Grey quartz-rich calcareous phyllite, 2) Feldspathic psammite, including some schists and "quartzites", 3) Carbonate rich calcareous phyllite including some coarse chloritic schists, 4) Grey-green quartz-rich calcareous phyllite.

Some minor evidence was found for graded bedding in the feldspathic psammite with differential weathering of the quartzite members;



to indicate the rocks were in fact the right way up, thus enabling true stratigraphy to be defined.

1) Grey quartz-rich calcareous phyllite

This rock is a rather more resistant member of the calcareous phyllite group, very rich quartz and white micas rendering the rock a very grey colour. In hand specimen the rock appears grey to occasionally grey-green and has the typical segregate bands of quartz-carbonate laminae and phyllosilicates. The phyllosilicates appear to be predominantly muscovite with some chlorite and biotite, whilst the quartz laminae are quartz with carbonate, the latter only visible in very small isolated grains. The rock only partly reacts with acid due to the small amounts of carbonate present.

Iron oxides often stain the rock indicating that the carbonate may be iron-rich.

2) <u>Feldspathic psammite</u>

This rock is in fact a series of lithologies, but the dominant lithology is a feldspathic psammite and for ease of description, this name will be applied to the whole series.

The series is variable in type but is of generally 3 types, (i) Feldspathic psammite, (ii) Alternating thin grey/green/black phyllites and thicker "quartzites", (iii) Quartz/feldspar/sericite schist with chlorite schists.

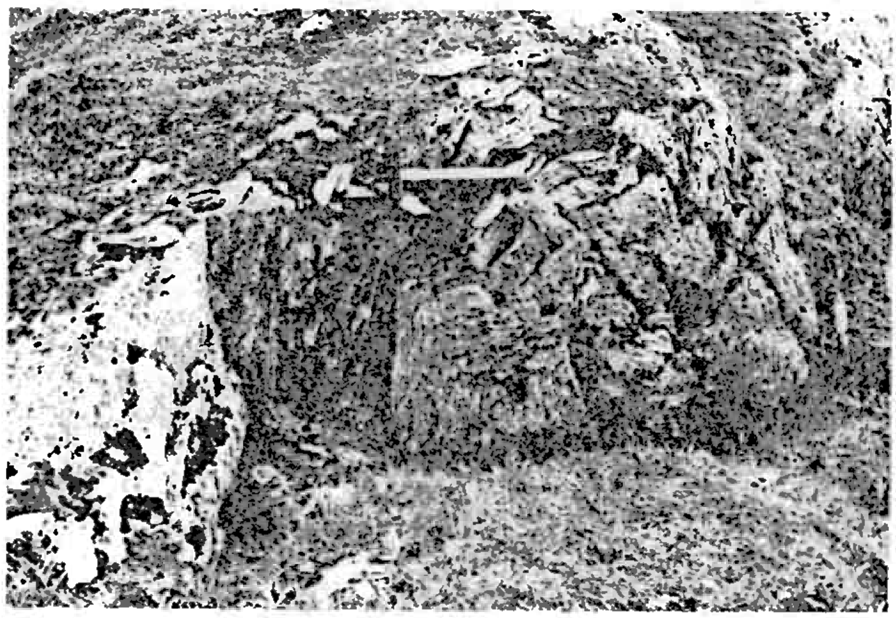
The latter two are minor members but of these (ii) can be used to show way up as the beds grade into finer phyllites towards the top of the quartzite unit. These appear to be rhythmically layered turbidites. Type (iii) are possibly volcanic in origin and are discussed in the project.

The feldspathic psammite in hand specimen is an apparently coarser rock similar in bulk composition to the other members of the calcareous phyllite group. There is a banded fabric of coarse quartz carbonate with partings of phyllosilicates being mainly chlorite and muscovite; but the characteristic feature is the presence of up to 20% microcline as up to 5mm x 5mm clasts.

This lithology has been compared (see Appendix II) with rocks mapped by Kollung and this has lead to correlation directly with an adjacent area. General outcrop is shown in photograph 4

3) <u>Carbonate rich calcareous phyllite</u>

This lithology is very apparent by it's rapid weathering to a well pitted surface when exposed (see photograph 19.)



Photograph 4: General appearance of feldspathic psammite in outcrop.

In hand specimen it is a very well foliated rock of quartz carbonate and phyllosilicate segregations approximately 1mm thick. Carbonate is very apparent with lenses forming small concentrations of up to 2mm x 1mm in the quartz segregations. The phyllosilicates are muscovite and sericite, but biotite is not apparent.

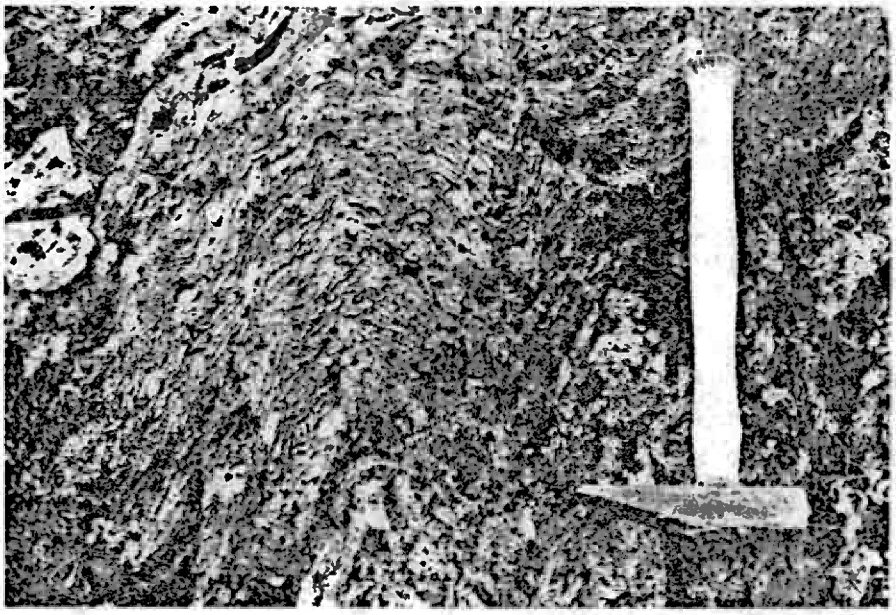
Towards the top of the group, and in fact forming the boundary horizon to the group, there are two fairly thin horizons (1-2m wide) of a coarse chloritic schist which is characterised by coarse prograde amphibole crystals, now having suffered retrograde alteration to chlorite and epidote. The rock contains mostly chlorite, feldspar with some quartz and in parts biotite. This rock type is discussed in the project.

4) Grey-green quartz rich calcareous phyllite

This rock type is the very uppermost in the calcareous phyllite group, and lies, structurally, directly below the bituminous phyllite.

The rock is generally grey-green in colour with typical appearance (photograph 5). The segregations of quartz with carbonate and phyllosilicates, are apparent but quartz content is much higher than the lithology below, but it contains less carbonate. Typically the phyllosilicates are dominantly chlorite, muscovite and sericite, no biotite being apparent.

Also occurring within this sequence are what are probably small gabbro intrusions. Near Henriksvatn (see 1:5,000 map) boudinaged pods of very chloritic schists are found containing no quartz evidently, and texturally appear to be intrusive gabbros. This appears intermittently in a high structural position in the phyllite.



Photograph 5: General appearance of grey-green quartz-rich calc. phyllite at outcrop.

Bituminous Phyllite

Referred to as part of the Ranster formation by Kollung in the adjoining area, this is found to lie structurally above the Calcareous phyllite group and the lack of evidence for a thrusted contact shows it to be younger.

The phyllite is generally dark grey-black in hand specimen and when rubbed, soils the fingers heavily with black graphitic material. The phyllite is well crenulated showing strong s1 schistosity crenulated by penetrant s2. A strong fabric of the alternate quartz rich/ phyllosilicate bands of 1-2mm thickness is evident.

Interestingly, there seems to be a strong association between volcanic activity and the presence of a bituminous phyllite: and as pointed out by Hutchinson (1977) the association of bitumen bearing phyllite, spilitic volcanism and mineralisation of the base metal massive sulphide type is often prominent. This is shown very well at Stekenjokk (Juve (1975)).

Meta Volcanic group

Named the Huddingsdal Volcanics by Kollung and the Skogsbacken Volcanite group by Sjøstrand (1973), these rocks are apparently well interbanded and often alternating bands of acid/basic tuffaceous material.

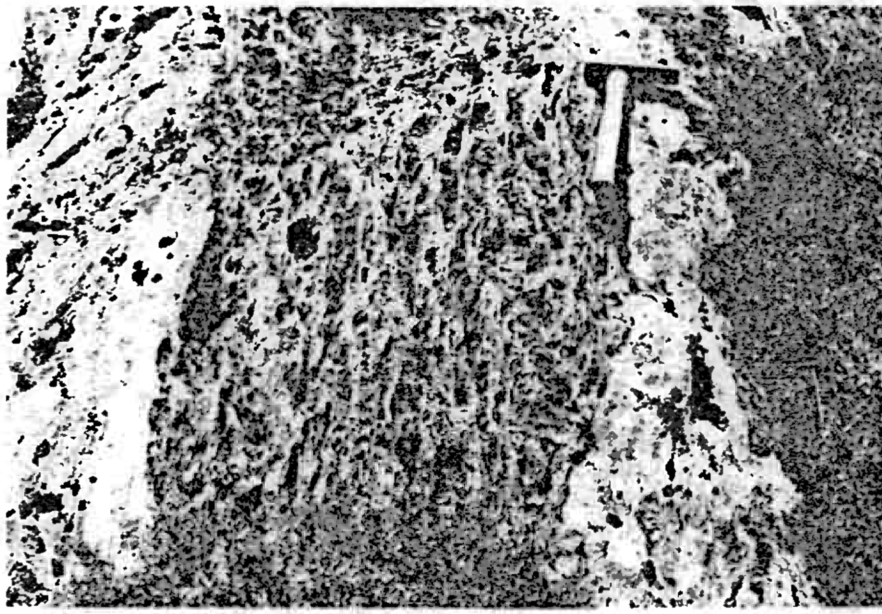
In hand specimen the acid rocks are evident as massive or laminated quartz, feldspar, sericite, chlorite schists with abundent pyrite in some cases. The basic rocks are present as chlorite, epidote, carbonate schists, some apparently silicified and some apparently containing quartz, carbonate filled 'vesicles' up to 3mm x 2mm in size. These rocks are discussed further in the project. (Photographs 7a, b, c)

d) The Upper nappe group (Gellvernokko Nappe)

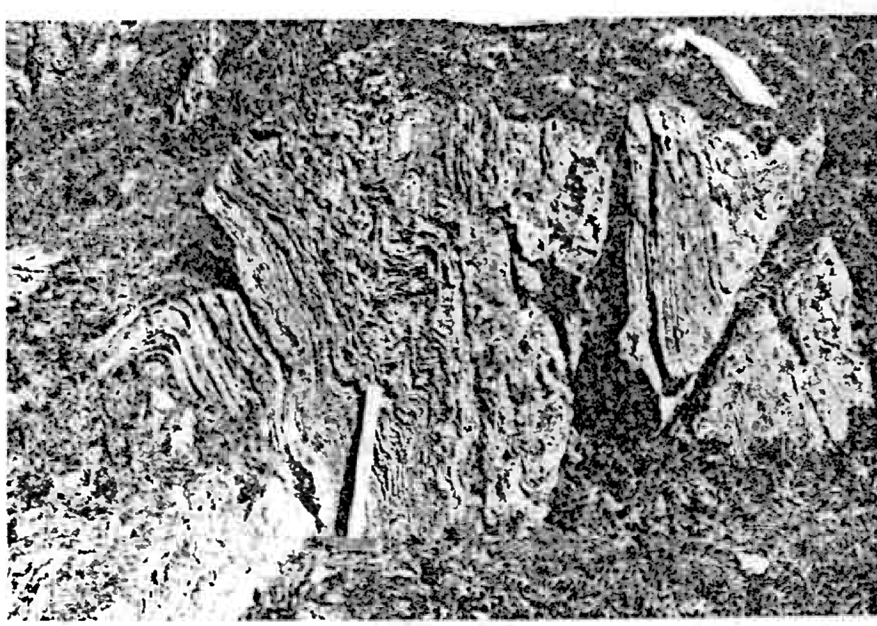
This group probably corresponds to the Røyrvik group mapped by previous Norwegian authors and the Remdalen group by Zachrisson (1969).

There are apparently two main members of this group, but it must be pointed out that mapping was only extended to the borders of this group, except for some preliminary mapping around the Gaetietjahke Skjerp. These two units are i) a generally bituminous phyllite, very similar in character to the phyllite found above the calcareous phyllite and ii) a chloritic schist, which is green-grey in colour and has the characteristic alternate quartz/phyllosilicate bands common to most rock types in the area. This schist is quartz rich mainly 70% SiO_2, the rest comprising chlorite, epidote, muscovite (up to 15% by vol), biotite (especially as porphyroblasts) and occasionally some actinolite needles.

A stratigraphy can thus be drawn up (see enclosure I with units placed structurally lowest at the bottom.



Photograph 7a: Typical interbanded acid/basic tuff units of the meta-volcanic group.Carbonate-rich basics show preferential weathering.



Photograph 7b: Interbanded acid/basic meta-volcanics.

6: Metamorphism

Metamorphism has occurred as at least two separate recognisable events in the mapped sequences (excluding the basement units which are outside the scope of this report).

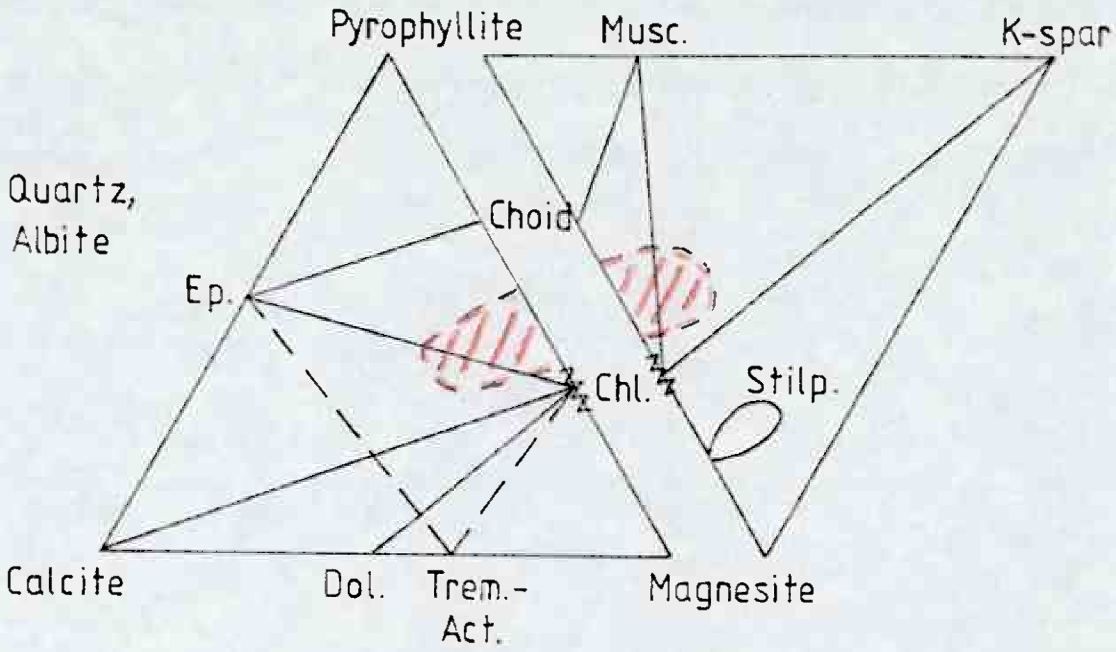
The first phase of metamorphism is peculiar only to the meta-volcanic suite and the volcanogenic bands of the calcareous phyllite. This is a result of spilitisation which occurred either contemporaneously with formation or else very soon after the igneous event leading to their formation (this is discussed in depth in the Special Project in Section B).

The spilitisation, which may be considered a metamorphic episode, involved the albitisation of plagioclase and the destruction of pyroxene by addition of OH^-, with the formation of prograde actinolites, and possibly hornblende, together with chlorite, epidote and sphene. This would suggest reequilibration in the quartz-albite-epidote-biotite sub-facies of greenschist grade as indicated by the ACF diagram 14b The field of the rocks in this group is indicated on the diagram which correlates the whole rock geochemistry (see Section B) with the observed petrology.

The second phase of metamorphism is related to the D1 deformation phase which resulted in the nappe complexes formed during the Caledonian orogeny.

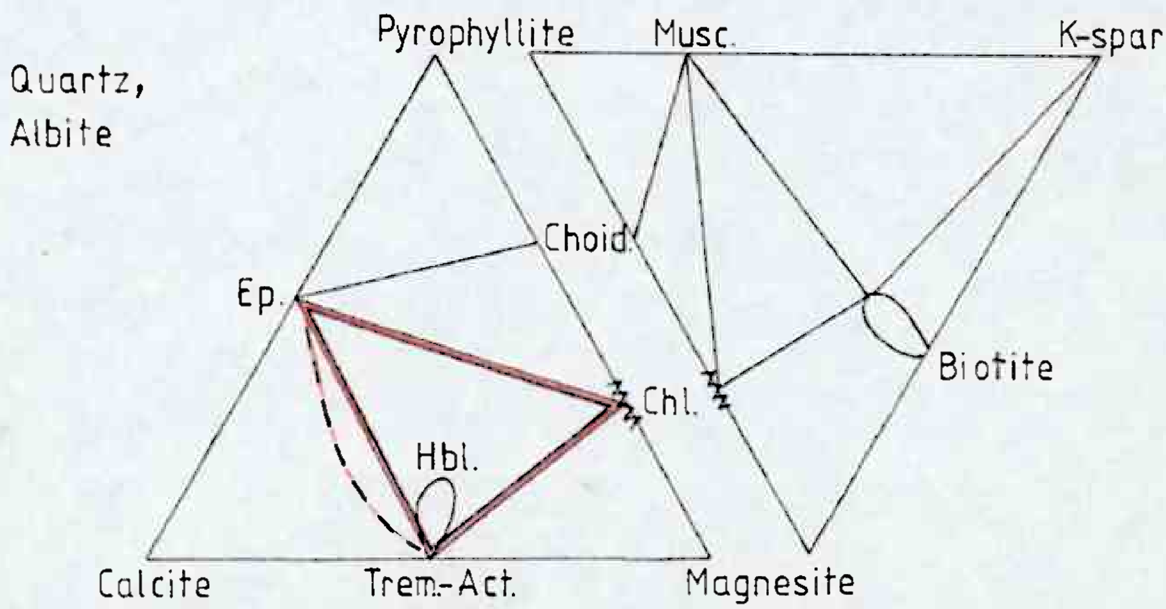
Triangular ACF diagrams of the Greenschist metamorphic facies

DIAGRAM I4a: Quartz-albite-chlorite-muscovite sub-facies.



 Average plot of calc. phyllites.

DIAGRAM I4b: Quartz-albite-epidote-biotite sub-facies.



 Average plot of volcanics and volcanogenic calc."phyllites."

(AFTER HATCH, WELLS, AND WELLS)

This phase of combined deformation and metamorphism has also resulted in the segregations of quartz,calcite and phyllosilicates common to all the phyllites,parallel to sl.

The assemblage found in the phyllites is character istically quartz, muscovite, chlorite, plagioclase, calcite together with small amounts of epidote , possibly dolomite and sphene. Actinolite was also seen in isolated occurrences.

This is a typical greenschist assemblage, but of a slightly lower grade, evidently less hydrous with no amphiboles present,except in rare cases where actinolite was noted.

It probably corresponds to the quartz-albite-chlorite-muscovite sub-facies with the field of interest marked on the ACF representation of this facies,in diagram 14a.

This second phase can be seen in the meta-volcanics as a retrograde alteration, where the amphiboles show a pseudomorphing by chlorite and epidote (see example in photograph 25), which indicates the lowering of grade to the less hydrous facies.

7: Structural Geology (Introduction)

The structural geology of the area is dominated by the presence of (i) Major nappe complexes and (ii) Major deformation episodes. These have been recognised by previous authors who have worked in the area and the major features have been concisely summarised by Zachrisson (1969): the features that he considered important are shown in diagram 8 . The major fold axes shown in this diagram are considered to be the result of f2 folding, f1 folding being considered isoclinal in the region.

(i) Major nappe complexes

Very strong thrust features separated the nappe complexes in the area, the features being of generally low angle, and sub-parallel to both bedding and the s1 schistosity. The contacts were also folded by f2 structures into the major features dominant in the area, and thus it must be concluded that the formation of the nappes, and their associated thrusting, must pre-date the f2 folding phase, probably occurring during the D1 deformation.

(ii) Major deformation episodes

In the area mapped 3 successive deformation phases were recorded which for ease of description I will refer to as D1, D2 and D3 respectively. D1 corresponds to D1 mapped by other authors.

D1 was found to be represented as isoclinal fold closures: examples of such closures penetrated by the s1 schistosity were found during the course of mapping. In the lower quartzites especially, s1 was found to differ from s0 (bedding) by anything up to 20° generally and, of course, much more at actual fold closures. Except at closures, the strike of s1 and s0 was coincident.

At this stage it must be said that multiple deformation phases were disclosed in the basement sequences, but rocks overlying the basement sequence have D1 as the first deformation "overprint" on bedding and thus it seems deformation of the basement pre-dates deposition of the cover sequences.

The D2 deformation phase in the area is represented by more open "rolling" folds of alternating antiform and synform with wavelengths of 20 - 40 km. These are the folds shown in diagram 8 . On a very detailed scale the deformation is shown as a crenulation cleavage to the existing well developed s1 schistosity, and this is well shown in most localities, although in the more competent quartzites this is generally very poorly developed.

There is also evidence for a third deformation phase D3. This is very poorly represented in the area and appears as shallow dipping "kink" folding to s2 of the whole sequence, but on a local scale only. This was, in fact, measured only at a few localities.

Lastly, it was apparent that there were very large fractures cutting the area: these were very apparent, especially on air photographs. After careful study there was found to be little or no movement along these fractures and thus it was concluded that these were very late-stage tensional features which had apparently disturbed the rock sequence very little.

(i) Major Thrusted Contacts

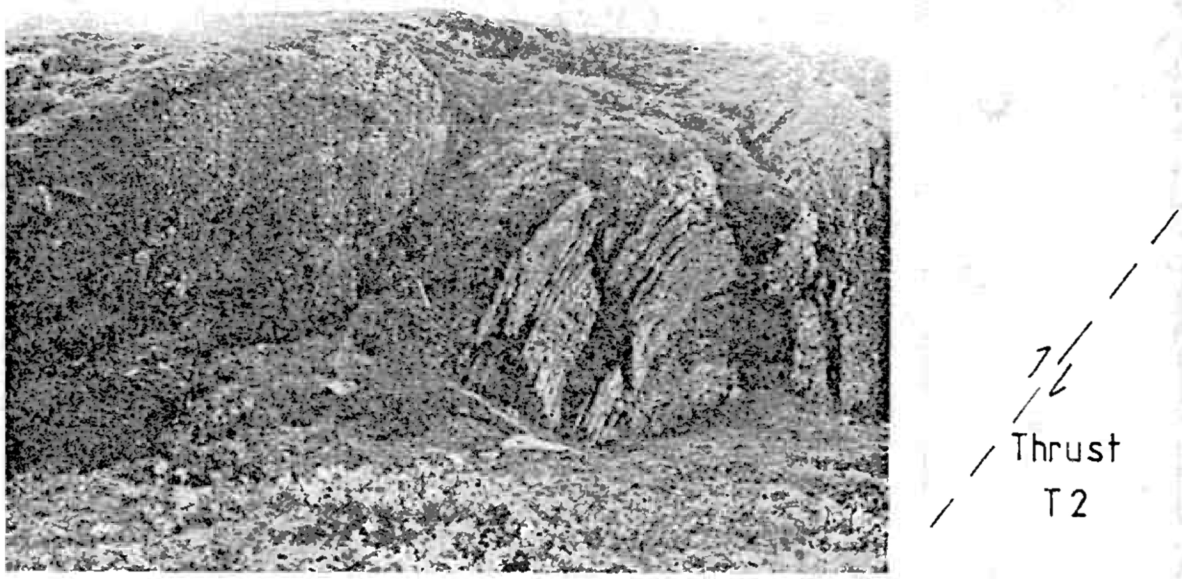
Several major thrust contacts were found in the area during the course of mapping: which divided the lithologies into convenient structural groupings, the contacts being placed as shown on the 1:5000 map of the whole area (see Enclosure I). It is convenient to consider these thrusts in ascending structural order from the Pre-Cambrian Børgefjell basement window: thus in a south easterly progression across the area.

The first tectonic discontinuity is found between the basement greisses, together with their autochtonous sediment cover, and the lowest thrust sequence of quartzites and mica schists of believed Eo-Cambrian age (referred to as T1 on the main map, Enclosure I).

The thrust is clearly marked by a distinct break in slope over much of its extent, and structural features either side of it are clearly different. To the north west, the rocks are characterised by numerous deformation phases, whilst the quartzites and mica schists preserve only two major deformation episodes - D1 and D2.

The second tectonic discontinuity is found between the quartzite and mica schist group (which will now be referred to as the Lower nappe group), and the so called calcareous phyllite group, which together with the overlying bituminous phyllite and meta-volcanic rocks will be grouped as the Middle nappe group.

This thrust is shown on the 1:5000 sheet as T2: and again is a feature which is conspicuous in some areas by a break in slope. A ridge of overthrust calcareous phyllite occurs over much of its length, itself incised by cross-cutting streams exploiting the late feature fractures (see photograph 8). This is shown clearly by the aerial photographs. In the north east of the area near Orrevatn this thrust is shown by a 6 metre high, sheer face of the Middle nappe group.



Photograph 8: Overthrust ridge of calcareous phyllite, incised by cross-cutting stream which exploits late stage tensional feature, feldspathic psammite group is conspicuous.

Location A see 1:5000 sheet.

Another exposure shows calcareous phyllite as a small ridge, directly overlying a heavily deformed and shattered phyllite, which itself structurally overlies micaceous quartzites of the Lower group. This is shown in photograph 9 .

The feldspathic psammite horizon which was mapped toward the contact with the Lower group was seen to be truncated by the thrust feature, this horizon appearing only intermittently along the thrust extent.

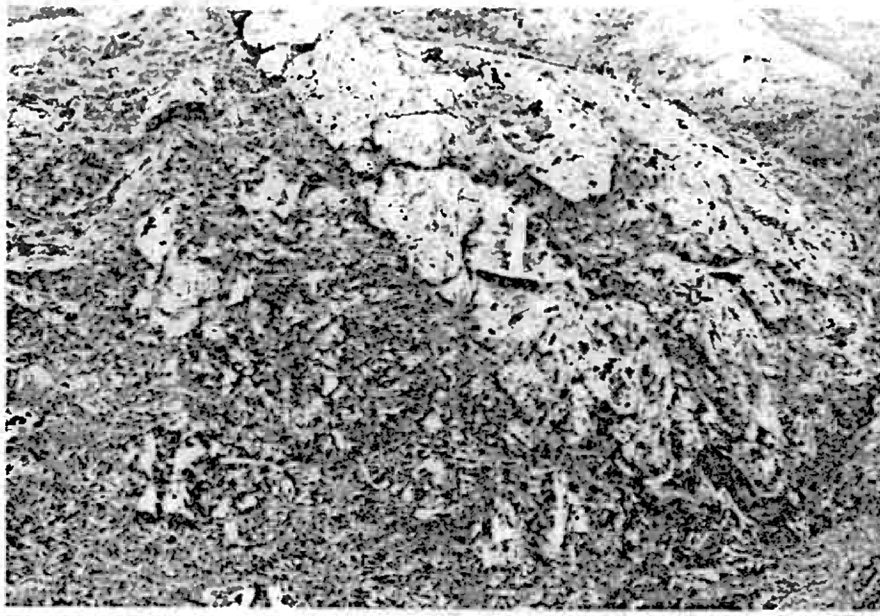
Finally small tectonic segregations were often found in the region of this thrust, occurring as up to 4cm "knots" of feldspar and quartz with some small cubes of galena.

The third major tectonic discontinuity is found above the meta-volcanic suite of rocks, occurring between these rocks and the overlying bituminous phyllites and chloritic schists (which will be called the Upper nappe group).

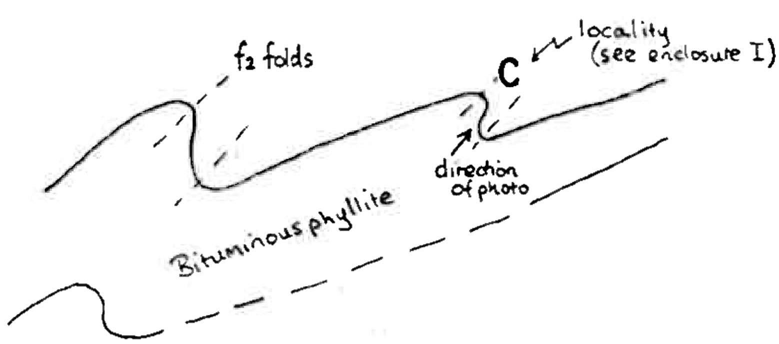
Again, aerial photographs show strongly the presence of a ridge, structurally higher, overlying the volcanic rocks. Field evidence appears to be confined to the presence of this ridge, but also discordance of s1 across the contact is noted in the Gaetietjahke area.

Kollung (1978) places another thrust between the bituminous phyllite of the Middle nappe group and the calcareous phyllite series. The present author found some evidence for this. In exposures to the north east of the area, the bituminous phyllite is seen to lie, in part tectonically discontinuously, on calcareous phyllite and be conformably overlain by the meta-volcanics (see photographs 10 and 11). The bituminous phyllite appears very highly deformed at outcrop, mostly, and is very friable, the present author concluding that some minor shearing has occurred within the lithology during heavy deformation

Photograph 9: Small ridge of calcareous phyllite, overthrusting mica-schists.
Location B on 1:5000 sheet



Photograph 10: Slight tectonic discontinuity
between bituminous phyllite
and calcareous phyllite in a
pinched in, overturned fold (see below)



and "pinched in" folding, but the fact that the lithology is so persistent in strike extent and in very many places appears totally conformable upon the calcareous phyllite, suggests no major thrust can be placed here.

Correlation of these thrusts with previous mapping in adjacent areas seems quite good and the present author concludes that the Middle nappe group corresponds to the Lower Köli nappe of Zachrisson (1969) and others, and that the Upper nappe group corresponds to his Gellvernokko Nappe (see diagram 8)

The Lower nappe group presents a problem in its positioning within the previous structural models for the area: but Zachrisson (1973) indicates that the Seve nappe, which structurally underlies the Lower Koli nappe, wedges out to the west and is not present below the Lower Koli in this area. It must be concluded that the Lower nappe sequence in this area corresponds to one of the "Lower nappes" placed on the basement by previous authors, but it must be stressed, tectonically distinct from the basement.

Deformation of the basement is not considered here but it is noted that there appear to be multiple deformations of the basement series which pre-date any deformation in the cover sequences.

(ii) D1 deformation phase

The D1 deformation phase is strongly represented in the area, predominantly as the major schistosity s1. The D1 deformation is related to strongly isoclinal folding, s1 schistosity being preserved generally parallel to bedding with discordance of less than 20° of dip in most cases.

South west of Henriksvatn a major f1 closure was mapped. It is a moderate, to steeply, inclined fold gently plunging towards the north-east. Minor structures at the closure zone indicate an f1 plunge of 20° to roughly 050° (see photograph 12) and from the mapped outcrop pattern, a synformal closure is postulated. The plot of s0 (bedding) - poles around this closure on a stereonet shows up this f1 closure (see diagram 9), indicating a synformal fold axis by the minor structures. The fact that this fold structure is well preserved is due to the very small effect of D2 on the quartzites and D2 is generally represented by a gentle tilting.

This would then place the mica schists structurally below the quartzites. S1 is fairly uniform throughout this area, constantly dipping from 45-60° towards the south east, penetrating the fold closure.

In the quartzite and mica schists generally, S1 shows moderate effects of later deformations although a contoured plot of s1 (diagram 10) groups them mainly around 020-024/30-50E where 20% of the 111 readings are situated. f1 plunges plot roughly around 20° to 050° and some at approximately 18° to 180° from the Orrevatn area.

The D1 deformation in the overlying sequences is preserved almost entirely as the S1 schistosity which is sub-parallel to bedding. This deformation has lead to the segregation of quartz rich bands and phyllosilicate bands in the phyllites and schists of these series, to give them the characteristic alternate banding of 1-2mm thickness which is discussed in more detail in the lithology section. Minor and major f1 structures are almost totally lacking except for a few examples of the former, mainly in the meta-volcanics. Some of the acidic bands show the isoclinal fold style of S1 (photograph 13) and

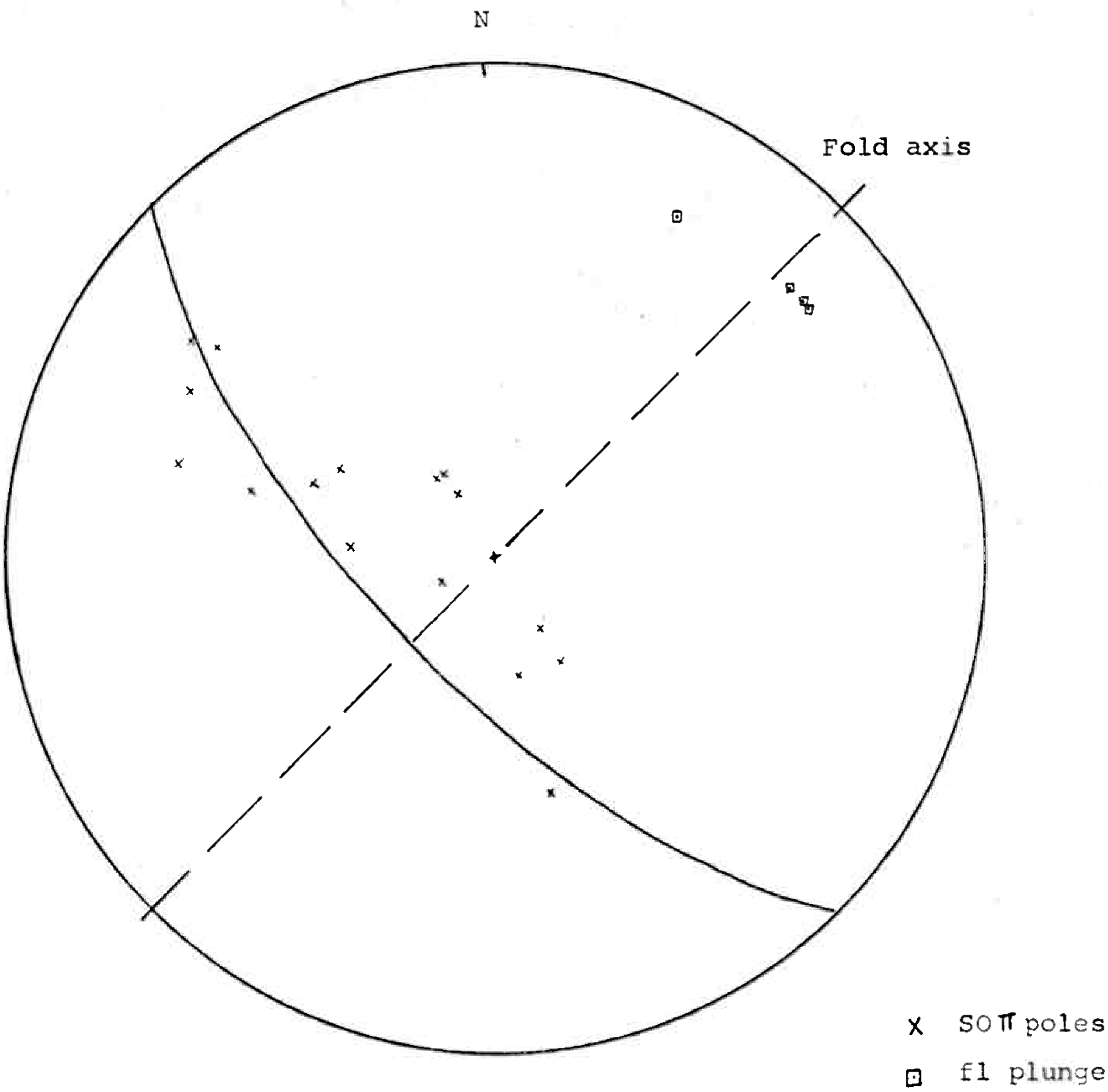


DIAGRAM 9 Plot of s0 (bedding) and f1 plunges in the quartzite units around the f1 closure on the SW shore of Henriksvatn.

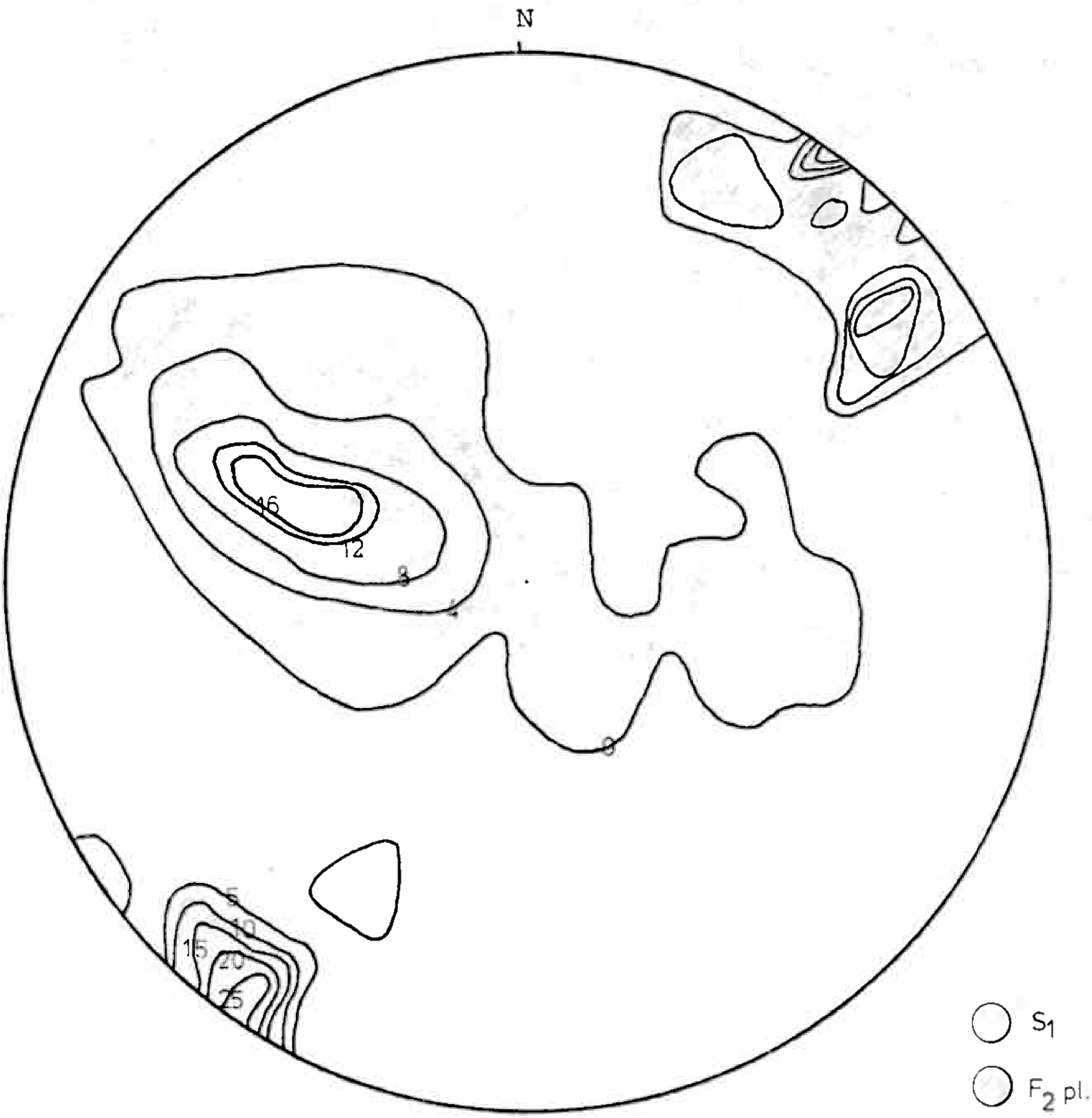
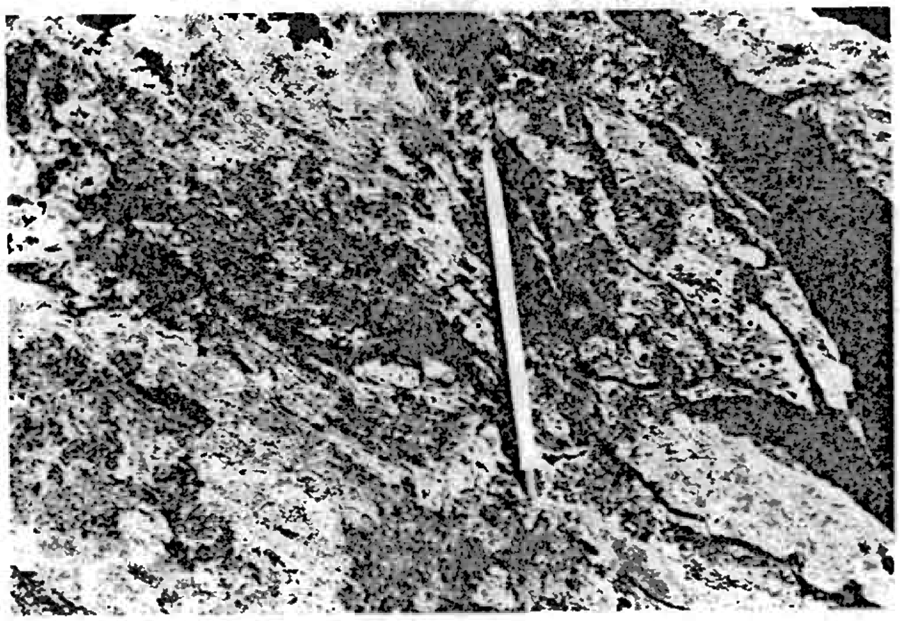


DIAGRAM 10 Contour plot of s1 and f2 in the Lower nappe group. (For s1 contours at 0,4,8,12,16 20%, for f2 contours at 0,5,10,15,20, 25%) π poles plotted (111 data)



Photograph 12: Minor f1 closure in more micaceous unit shown by differential weathering

Photograph 13: Minor f1 closure seen in acid volcanic band.

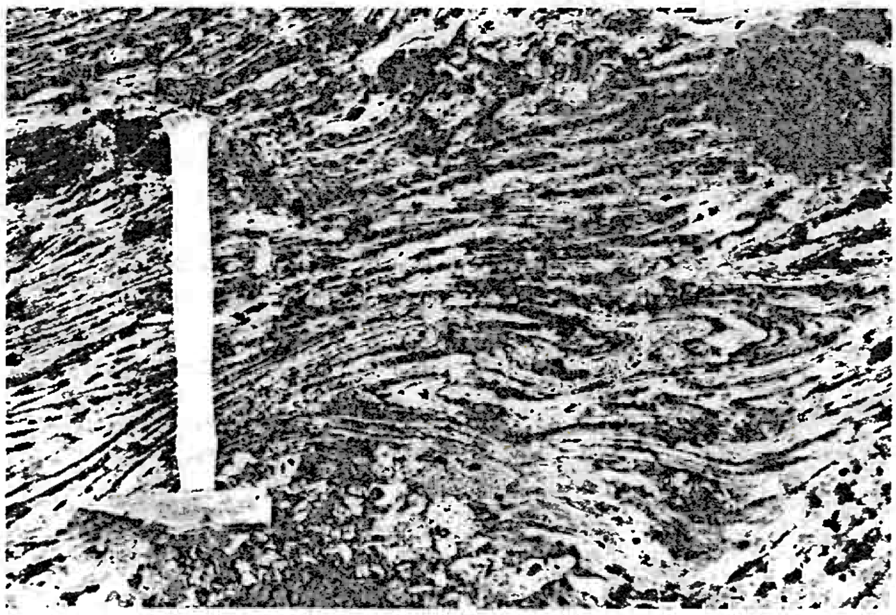
weathering picks out some f1 closures in carbonate chlorite schists (photograph 14).

(iii) D2 deformation phase

The D2 deformation phase is again very strongly represented in the area, especially in the less competent rock types. The D2 phase is associated with the large open folds described earlier, a major synformal closure being placed by previous authors along the Norwegian Swedish border.

In the quartzite and mica schist group the effects of D2 are less apparent. The pure quartzites do not show the development of an S2 cleavage although a strong crenulation to the more micaceous quartzites and mica-schists is very evident. D2 is shown to deform the previous S1 schistosity as more of a general tilting from the presumed sub-horizontal of the nappe formation, to a dip of 45-70° to the south-east. A plot of s1 and s2 π -poles together with f2 plunges shows the broad pattern of deformation (see diagram 11). A best fit -axis is shown on the diagram and thus is indicative of a fold axial plane striking 028°. The f2 plunges are bimodal but both sets lie on the E-W line when the -axis is rotated to N-S, and thus a sub-vertical to vertical axial plane to the folds is postulated. The skewed distribution of data points indicates that we are probably on one limb of a major f2 fold closure.

The calcareous phyllite group showed the D2 features very clearly. As well as a strong crenulation to the s1 schistosity in the more phyllitic members (photographs 15 and 16), some parasitic f2 fold closures were mapped, being elucidated during mapping of the feldspathic psammite horizon and coarse chloritic grit bands (see 1:5000 sheet diagram 1 photographs 17 and 18). The plunges of f2 measured on these folds, together with the outcrop pattern mapped, indicated the presence of



Photograph 14: Weathering of carbonates picks out minor f1 closure in basic volcanics

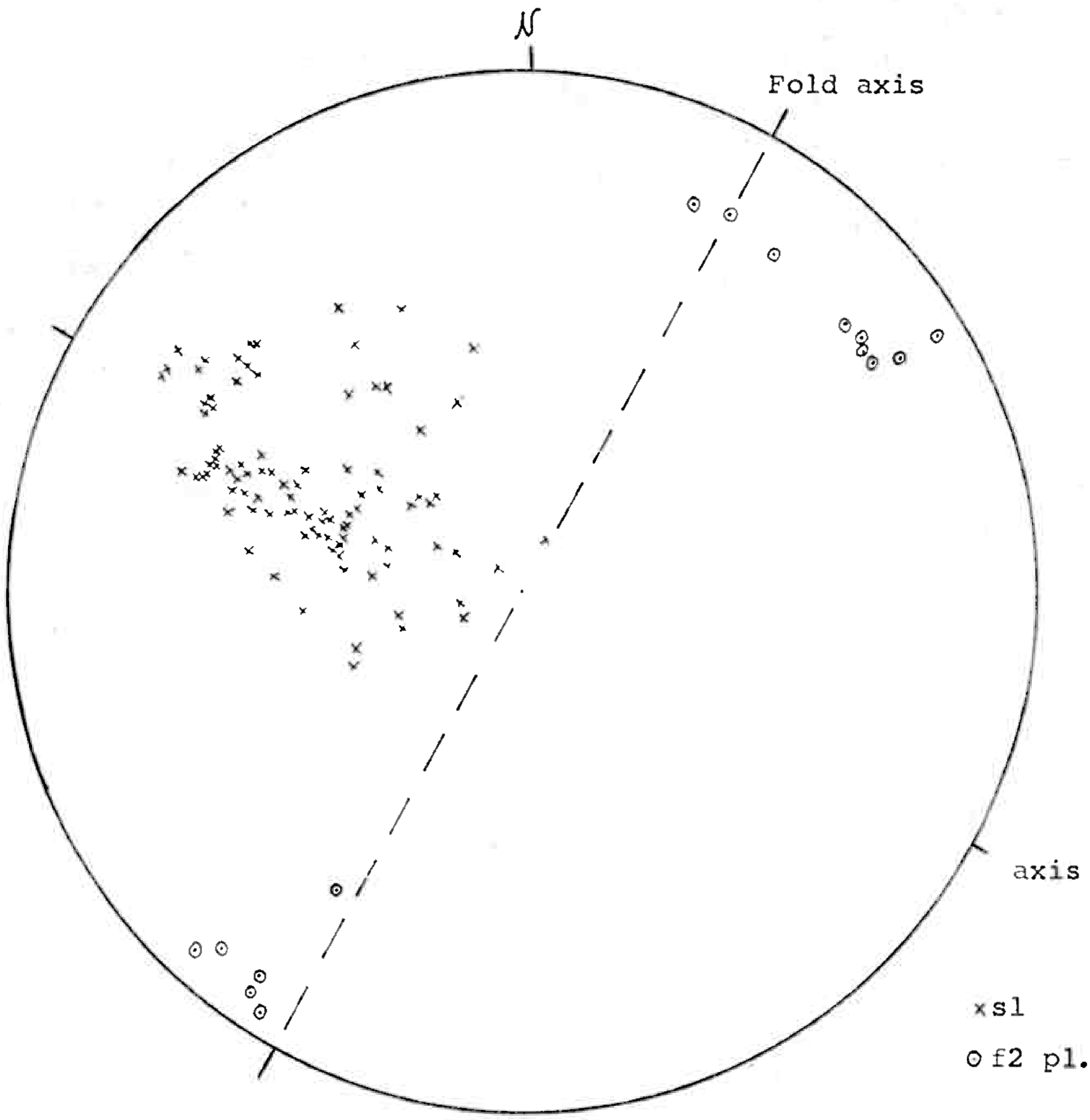
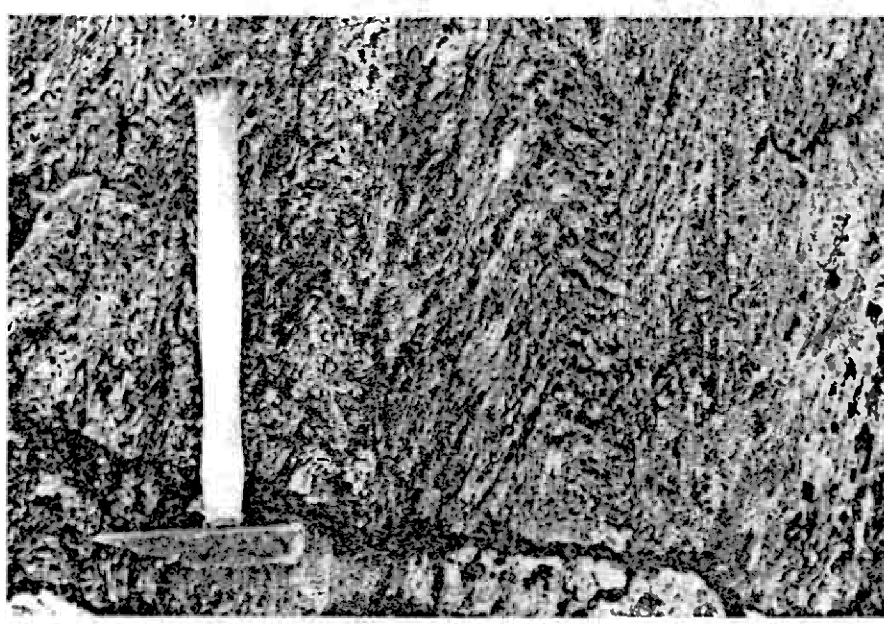
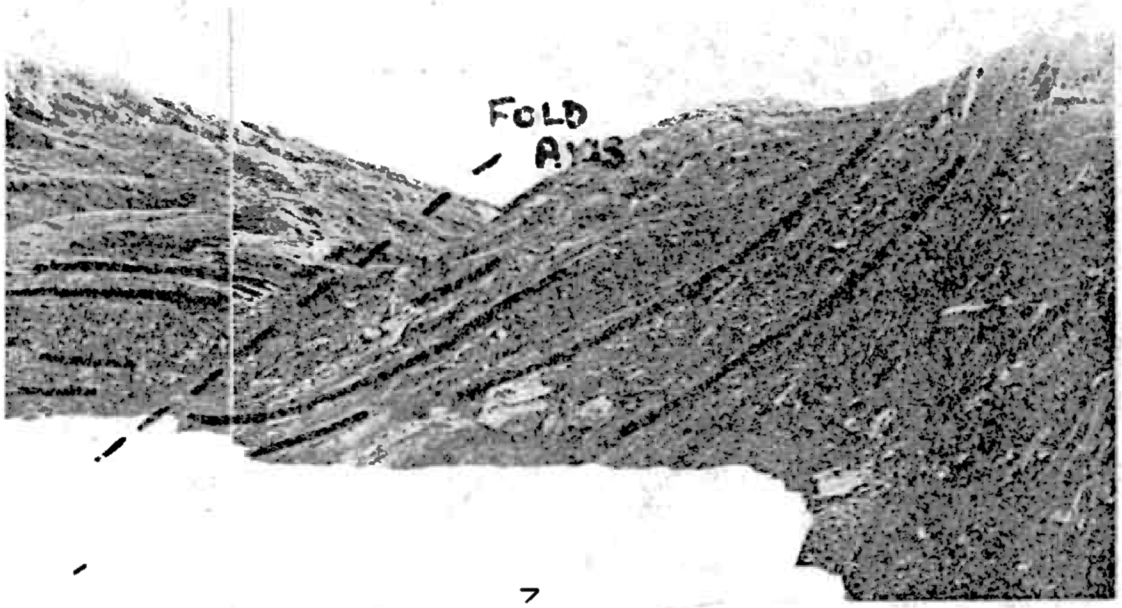


DIAGRAM 11: Plot of s1 and f2 plunge in Lower nappe group indicating one limb of a major fold closure.

Photograph 15: Strong s2 cleavage, cross-cutting the s1 cleavage which is itself shown by the quartz-rich segregate bands.



Photograph 16: s2 cleavage crenulating existing s1.



Photograph 17 : Major parasitic f2 fold in feldspathic psammite group
Locality D see 1:5000 sheet.

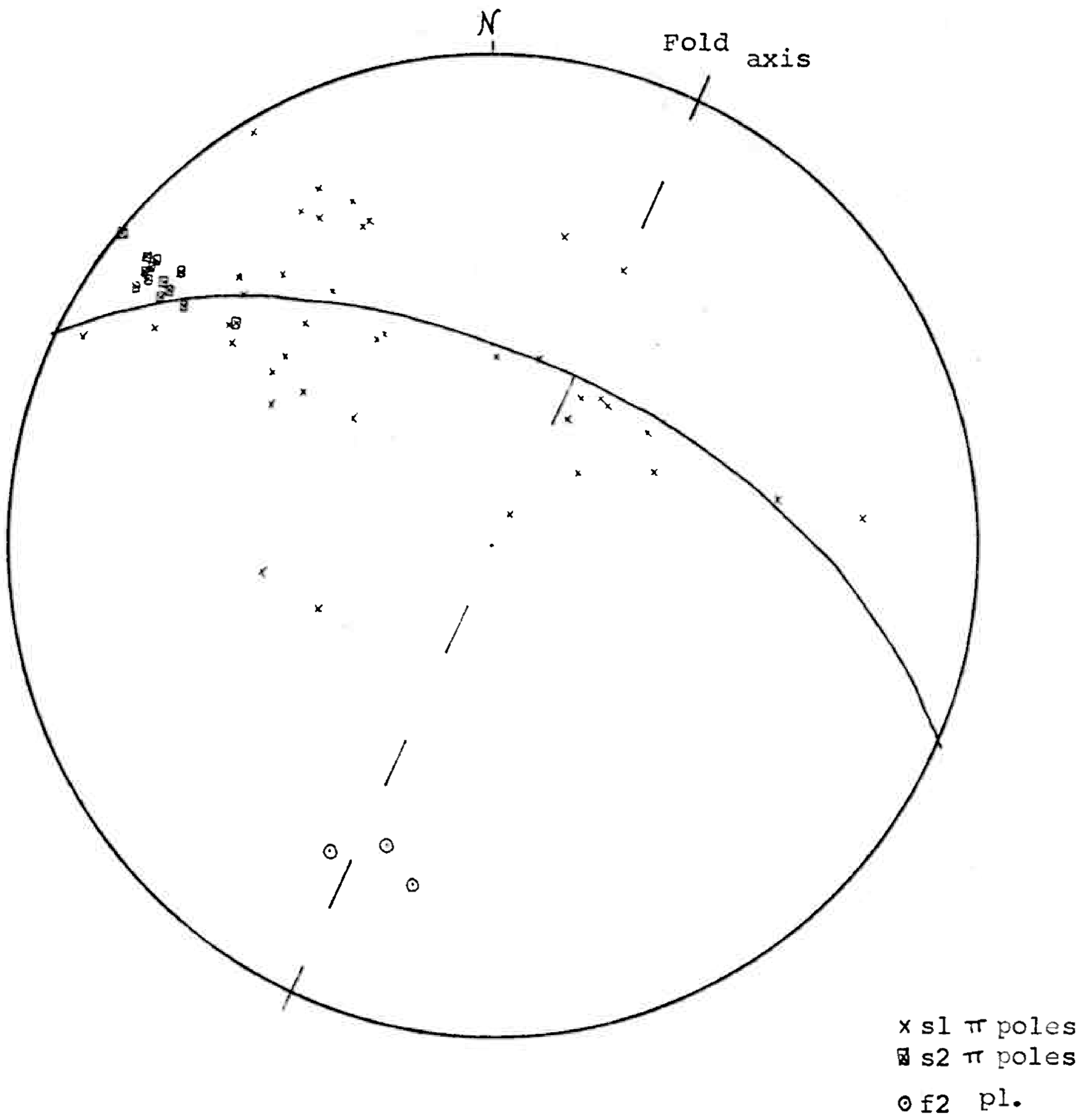


DIAGRAM 12a: Plot of s1, s2 and f2
feldspathic psammite unit
indicating fold style

a larger synformal closure towards the Norwegian/Swedish border, confirming previous work. There is evidence for small parasitic S2 closures at the bituminous phyllite and meta-volcanics boundary too, with a flattening of S1 in the area of (indicated on Enclosure I), leading to an outlier of volcanics in bituminour phyllite (see photograph 18 and diagram 12b).

Good examples of f2 parasitic folding were shown by differential weathering of more carbonate rich sediments (see photograph 19), and the penetrative S2 cleavage can be seen.

The bimodal plunge of the f2 folds is shown in many places, especially by the well weathered alternating acid/basic meta volcanics as shown by photographs 20, 21 . A plot of s1 and s2 -poles together with f2 plunges is shown in diagram 13. It indicates a major fold regime with fold axis striking 030°. f2 is generally bimodal in plunge, but again suggests upright folding with a vertical axial plane. From mapping, the presence of a large fold closure on the Norwegian/ Swedish border is indicated.

There is strong correlation of D2 features throughout all the nappe groups as shown on the stereonets (Appendix III) and it seems that there has been strong tectonic correlation in all groups after the D1 deformation phase which most likely resulted in the nappe features.

(iv) D3 deformation

As stated, this deformation is poorly represented in the area. It is shown mainly in the meta-volcanic suite as low angle "kinks" (see photographs 22 and 23). It does not seem to have lead to any major structural features.

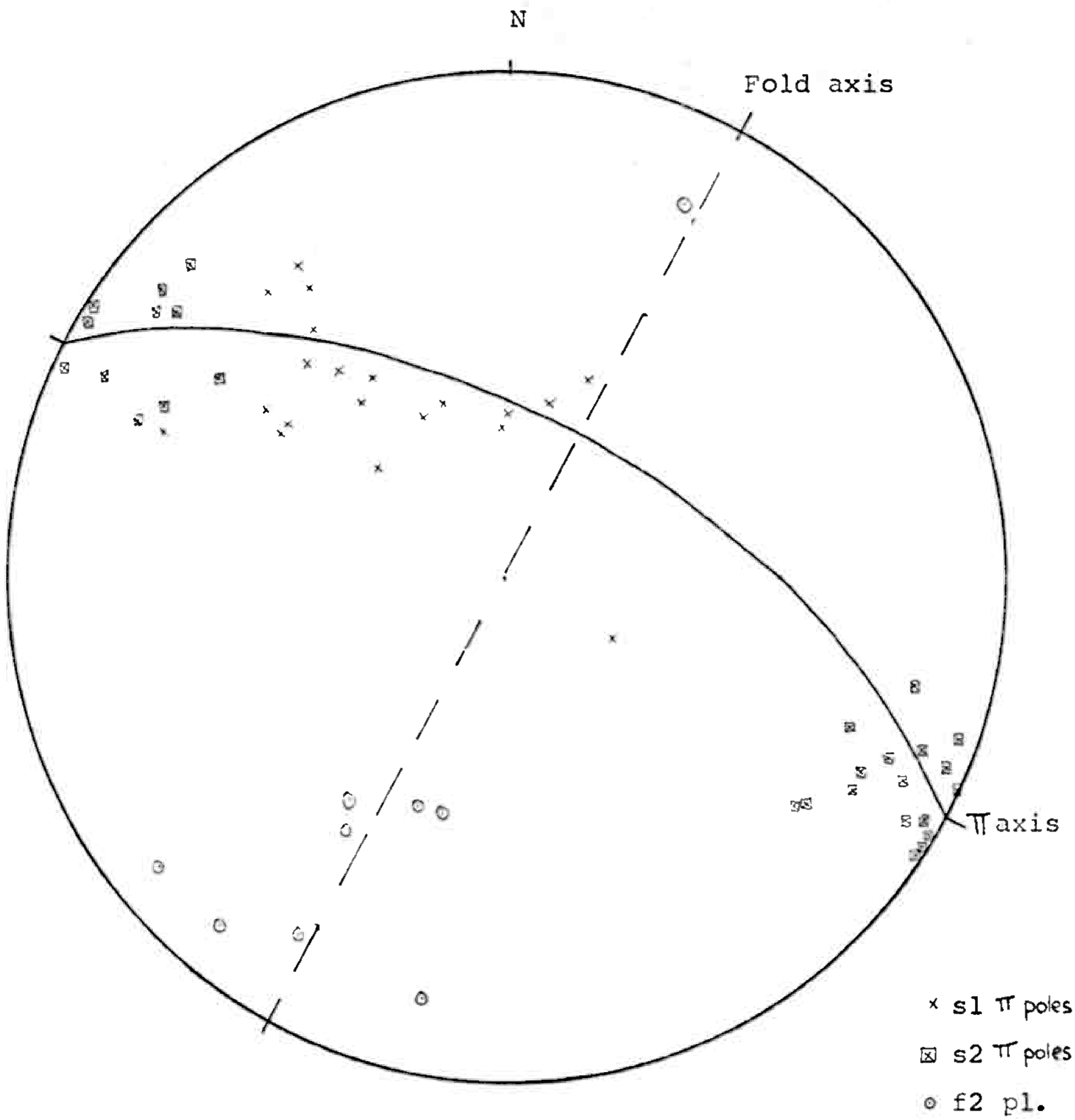
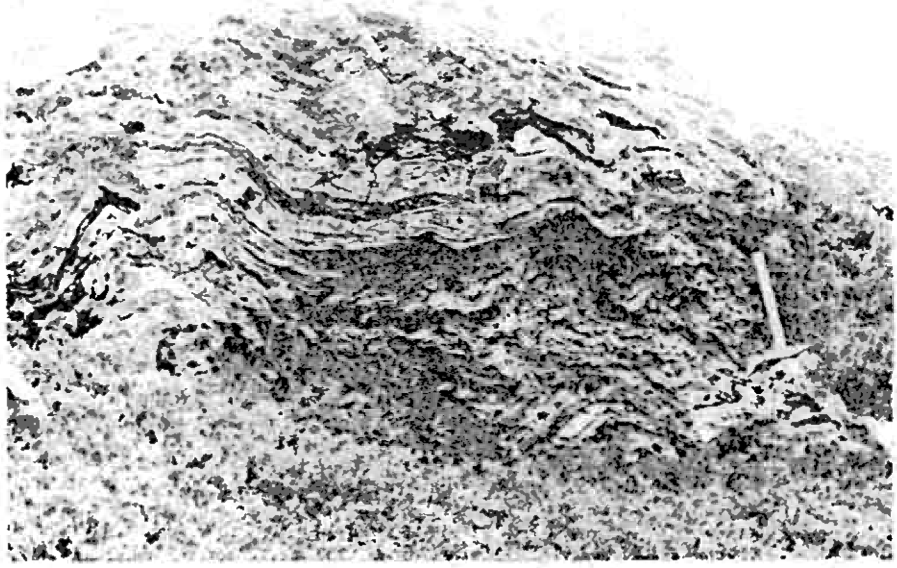


DIAGRAM 12b: Plot of s1, s2 and f2 plunges in bituminous phyllite and meta-volcanic units.



Photograph 18: Flat lying meta-volcanic bands occurring as an outlier in the bituminous phyllite group at Loclity E- see 1:5000 map

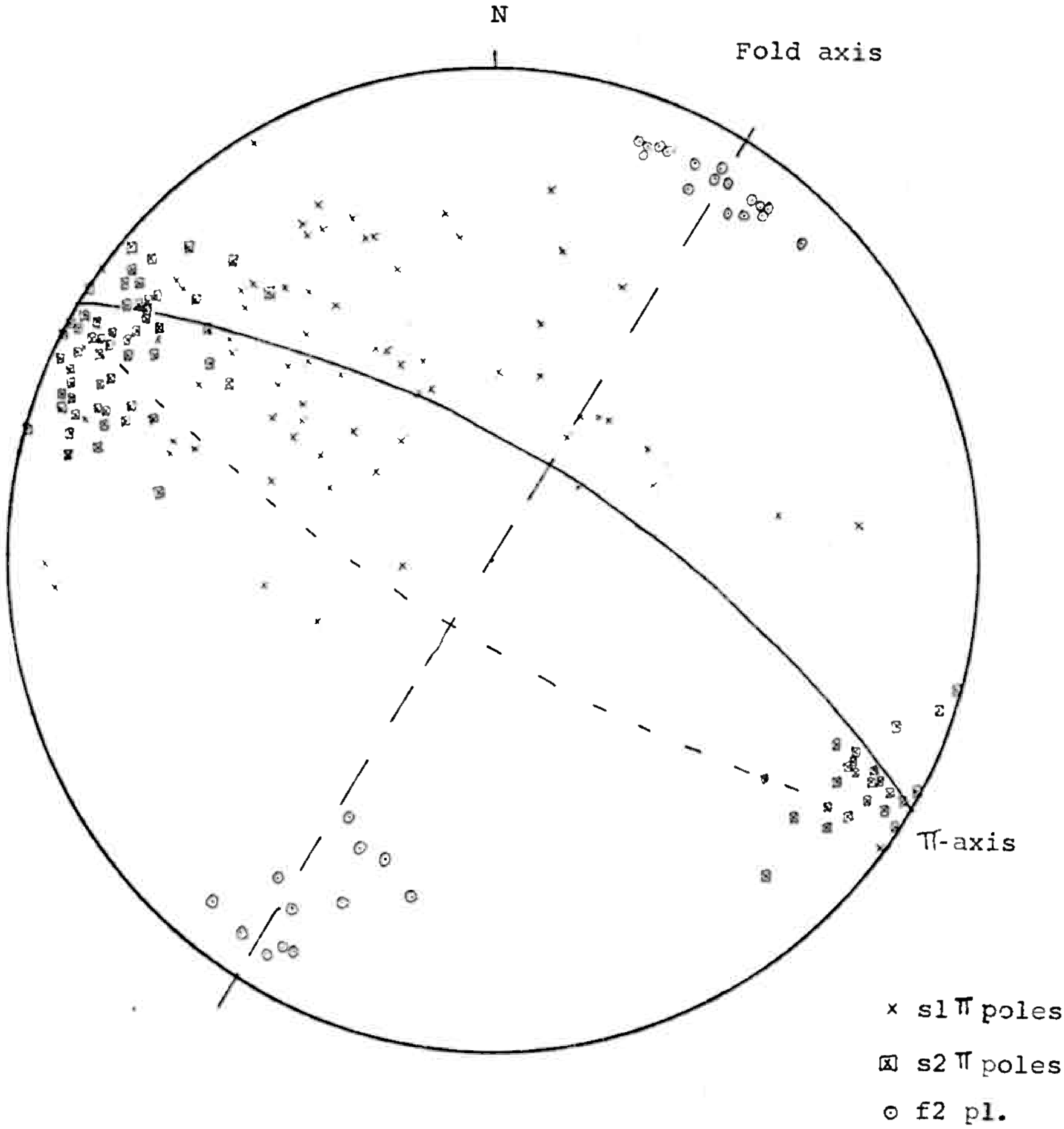
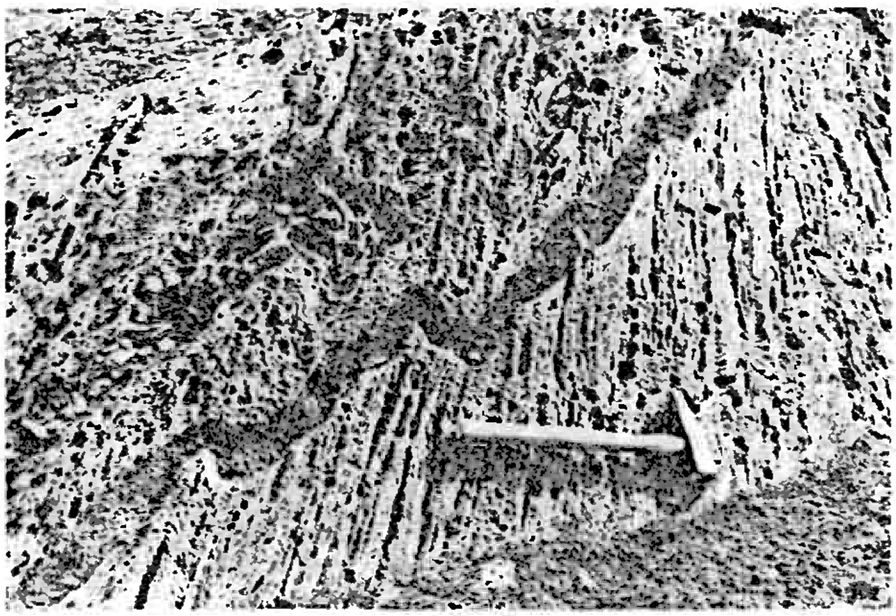
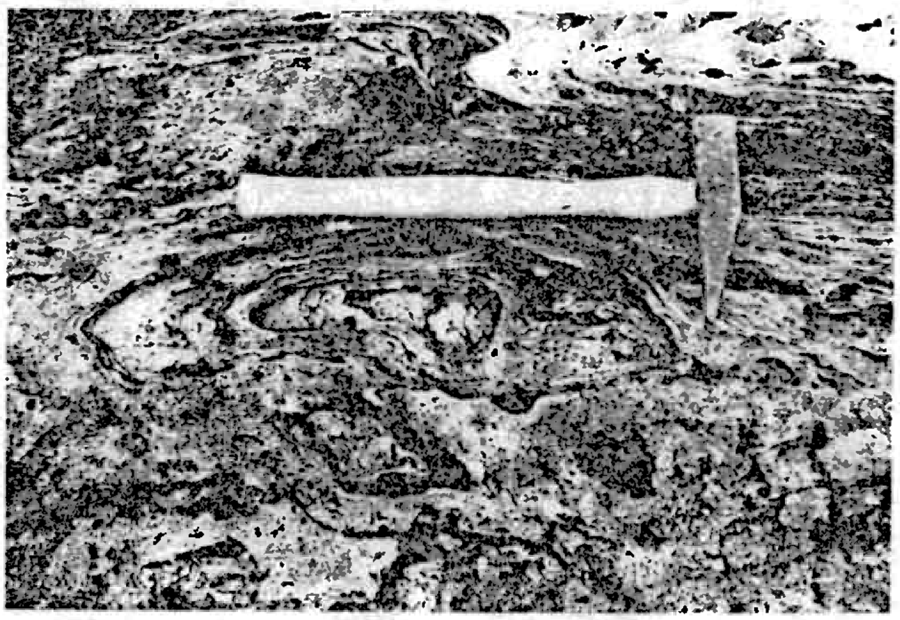
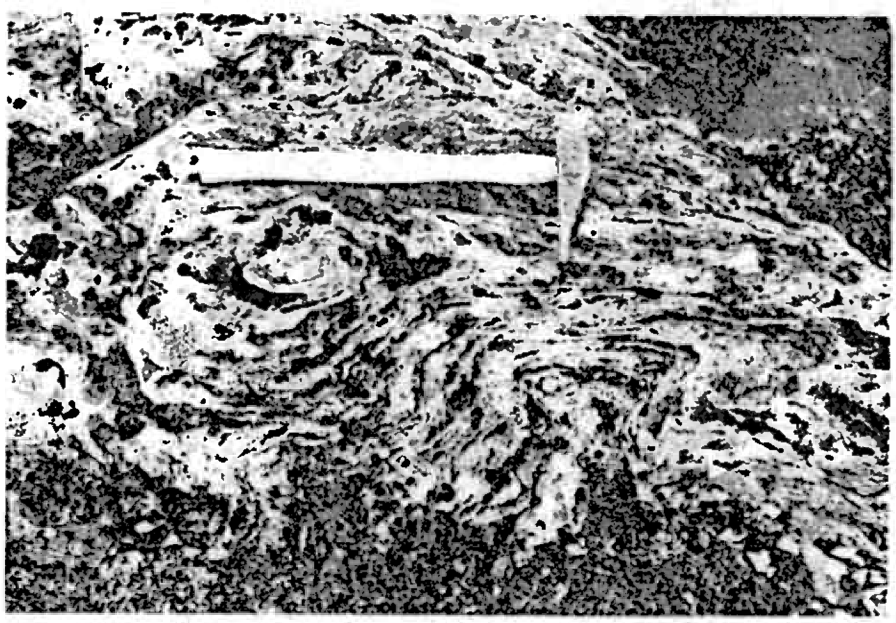


DIAGRAM 13: Plot of s1, s2 and f2 plunges in all the calcareous phyllite units.

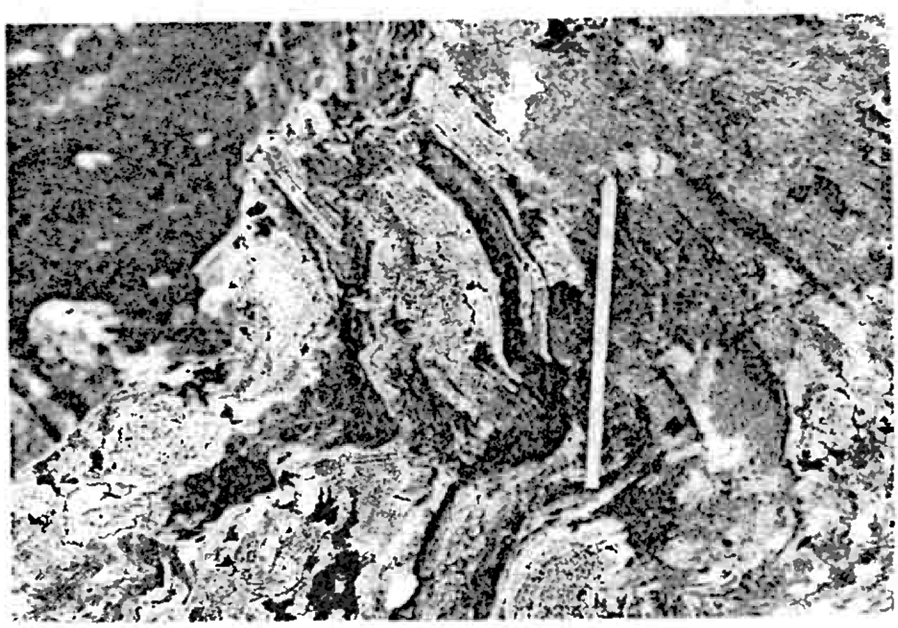


Photograph 19: Parasitic f2 folding indicated by weathering in a carbonate rich band s2 cleavage seen strongly cross-cutting the small closures. s1 dips generally eastwards.





Photographs 20 and 21: Bimodal f2 plunges indicated in banded meta-volcanics.



Photographs 22 and 23: Minor kink folding representing D3 deformation.

8: DISCUSSION OF MINERALISED SHOWINGS (SKJERPS)

Skjerp 1

This zone was located along the south-east side of two lakes, running from grid reference 555035 to 558037 which run in a strike direction of 060° (see diagram 15). The zone was indicated by a regional stream sediment survey carried out previously, slightly anomalous values of zinc and significantly anomalous values of lead being recorded for the stream draining north-east into Orrevatn (see diagrams 1). Previous workers in the area (Brenna 1966 and unknown N.G.U. Archive records) had indicated the presence of a "broad zone", as stated by Brenna, "with rusty spots" occurring within the calcareous phyllite group. On his examination Brenna recorded small concentrations of sulphide minerals with flecks of chalcopyrite. The minerals occurred in "partings" of what were called "normal" mica schists and bituminous phyllites.

After examination the zone was found to consist of a rusty zone, approximately 1.5 metres wide, with a visible strike of several hundred metres. This zone had a strike of approximately 060°, parallel to the two lakes at the locality.

After careful geological mapping of the zone, a detailed map of the Skjerp and the surrounding area could be produced. This is shown in diagram 15. The rusty horizon was thus stratigraphically controlled within a bituminous phyllite band, occurring in a sequence of chlorite/ carbonate schists, chloritic grits and acid/basic banded meta-volcanics.

The rust zone itself comprised a quartz-rich bituminous phyllite with laminated quartz-rich layers alternating with bituminous rich layers: This bituminous layer was very highly weather, and it was decided that further examination would necessitate the blasting of a trench perpendicular to sample unweathered material, as no "Ore Minerals"

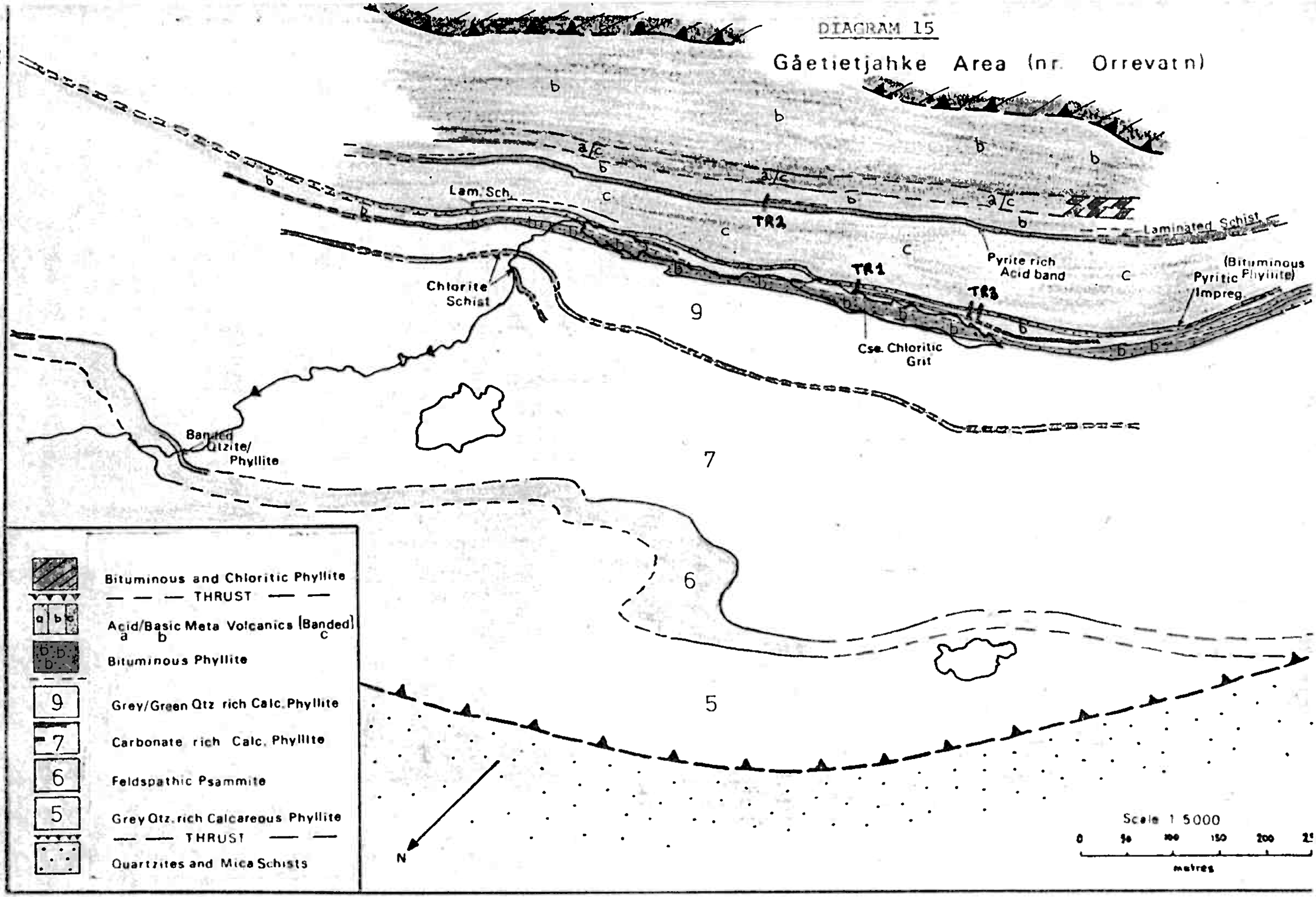
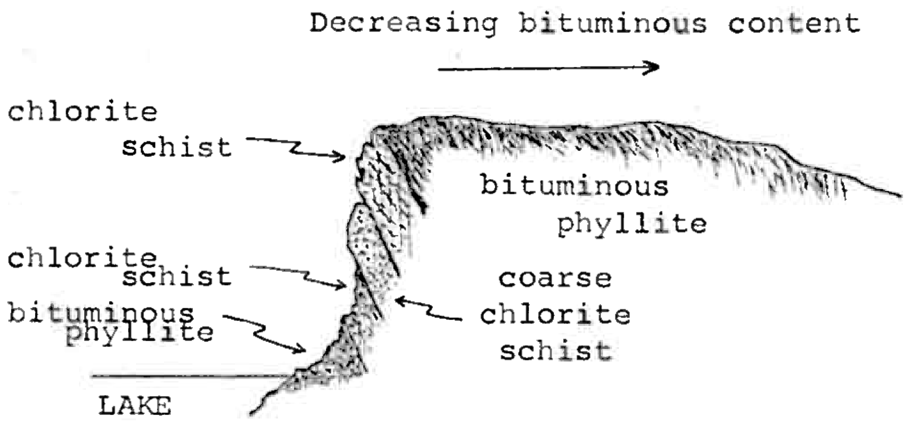


DIAGRAM 15
Gåetietjahke Area (nr. Orrevatn)
Lam. Sch.
TR2
TR1
TR3
Laminated Schist
Pyrite rich
Acid band
(Bituminous
Phyllite)
Pyritic
Impreg.
Chlorite
Schist
Cse. Chloritic
Grit
Banded
Qtzite/
Phyllite
9
7
6
5
N
Bituminous and Chloritic Phyllite
THRUST
Acid/Basic Meta Volcanics (Banded)
a b c
Bituminous Phyllite
Grey/Green Qtz rich Calc. Phyllite
Carbonate rich Calc. Phyllite
Feldspathic Psammite
Grey Qtz. rich Calcareous Phyllite
THRUST
Quartzites and Mica Schists
Scale 1 5000
0 50 100 150 200 250
metres

were visible, only limonitic staining.

A detailed geological study was made at a section determined along a line trending 138°, perpendicular to strike:



Two possible zones for trenching were designated at TR1 and TR3 (see diagram 15). TR3 was within the strike extension of the rusty zone.

The impregnation diminished along strike being indiscernible beyond the extents marked on diagram 15 .

Trenching at TR1 TR3

Two areas were designated for trenching along the rusty stained bituminous phyllite, and one trench (at TR1) was blasted right across the zone in a direction of 140° from the base of the bituminous phyllite to a distance of 2.0m along 140°. The second trench (at TR3) was a comparable zone 300m along strike, south of TR1.

Samples were taken at geologically significant points: these samples were logged petrologically and samples were sent to be crushed for base metal analyses. The results of the analyses are shown in diagram 17 and the petrographic report follows the section at the end of the chapter. (Appendix I)

Skjerp 2

Approximately 75 metres south-east of the bituminous phyllite rust zone, another rusty outcrop was found, with a strike and direction similar to the bituminous phyllite rust zone.

It was also stratigraphically/lithologically controlled in a 0.5 metre wide band. Mapping showed this to be a quartz pyrite - sericite schist occurring in a sequence of banded acid/basic volcanic rocks, being overlain directly by an apparently "Keratophyric" band, and underlain by chlorite-sericite schists. Again weathering to this band was quite persuasive and blasting across strike was suggested to enable fresh unweathered material to be obtained. The zone appeared to decrease in concentration of impregnated pyrite NE and SW along the strike extent, and the impregnated zone appeared to split and peter out as indicated on diagram 15 .

Petrographic logging of the blasted trench, analyses for base metals are shown in the section at the end of the report (Appendix I). and diagram 17.

Skjerp 3

This zone had previously been recognised by Foslie (1926) on his original map and is located 300m south of Røys 201[2]. Brenna (1966) made a study of the area, and found a rusty zone approximately 100 - 150 metres long. The zone was located within bituminous quartz-rich phyllite which had suffered persuasive weathering. Brenna claimed to have found clear impregnations of pyrrhotite and small amounts of chalcopyrite but says that mineralisation is generally poor.

2 State boundary marker

DIAGRAM 17: Base metal analyses for trench samples

(in µg/g or ppm)

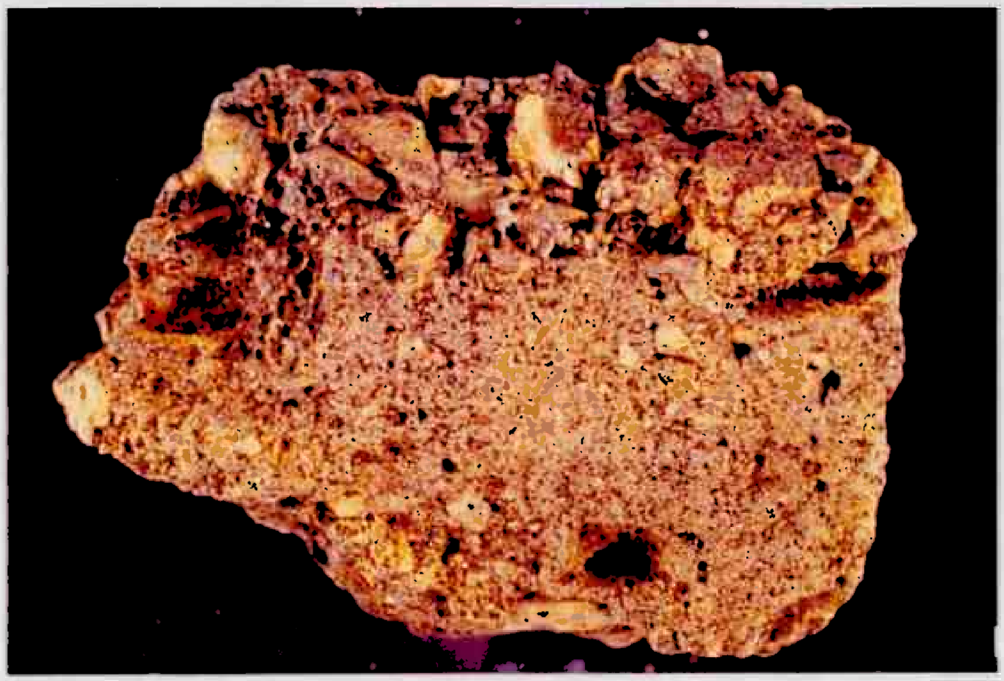
SAMPLE	COPPER	ZINC	LEAD
HR 1-1	30.112	151.7	25.46
HR 1-2	52.182	155.0	24.70
HR 1-3	83.272	128.4	25.67
HR 2-1	7.343	226.8	41.75
HR 2-2	36.217	164.9	40.80
HR 2-3	23.562	300.7	40.04
HR 2-4	23.062	152.0	63.99
HR 3n-1	15.832	70.18	20.32
HR 3s-1	78.892	154.50	19.08
HR 3s-2	37.732	139.9	17.32
RH 148 (SKJERP 2)	213.822	89.37	9.049

The present author made a brief study of this area and a preliminary geological map of the zone was made (diagram 18). The zone occurs within a sequence of quartz rich bituminous phyllites and green chloritic phyllites. S1 dipping generally NW - NNW towards the synformal f2 closure running roughly parallel to the border, just NW of Gaetietjahke. The rust zone consists of a 150 - 160 metre by 2 - 3 metre zone of poison ground (a sample of ferricrete gossan RH 148 was collected for analysis, see photo 24). The zone was deeply weathered, fresh rock not being visible WSW along strike. The poison ground peters out within Swedish territory and becomes represented by a pyritic impregnated bituminous phyllite. This pyritic impregnated horizon shows some response to a sensitive magnet indicating the possible presence of magnetite or pyrrhotite.

Examination of the rust zone shows a fairly sharp truncated contact towards the NNW and although the boundary is obscured by vegetation, it is apparent that the rust horizon terminates abruptly, possibly faulted. The bituminous phyllite host lies structurally above and also below green chloritic schist horizons. No further work was planned as the rust zone lies within Swedish territory.

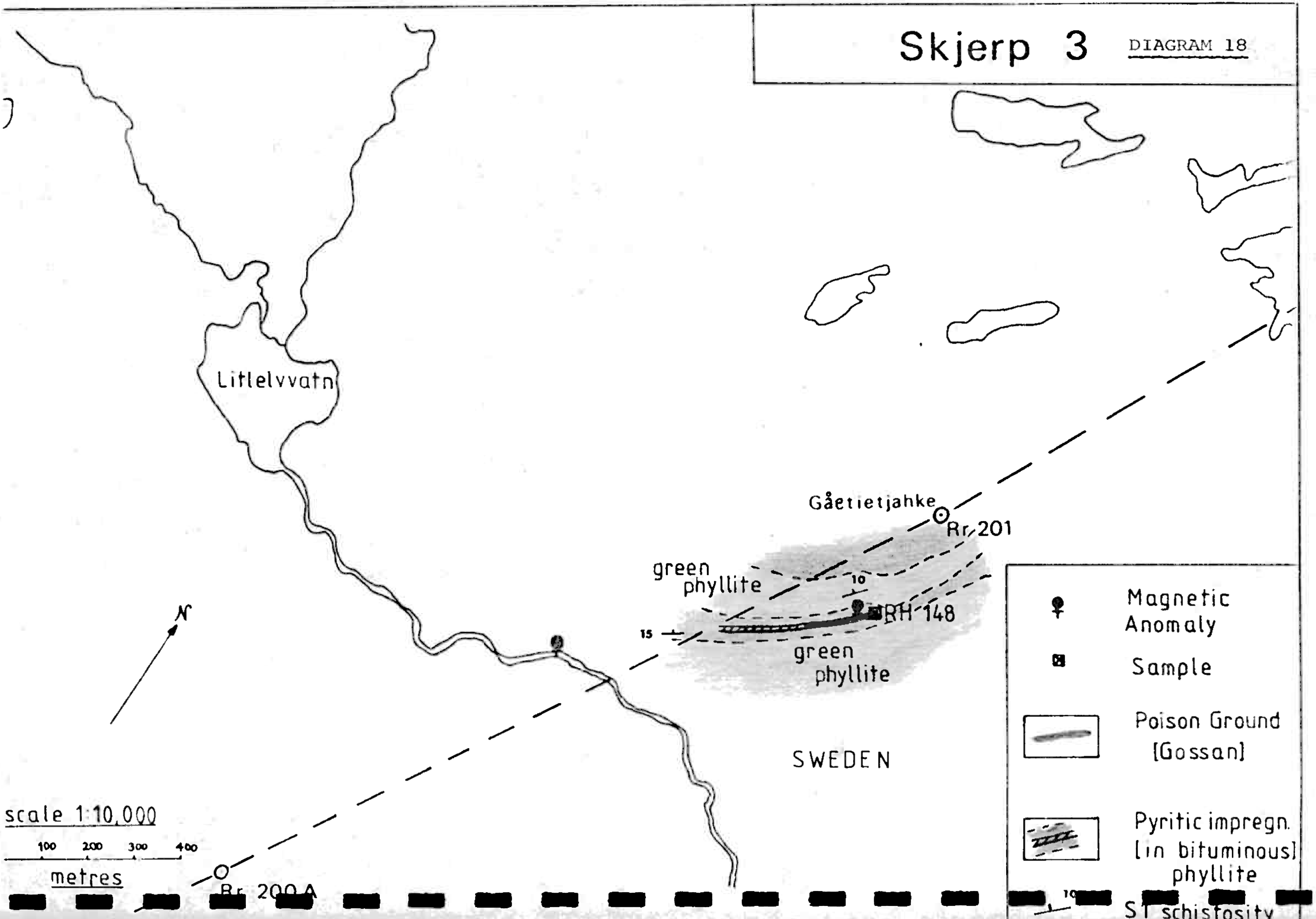
It is suggested that a soil sample traverse along the Swedish/Norwegian border, across the presumed strike extension of the impregnated bituminous phyllite should be made to ascertain further strike extent of this zone. Trenching and sampling is also desirable in a future study

Analysis of the gossan is also shown in diagram 17.



Photograph 24 : sample RH 148

72


Skjerp 3
DIAGRAM 18
Litlelvvatn
Gåetietjahke
Rr 201
green phyllite
10
RH 148
15
green phyllite
SWEDEN
scale 1:10,000
100
200
300
400
metres
Rr 200A
Magnetic Anomaly
Sample
Poison Ground [Gossan]
Pyritic impregn. [in bituminous] phyllite
10
ST schistosity

9: Conclusions

The mapping area is characterised by tectonically distinct units containing meta-sediments and volcanics which are themselves tectonically distinct from the basement sequences.

A stratigraphy has been compiled and is shown in Enclosure I.

The basement shows strong evidence of multiple deformations which pre-date all the cover sequences and is considered to be Pre-Cambrian.

Overlying the basement are aseries of 3 nappes a) Lower b) Middle and c) Upper nappe groups. The upper 2 nappes are equivalent to the Lower Köli and Gelvernokko nappes respectively which have been mapped by previous authors; the Lower nappe being of uncertain stratigraphic position.

In the cover sequences are preserved 3 deformation phases, the first, D1 , corresponding to isoclinal folding and formation of the nappes. The isoclinal folding is represented in the main by the major schistosity sub-parallel to bedding, but fold closures were found.

D2 occurred after nappe formation and has resulted in large open folds of 40 km wavelength, and locally as the crenulation s2 and some parasitic fold closures.

D3 is represented only by minor "kink"folding.

The Lower nappe is characterised by feldspathic quartzites, psammites and mica schists of reputed Eo-Cambrian age. The Middle nappe group is dominated by the segregate-banded calcareou phyllite and its intercalated volcanogenic units and overlying bituminous phyllites and meta-volcanics. Finally the Upper nappe appeared to be dominated by chlorite schists and bituminous phyllites although this group was only mapped superficially. These two upper nappes are considered to be from Ordivician to Silurian in age although no fossil evidence has ever been found.

Mineralisation in the area was confined to a small showing in the Upper nappe group and some base metal enrichment to some of the volcanic units of the Middle group.

It is suggested therefore that further exploration in the area should be centered on these units.

The final map is shown together with an E-W section as Enclosures I and II respectively.

APPENDIX I

LOGGING OF SKJERP TRENCHES

Logging of Trenches

Trench TR1

Trench trending 150° over approximately 10 metres. Blasting and sampling over first 2 metres from NW end. Logging moving SE. Sheet dip of s1/s2 approximately 050/45E. (Trench shown on diagram 19).

0.0 - 0.9m HR 1-1

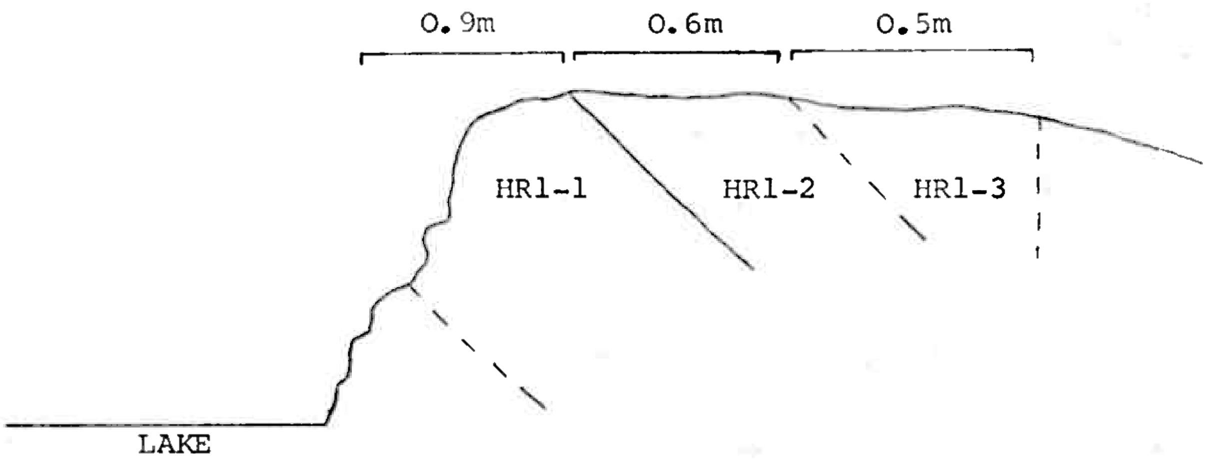
Fine grained chlorite carbonate schist. Highly chloritic, basic composition material. Grain size less than 0.1mm thus difficult to define the mineralogy. Quartz and probably ferroan calcite form discontinuous, highly flattened, "bands" between schistose partings of approximately 0.5mm in width. No obvious sulphides are present. Possibly some quartz-carbonate filled vesicles of maximum 1.5mm diameter indicate that this could be a basic lava, though these could be tectonic in origin.

It was difficult to obtain totally fresh material so sample may be slightly leached.

0.9 - 1.5m HR 1-2

Laminated graphitic schist. Fine laminae of probably hydrothermal, pre-tectonic quartz of approximately 0.2 - 0.8mm in width. Highly schistose partings of graphite, sericite and probably chlorite. Pyrrhotite occurs as anhedral clusters and dispersed grains of about 0.1mm in size occurring throughout the rock. Lesser pyrite is also present. It is difficult to see any clear association with graphite or quartz in hand specimen. Lithology is variable in abundance of laminations, graphitic content and pyrrhotite content.

Trench 1 section



Trench 2 section

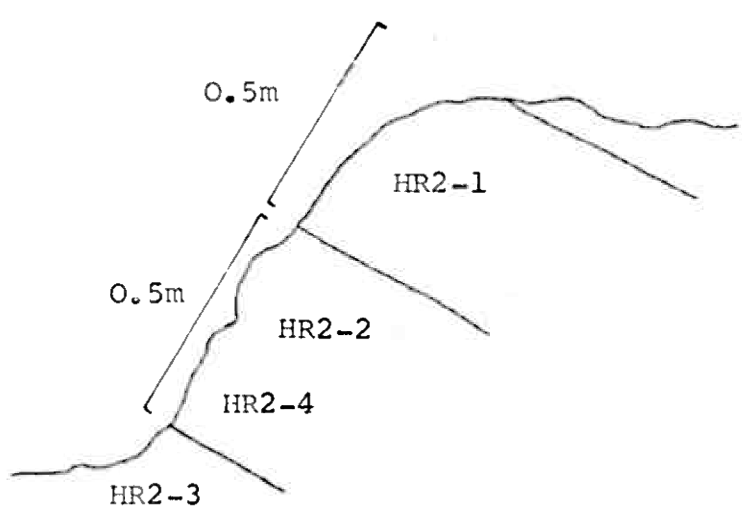


DIAGRAM 19: Trench sample locations

1.5 - 2.0m HR 1-3

Laminated highly graphitic schist. Same lithology as HR 1-2 though here lithology is more graphitic and with lesser silica laminae. Pyrrhotite is also less abundant but still present, particularly in more laminated facies. This would suggest a possible connection with the quartz laminations. No obvious macroscopic ore-minerals. Pyrrhotite content less than 0.5%.

Beyond 2m no blasting was possible. The graphitic horizon continues though graphite content decreases. Relative content of quartz laminations remains approximately constant. Gradual transition to laminated chlorite-sericite schist is seen, though weathering makes it difficult to be precise without further blasting.

Trench TR2

Blasting was carried out over 1 metre along a line 150° in two main lithological units (HR 2-1 and HR 2-2). Sheet dip s1/s2 is approximately 050/45 SE. Logging moving NW. (Trench shown on diagram 19).

0.0 - 0.5m HR 2-1

Lithology structually overlies HR 2-2. It is very difficult to obtain fresh material even when blasted, thus sample may be slightly leached. Lithology has a strike extent of at least 3 metres SE.

Lithology is a laminated chlorite-sericite schist. It is probably basic in composition, now completely recrystallised, with laminations of probably hydrothermal quartz and pyrite. Laminations are from 0.5 - 2.0mm in thickness. Pyrite occurs as dispersed euhedra up to 0.5mm cubes. Laminations contain less than 1% pyrite and constitute approcimately 40 to 50% of the rock by volume.

Possibly this lithology is a basic tuff though complete metamorphic reconstitution has destroyed all macroscopic original textures.

<u>0.5 - 1.25m HR 2-2</u> (Also thin section HR 2-2b)

Sample taken over o.5 metres of horizon. Evidently horizon continues at least along strike 5 metres to SW and NE.

Lithology is highly flattened quartz-pyrite-sericite "exhalite". Bulk of rock is recrystallised quartz, approximately 80% by volume, grain size up to 0.5mm across. Pyrite occurs as dispersed euhedral clusters up to 1mm in size concentrated along s1 planes and constitute approximately 10% of the rock by volume. Sericite, approximately 10% by volume, forms schistose partings along s1 planes. There are no obviously associated "Ore Minerals" though isolated grains of possibly chalcopyrite were observed.

<u>1.25 - 1.75m HR 2-3</u>

Highly altered schistose meta rhyo-dacite "keratophyre". Chlorite after probably original ferro-magnesian mineral phases and sericite after original plagioclase feldspar, probably, are concentrated along s1 schistosity planes. They form schistose partings approximately 0.1mm thick between residual bands of almost pure quartz. Pyrite as euhedra up to o.5mm in size occur through the rock and constitute less than 1% by volume.

Definite contacts of the "keratophyre" not visible,but band probably 0.5 metres wide.

<u>Trench TR3</u>

No real trench blasted. Strike extension of rusty horizon blasted in TR1. Small pits blasted 8m apart for comparative analysis with TR1. Sheet dip approximately 050/45 SE

HR 3s-1

Laminated graphitic schist. Lithology is same horizon as HR 1-2 and HR 1-3. Fine laminae of possibly hydrothermal quartz of 0.1 to 0.5mm thickness separated by schistose partings of fine grained graphite, sericite and lesser chlorite. Quartz laminations are generally less abundant than TR1, being 20 - 40% by volume. Trace amounts of very fine grained sulphide mineral phase, probably pyrrhotite.

Sampling over approximately 20cm.

HR 3s-2

Laminated sericite schist. Laminae of possibly hydrothermal quartz 0.1 - 1.0mm thick are present with schistose micaceous partings flattened parallel to s1 of dominantly sericite and chlorite, no obvious graphite is present. No macroscopic sulphide minerals can be observed.

This lithology structurally underlies HR 3s-1. Sampling over approximately 15cm.

Beneath HR 3s-2, alternation of graphitic schist and sericite schist seen again in approximately 0.5 metre bands.

HR 3n-1

Schistose laminated quartz-sericite schist. Banded texture due to quartz laminae which are possibly primary laminations though no conclusive macroscopic evidence can be seen. Schistose partings of dominantly sericite with minor chlorite and also a dark green micaceous mineral, probably biotite. No obvious macroscopic sulphide mineral phases can be seen. Brown ferruginous weathering (probably from micas) probably means some leaching of base metals.

Weathering of this lithology makes it difficult to ascertain if any feldspar is present, but it appears that this rock is dominantly quartz and sericite. Lithology is either laminated hydrothermal chert horizon or highly altered keratophyre. Weathering destroys most of the textual evidence.

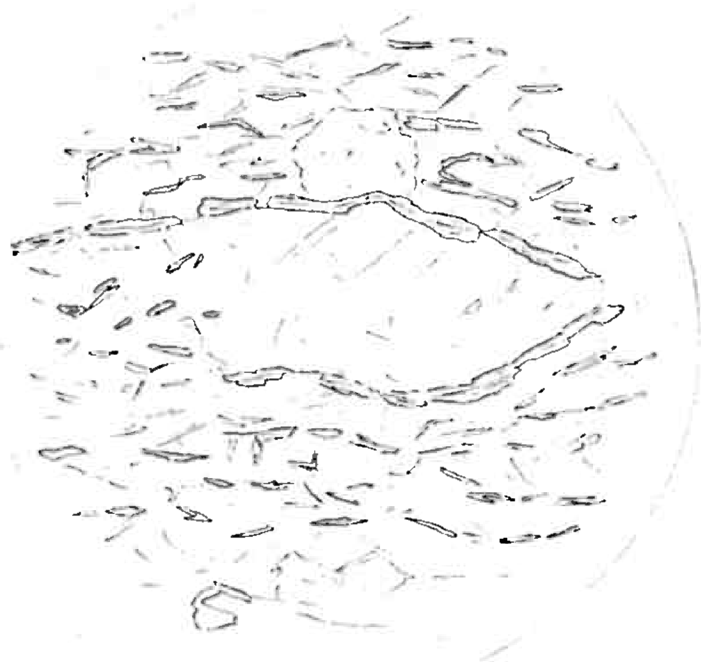
This horizon lies structurally above HR 3s-1 and HR 3s-2, and approximately 8 metres to the NE.

HR 3n-2

Tectonic segregations of quartz within this lithology contain galena concentrations along the contact with the host rock. Some sphalerite may be present though it is dominantly galena.

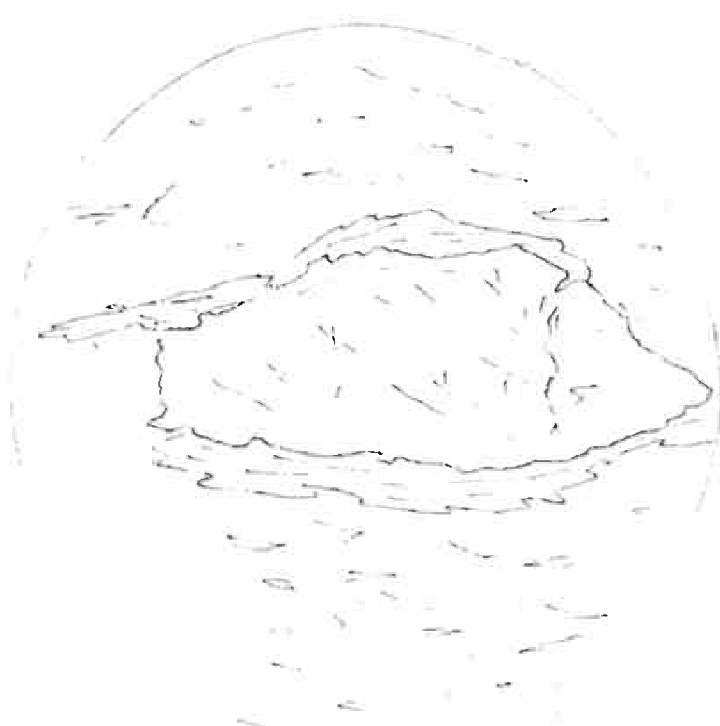
APPENDIX II

LITHOLOGICAL COMPARISON WITH UNITS FROM ADJOINING AREA



RH 126 x3 lens

Feld spar with chlorite corona in qtz, chlorite, albite groundmass.



RH 120 x3 lens

Feldspar with sericite corona in a qtz, chlorite, albite groundmass

RH 120

Quartz, feldspar, muscovite coarse schist/grit

Large twinned perthitic and cross-hatched twinned microcline clasts with sericitic coronas (see sketch and photograph.

Feldspars often sausseritised with quartz, sericite peppered throughout feldspar.

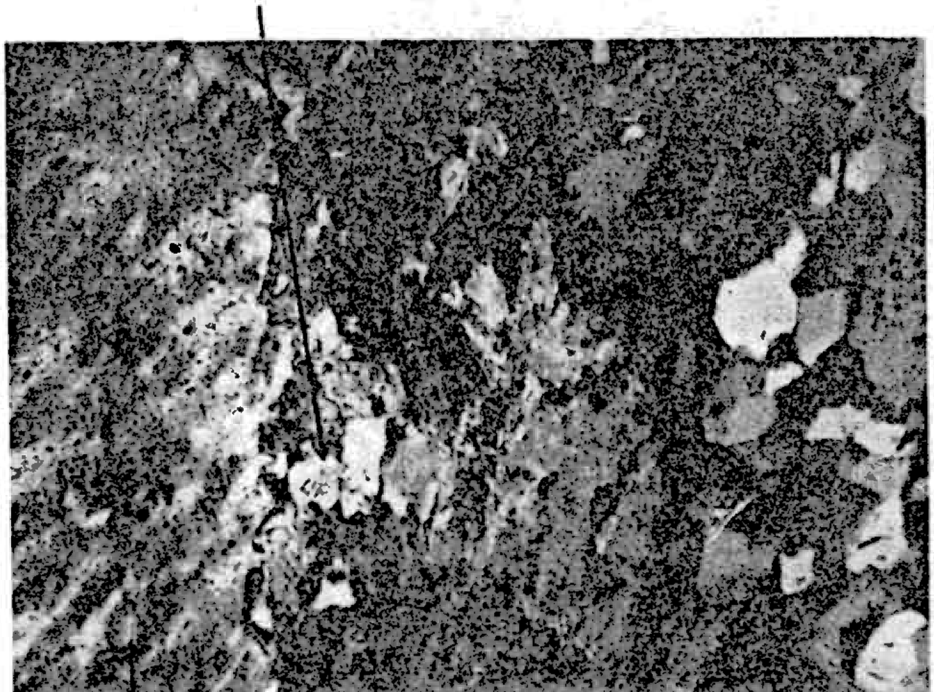
Clasts set in fine quartz sericite/muscovite groundmass.

Segregate, alternate bands of mainly quartz with biotite, muscovite rich bands, leads to macro-schistosity.

20% feldspar- albite+microcline

50% quartz

30% phyllosilicates (20% muscovite/sericite, 10% biotite)



RH 126

Quartz, feldspar, muscovite, chlorite coarse schist

Represents same horizon as RH 120 (120 mapped in adjoining area) and thus 126 used to correlate stratigraphy with previous authors (Kollung 1978).

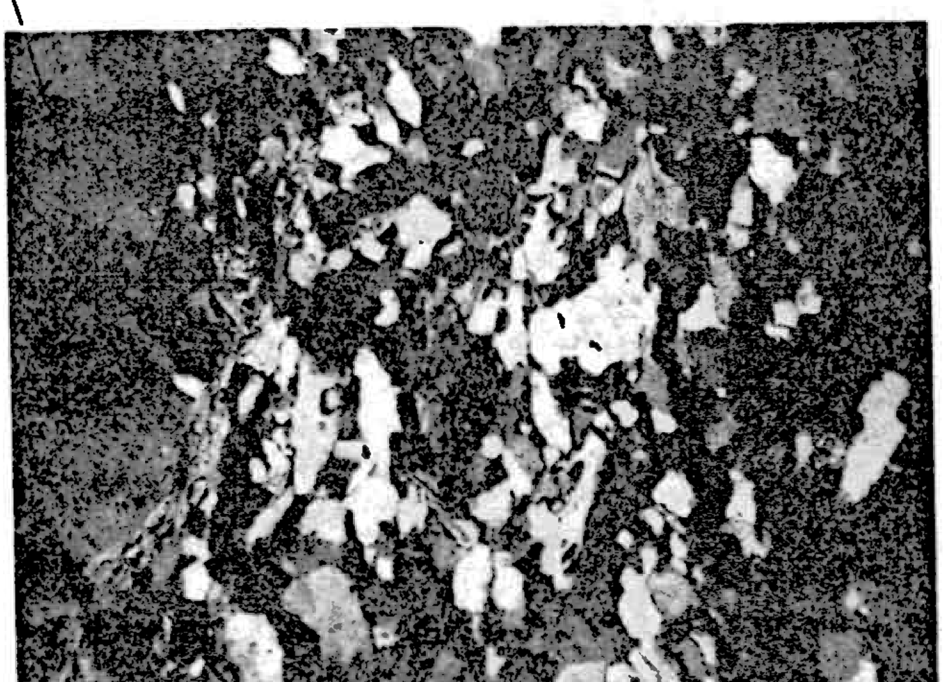
Contains more chlorite than 120, with very little muscovite

30% feldspar

60% quartz

10% phyllosilicates

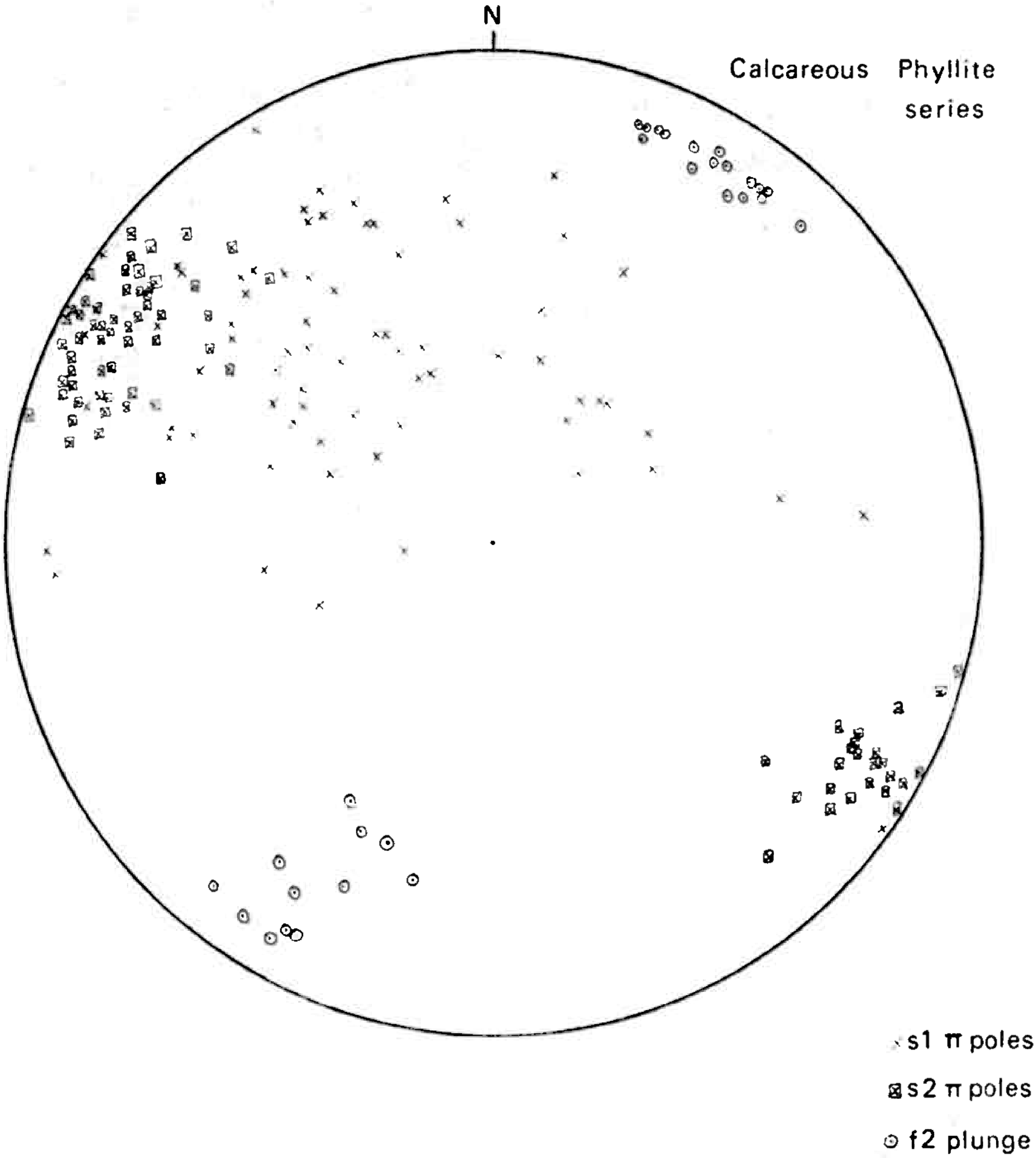
Large microcline

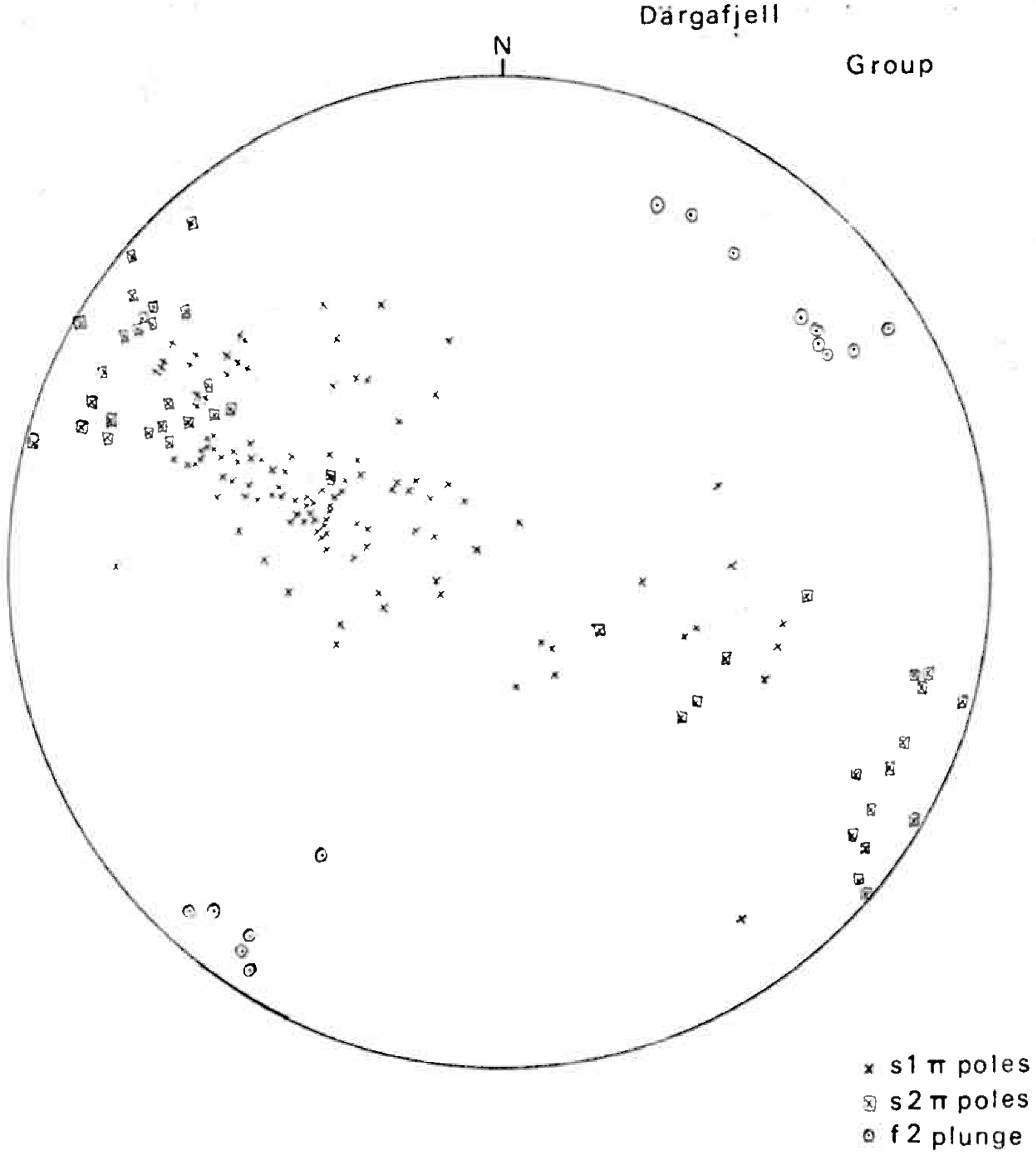


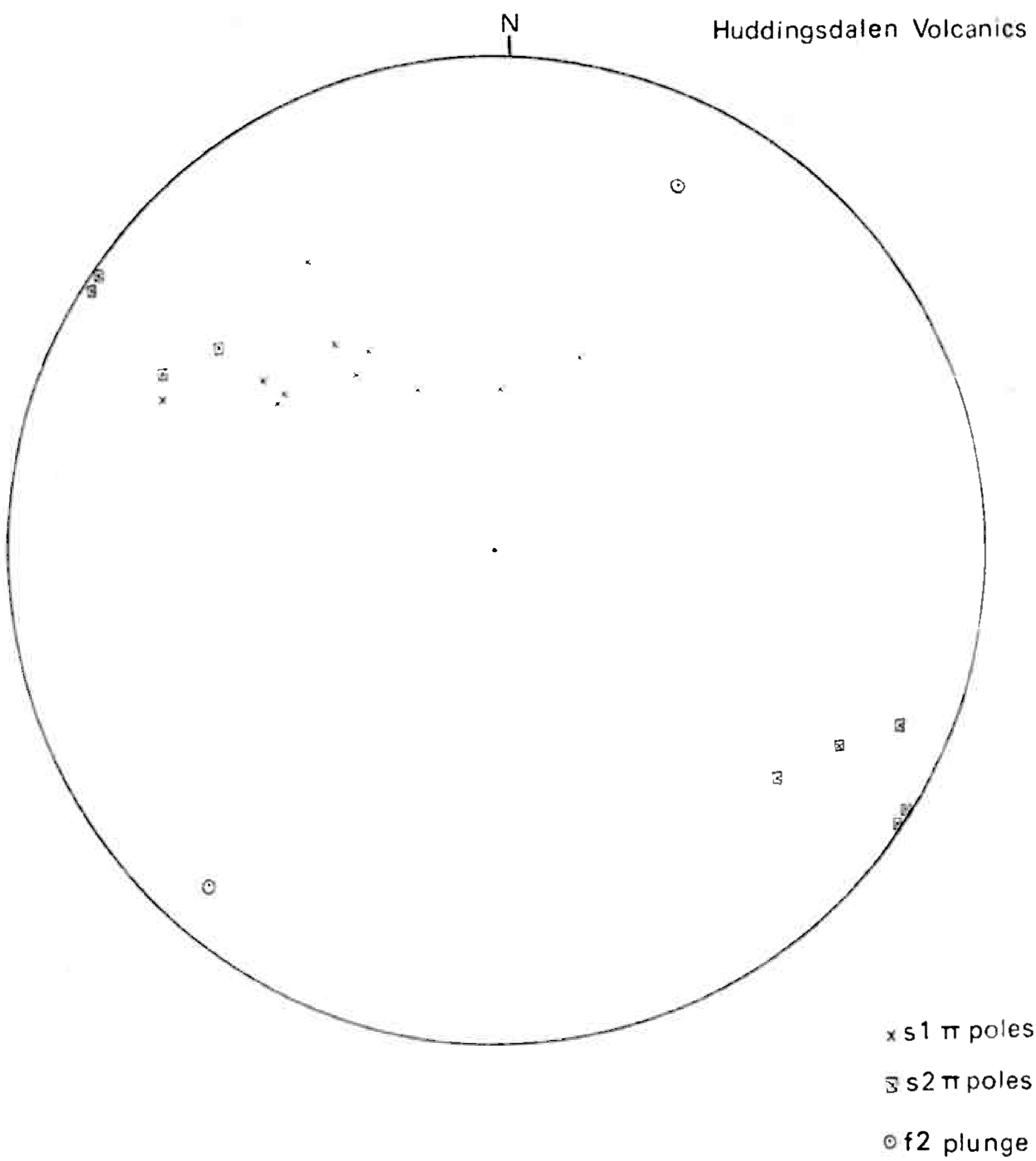
Sericite "corona"

APPENDIX III

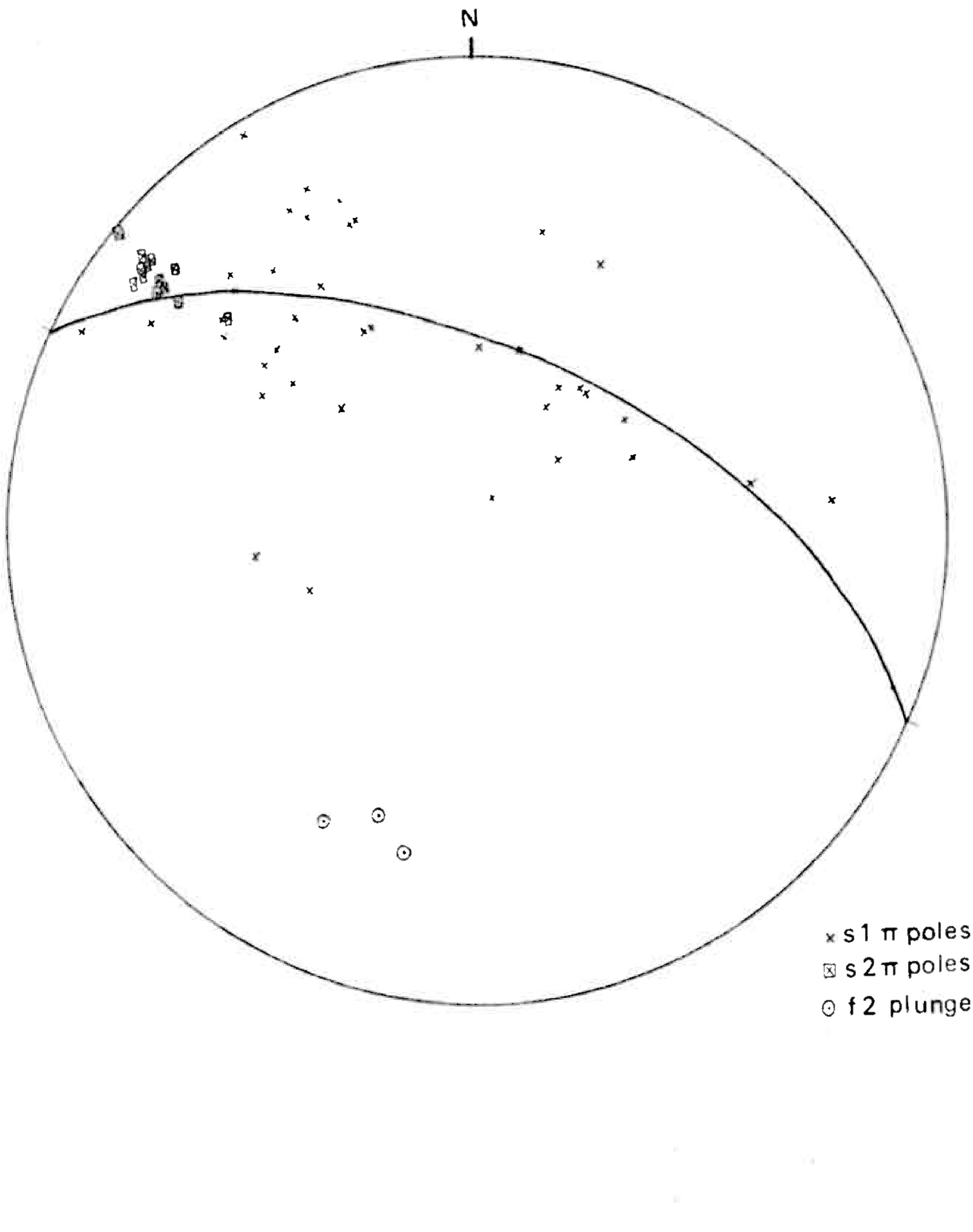
STEREONETS


N
Calcareous Phyllite series
s1 π poles
s2 π poles
f2 plunge


Dårgafjell
Group
N
s1 π poles
s2 π poles
f2 plunge


Huddingsdalen Volcanics
N
s1 π poles
s2 π poles
f2 plunge

Feldspathic Psammite



SECTION B

1: AIM OF SPECIAL PROJECT

The aim of the project was to extend the understanding of the lithologies which had been gained by petrology

It was decided that a study of the whole rock geochemistry of the rocks would be made, based on the suite of specimens shown in the sample location map overleaf.

Preparation and analysis of the specimens is shown in Appendix IV and the uncorrected results are shown in Appendix V ,together with calculated oxides.

2: DISCUSSION OF GEOCHEMISTRY OF THE CALCAREOUS PHYLLITE GROUP

The calcareous phyllite has been mapped and divided into the four major units; i) Grey-quartz rich calcareous phyllite, ii) Feldspathic psammite, iii) Carbonate rich calcareous phyllite, and iv) Grey-green quartz rich calcareous phyllite. These lithological differences are quite apparent in geochemical profiles constructed across the group.

The most striking difference is shown by the plot of soda and potash, which is shown in diagram 20. There is a broadly consistent trace for much of the group, but there are some very strongly anomalous results for samples RH 128, RH 128a and RH 128c of the feldspathic psammite unit and samples DB24, DB18A and RH74 of the upper chloritic grit band; and also sample DB 19 + 10 which was placed within the meta-volcanic group.

In these samples there is strong enrichment of soda with depletion of potash.

A plot of iron oxide against silica indicates further, this strong difference between these sediments and the calcareous phyllite group as a whole (see diagram 21). These anomalous sediments plotted within the zones of the meta-volcanic rocks, the chlorite rich sediments plotting with the basic volcanics and the feldspar-quartz rich sediments plotting with the acid volcanics.

The nature of these sediments is so different to these sediments is so different to the calcareous phyllite group as a whole, that they will be considered with and compared to the meta-volcanic group (see later discussion).

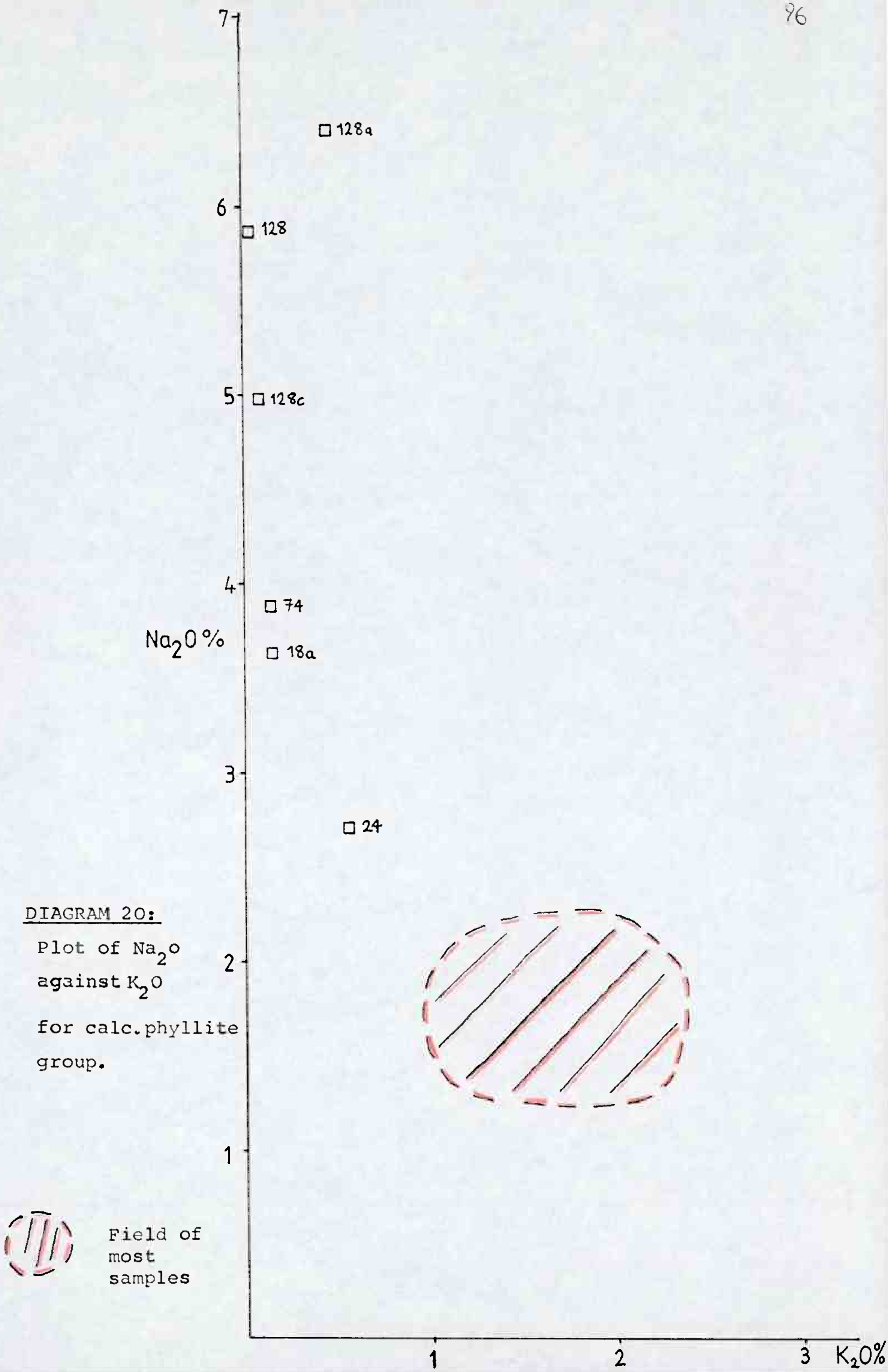
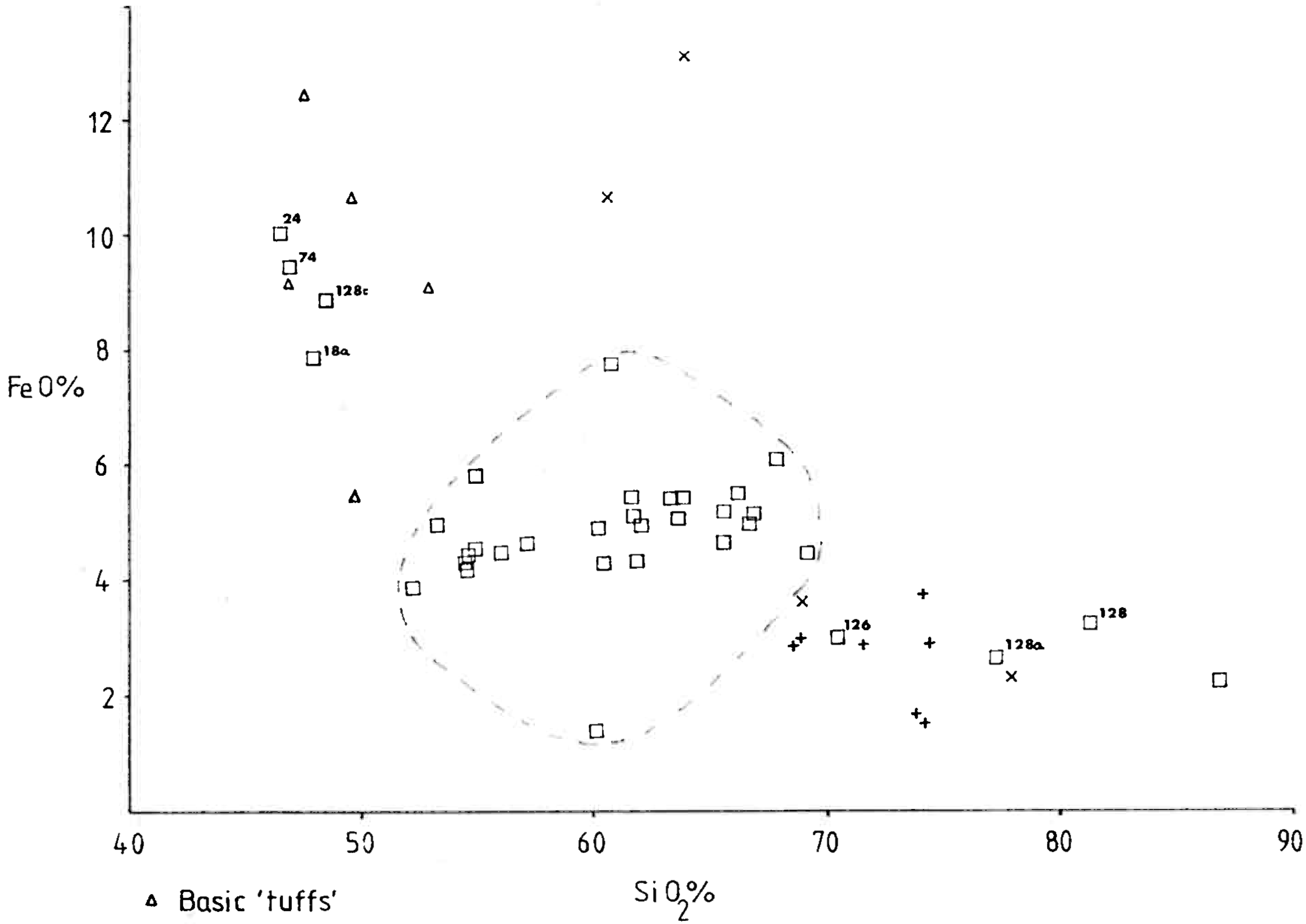


DIAGRAM 20:

Plot of Na_2O against K_2O for calc.phyllite group.



Δ Basic 'tuffs'
□ Calc phyllite group
\+ Acid 'tuffs'
× Trench samples

DIAGRAM 21: plot of FeO against SiO_2 for all samples.

Silica content in the group shows the expected trend (diagram 22). The lowest unit is evidently very silica rich which corresponds to the high percentage of quartz in the rock. Silica drops in the carbonate-rich facies and this drop continues consistently across the group, corresponding to the increase of phyllosilicates in the rock.

The profile of calcium across the group is shown in diagram 23.

This shows a very low value for the grey quartz-rich facies, and this is due to the generally low carbonate content of the rock whereas there is a sharp increase of calcium content in the carbonate-rich facies, to be expected with the high carbonate content. Sample DB14 has an anomolously low value and is possibly leached of some of the carbonate content.

Magnesium (diagram 24) follows calcite sympathetically and thus it may be supposed that some of the carbonate is dolomitic.

Aluminium, rubidium and potassium are plotted on a combined profile in diagram 25. The lower two groups show a sympathetic enrichment of these three elements, whilst the upper two units have generally constant values for the three elements.

This sympathetic enrichment in the lower two units was thought to be due to the presence of microcline in these lower units as large clasts of microcline feldspar were seen in slide RH 126, and it was suggested that there is a change of sediment type between the feldspathic psammite and the upper units from a microline feldspar to an albite feldspar, since rubidium and potassium are dominant cations. To this end

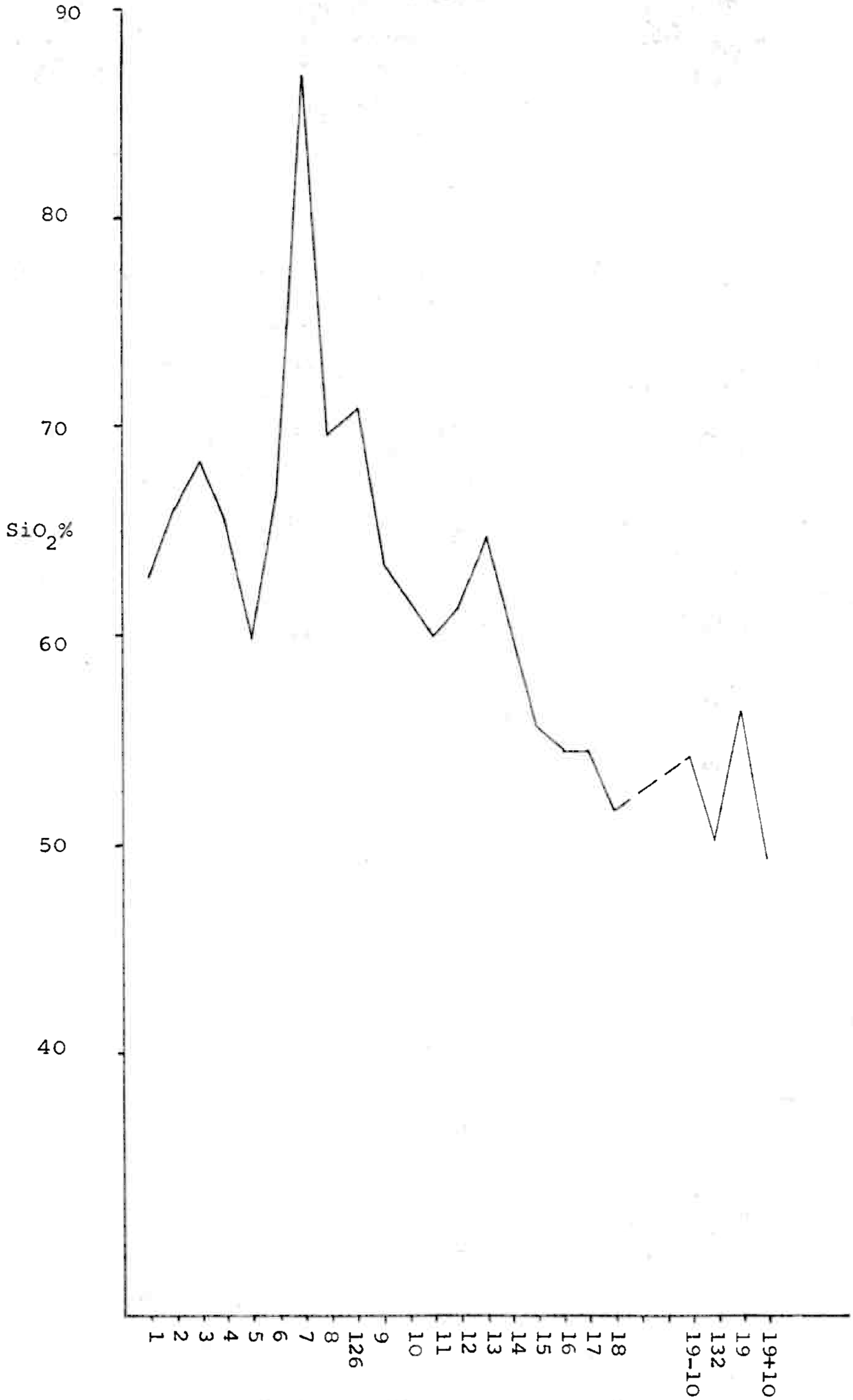


DIAGRAM 22: Silica in the calc.phyllite

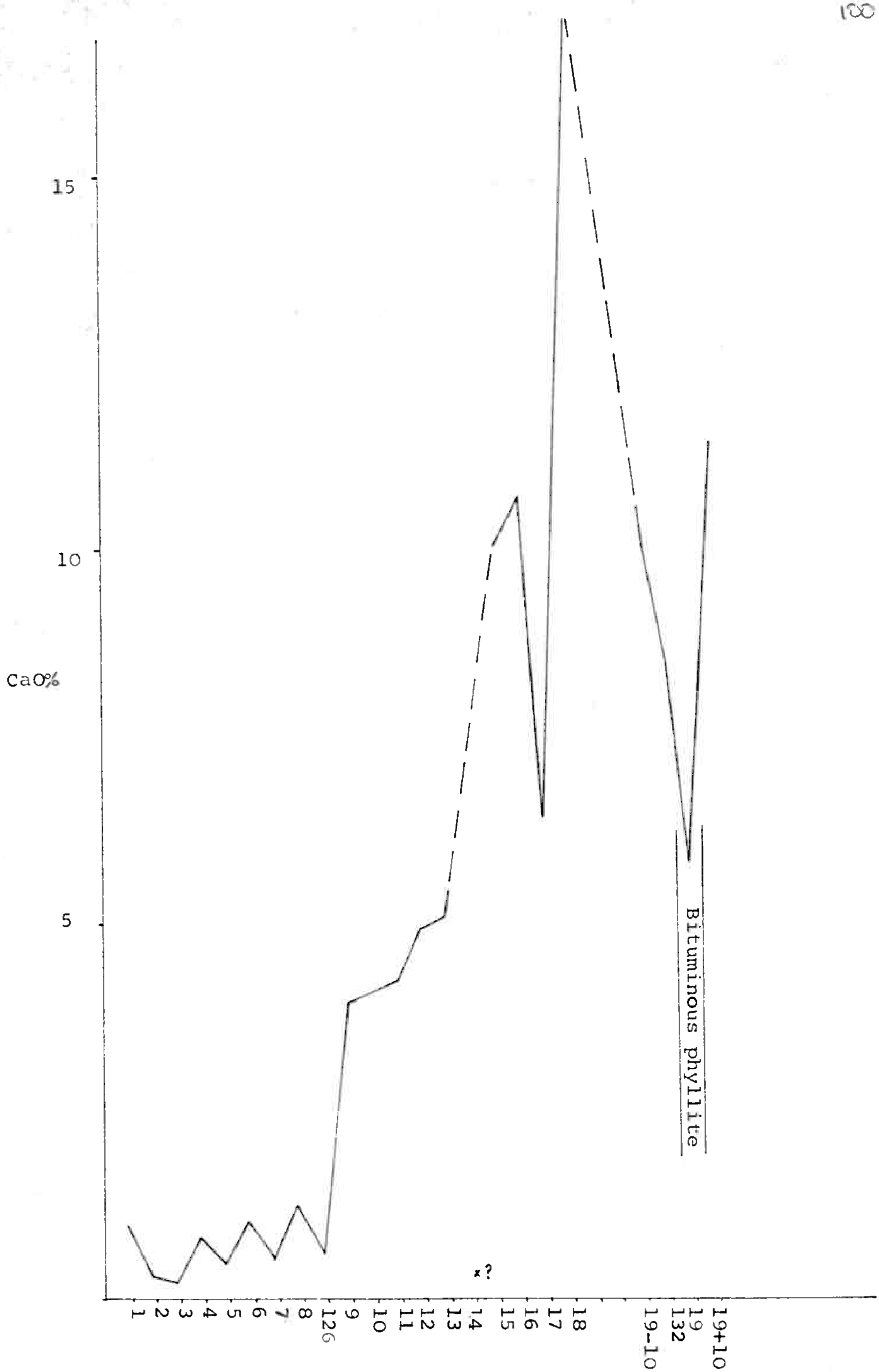


DIAGRAM 23: CaO% for calc.phyllite

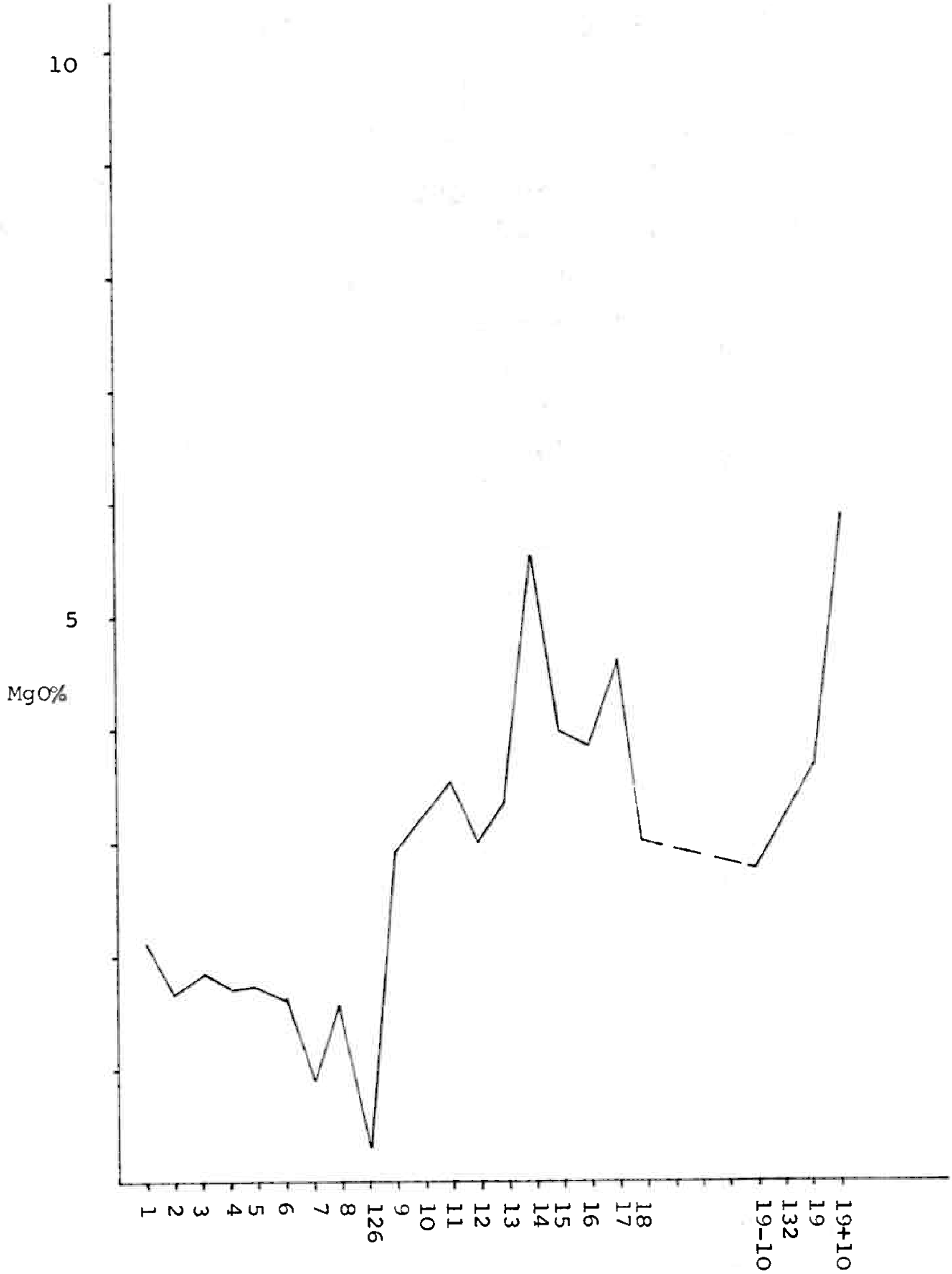


DIAGRAM 24: MgO% in the calc.phyllite

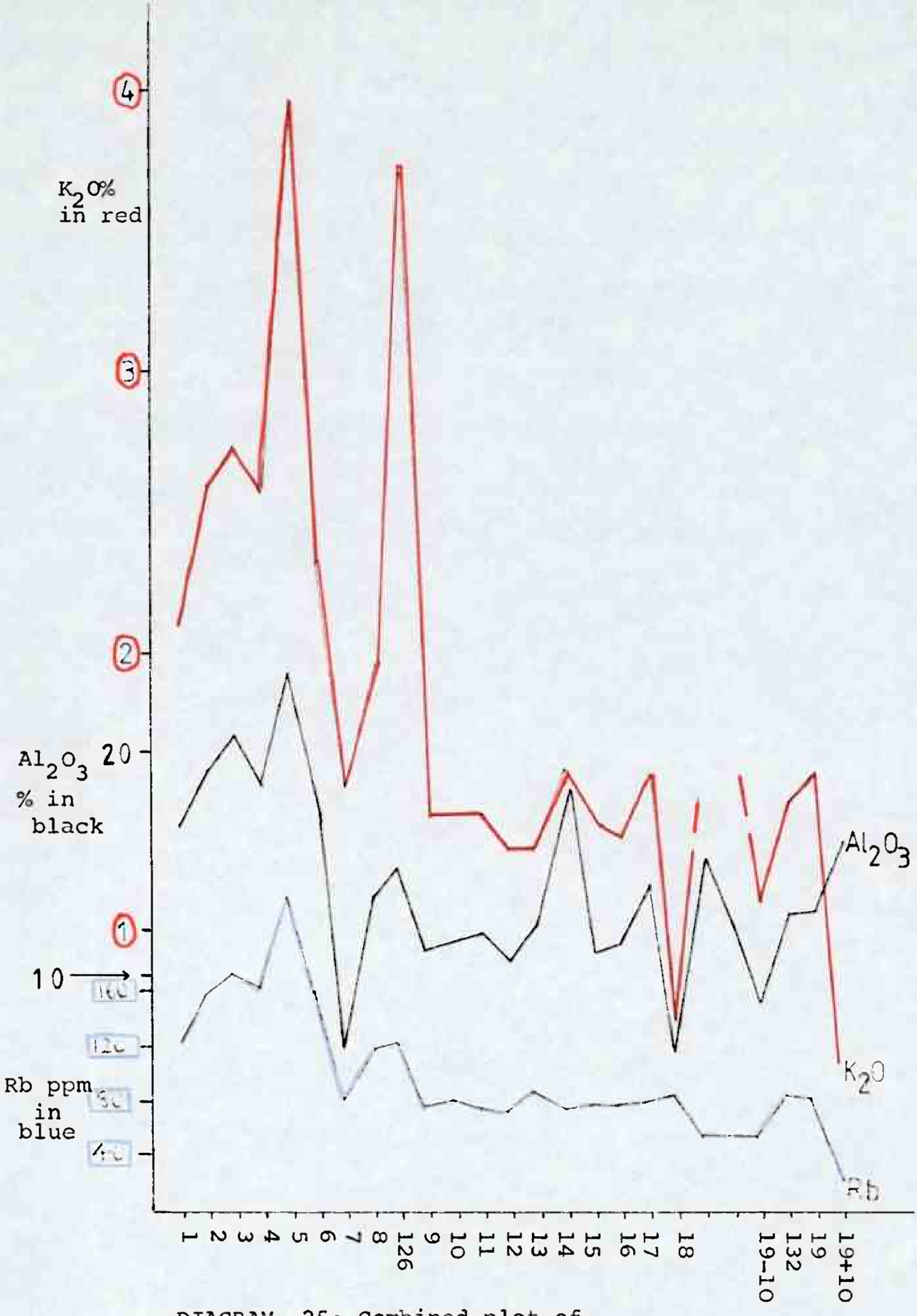


DIAGRAM 25: Combined plot of Al_2O_3, K_2O and Rb in calc. phyllite

it was decided to emply X-ray diffraction to ascertain the feldspars present in a) The grey quartz-rich calcareous phyllite b) The feldspathic psammite and c) The overlying carbonate rich calcareous phyllite.

Samples DB6 and DB5 from the lowest group), RH 126 (from the feldspathic psammite), RH 128 and RH 128C (from the interclated chlorite schists and quartz-feldspar grits) and finally RH 132 from the overlying calcareous phyllite.

Smear mounts were prepared from sorted samples of these rocks (see Appendix VI for sample preparation) and then were scanned; the resulting traces shown in Appendix VII RH 126 clearly showed the strong presence of microcline of most probably intermediate composition from the values of d spacing as wellas a plagioclase, most likely albite, quartz and a small amount of carbonate.

RH132 however showed the presence only of a, probably albitic, plagioclase feldspar together with quartz , some chlorite (probably clinochlore) and muscovite/sercite.
RH 128 and 128c which from the upper part of the feldspathic psammite unit also show only albite plagioclase together with quartz in 128 and together with chlorite and calcite in 128 c. The traces for DB 6 and DB5 were then analysed.

The sorted sample DB 6 gave a trace for only quartz, so it seemed sorting had removed the feldspar.

The unsorted sample DB5 gave a good trace indicating the presence of only an albitic plagioclase feldspar. This showed that the elevated value for potassium, rubiduim and aluminium was not due to the presence of microcline.

On further examination the trace showed a strong trace for chlorite and muscovite, the peaks for the latter mineral indicating a large muscovite/sercite content. Muscovite is able to take rubidium into the lattice, substituting for potassium.

The group then is seen to represent a series of meta-sediments characterised by variable contents of quartz, albite, carbonates, phyllosilicates and in one restricted horizon, microcline.

Lithological differences were picked up by the whole rock geochemistry and the very different nature of some of the units was indicated.

The results of the study compiled, together with the petrological studies is shown in table form in diagram 26 .

GREY-GREEN QTZ-RICH CALCAREOUS PHYLLITE	HIGH Ca, Mg LOWER Al, K, Rb	HIGH CALCITE LESS MUSCOVITE
CARBONATE-RICH CALCAREOUS PHYLLITE	HIGH Ca, Mg LOWER Al, K, Rb	HIGH CALCITE LESS MUSCOVITE
FELDSPATHIC PSAMMITE	HIGH K LOW Ca	HIGH MICROCLINE VERY LITTLE CALCITE
GREY QTZ-RICH CALCAREOUS PHYLLITE	HIGH Al, K, Rb LOW Ca, Mg	HIGH MUSCOVITE VERY LITTLE CALCITE

DIAGRAM 26: Mineralogic features indicated by geochemistry.

3: DISCUSSION OF META-VOLCANIC SUITE AND "ANOMALOUS" CALCAREOUS PHYLLITE MEMBERS

The specimens and sections available of this rock group (the latter represented by slides RH 124 and RH 134) have a strongly igneous character.

Specimens such as RH 134 and RH 129 showed possibly extrusive origin whilst other specimens showed strong evidence of clastic banding (RH 137 and RH 40) indicating volcano clastic origin.

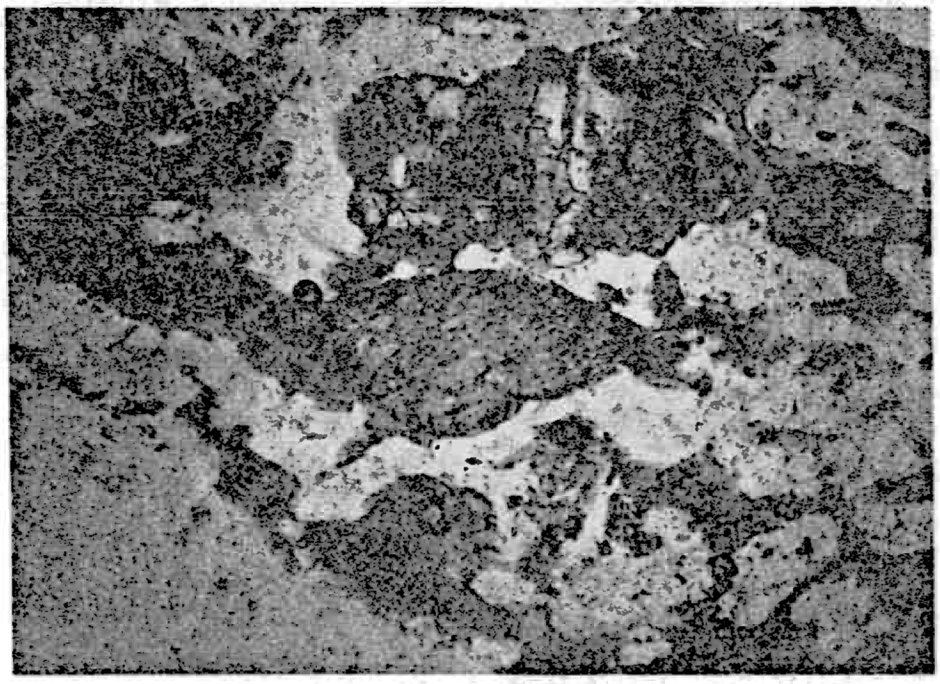
Similarly, the selected rocks from the feldspathic psammite and chlorite grit horizons had typical "igneous mineral assemblages", all these types showing clastic textures however. Specimens RH 128, RH 129 and RH 128 a showed evidence of possible grading from a coarse feldspathic grit at the base of units to a finer quartz-feldspar sediment towards the top.

In section specimens from both the volcanic suite and the rocks from the calcareous phyllite group showed remarkable similarities. The acid volcanic RH 134 showed large albite phenocrysts in a fine quartz/plagioclase (mostly albite) groundmass, with small acicular chlorites elongated parallel to the visual fabric of the rock. The acid rock from the calcareous phyllite group RH 129 showed small "grains" of albite plagioclase and biotite (with pleochroic haloes) with large polycrystalline quartz lenses and elongated laminae, themselves often set in a sericitic matrix. These polysynthetic quartz lenses and laminae could possibly represent hydrothermal chert laminae or else silica "shards" elongated during deformation. In either case the rock is very clearly clastic in origin but recrystallised. In section the basic volcanic rock represented by RH 124 is apparent by large, often altered albite porphyroblasts, often shot through by acicular epidote and by the large masses of chlorite, often after hornblende (see photograph 25). The albite shows complete sericitisation in parts and there are some very corroded augites (probably iron rich) which indicate the strong alteration. The rock has subsequently suffered strong pervasive silicification, being shot through with fire micro-crystalline quartz. Finally carbonate is seen to infill ovoid cavities in the rock, possibly representing corroded primary minerals or vesicles although a strong fabric preserved by aligned relict hornblende rhombs suggests the rock may have been a banded tuff.

The basic calcareous phyllite rock represented in section by RH 128c has a very irregular, altered texture. It contains strongly idioblastic epidotes and irregular chlorites together with large, evidently sausseritized plagioclase with cross cutting epidotes and coronic chlorites. Plagioclase also appears to be present in the groundmass together with ferromagnesians, mostly comprising epidote and chlorite.

These sections then give clear indications of a volcanic origin to the rocks, either as extrusive flows possibly or as volcano-clastic sediments.

These rocks will now be considered with respect to their geochemistry, obtained from the plasma spectrometer results with the aim of unifying geochemistry and petrology into a classification of these rocks.



Photograph 25: Pseudomorph of chlorite after amphibole, preserving the characteristic rhombic section of amphiboles and the characteristic cleavage.

Geochemical data is shown in the Appendix, major oxide percentages for these rocks calculated and shown in diagram 27 .

A plot of titanium oxide against silica (diagram 28) shows relationships of the rocks to a superimposed classification based on work by Woollard (1968) in the cascade range, North America, a suite of rocks from a quaternary plate margin. As can be seen the correlation of the rocks in this area is good, with the basic "tuffs" and basic calcareous phyllite rocks plotting in the basaltic andesite to basalt range mainly and the acid "tuffs" and acid calcareous phyllite rocks having an affinity to the dacite - rhyolite range.

There is a noteable bimodal spread of rocks which is not due to sample selectivity as characteristic rocks of all volcanic types were taken.

The "spread" for the calcareous phyllite group as a whole is shown on the diagram to indicate the lack of correlation of these to the volcanic group.

A plot of total alkalis against silica is shown in diagram 29 and again plotted on the diagram are the average values for rock types found in the cascades region of North America.

The volcanics and the "volcanic" calcareous phyllite rocks lie quite close to normal igenous values for total alkalis/ silica content, the basic rocks showing enrichment to a more "alkali" composition except for HR 1-1 which appears more "tholeiitic". The acid rocks appear in the "tholeiitic" domain. The rest of the calcareous phyllite group plots fairly central on the diagram, quite distinct from the two

DIAGRAM 27: Oxide percentages calculated for samples

SAMPLE	SiO_2	CaO	Al_2O_3	K_2O	Na_2O	MgO	FeO	TiO_2	TOTAL%
134	74.45	.328	12.1	.049	6.826	.452	1.794	.432	96.451
38	71.89	.684	13.8	.056	5.823	1.613	2.773	.286	96.925
138	74.24	.643	16.2	.389	7.104	1.400	3.854	.191	104.021
128	81.94	.828	13.35	.043	5.912	.477	3.174	.168	105.71
128a	77.45	.263	13.95	.107	6.15	1.165	2.569	.205	101.853
125	68.46	.243	18.45	1.667	5.583	1.13	2.98	.227	98.74
137	74.45	1.470	15.5	.452	6.353	.307	1.688	.128	100.348
39	74.45	.114	14.6	1.123	5.136	.804	1.593	.114	98.02
HR 2-3	78.52	1.635	11.2	.851	3.565	.997	2.48	.118	99.37
F	74.45	1.005	14.6	.537	5.998	1.149	2.922	.209	100.87
HR 2-1	68.89	3.169	12.35	.810	1.704	6.719	5.281	.281	99.20
HR 2-2	60.55	.229	14.3	3.031	.152	1.819	19.13	.629	99.87
HR 2-4	63.54	.281	14.2	3.178	.172	1.507	17.22	.551	100.65
				BASIC ROCKS (BELOW) HAVE NO ALLOWANCES FOR CO_2 LOSS					
128c	48.35	3.865	18.35	.096	4.717	6.993	8.870	.703	91.94
124	52.85	5.456	18.6	.113	5.115	6.568	9.101	.698	93.05
40	49.64	5.014	16.6	.103	3.899	11.365	10.68	.819	98.12
74	47.07	7.495	17.75	.116	3.906	8.662	9.332	1.934	96.27
18a	47.92	8.801	14.15	.154	3.643	6.721	7.933	1.286	90.61
19+10	49.64	11.667	18.05	.490	3.245	5.927	5.441	1.369	95.83
HR 1-1	47.50	7.623	14.5	.006	2.439	6.756	12.548	2.291	93.66
24	46.43	7.382	16.35	.69	2.605	9.74	10.202	2.20	95.60

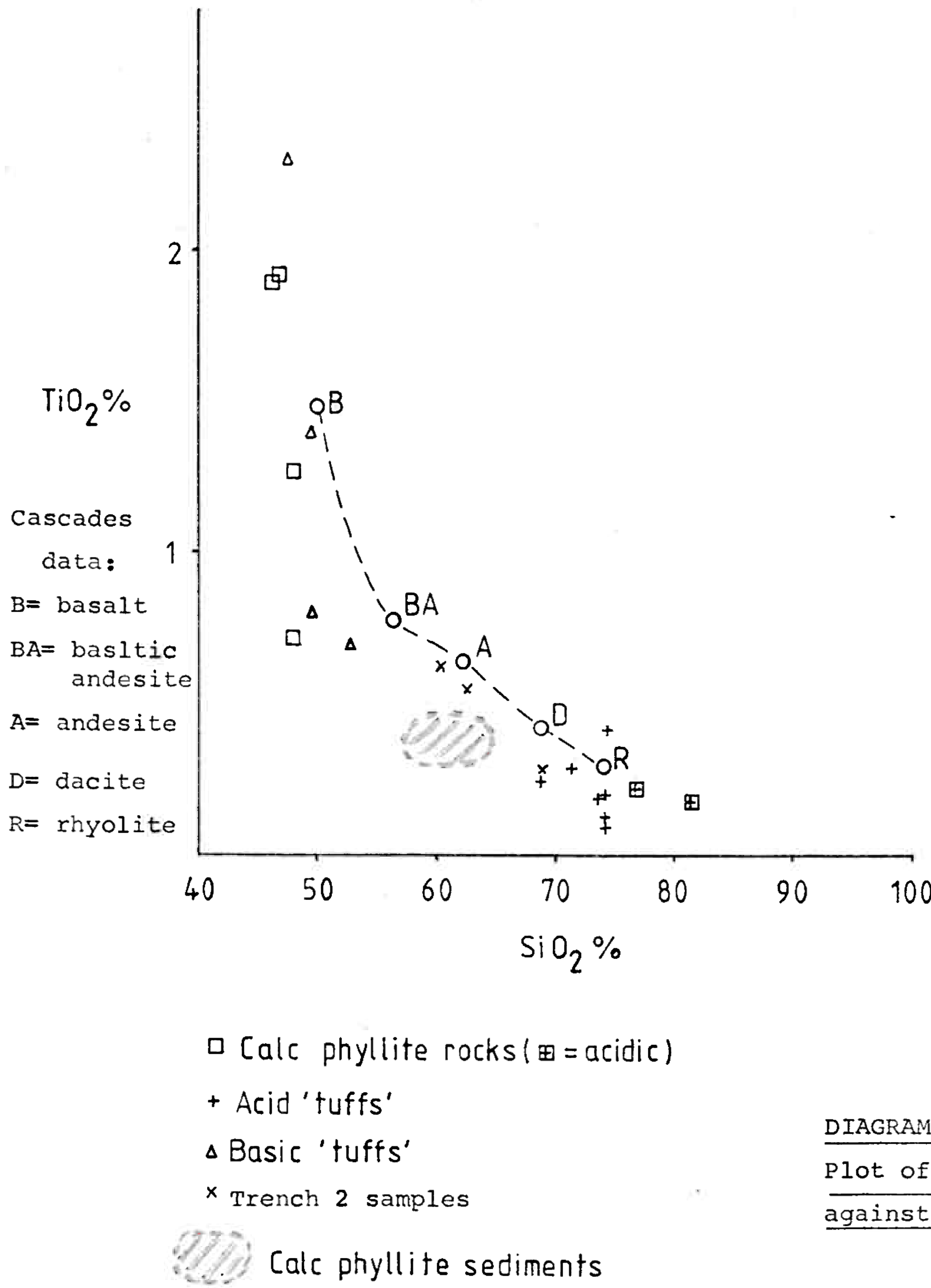


DIAGRAM 28: Plot of TiO_2 against silica

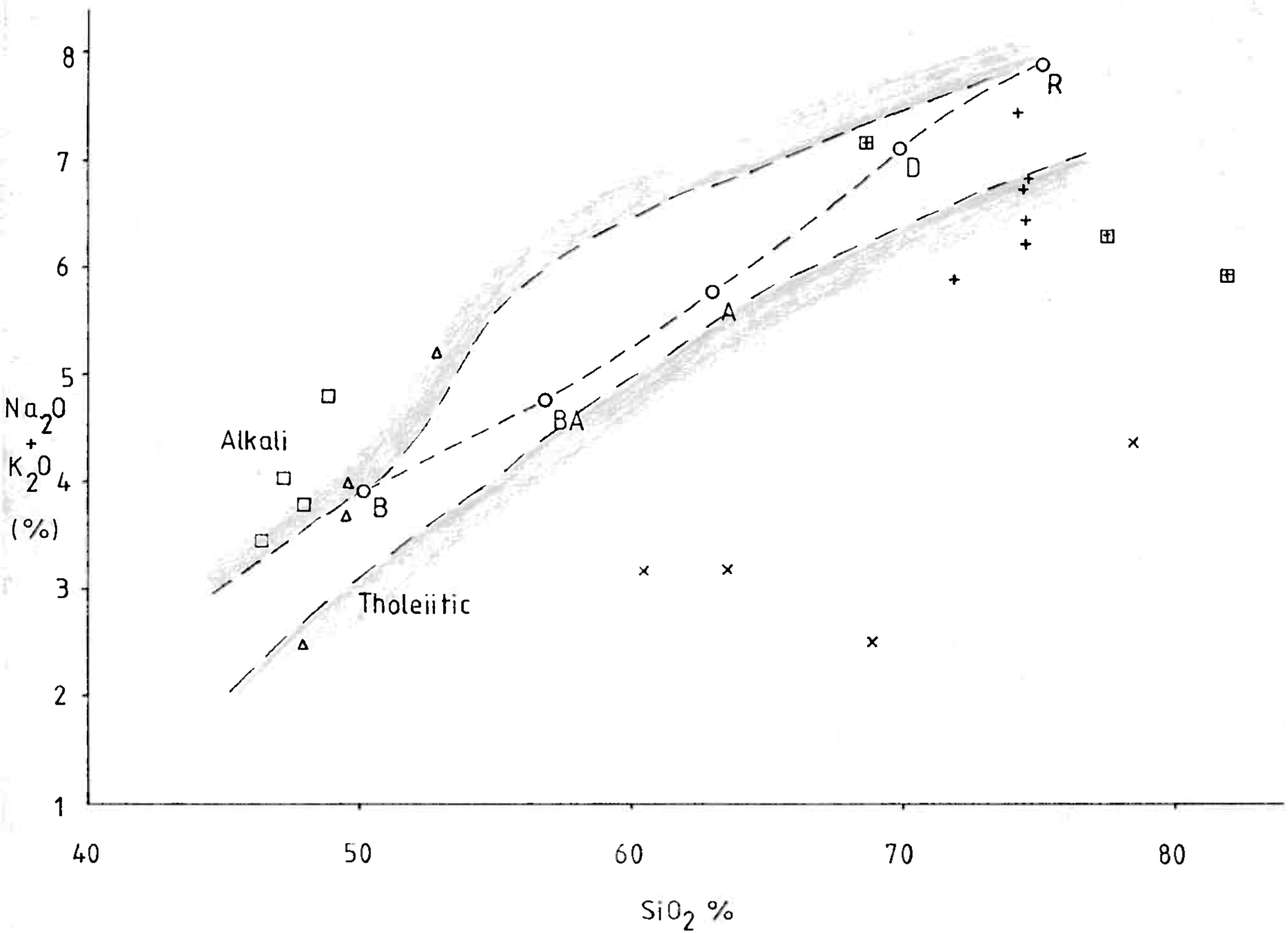


DIAGRAM 29: Plot of Alkalis against silica (Key see diag 28)

groups of acid and basic rocks.

Again the basic rock types correspond roughly to basaltic alkalis composition (slightly enriched as said before) whilst the acid rocks appear to be equivalent to slightly alkali depleted thyolites.

This indication of two separate igneous species is further shown by a plot of titanium oxide against iron to magnesium ratio. According to work done by Myashiro (1974), tholeiitic rocks are characterised by first an increase of TiO_2 content with increasing FeO: MgO ratio and then a decrease, whilst in a typical calcareous alkaline series the TiO_2 content decreases with increasing FeO: MgO. Myashiro defined average trends for tholeiite and calcareous-alkaline suites and these together with the values for the samples collected are presented in diagram 30 .

There is strong correlation of the acid rocks with the calcareous alkaline trend and the basic rocks with the tholeiitic trend. As Myashiro points out, most tholeiite series in immature island arcs are basaltic to andesitic in composition whilst the calcareous-alkaline series is mainly andesitic to dacitic in the same environment.

He also points out that large amounts of andesitic rocks are only present where there is a development of continental-type crust at a plate margin.

As can be seen on a plot of calcium against silica diagram, there is a bimodal distribution of data into basic and acid rocks with no intermediate rocks of andesitic composition.

The information from the plot of alkalis and silica (diagram 29) will be considered further, as the volcanic suite of

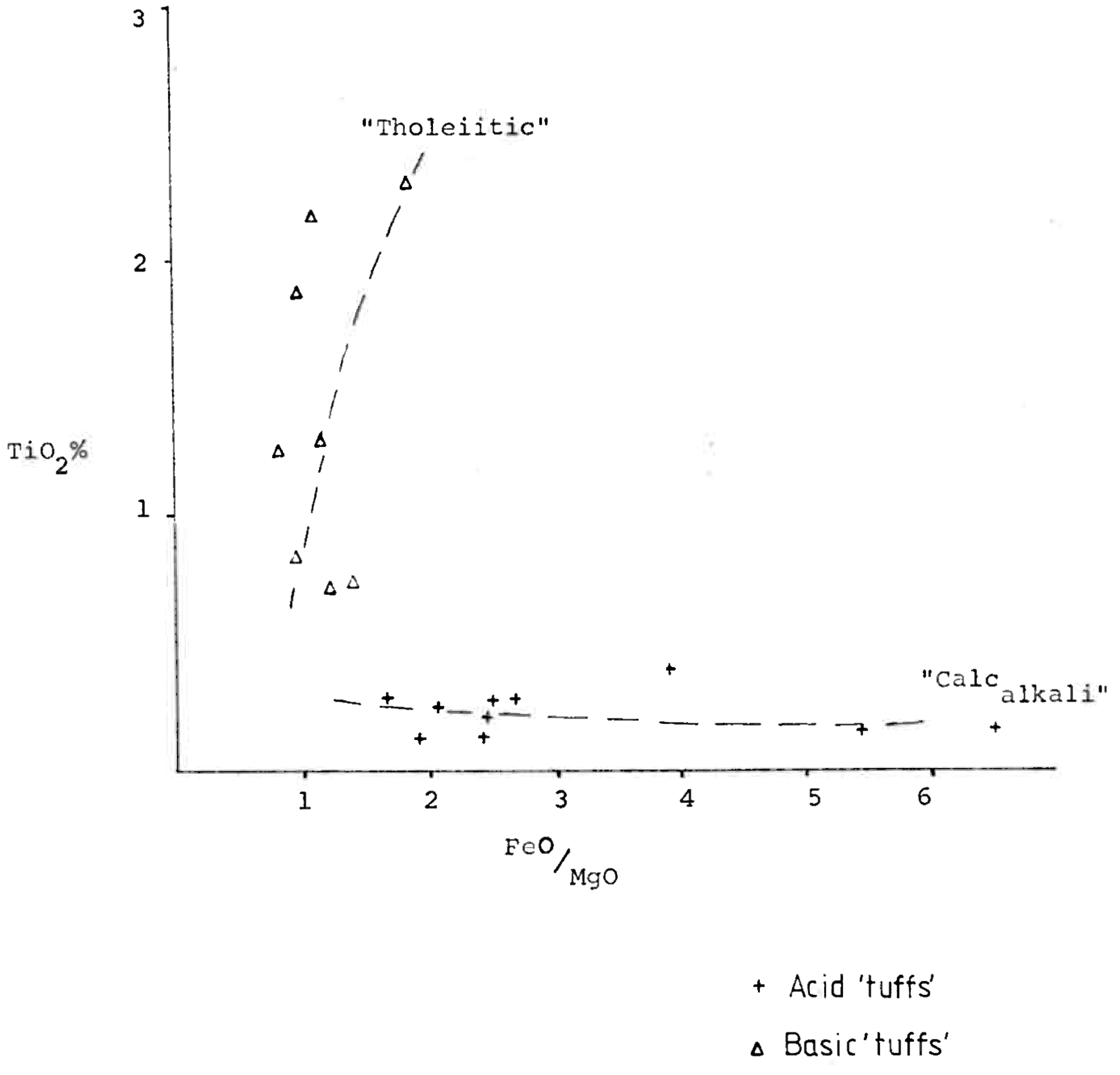


DIAGRAM 30: TiO_2 plot against FeO:Mgo ratio Indicating two trends.

mapped in this area has been shown to contain keratophyres in neighbouring Sweden by various authors, and it is indeed the interpolated lateral equivalents of the "meta-volcanic group" mapped by the present author that contains the Stekenjokk quartz-keratophyre formation (Juve 1975).

If a Marker diagram is plotted with a superimposed "igneous spectrum" as defined in Hughes (1972) from two volcanic suites from Cascades, U.S.A., plutonic rocks from Oslo, Younger Granites of Nigeria and the San Juan provinces, both the acid and basic rock species are seen to lie mostly to the left of the igneous "envelope". (Also plotted are Trench 2 sample but these are considered later on). (Diagram 31).

The significance of their lying to the left of the envelope is as Hughes (1972) says, indicative of alteration. The rocks are soda enriched (consequently depletion in potash) and in most cases show very little potash present at all. This immediately suggests spilitic alteration has occurred and the fact that keratophyres have been previously mapped in this unit would add historical argument to this.

Hughes (1972) defines a zone of "average" spilite from between 5-20 along the bottom scale and between 3 and 4.5% total alkolioxides. He indicates that keratophyres can not be so generalised, indeed potash rich keratophyres can be found (various authors). From the graph it is apparent that the basic rocks correlate reasonably well with Hughes's spilites whilst the acid rocks show some affinity to his soda rich described keratophyres.

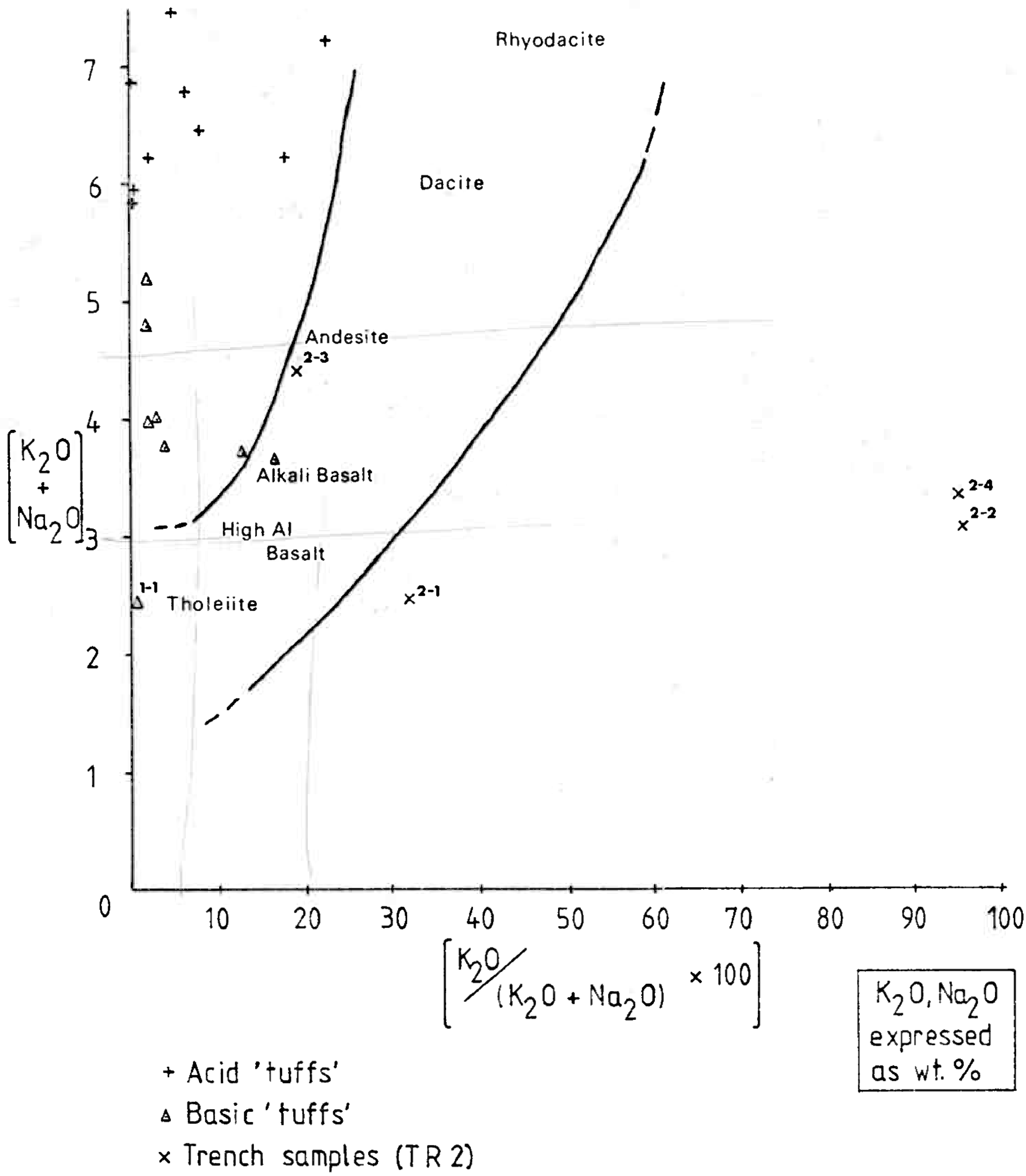


DIAGRAM 31:
Harker diagram after
Hughes (1972)

A triangular plot of soda , lime and potash shows the strong potash depletion in both the basic and acid rocks, the more basic rocks showing a higher calcium content that the acid rocks, which is to be expected. (Diagram 32)

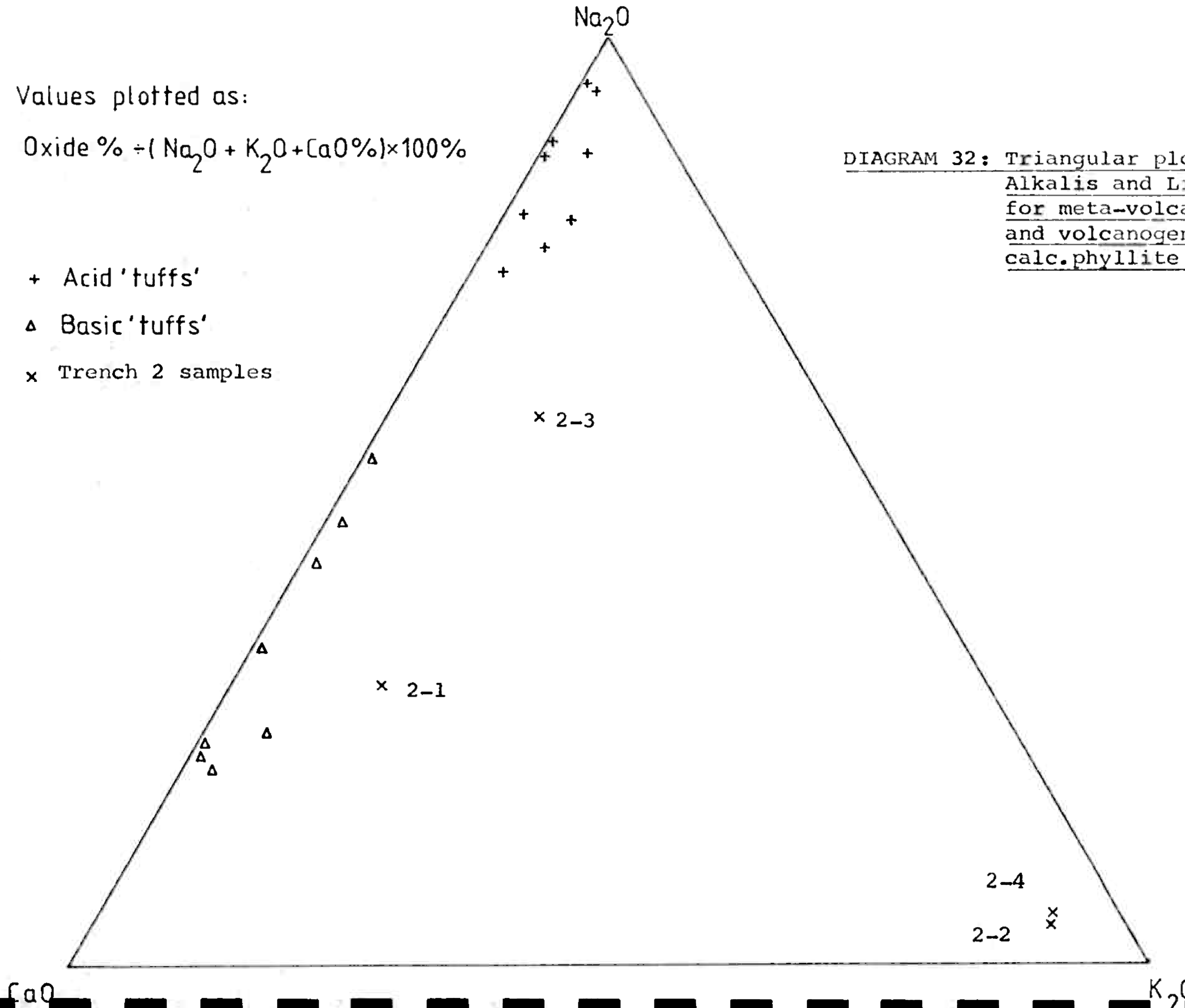
The mechanisms of spilitic alteration are quite widely disputed, but it is evident that there are basically two genetic proposals for spilites. These are a) derived from crystallisation of melts and b) derived from mineral adjustments in materials already cooled and consolidated. No discussion will be made of these two conflicting theories but needless to say it is difficult to conceive of a single model to account for the diversity of spilitic assemblages.

It used to be assumed that spilitization was a submarine process, but even this has been brought in to doubt by Vallance (1974) who suggests some now spilitic assemblages may have been erupted subaerially.

What is apparent is the need for high water and carbon dioxide contents to the system to permit ion exchange resulting in these "spilitised" assemblages.

Generally the process of spilitisation is represented by the albitisation of plagioclase, which in the case of a basalt would have the composition of labradorite or bytownite. Spilitisation, as said earlier, involves hydrolysation and ion exchange, and has been acknowledged by most authors to occur at, or close to, the sea floor-sea water interface. In this environment we would expect alkaline conditons where Ca^{2+}, Na^{+} and K^{+} ions are more soluble than the aluminium, iron and magnesium species.

DIAGRAM 32: Triangular plot of Alkalis and Lime for meta-volcanics and volcanogenic calc.phyllite units



Albitisation of plagioclase was quantified by Turner (1948) in this reaction:

$$NaCaAl_3Si_5O_{16} + Na^+ + Si^{4+} = 2NaAlSi_3O_8 + Ca^{2+} + Al^{3+}$$

labradorite albite

thus the "anorthite" in the plagioclase is converted to albite.

This is not the complete answer as Shteinberg(1964) notes that a rock altered in this way of average basaltic composition, would be subject to a 6.7 wt% gain of silica and a 5.6 wt% loss of Al_2O_3, which from analyses of spilites we know not to be the case.

Indeed the pyroxenes of the basalts are involved in the process and a likely spilitisation reaction is shown by Narebski(1974), whereby labradorite and pyroxene in the approximate ratio of 1:1 are altered in the presence of soda and carbon dioxide bearing solutions, to albite, epidote,chlorite ,sphene and calcite.

This seems to tie in well with the assemblages seen in the basic tuffs of the meta-volcanics and the volcanogenic members of the calcareous phyllite group.

In thin sections of these rocks there is abundant chlorite, epidote, albite, calcite and in section RH 124, small sphenes are seen dispersed in large chlorite masses .

In conclusion, it appears that the meta-volcanic suite of rocks represents a spilitic suite of keratophyres and basic spilites, highly enriched in soda and sympathetically depleted in potash. It is apparent that there are no rocks of intermediate composition, which if the plate margin defined by the Caledonian Front is assumed, fits well into the ensimatic island arc model suggested in Halls et al. (1977) on comparitive data from Miyashiro (1974), who attributes the lack of intermediate rocks to an immature consuming plate margin on oceanic crust.

What is also apparent from the studies is the presence of spilitic and keratophyric tuffs, intercalated in the calcareous phyllite units, which does much to explain the presence of sulphide showings of copper and zinc in adjacent areas within the calcareous phyllite group.

DISCUSSION OF TRENCH 2

During the investigation of the meta-volcanic suite it became apparent that rocks 2-4 and 2-2 from trench 2 were misfits and did not fit into the same pattern as the spilites and keratophyres; and plotted well outside the pattern described by the meta-volcanic suite.

This was first apparent in the FeO against silica plot, where samples 2-2 and 2-4 plotted well outside the areas defined by the basic volcanics, calcareous phyllite group and the acid volcanics. This ties in with the sample description (see section on trenching) where over 10% of free pyrite was noted.

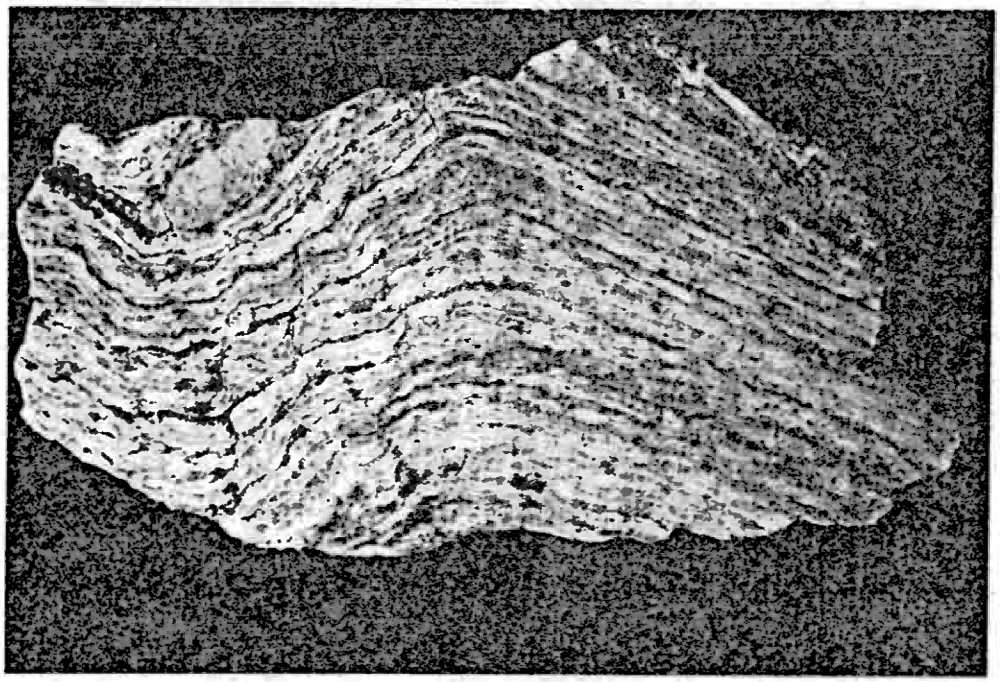
TiO_2 against silica plot again showed 2-2 and 2-4 to plot well outside the two groups defined by the volcanics, and plot within the "andesitic" range.

These rocks 2-2 and 2-4 were taken from the second rust zone mapped at skjerp 2 and occurred structurally beneath 2-1 and structurally above 2-3.

Rocks 2-1 and 2-3 show slight geochemical discrepencies with the meta-volcanic rocks but evidently have more affinity to these than the types 2-2 and 2-4.

In hand specimen (thin sections not available) rock 2-1 was a quartz rich chlorite, carbonate schist with a large content of fine quartz, but visually appeared to be a silicifed basic tuff. Elongate lenses of quartz up to 2 mm long indicate possible intercalated chert laminations or silica "shards".

The hand specimen of 2-3 was slabbed and is shown in photograph 26. It is a quartz, chlorite schistose rock with



Photograph 26: Slabbed specimen of HR 2-3.
(Actual size)

abundant pyrite grains constituting about 1% of the rock. The general appearance is of a banded acid tuff rich in pyrite. A strike extension to this horizon was mapped and sample RH 139 was taken from this horizon. In this sample, what appeared to be primary laminations of chert were seen, this is shown by the slabbed specimen in photograph 27.

The plot of alkalis shown in diagram 29 places the samples 2-4 and 2-2 well outside the range expected for the igneous spectrum, but in the reverse sense to the spilites and herato-phyres. Samples 2-1 and 2-3 also show this sense of "shift", sample 2-3 plotting within the "andesite" range of alkali con-tent.

It is apparent that these rocks show varying degrees of enrichment of potassium at the expense of sodium. This is further shown by the triangular plot of lime, potash and soda (see diagram 32).

Evidence is shown for the visual classification of sample 2-1 as a silicified basic tuff and sample 2-3 as a keratophyric tuff by the closeness of the plot to the spilites and keratophyres respectively.

Samples 2-4 and 2-2 show very strong potash enrichment whereas the bordering horizons of 2-1 and 2-3 show this potash enrichment from the more "normal" spilite and keratophyre less strongly.

This is unusual in a suite of volcanic rocks noted for soda enrichment.

A thin section of 2-2 was available as HR 2-2b and a close

Photograph 27: Slabbed specimen of RH 139, showing possible primary chert laminations.

(Actual size)

study of this rock was necessary to elucidate the assemblage and any possible alteration of the minerals.

The rock is predominantly quartz andsericite, with large idioblastic grains of pyrite. Deformation of the rock must have been severe as much of the quartz shows strongly undulo se, sweeping extinction, it is apparent that the quartz crystals have a well disturbed crystal lattice.

Most of the pyrite cubes are idioblastic, probably annealed after deformation although some show cataclastic textures where cubes have abraded one another during deformation.

Sercite or muscovite occurs generally as two types. There is a coarser type of sub-idiomorphic crystal which usually occurs with the quartz and pyrite, and is probably muscovite s.s. The other type is fine grained and occurs in 0.5 mm bands which separate generally quartz "muscovite" and pyrite rich segregations. These fine grained sercite bands contain small pyrite grains.

Also apparent is the "alteration" mineral which is shown in the photographs 28 and 29 . As can be seen in the photographs this "alteration" appears to pseudomorph a sub-idiomorphic grain. On closer examination is apparent that this alteration consists of very fine quartz and another unidentified mineral.

It was impossible to recognise the mineral in thin section, apart from its low birefrigence and low relief, refractive index apparently lower than quartz.

The idiomorphic pseudomorph is suggestive of an altered feldspar however.

Since a probe slide of the specimen was available, an electron microprobe scan was suggested to elucidate the composition of the mineral. The slide was carbon coated and the mineral was analysed.

The readout from the microprobe is shown in diagram 33 .

It was analysed on the assumption of 32 oxygens, i.e. a feldspar, since on an initial scan the peaks for aluminium, silicon and potassium were quite high and a potash feldspar was considered.

The analysis was possibly doubtful due to the low total oxide content, the presence of fine sericite and quartz as well confused the analysis.

However, the recorded values of oxide percentages resemble analyses for orthoclase (Deer, Howie and Zussman)

It was concluded, therefore, that the mineral was probably a fine grained potash feldspar with intergrowths of sericitic and quartz alteration products.

The horizon represented by samples 2-2 and 2-4 is the pyrite rich quartz, sericite schist shown on diagram . It represents something of an enigma as a potash enriched rock within a group of soda enriched spilites and keratophyres. It resembles most closely the kerotophyres mapped in the area but chemical differences are clearly shown in comparison (see diagram 27).

Potash is generally low in spilites (Carmichael, Turner and Verhoogen 1974), but potash spilites are known (Fiala 1974), and are considered to have a primary magmatic origin and examples of potash

ANALYSE? NO
TRACK NO.=10
KSPAR TRK 10 LIVETIME(SEC)= 100

ENERGY	RES	AREA
1.9	89.45	73142

TOTAL AREA= 231295
......

FIT INDEX= 1.02

ELMT	APP.CONC	ERROR(WT%)	
NA	.072	.092*	< 2 SIGMA*
MG	1.193	.068	
AL	10.807	.096	
SI	25.416	.114	
P	- .040	.042*	< 2 SIGMA*
S	.025	.032*	< 2 SIGMA*
CL	.021	.033*	< 2 SIGMA*
K	6.211	.071	
CA	.039	.044*	< 2 SIGMA*
TI	.170	.042	
MN	.030	.055*	< 2 SIGMA*
FE	1.145	.084	
NI	.019	.088*	< 2 SIGMA*

NO. OF O ATOMS=32 [1 2 ZAF'S]

15.00 KV TILT= .00 ELEV=75.00 AZIM= .00 COSINE=1.000

SPECTRUM: KSPAR TRK 10 ZOMBOID

LAST ELMT BY STOICHIOMETRY

contamination from other altn product?

ELMT	ZAF	%ELMT	%OXIDE	FORMULA
NA	.942	.077	.103	.038
MG	.936	1.274	2.112	.604
AL	.967	11.193	21.151	4.784
SI	.923	27.642	59.132	11.348
P	.906	.000	.000	.000
S	.899	.028	.069	.010
CL	.900	.024	.029	.008
K	.865	7.185	8.656	2.119
CA	.961	.041	.057	.012
TI	.830	.205	.342	.049
MN	.808	.037	.048	.008
FE	.819	1.398	1.798	.289
NI	.822	.023	.029	.004
O	.485	44.399	.000	32.000
TOTAL		93.525	93.525	

NEXT=

DIAGRAM 33: Electron microprobe scan on the "alteration" mineral.

enriched rocks have even been noted within soda rich spilitic suites.

his possibly explains the horizon, and it may represent a potash enriched intrusive body which post-dates the spilitic suite into which it was introduced, accompanied by high H_2O content,which lead to the slight alteration and potash enrichment to the bordering horizons 2-3 znd 2-1.

Alternatively the rock may represent a highly altered spilite where all the soda has been removed and replaced by potash, and indeed indications of pervasive alteration has been shown.

This alteration must have been very specific and perhaps the high content of free pyrite has something to do with this, although the potash enrichment of the bordering horizons could be argued to represent this secondary alteration phenomenon as well as the noted zinc enrichment in the samples.

It seems difficult to accept such a specific secondary potash enrichment and the present author suggests that the horizon represents a ptash rich intruded body which has subsequently suffered some sericitisation to the potash feldspars present.

BASE METALS IN THE MAPPED UNITS

Base metal element contents are plotted for the sample profile across the calcareous phyllite group in diagram 34. The profile includes all rock units in the group.

What is apparent is the generally constant background values of base metals in the sediments, with notable exceptions found in the feldspathic psammite unit and also in the chlorite rich horizon represented by sample RH 72.

As discussed earlier the feldspathic psammite unit contains intercalated volcanogenic sediments , and this enrichment of base metals is perhaps indicative of the presence of metalliferous brines associated with the volcanism.

The author suggests that any mineralisation which is to be found in this group is likely to be related to the volcanogenic units of the group.

The basic volcanics are typified by generally enhanced values of Cu and Zn (see Appendix V), and this is most likely due to the substitution of these elements in the ferromagnesium minerals, whilst the acid volcanics have base metal contents very similar to the sediments.

Finally it is noted that the bituminous phyllite units are slightly Cu enhanced, due probably to the localised reducing conditions created by the formation of the hydrocarbons and iron sulphides.

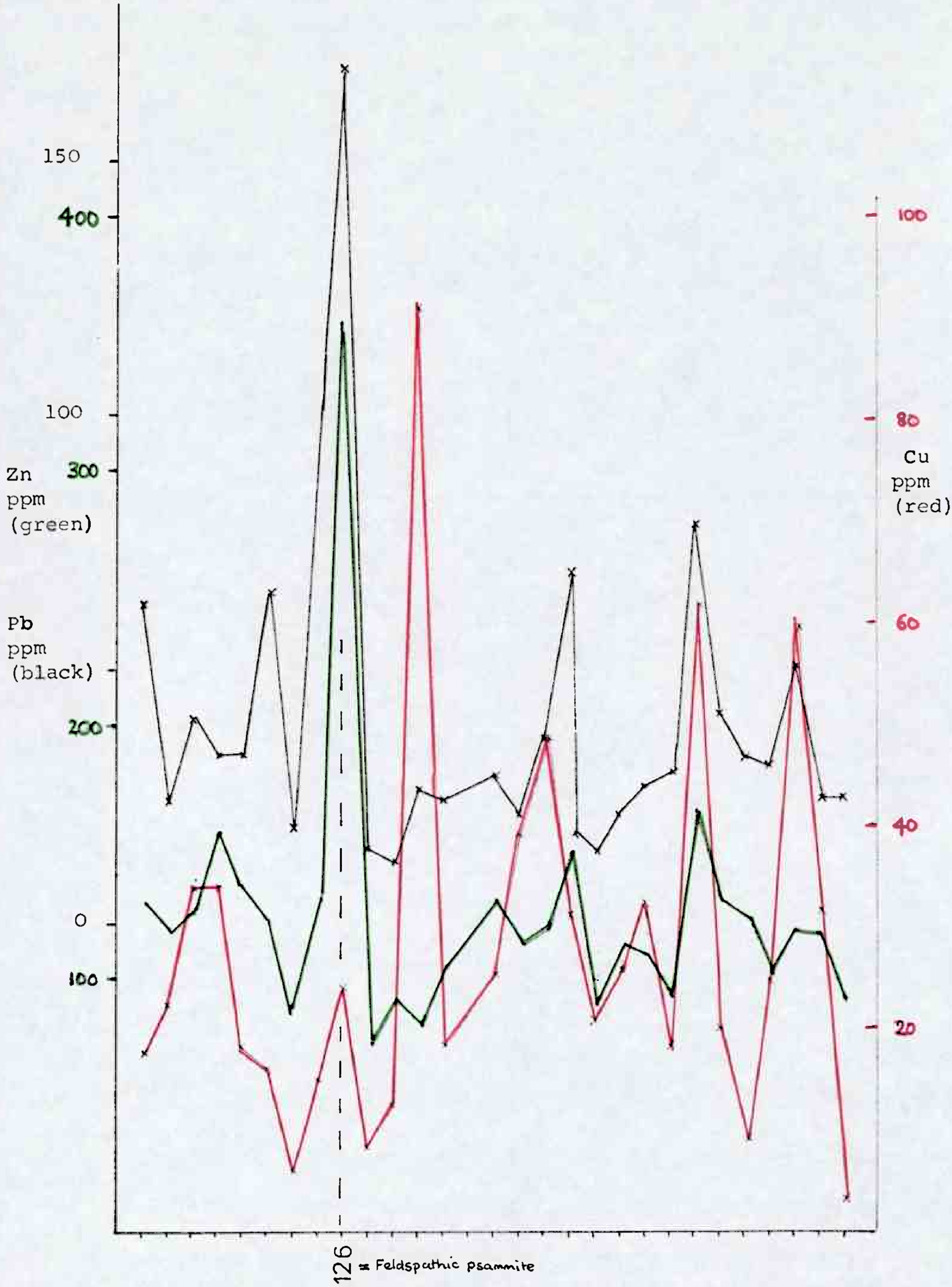


DIAGRAM 34: Plot of base metals for calc.phyllite group

Base metals in the trench samples is dealt with in the report.

APPENDIX IV

PREPARATION OF GEOCHEMICAL SAMPLES AND ANALYSIS METHOD

Preparation of Samples For Whole Rock Analysis

Selected samples were cleared by washing, and weathered material was removed as far as was possible, too heavily weathered samples were discorded. Primary crushing was done by jaw crusher with the apertive set at ¼".

For each sample I split, crushed and then seived it through a brass seive with a mesh apertive of 3.35mm (⅛"). Oversize material was then returned to the jaw crusher and processed for a further time, being seived again after this crushing in the same seive. Oversize material after this second crushing was then put aside as "Waste"; as it was considered that the seived material accurately respresented the sample, the samples all being fairly fine grained (Less than 2mm diameter) homogeneous rocks, with no fractionation at this grain size being expected.

The sample passing through the 3.35 seive was collected and passed to the secondary grinding stage, a Tema agate mill being selected.

I coned and quartered the samples carefully, to prevent size/density fractionation, until a suitable size (Half fill of the Tema mill) was retained for milling.

I milled the samples for 5 minutes each, and the product was then passed to a 200 mesh seive, all the -200 mesh fraction being collected as a representative sample.

Each piece of equipment was thoroughly cleaned inturn, the fine material removed carefully by a paintbrush and added to the retained product. Samples were collected in individual sample bags and were ready for the analytical stage.

Pre Analysis Preparation

For the method of attack chosen, 250mg of each sample was required.

The samples were weighed on a slip of glazed paper on an open pan balance calibrated to 1mg intervals. A vibrating spatula was employed enabling 250mg to be precisely weighed directly onto the balance. Each of the 25omg samples was weighed in a random order and placed into clean plastic beakers, numbered from 1 to 100 inclusive together with randomly introduced standard samples, blank samples and duplicates. 8 duplicates, 4 standards of Z1 standard, 4 standards of Z3 standard and 4 blank samples were included with 80 samples to be analysed. I had 55 samples to be analysed and 25 samples belonging to Steven Hide were included in the batch.

Samples then passed to the digestion process.

Hydrofluoric, Nitric and Perchloric acid attack for rock, soil or sediment

Reagents

(a) Hydrofluoric acid (40%)

(b) Perchloric acid (60%)

(c) Nitric acid (70%)

(d) Hydrochloric acid (6M). Dilute hydrochloric acid (534ml, 36% acid) to 1 l with water.

Equipment

(a) PTFE beakers (50ml)

(b) Graduated flasks (25ml) or graduated test tubes (10ml)

(c) Hotplate sited in a suitable fume cupboard

(d) Polythene measuring cylinder and plastic tray for dispensing hydrofluoric acid

(e) Liquid dispensers (4)

Procedures

(a) Weigh each sample (0.250g, -200 mesh) into a clean, dry, numbered PTFE beaker.

(b) Weigh standard and duplicate samples, and leave empty beakers at random intervals for blank determinations.

(c) Add nitric acid (3.0ml) followed by perchloric acid (3.0ml) to each beaker.

(d) Then add hydrofluoric acid (10ml) to each beaker.

(e) Heat the beakers on a hotplate until dense white fumes are seen (1-1.5 hour).

(f) Heat for a further 20 minutes and then allow the beakers to cool.

(g) Add further hydrofluoric acid (2ml) to each beaker.

(h) Heat the beakers on the hotplate until the solution is gently evaporated to dryness (about 4 hours) and allow the beakers to cool.

(i) Add further perchloric acid to each beaker (2.0ml).

(j) Head gently, evaporate to dryness and allow the beakers to cool.

(k) Add hydrochloric acid (2.0ml) if the final volume is 10ml, or 5.0ml if the final volume is 25ml, to each beaker and warm gently.

(l) Transfer the solution from the beakers to either graduated flasks (25ml for a dilution factor of 100) or to graduated test tubes (10ml for a dilution factor of 40) and dilute to volume with water.

Remarks

(a) This method will completely digest most constituents of rocks, soils and sediments. A few minerals will partly or completely resist attack, e.g. barite, chromite, cassiterite, tourmaline, kyanite, some spinels and magnetites, rutile, zircon and wolframite.

(b) When using PTFE beakers on a hotplate, care should be taken not to exceed the temperatures at which PTFE becomes plastic (240°C).

(c) A shortened form of this method can be used for less resistant samples by omitting steps f, g, i and j from the above method. The double fuming with perchloric acid is necessary for calcareous samples (i.e. 10% Ca) to destroy the insoluble calcium fluoride residue.

(d) This method must not be attempted on samples containing oil or bitumen.

Hydrofluoric acid-Boric acid attack for silicon determination in rock, soil, or sediment

This method is use for the determination of silicon, but the solution can also be used for other major constituents. It is based on decomposition of the sample with hydrofluoric and hydrochloric acids in a polypropylene bottle. Boric acid solution is added to dissolve precipitated fluorides.[10, 11]

Reagents

(a) Hydrofluoric acid (40%)

(b) Hydrochloric acid (36%)

(c) Saturated boric acid solution. Weigh out 200 $\pm$5g boric acid into a beaker, add 1000 $\pm$50ml water, cover the beaker and heat until the acid has dissolved. Cool to 40 $\pm$10°C and decant into a bottle.

Equipment

(a) Polypropylene bottles with screw caps (125ml)

(b) Water bath or an oven

(c) Plastic tray and plastic dispenser for hydrofluoric acid

(d) Liquid dispenser

(e) Measuring cylinder, 50ml.

Procedures

(a) Weigh each sample (0.100g, -80 mesh) into a dry, numbered polypropylene bottle.

(b) Weigh standard and duplicate samples, and leave empty bottles at random intervals for blank determinations.

(c) Add hydrochloric acid (1.0ml) to each bottle, wetting the sample thoroughly.

d) Add hydrofluoric acid (5.0ml) to each bottle and close firmly.

(e) Place the bottles in either an air oven (or a water bath) at 95 $\pm 5^{o}C$ and leave for one hour. Allow the bottles to cool.

(f) Add boric acid solution (50ml) to each bottle, close firmly and replace it in the air oven for a further hour. Allow the bottles to cool.

(g) Add water (44.0ml) to each bottle and mix thoroughly.

(h) Use this solution for the determination of silicon.

Remarks

(a) Ensure that the bottles used are of polypropylene or other plastic material that will withstand temperatures up to about $130^{o}C$. If the screw caps do not give a tight seal, this can be improved by using 'washers' cut from thin plastic film.

(b) This method is suitable for the same range of minerals as method 3.3.

(c) The hydrofluoric-boric acid solutions should not be left in contact with glass apparatus for more than two hours to avoid etching the glassware and contaminating the sample solutions with silicon.

(d) Other elements can be determined on the same solution. Make the calibrators for aluminium with the same concentration of hydro-fluoric-boric acid as the sample solution. Determine magnesium and calcium by using the dinitrogen oxide-acetylene flame, making a dilution of the sample solution to contain 1000 g ml^{-1} of potassium as an ionisation suppressant. Determine sodium and potassium by using the air-acetylene flame making an appropriate dilution of the sample solution to contain 1000 g ml^{-1} of caesium as an ionisation suppressant.

(e) For samples with low ($<$5%) silicon content, use higher sample weights (up to 0.5g).

(f) The dilution factor for this method is 1000.

APPENDIX V

GEOCHEMICAL DATA

E11/HERRINGTON/HINDE

(RESULTS ARE REPORTED IN MICROGRAM / GRAM OF SOLID)

DATE OF ANALYSIS: [illegible]

SAMPLE	LI	NA	K	RB	BE	MG	CA	SR	BA	AL	LA	TI	V
81 HR3N-1	14.29	22596	10649	63.15	0.977	6142	1020.	31.49	140.3	64720	3.266	1137	50.31
82 DB22	26.16	11838	8371	54.18	1.391	25415	80151	221.9	203.9	63968	48.93	5076	143.1
83 DB3	36.79	18680	27729	173.7	3.077	11236	2162	68.46	572.4	109758	56.84	5814	138.8
0 IGNORE	0.062	18.13	11.69	2.045	0.023	9.564	24.93	0.143	1.688	14.46	0.307	< 0.000	0.006
84 BLK	0.055	17.68	5.481	1.389	0.417	8.457	29.11	0.168	2.058	8.450	0.414	2.450	< 0.000
85 DB14	36.57	10894	13183	97.59	2.597	32370	2429	35.53	468.7	100237	13.66	1563	163.3
0 IGNORE	0.126	7.723	9.943	5.983	0.010	15.40	8.990	0.085	0.077	22.43	0.445	< 0.000	< 0.000
86 DB15D	24.61	10033	11779	74.43	1.737	24173	72704	199.1	292.3	70933	51.61	5172	147.9
87 DB17	29.31	10700	13197	81.99	1.914	20250	46578	120.8	330.3	87735	34.02	5191	170.4
88 Z1	34.10	699.0	4443	39.72	1.307	3293	1669	30.84	266.2	27521	29.63	2001	53.39
89 DB15B	25.30	10623	11036	76.39	1.740	24769	75059	205.5	301.8	75619	53.18	5237	151.1
90 DB6	[illegible].54	17728	19269	152.4	2.[illegible]	9812	[illegible]8603	98.89	607.0	97716	34.91	4770	110.6
91 HR3S-2	27.37	21033	11573	77.17	1.817	16535	4437	43.44	274.2	83614	19.77	5772	177.4
92 HR3S-1	24.32	17298	17603	115.2	2.[illegible]	14327	4700	42.16	93.77	89562	10.22	5996	218.7
93 DB2	38.50	20239	21876	152.9	2.212	10031	2665	59.76	452.5	103236	20.61	4879	130.5
94 DB14D	25.13	11657	11330	77.20	1.601	23375	77734	209.2	318.8	70773	52.92	1605	101.8
95 DB1	[illegible].72	12006	33410	244.7	2.415	10525	4182	100.2	900.5	123850	26.85	2067	132.2
96 DB4	[illegible].14	18008	21283	159.7	2.266	10522	6276	90.22	505.6	101138	52.51	5402	126.4
97 Z3	[illegible].13	1387	6284	74.03	2.355	4225	25511	153.3	255.2	52480	41.62	2745	178.0
98 DB16D	[illegible].24	11739	10975	79.00	3.724	28527	80368	215.3	317.4	71717	53.22	1524	100.5
99 DB13	[illegible].71	15525	10872	70.22	[illegible].724	20364	37513	147.4	299.5	71127	43.87	5087	149.0
100 DB12	[illegible].15	13012	10665	72.35	[illegible]	17782	36107	105.8	305.8	6[illegible]55	38.32	4324	135.1

[redacted]

RESULTS ARE REPORTED IN MICROGRAMS / GRAM OF SOLID

-? R137AB 1105 — 1362 76763 31.08 — [illegible] — 1220 4.904 3.21 5.5

-12 R137AB 115.8 — 1375 78456 31.66 — 9.46 — 1310 4.975 2.27 156.5

DATE OF ANALYSIS: [illegible]

SAMPLE	LI	NA	K	RB	BE	MG	CA	SR	BA	AL	LA	TI	V
STD1	< 0.000	< 0.000	< 0.000	< 0.000	0.000	0.0[illegible]	0.0[illegible]	0.001	0.002	< 0.00[illegible]	0.0[illegible]1	0.0[illegible]	0.036
STD11	0.011	315.8	335.7	0.150	0.002	1647	1929	6.396	0.252	872.[illegible]	0.440	91.93	1.009
STD4	10.45	0.571	0.338	10.02	0.982	0.124	0.334	10.14	9.947	0.196	10.06	[illegible]	10.02
1 RB14B	4.310	3886	3202	12.60	0.805	2739	2513	31.90	232.6	21811	7.866	1964	134.7
2 145D	48.11	15307	16469	116.3	2.352	23185	6296	[illegible]	170.0	96497	53.02	1447	140.8
3 132	23.27	13952	12279	84.51	1.803	19692	61172	135.3	325.2	77130	62.59	1999	114.5
4 74	24.88	38990	775.9	6.658	1.446	52380	53610	327.8	33.17	94056	23.27	11574	311.6
5 39	9.914	38117	9331	21.80	0.848	4860	859.9	31.01	257.3	[illegible]	10.77	687.0	27.59
6 126	3.735	27094	31300	119.9	2.909	1694	4946	[illegible]	564.9	[illegible]	160.5	2228	28.65
7 125	5.975	41433	13848	26.17	1.122	6833	1770	[illegible].81	308.4	97679	9.372	1360	94.42
8 72	13.60	31304	20754	93.49	3.743	11059	14301	[illegible]	302.8	70856	47.66	3521	122.5
9 137	1.781	47142	3761	12.71	0.503	1861	10540	[illegible]1.9	135.8	82120	15.32	759.5	22.63
10 145D	44.31	13603	16704	116.5	2.267	22264	4501	64.68	477.9	94189	56.72	1550	128.6
11 124	15.44	37934	943.9	4.752	0.849	39613	39039	[illegible].19	22.32	98532	12.43	4188	281.5
12 130	4.221	52713	3240	14.06	0.399	8450	4037	[illegible].42	71.84	85656	5.555	2591	40.42
13 21	32.83	679.6	4528	34.80	1.025	1260	1555	36.20	297.5	26501	25.80	1396	46.96
14 128B	24.14	35010	1876	2.734	1.190	42174	97645	[illegible].50	33.55	97107	12.61	4415	356.[illegible]
15 BLK	< 0.000	20.31	4.190	< 0.000	0.010	12.72	68.38	[illegible].71	95.18	21.3[illegible]	0.248	0.200	0.077
16 40	23.15	20710	858.0	2.061	1.172	68545	25820	[illegible].42	19.70	[illegible]	[illegible].12	1909	265.7
17 38	7.753	43212	471.4	3.071	0.532	9738	4720	[illegible].97	19.47	73150	10.53	1717	39.26
18 134	1.242	50656	417.0	2.407	0.464	1734	2337	21.82	11.33	74631	2.100	1144	[illegible]
19 128A	4.244	45643	896.7	1.864	0.600	7032	1923	38.28	48.61	73789	2.684	1231	39.[illegible]
20 128OD	24.79	35763	300.4	1.749	1.211	42658	28404	[illegible].76	35.55	73910	12.22	1213	[illegible]
701 STD1	0.002	0.104	< 0.000	0.007	0.000	0.092	0.041	0.002	0.003	0.0[illegible]	0.001	0.017	< 0.[illegible]
702 STD11	0.471	12224	9346	2.295	0.003	65130	72774	[illegible].22	9.313	[illegible]	7.42	3549	40.[illegible]
21 11	33.73	16065	22207	16.6	3.109	9601	450.7	[illegible].34	561.4	10392[illegible]	7.696	2362	[illegible].5
22 F	3.187	44510	4461	15.29	0.405	6936	7228	112.4	79.53	77114	3.403	1355	[illegible]
23 128	1.349	40877	365.9	3.855	0.227	2885	5758	98.42	11.49	69537	2.51	1009	37.97
24 HR2-1	14.75	12655	6730	9.797	0.349	40523	22674	31.30	70.66	65409	1.421	1853	41.86
25 Z3	39.77	1121	4801	55.67	1.843	3108	19245	118.4	378.8	40119	32.04	2011	153.9
26 HR2-2D	11.04	1141	25168	40.75	1.596	10929	2101	[illegible]	17.39	[illegible]	[illegible]	3488	[illegible]
27 HR2-4	8.928	1270	26392	45.80	1.470	9099	2031	[illegible].959	21.01	75160	[illegible].037	3305	382.3
28 HR2-3	1.087	26461	7073	13.49	0.409	6020	11730	33.24	70.12	59741	[illegible].993	709.9	23.34
29 HR1-1	39.20	13106	54.2	2.275	1.518	40749	54521	128.3	4.636	76903	20.92	13737	[illegible].6
30 HR2-2D	9.336	1408	17872	34.36	1.654	11229	2192	0.504	18.01	78973	1.732	[illegible]	[illegible].9
703 STD1	0.076	< 0.000	< [illegible]000	< 0.000	0.002	0.914	1.742	0.057	0.090	< 0.000	< 0.000	< 0.000	< 0.000
704 STD11	0.513	12152	7228	3.770	0.088	67493	83977	37.14	9.536	34763	18.38	[illegible]	42.25
705 STD4	417.3	22.63	6.932	402.6	39.85	4.944	14.25	412.2	405.8	9.141	412.1	0.[illegible]25	404.1
31 1-2	33.32	10507	19113	121.0	2.327	15593	5264	29.72	63.98	84622	11.43	5671	[illegible].5
32 1-3	22.45	10669	20877	118.8	2.342	13516	4431	25.72	177.9	83159	5.530	5196	198.9
33 21	24.97	18525	7504	47.55	1.524	21176	25010	101.3	257.8	68438	39.72	3722	127.3
34 BB20	31.95	5252	16914	115.3	2.379	17705	15014	75.33	610.0	73593	31.89	2373	161.5
35 19110D	13.07	23957	4074	21.29	4.373	35494	81783	484.5	139.3	95469	24.08	7970	280.5
36 Z1	32.86	758.6	3899	34.53	1.005	1265	1602	39.21	272.4	26724	27.69	2150	56.41
37 19-10	18.88	12469	9012	55.87	1.352	16902	72347	298.8	245.8	59251	42.93	3127	90.24
38 BLK	0.239	16.69	9.786	2.912	0.015	8.653	28.95	0.191	1.997	11.19	0.347	0.395	0.062
39 19	27.31	13357	13039	79.73	1.028	22169	41958	206.4	328.3	76605	41.77	2847	132.4
40 19110B	14.84	24039	4058	20.41	1.414	35749	85423	487.4	139.1	94211	24.08	9211	286.1
41 18A	15.91	27040	1389	12.98	1.647	40575	69239	592.1	20.31	74822	40.69	7713	228.3
42 BB9	29.33	13007	11527	72.62	1.581	17540	29058	161.7	293.8	69438	41.29	3119	123.8
43 18	17.06	9405	7726	54.99	1.267	18488	105941	413.4	241.3	39667	57.30	1162	76.93
44 BBC	36.59	19811	14244	11[illegible].7	2.241	5560	9921	[illegible]	754.1	85559	40.66	4651	117.6
45 BB7	21.63	16105	12697	80.17	1.097	5163	4315	53.13	435.6	50395	13.84	2816	62.84
46 Z3	46.93	1433	5736	65.72	2.166	3786	22380	140.5	261.4	47195	37.88	2514	179.9
47 BB1	31.41	25386	17292	121.6	2.120	12927	[illegible]	69.72	[illegible]	[illegible]	22.12	[illegible]	122.9
48 BB11	32.75	12899	11810	76.67	1.832	21465	30152	151.7	324.4	71892	49.47	2754	128.7
49 BB24	33.27	19311	5731	26.65	1.605	[illegible]	[illegible]	[illegible]	153.4	[illegible]	24.17	[illegible]	[illegible]
50 BB23	38.06	15628	12219	69.88	1.820	[illegible]	[illegible]	[illegible]	335.2	[illegible]	47.93	[illegible]	[illegible]
15 BLKRPT	0.135	21.87	12.67	2.365	0.007	15.25	[illegible]	0.509	94.98	21.31	0.644	1.[illegible]	[illegible]

Date	Job	Sheet
1/4/80	E11	11

Analysis: Attack No 4
Method: HF, H_3BO_3

Remarks: DF 1950

Requested by: MHR
Project:
Analyst: AD.
Calculations checked by:

Sample No.	Tube No.	%Si		%Si		%Si		%Si
DB6		31.2	AS16	38.5	DB1	29.5	AS18	34.9
DB10		30.1	HR21-2	31.2	DB9	29.8	AS55A	35.4
DB14		30.6	AS12A	23.4	AS10B	23.2	AS13	33.4
HR352		31.8	ARI-3	31.9	AS70B	34.8	RH124	24.7
DB2		31.0	DB23	28.9	AS53	25.3	RH138	34.7
HR2-3		36.7	DB21	29.0	BLANK	0.0	RH148	9.6
DB15		26.1	DB13	30.4	AS29A	23.9	RH145	29.1
HR351		32.5	RH132	24.7	AS19	25.1	AS18	35.1
DB17		25.6	RH39	34.8	AS14	23.7	BLANK	0.0
DB6		31.3	DB24	21.7	AS10B	22.7	AS3	21.8
DB16		25.6	BLANK	0.0	AS38B	24.4	RH134	34.8
BLANK		0.0	RH1289	36.2	AS18B	38.2	RH74	22.0
DB5		28.1	AS16	38.3	AS66B	39.0	RH126	33.1
HR2-1		32.2	DB20	28.9	AS66B	39.1	RH38	33.6
HR2-2		28.3	DB3	32.0	AS29A	25.5	RH128	28.3
HR2-4		29.7	DB18A	22.4	AS28B	37.8	RH125	32.0
DB12		28.8	DB19 (+4)	23.2	DB7	40.7	RH11	30.9
HR1-1		22.0	RHB2	23.5	DB8	32.6	AS8	22.0
AS12A		24.4	DB19 (-10)	25.5	DB14	28.3	RH137	34.8
DB22		25.5	DB19	26.8	AS50B	37.8	RH72	29.7
HR3N-1		37.7	AS61A	33.2	AS57	26.4	F	34.8
HR1-1		22.2	DB18	24.4	AS62A	34.8	DB11	28.1
RH128L		22.6	DB20	28.3	AS17	25.1		
AS71B		23.2	RH40	23.2	AS15	22.2		
AS33A		23.0			AS50B	37.7		

Analysis Na_2O % oxide

Method

Remarks (value - bl.) * $\frac{\text{Oxide wt}}{2 \times \text{Na wt}}$ $\times 10^{-4}$

$\frac{61.982}{45.980}$

Date	Job	Sheet
/ /		/

Requested by

Project

Analyst

Calculations checked by

Sample No.	Tube No.	% Na_2O		% Na_2O		% Na_2O
	148	0.512	2-2	0.198	3S-2	2.833
	145	2.129	1-2	1.414	3S-1	2.330
	132	1.878	1-3	1.436	DG2	2.726
	79	3.906	21 DE	2.495	16	1.569
	39	5.136	20	0.706	5	1.751
	126	4.000	19+10	3.227	4	2.533
	125	5.583	19-10	1.679	16	1.580
	72	4.219	12	1.725	13	2.091
	137	6.353	19+10	3.245	12	1.752
	145	1.232	18A	3.643		
	124	5.115	9	1.870		
	138	7.104	18	1.266		
	128c	4.717	8	2.668		
	40	3.822	7	2.169		
	38	5.223	1	3.420		
	134	6.226	DE 11	1.738		
	128a	6.150	24	2.605		
	128c	4.953	23	2.104		
	11	2.163	3N-1	3.044		
	5	5.218	22	1.600		
	128	5.912	3	2.516		
	HR 2-1	1.704	14	1.467		
	2-2	0.152	15	1.350		
	2-4	0.172	17	1.440		
	2-3	3.565	15	1.430		
	1-1	2.439	6	2.387		

Date	Job	Sheet
/ /		/

Analysis ....
Method ....

Requested by ....
Project ....
Analyst ....
Calculations checked by ....

Remarks ....

Sample No.	Tube No.	CaO %		CaO %		CaO %				
	1	1.044	128c	3.865	24	7.382				
	2	0.367	126	0.686						
	3	0.297	132	8.553						
	4	0.872	145	0.875						
	5	0.579	32	0.114						
	6	1.198	125	0.243						
	7	0.598	137	1.470						
	8	1.322	145	0.904						
	9	4.060	124	5.456						
	11	4.213	138	0.643						
	12	5.046	40	5.014						
	13	5.243	38	0.684						
	14	0.334	134	0.328						
	15	10.167	11	0.058						
	16	10.871	F	1.005						
	17	6.511	HR2-1	3.169						
	18	17.616	2-2	0.299						
	18A	2.801	2-4	0.281						
	19-10	10.117	2-3	1.635						
	19	5.985	1-1	7.623						
	19-10	11.667	2-2	0.301						
	79	7.495	1-2	0.731						
	72	1.995	1-3	0.614						
	128	0.828	3N-1	0.138						
	128a	0.263	35-2	0.615						
	128c	3.975	35-1	0.669						

Date	Job	Sheet
/ /		/

Requested by

Project

Analyst

Calculations checked by

Analysis

Method

Remarks

Sample No.	Tube No.	K_2O %		K_2O %		K_2O %					
145		1.983	2-2	2.152	35-2	1.393					
148		0.385	1-2	2.301	S-1	2.129					
132		1.478	1-3	2.514	2	2.632					
74		0.116	21	0.903	16	1.369					
32		1.123	20	2.037	5	4.028					
126		3.757	19+10	0.490	4	2.557					
125		1.667	19-10	1.085	16	1.321					
72		2.492	18	1.560	13	1.304					
137		0.452	19+10	0.488	12	1.287					
145		2.011	18A	0.154							
124		0.113	9	1.388							
138		0.389	18	0.954							
128c		0.225	8	1.956							
40		0.103	7	1.529							
38		0.036	DB1	2.082							
134		0.049	DB11	1.425							
128a		0.107	DB24	0.690							
128c		0.096	DB23	1.471							
11		2.674	3N-1	1.282							
F		0.537	22	1.008							
128		0.043	3	2.738							
2-1		0.310	DB14	1.587							
2-2		3.031	6	1.418							
2-4		3.178	14	1.568							
2-2		0.851	15	1.425							
1-1		0.006	6	2.323							

Analysis MnO

Method

Remarks

Date	Job	Sheet
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Requested by

Project

Analyst

Calculations checked by

Sample No.	Tube No.	MnO %		MnO %		MnO %				
148		0·560	2-2	0·093	35-2	0·066				
145		0·152	1-2	0·052	35-1	0·055				
132		0·095	1-3	0·043	2	0·126				
74		0·173	16, 21	0·061	16	0·065				
37		0·022	20	0·056	5	0·104				
126		0·086	19+10	0·109	4	0·161				
125		0·030	19-10	0·104	16	0·067				
72		0·099	19	0·026	13	0·100				
137		0·032	19+10	0·111	12	0·128				
145		0·148	18A	0·192						
124		0·167	9	0·073						
138		0·032	18	0·118						
128c		0·143	8	0·120						
40		0·182	7	0·033						
38		0·044	1	0·110						
139		0·069	11	0·088						
128a		0·064	24	0·169						
129c		0·148	23	0·071						
11		0·010	3N-1	0·013						
F		0·031	22	0·076						
128		0·025	3	0·092						
2-1		0·266	14	0·083						
2-2		0·043	15	0·032						
2-4		0·032	17	0·079						
2-5		0·039	15	0·074						
1-1		0·121	4+6	0·085						

Analysis MgO %

Method

Remarks

Date	Job	Sheet
/ /		/

Requested by

Project

Analyst

Calculations checked by

Sample No.	Tube No.	MgO %		MgO %		MgO %				
148		0.453	2-2	1.861	3S-2	2.741				
145		3.443	1-2	2.584	3S-1	2.379				
132		3.264	1-3	2.240	2	1.662				
74		2.662	21	3.510	16	3.878				
32		0.809	20	2.935	5	1.799				
126		0.279	19+10	5.855	4	1.743				
125		1.130	19-10	2.801	16	3.900				
72		1.832	19	3.675	13	3.376				
137		0.307	13+10	5.927	12	2.981				
145		3.691	18A	6.721						
129		6.568	9	2.907						
138		1.400	18	3.059						
129c		1.993	8	1.602						
40		11.365	7	0.855						
35		1.613	1	2.151						
134		0.452	11	3.558						
128a		1.165	29	2.740						
128c		7.072	13	4.141						
11		1.604	3N-1	1.017						
F		1.149	22	4.213						
128		0.477	3	1.862						
2-1		6.719	DB14	5.367						
2-2		1.819	DB15	4.007						
2-4		1.507	17	4.683						
2-3		0.997	15	4.106						
1-1		6.256	6	1.627						

Date	Job	Sheet
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Analysis FeO %
Method

Remarks

Requested by
Project
Analyst
Calculations checked by

Sample No.	Tube No.	FeO %		FeO %		FeO %				
148		94.747	2-2	10.442	35-2	5.629				
145		6.603	1-2	4.827	35-1	4.855				
132		4.993	1-3	5.081	2	5.500				
74		9.332	0021	4.997	16	5.165				
39		1.593	20	4.335	5	4.873				
126		3.000	15+10	5.221	4	5.267				
125		7.980	19-10	4.231	16	4.441				
72		5.618	19	4.767	13	4.713				
137		1.688	19+10	5.991	12	5.167				
145		6.457	18A	7.933						
129		9.101	9	5.101						
138		3.854	18	5.825						
128c		8.270	8	4.909						
40		10.680	7	2.247						
29		2.973	1	5.456						
134		1.799	11	4.877						
128a		2.569	24	10.202						
128c		9.390	23	5.489						
11		1.928	2N-1	1.521						
F		2.922	22	4.463						
128		3.174	3	6.016						
MR 2-1		3.762	14	7.332						
2-2		10.792	15	4.966						
2-4		13.211	17	5.815						
2-3		2.480	15	4.531						
1-1		12.548	6	5.037						

Date	Job	Sheet
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Analysis ....
Method ....

Requested by ....
Project ....
Analyst ....
Calculations checked by ....

Remarks ....

Sample No.	Tube No.	SiO_2 %		SiO_2 %		SiO_2 %		SiO_2 %		
DB 6		66.75		82.37	1	63.16		74.67		
10		64 40	1-2	66.75	9	63 76		75 74		
4		55 47		50.06		49.64		71 46		
35-2		68.04	1	68.25		74 45	FH 174	52.85		
2		66.32	DB23	61 93		54.13	FH 158	74.24		
2-3		78 52	21	62.05		0	FH 148	20.54		
15		55.84	13	65 09		51 13	FH 145	62 26		
35-1		62 53	FH 132	52 85		53 70		75.10		
17		54 77	FH 39	74 45		50.71		0		
6		66.97	29	46.43		48.57		46.64		
16		54.77		0		52.20	FH 59	74.45		
		0	FH 128a	77.45		81.73	FH 74	47.07		
5		60.12		81.94		83.44	FH 126	70.82		
2-1		68.89	20	61.83		83 65	FH 58	71.89		
2-2		60 55	3	68.46		54.56	FH 128	81.04		
2-4		63 54	18A	47.92		80.87	FH 125	68.46		
12		61.52	19+10	49.64	7	87.02	FH 11	66.11		
1-1		47 07	FH 132	50.28	9	69 75		47 07		
		52 20	19-10	54 56	14	60.55	FH 137	74.45		
22		54 56	19	57 34		80.87	FH 72	63.54		
311-1		80 66		71 03		56.48	F	74 45		
1-1		47.50	18	52 20		74.45	11	60.12		
FH 128c		48 35	20	60.55		53.70				
		49 67	FH 140	49.64		47 50				
		49.21				80.66				

APPENDIX VI

PREPARATION OF XRD SAMPLES

PREPARATION OF XRD SAMPLES

5 samples were selected- DB6,126,128,128c and 132.

It was decided after discussion that a concentrated sample would be needed, with concentration of the feldspar grains and hopefully liberation of the phyllosilicates, which would confuse the feldspar traces.

The separation technique below was selected;

It was decided that the +200 mesh sample from the whole rock analyses would be used as i)the sample is sorted and ii)the sample may be examined by binocular microscope.

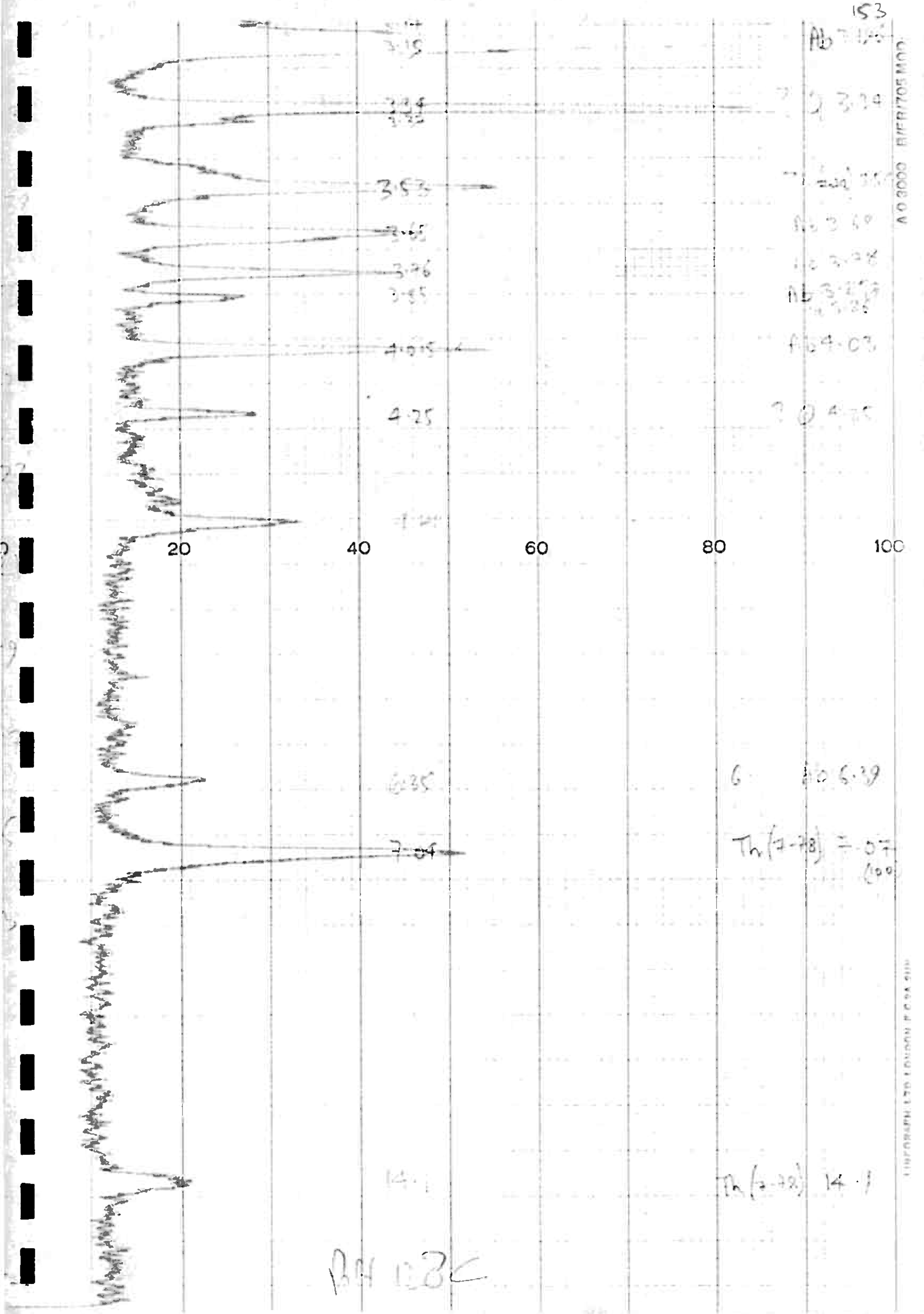
The samples were poured over clean computer paper and the fine polar phyllosilicates were retarded on the paper. The product was suitably concentrated after 2 pourings.

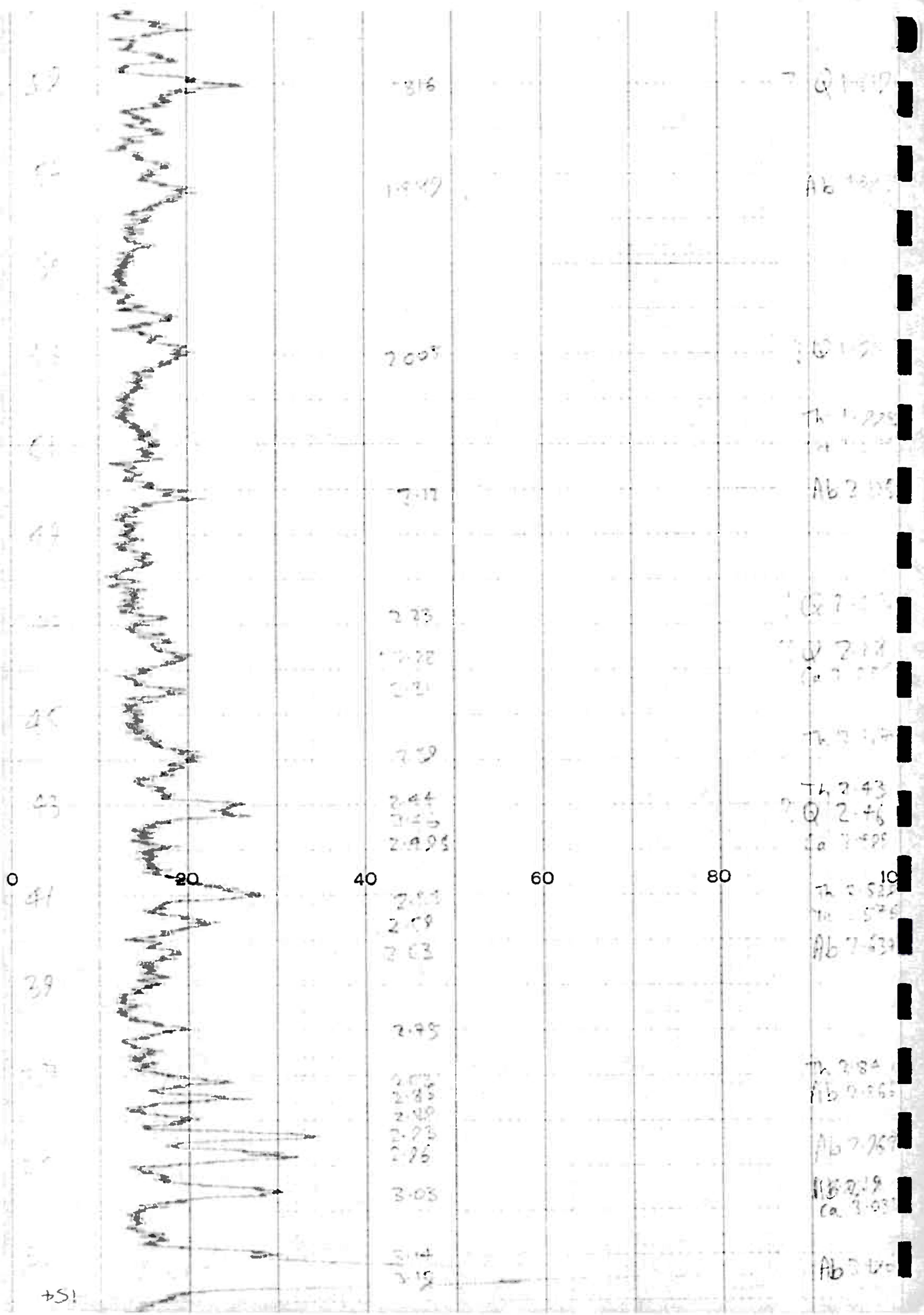
The sample was then crushed to -300 mesh and mixed with alcohol,applied to a smear mount and allowed to dry.

The samples were then run, the traces shown in Appendix VII.

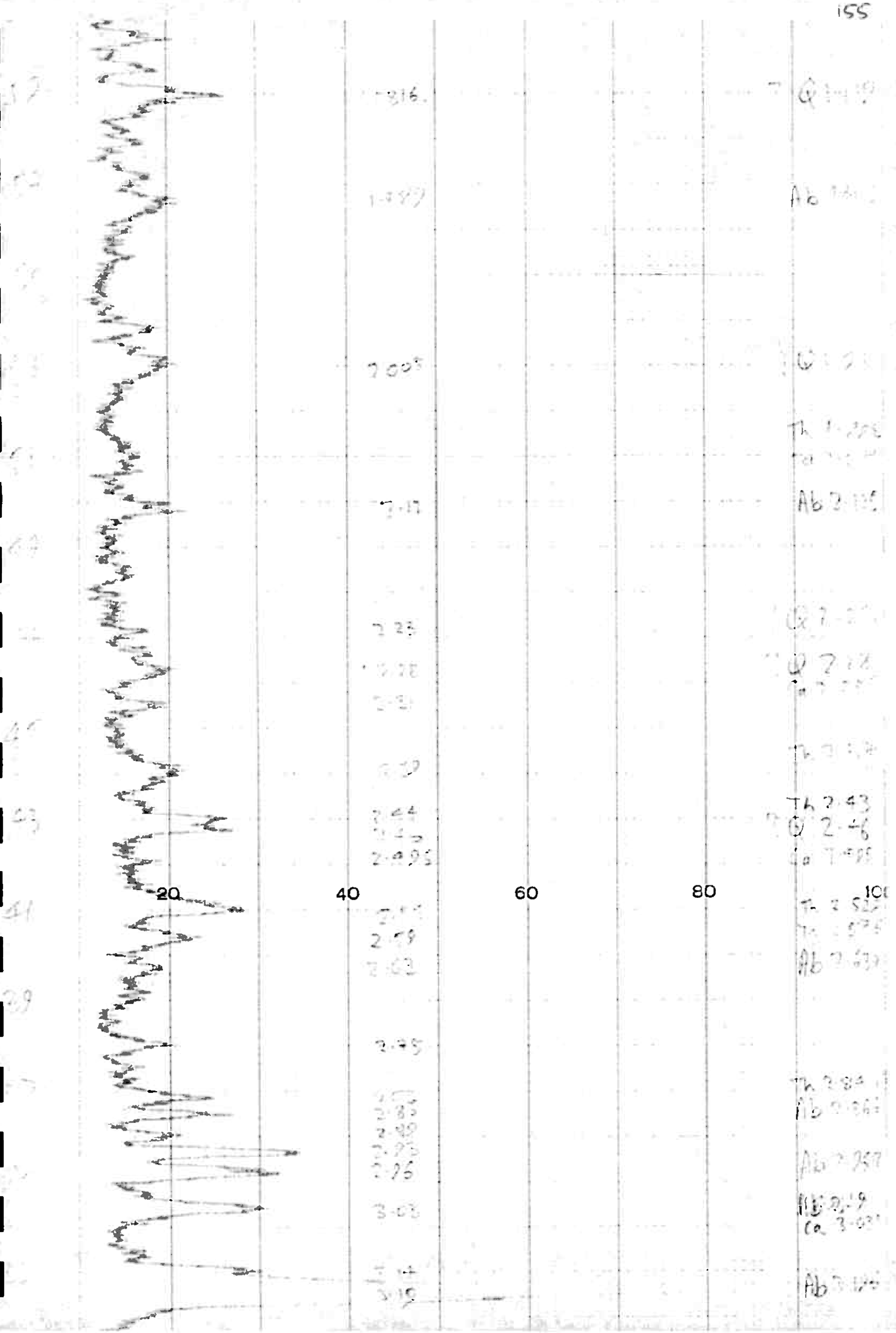
APPENDIX VII

XRD TRACES


20
40
60
80
100
3.19
3.34
3.53
3.65
3.76
3.85
4.05
4.25
6.35
7.04
14.1
Ab 3.19
3.34
Ab 4.03
Ab 6.39
Th (7-7.8) 7.07
Th (7-7.8) 14.1



0
20
40
60
80
2·95
3·03
Ab
Th 2·43
Q 2·46


20
40
60
80
2.59
2.85
2.96
3.03
TA 2.43

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