



Bergvesenet

Postboks 3021, 7002 Trondheim

Rapportarkivet

Bergvesenet rapport nr BV 2140	Intern Journal nr	Internt arkiv nr	Rapport lokalisering	Gradering Fortrolig
Kommer fra ..arkiv Sulitjelma Bergverk A/S	Ekstern rapport nr "532100004"	Oversendt fra	Fortrolig pga	Fortrolig fra dato:
Tittel Halo-geochemistry projekt. R.S.M. transfer report. April 1985. Elementsonering.				
Forfatter COOK N		Dato 1985	Bedrift Sulitjelma Gruber A/S	
Kommune	Fylke	Bergdistrikt	1: 50 000 kartblad	1: 250 000 kartblad
Fagområde	Dokument type	Forekomster		
Råstofftype	Erneord			
Sammendrag A review of progress in project 141 (Halo-geochemistry) with information on regional geochemistry and spilitisation, sulphide and silicate mineralogy and mineral compositions. (Including notes on the application of chlorite compositions to prospecting.) Kloritt. Elementsonering.				

SULITJELMA BERGVERK AS

Tlf: (081) 40500

Telex: 64065 SUA-N

Ref.nr: 532.100.

Krt.nr:

Prj.nr: 141

År: 1985

Forfatter: NIGEL COOK

Ant:

Tittel: HALO-GEOCHEMISTRY PROJECT.
R.S.M. TRANSFER REPORT
APRIL 1985

Fordeling
Sulitjelma:

Ngå,koord:

X1: Y1: Z:

X2: Y2:

Sulis koord:

X3: Y3: Z:

X4: Y4:

Resyme:

A review of progress in project 141 (HALO-geochemistry) with information on regional geochemistry and spilitisation, sulphide and silicate mineralogy and mineral compositions. (including notes on the application of chlorite compositions to prospecting.)

Andre:

Kommentar:

TRANSFER REPORT

NIGEL JOHN COOK

The Geochemistry and Mineralogy of the Sulitjelma
Ore bodies, and their associated hydrothermal
lithologies.

APRIL 1985

Explanation

This report is presented as a transfer report and is a resume of progress. Early work is reviewed and an account of current work is given.

Three previous reports are included in this report. These have been submitted to A/S Sulitjelma Bergverk during the past year, as routine progress reports. These are intended to provide an overview of topics worked upon. Diagrams and maps in these reports are copies of copies and some loss of clarity has occurred.

A handwritten signature in black ink, appearing to be 'Nigel Cook', with a long horizontal flourish extending to the right.

Nigel Cook

R.S.M. London

20 April 1985

CONTENTS

Introduction	2
Summary of initial work	5
Current work	8
Geochemistry	9
Sulphide mineralogy	19
Silicate mineralogy	24
Time plan	34

Introduction

This project was initiated in August 1982 by A/S Sulitjelma Bergverk, Norway in co-operation with RSM, London to run as a pilot project for one year, prior to a CASE studentship being awarded for a further duration.

The project set out to investigate the geochemistry of the Sulitjelma Cu-Zn orebodies, Northern Norway and their associated hydrothermal lithologies with a view to the development of techniques which could be used in the exploration for new orebodies. The Sulitjelma ore deposits are a group of 20 or more massive sulphide bodies with a total tonnage of 35 million tonnes. The average grades are 1.8% Cu and 0.6% Zn and the chief sulphide minerals are pyrite, pyrrhotite, chalcopyrite and sphalerite. The ore deposits are hosted by the Sulitjelma Amphibolite group of basic volcanics which have been regionally metamorphosed to middle amphibolite grade. These are interpreted as belonging to the Sulitjelma Ophiolite complex.

The deposits are recognised as being typical of the exhalative volcanogenic massive sulphide deposits of the Caledonides. The Sulitjelma ores occur typically within an ore horizon (Henceforth termed 'ore zone') and these layers can be readily traced over considerable distances. These zones, comprising chlorite schists and breccias, often keratophyric and extremely tectonised are considered to represent a mixture of highly altered tuff and exhalite horizons. These ore zones provide potential for the application of vectors of trace element distributions to point towards new

ore deposits lying within that ore zone.

Much of the project has been concerned with the detailed mapping, sampling, and analysis of particular ore zones around known ore bodies in the area to build up a picture of geochemical distributions that can serve as a model for exploration techniques. Use has been made of microscopy, microprobe and S.E.M. techniques to study petrographically both the sulphide and silicate phases observed.

The aims of the project were:

1. To establish the geochemical distribution of elements in the different ore bodies comprising the Sulitjelma group of deposits.
2. To provide information on the partition of trace-elements between phases and to identify the mineralogical controls upon the geochemical distributions.
3. To investigate the distribution of elements within each orebody, and its different component ore facies and to inspect trends of zonation which are present.
4. To apply vector profiles to the ore zones, tracing the distributions of selected elements away from known ore bodies and to relate the data to the exploration context.
5. To investigate the distributions of elements within the host and country rocks. This was to include exhalite horizons, associated clastic sediments and spilitised and non-spilitised amphibolites.
6. To establish the role which hydrothermal alteration, metamorphism, mineralogy and tectonism plays upon the

modification of the geochemical distributions.

7. To use the geochemical data to assist in studies useful to the understanding of the origin of the deposits.

The work has involved extensive underground work and the use of the drillcore archive of A/S Sulitjelma Bergverk. To date, some 1400 samples have been collected and analysed for a broad spectrum of major and trace elements, comprising about 35 000 individual analyses.

Summary of initial work

Initial work took place on the Giken II orebody (approx. 5 million tonnes grading 1.8% Cu and 0.5% Zn). The ore is massive to banded and is underlain by a disseminated ore-type reminiscent of a stockwork zone. The hanging wall is made up of phyllitic sediments. Sampling of the orebody and its sidewall lithologies was carried out underground and from drillcore material that cut the Giken ore zone. Sufficient information was obtained to construct a sequence of profiles perpendicular to the axis of the ore body and to draw contour maps for selected elements.

Patterns of element distribution within the orebody were revealed by the contour maps. For example, Ag was shown to be enriched in one particular area of the orebody. Comparison was made between trace-element distributions and known geological features such as veining. There was some evidence to suggest that some elements (Sb, Bi and Mo) were concentrated in and around veins, and it can be suggested that these represent late re-located material.

The profiles across the ore body indicated that many of the elements were anomalous within the orebody when compared to ore zone lithologies at a distance from the mineralisation. The two populations were treated to statistical analysis and a list of potentially useful elements was compiled. Profiles showing the distributions of these

elements across the axis of the orebody were subsequently smoothed out and certain of the elements were 'measured' to assess their potential as vectors that might be used to direct the geologist along the ore zones towards undiscovered mineralisation. Certain elements seemed suitable for further investigation: Ag, Co, Cd and Zn being those which showed the largest definable haloes around the Giken II deposit, with haloes of about 400 m. extending laterally away from the orebody. No halo patterns were found in the sediments in the hanging wall, and a zone of highly potassic alteration was identified in the footwall rocks.

The trace-element haloes recognised around the Giken II orebody have been used as a tested model and my work has been concerned with following up these patterns in two ways:

1. Studying a profile across the sagmo orebody to see if the same patterns apply.
2. To extensively sample an area of active exploration (The Sulitjelma South ore-field). About 200 samples have been collected from drillcore in this area and the samples have been analysed for the elements which showed the best patterns around the Giken II deposit. Vector techniques have been applied. Subsequent drilling has revealed trace mineralisation and that has coincided with my predictions using lithogeochemical vectors, based on the earlier studies of the Giken II orebody.

A further 60 samples have been collected from surface outcrops in the same area and represent a profile along an

ore zone, 4 km. in length. Two known ore-bodies lie along this profile and a further 4 anomalies have been recognised in my study. Drilling on one of these anomalies has located strong mineralisation, although not of economic thickness.

It is anticipated that further sampling during the Summer of 1985 will enable me to complete a geochemical picture of the ore zones in this exploration area.

Figs. i and ii illustrate an example of trace-element concentrations in samples collected along a profile across the axis of the ore body.

Geochemistry with reference to spilitisation and tectonic setting - A review

Using geochemical data of samples collected from surface outcrops of Sulitjelma Amphibolite distant to the ore deposits (15 to 20 km. away) and comparing this with average analyses of published data for marginal sea basalts, it can be shown that, in terms of major element geochemistry, these rocks are only slightly altered. In contrast to this, amphibolites collected from the volcanic pile above the ore deposits are seen to be highly altered with respect to a wide range of major and trace elements. (see table 1)

Plots can be used to show that the rocks from Sulitjelma itself, are highly spilitised, with many elements being gained and lost. The ratio $\text{Na}_2\text{O}/\text{K}_2\text{O}$ is used as an index of spilitisation since Na gain and associated Ca loss is characteristic of spilitisation. Fig. 1 illustrates the spilitic nature of the altered rocks compared to the unaltered equivalents. The so called "immobile elements" Ti, Zr and Y are also very different in the two groups of rocks. Whilst Ti changes very little, there is evidence to suggest that Y and Zr are far from immobile during the spilitisation process. Fig. 2 shows how the elements Zr and Cr behave with increasing $\text{Na}_2\text{O}/\text{CaO}$ during alteration. The implied mobility of Zr, Y, Cr and possibly other elements as well means that, using trace elements to provide information on tectonic setting is dangerous, when using the analytical data for the altered rocks. As a result, I have constructed discriminant plots based on the data set for

the unaltered basalts. The majority of the plots suggest that the basalts are from a marginal basin setting of some sort. (see figs. 3 and 4) That the basalts are from a MSB, rather than a MORB setting is amplified by a sequence of Rare Earth Element (REE) analyses (see fig. 5).

It is clear from the chemical analyses of the basalts at a distance from the ores, that, considerable loss of Cu has taken place. This suggests that the convective cell operates over very large distances, with copper being leached out, even though little alteration takes place.

A series of mass-balance calculations have been carried out to express the changes in chemistry from the unaltered to altered rocks. Three models are applied: (see table 2)

1. An isovolumetric model, in which there is no volume change.
2. A model with static Zr. This would involve huge volume loss, and such is the magnitude of this, that it is considered highly unlikely that it has happened.
3. A model of constant Ti. A small gain in volume is implied. This model is accepted as best fitting the available data.

Net gains: SiO_2 K_2O Na_2O Ba Sr Zr

Net losses: MnO CaO FeO* MgO Cu Cr

No change: TiO_2 Al_2O_3

Fig. 6 is an attempt to illustrate diagrammatically, the relative gains and losses involved.

The next stage was to consider the "alteration lithologies" around the orebodies, principally the potassic schists and the

chloritic schist horizons. The potassic schists characteristically underlie the ore and may represent a feeder zone. The chlorite schists represent a distal component of exhalite origin, coupled with highly altered tuffaceous volcanite which were at the rock-sea interface during hydrothermal activity. This zone was also probably the plane of considerable tectonic movement. In view of this, a direct geochemical comparison, as was carried out between altered and unaltered volcanics is not scientifically meaningful. However, it is seen that some of the elements depleted from the volcanic pile, are strongly enriched in these lithologies, notably MgO (see table 3). Higher Mn in the chloritic schists is attributed to an exhalite component. CaO is very low, extracted from the rocks, and lost into seawater. The potassic schists differ little from the chloritic schists, except for their higher levels of K_2O and of the related alkali trace elements (Sr, Ba, Rb.) It is seen as very important to relate this geochemistry to the mineralogical expression of alteration.

	Average (n=29) Marginal Basin Basalts (Literature)	Average (n=31) Slightly Altered Basalts	Average (n=17) Highly Altered Basalts
SiO ₂	49.6	49.8	54.1
K ₂ O	.4	.6	.8
Na ₂ O	3.2	3.3	4.4
CaO	11.0	9.0	5.9
MgO	7.6	7.4	4.7
FeO*	8.5	7.5	7.7
Cu	90	40	25
Sr	199	195	235
Ba	62	63	149
Zr	107	113	170

Table 1 A comparison of geochemistry of altered and unaltered volcanics from Sulitjelma with an average Marginal Sea Basalt. The slightly altered basalts were collected 15-20 km. from the Sulitjelma deposits. The altered rocks were collected from the volcanic pile above the ores.

Table 2

	Isovolumetric Model	Ti-static Model	Zr-static Model
SiO ₂	+ 9%	+ 15%	- 31%
TiO ₂	- 5%	no change	- 40%
K ₂ O	+ 117%	+ 125%	+ 37%
Na ₂ O	+ 38%	+ 45%	- 13%
Al ₂ O ₃	- 4%	+ 1%	- 40%
MnO	- 12%	- 8%	- 45%
CaO	- 46%	- 43%	- 66%
FeO*	- 10%	- 5%	- 43%
MgO	- 39%	- 36%	- 62%
Cu	- 72%	- 71%	- 83%
Ba	+ 140%	+ 152%	+ 51%
Sr	+ 18%	+ 24%	- 26%
Zr	+ 59%	+ 66%	no change
Cr	- 48%	- 45%	- 67%

Changes in element concentration during spilitic alteration of the Sulitjelma Amphibolites.

Three models are presented (i) Isovolumetric model

(ii) Ti-static model

(iii) Zr-static model

See text for explanation.

Fig 1a $\text{Na}_2\text{O}\%$ plotted against $\text{CaO}\%$ for altered and unaltered volcanics.

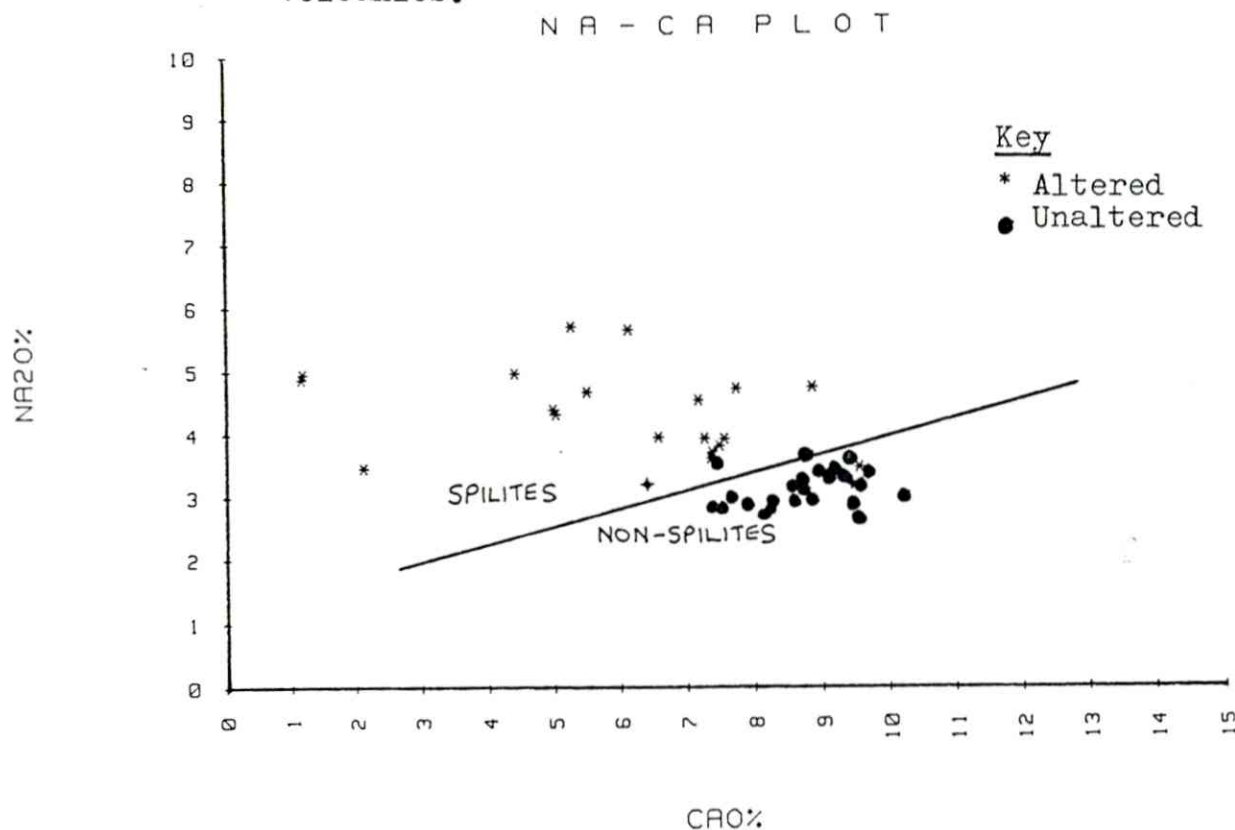
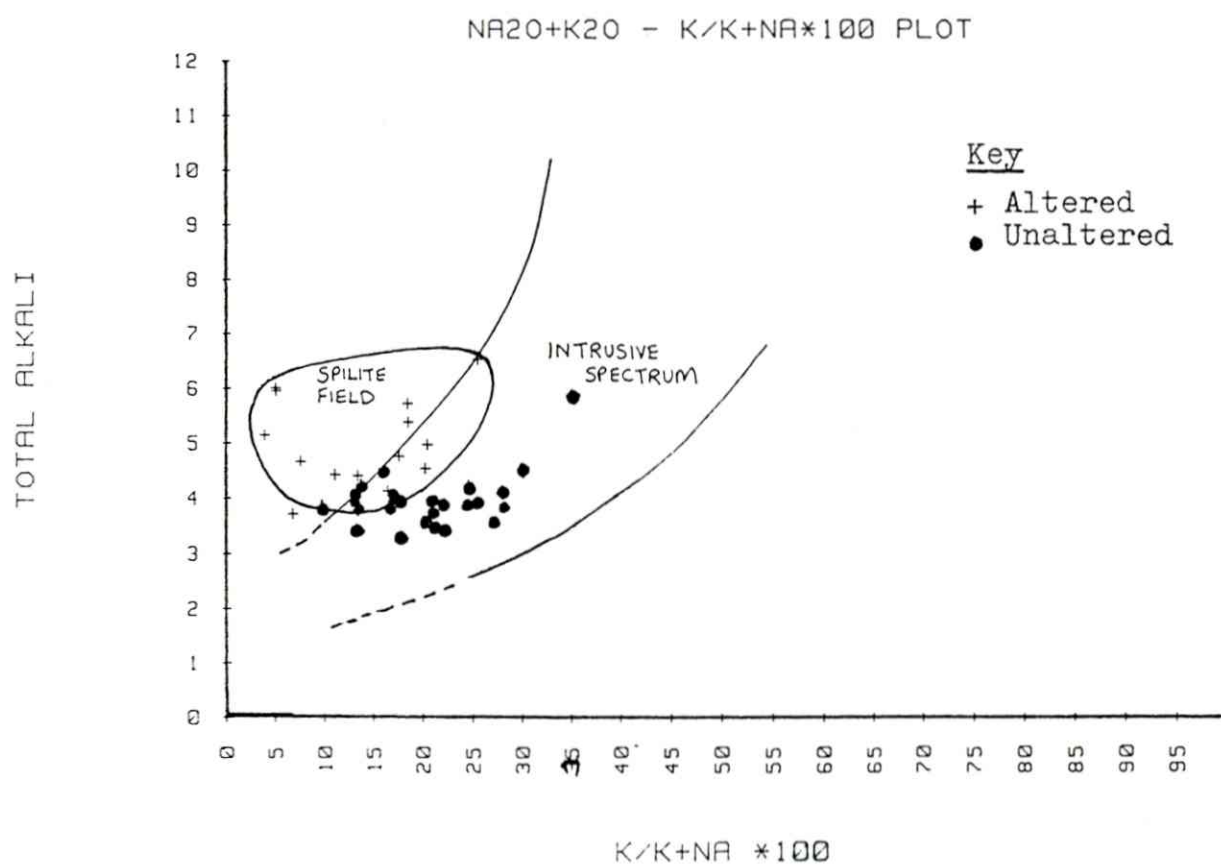
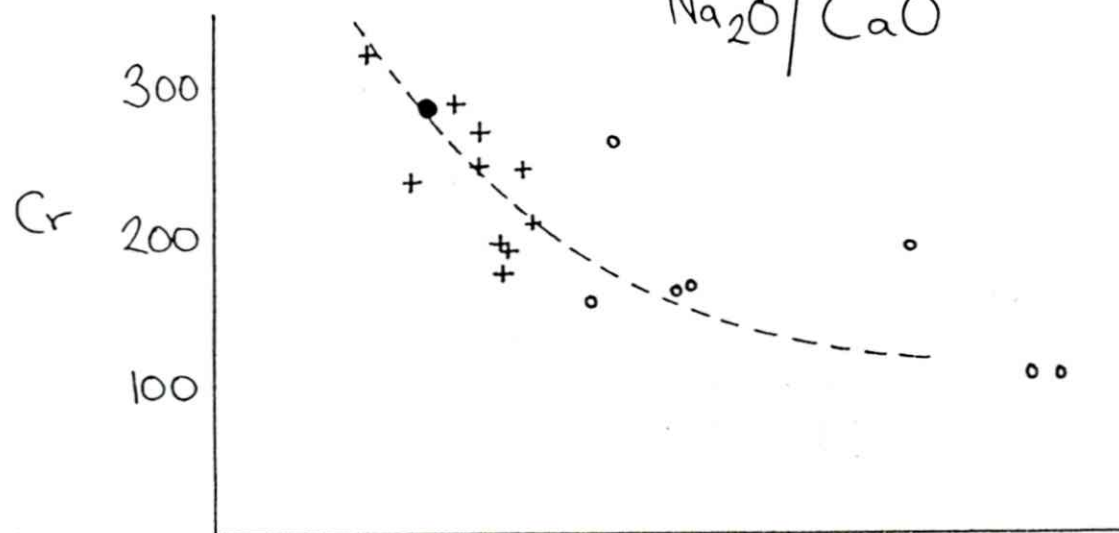
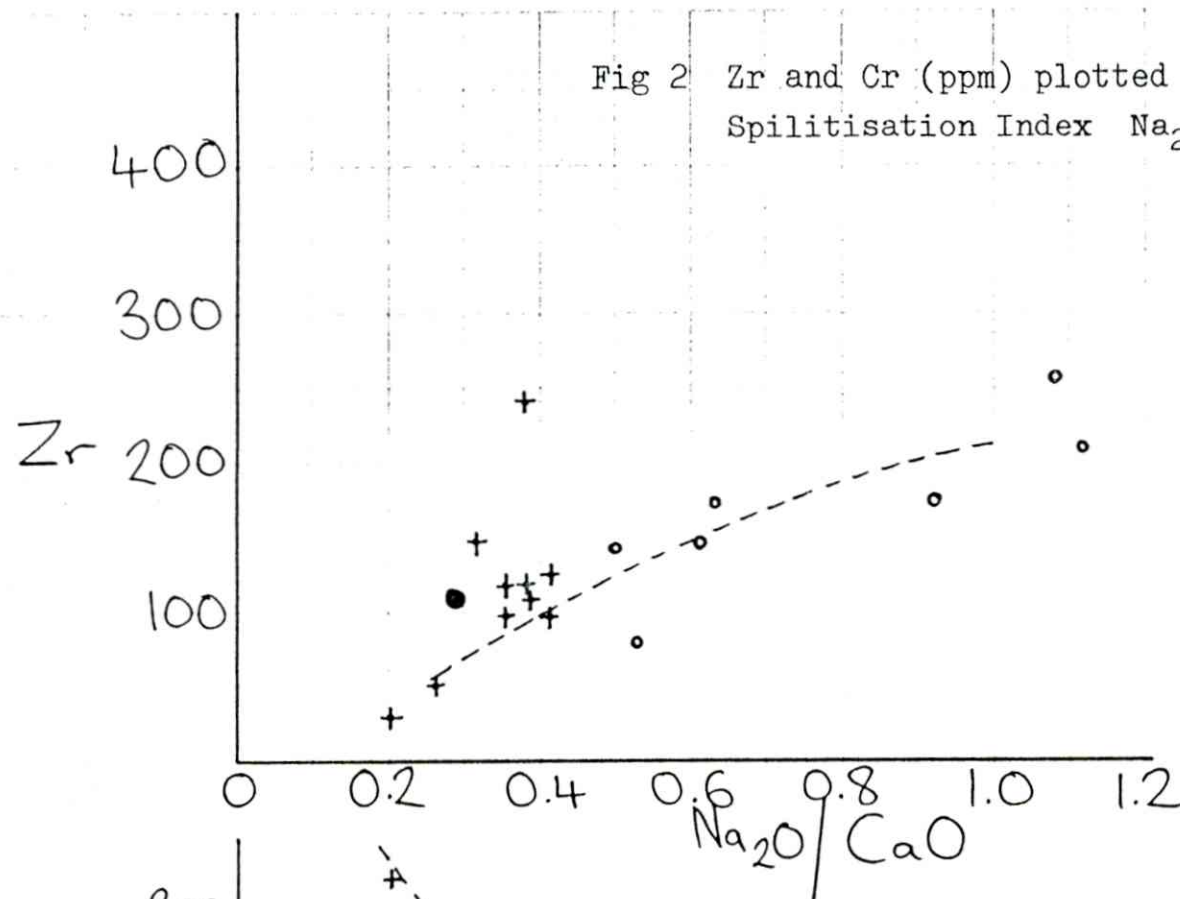


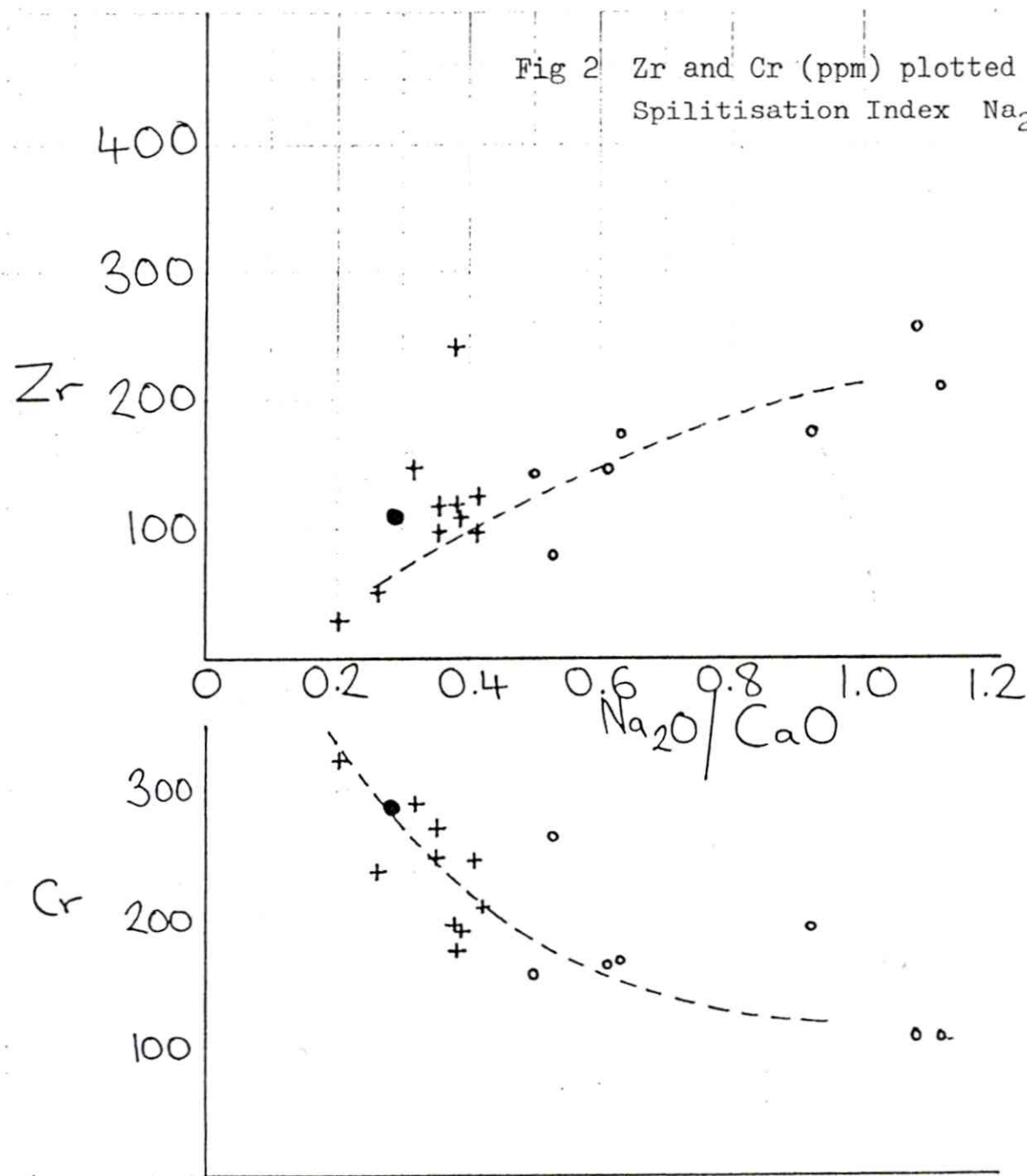
Fig 1b $\text{K}/\text{K}+\text{Na} \cdot 100$ plotted against total alkali for altered and unaltered volcanics.





Key

- + Unaltered volcanics
- o Altered volcanics
- Typical MORB



Key

- + Unaltered volcanics
- o Altered volcanics
- Typical MORB

Fig 3 $\text{TiO}_2\%$ plotted against FeO^*/MgO showing the tholeiitic trend of volcanics from Sulitjelma.

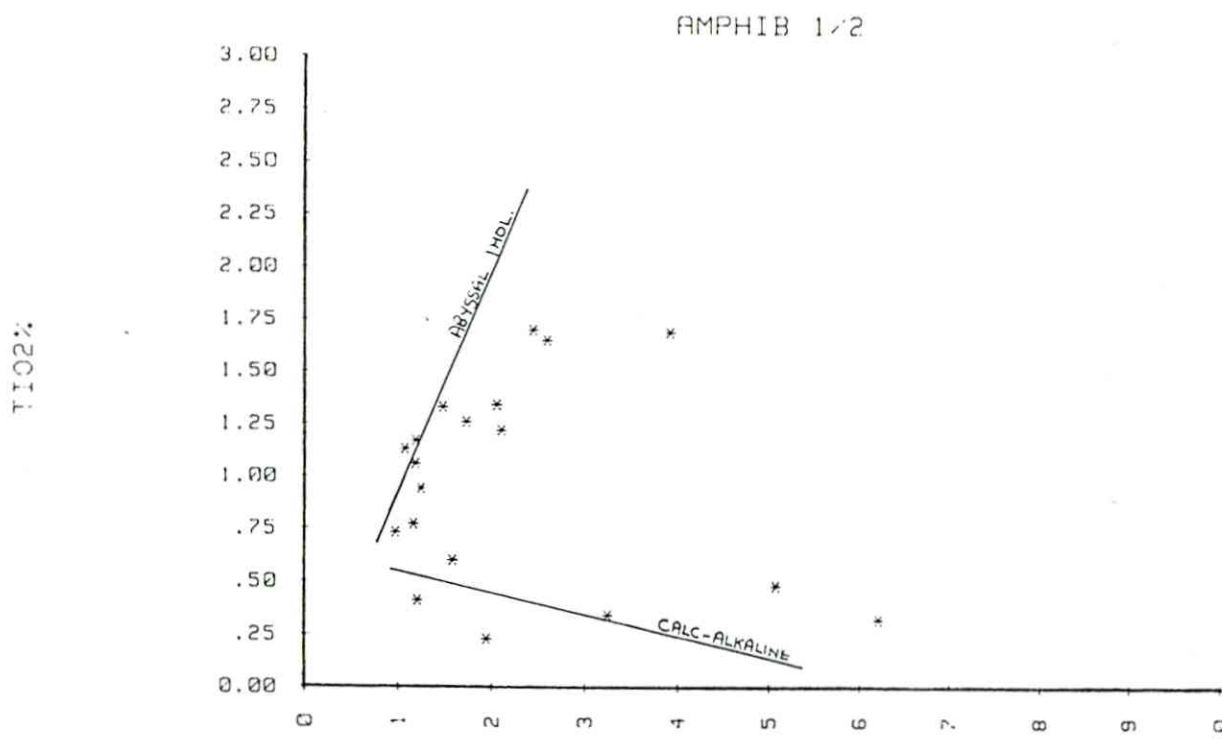
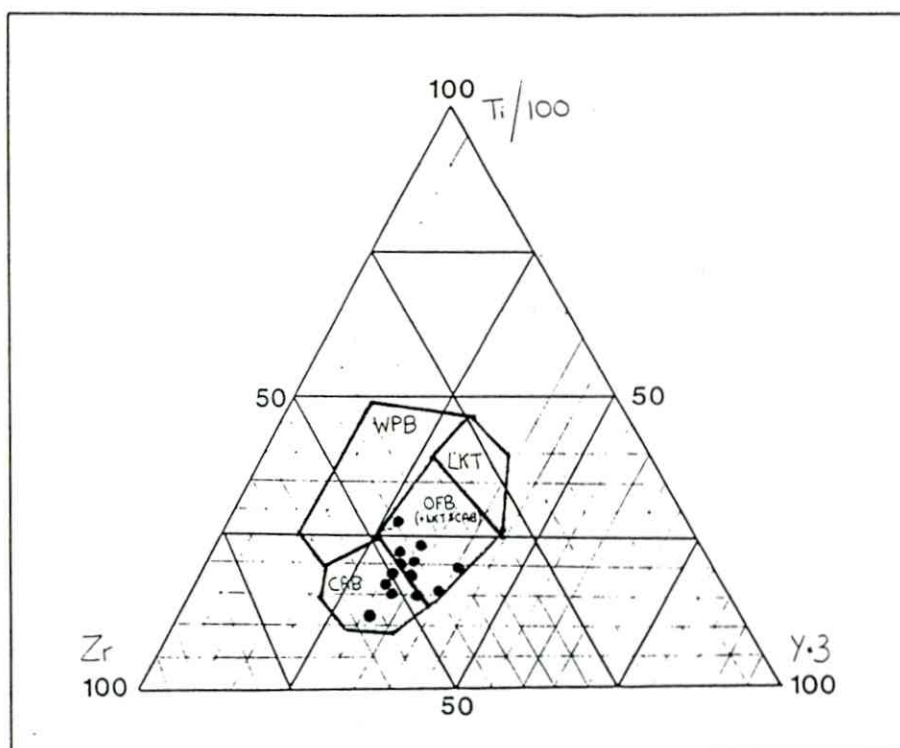
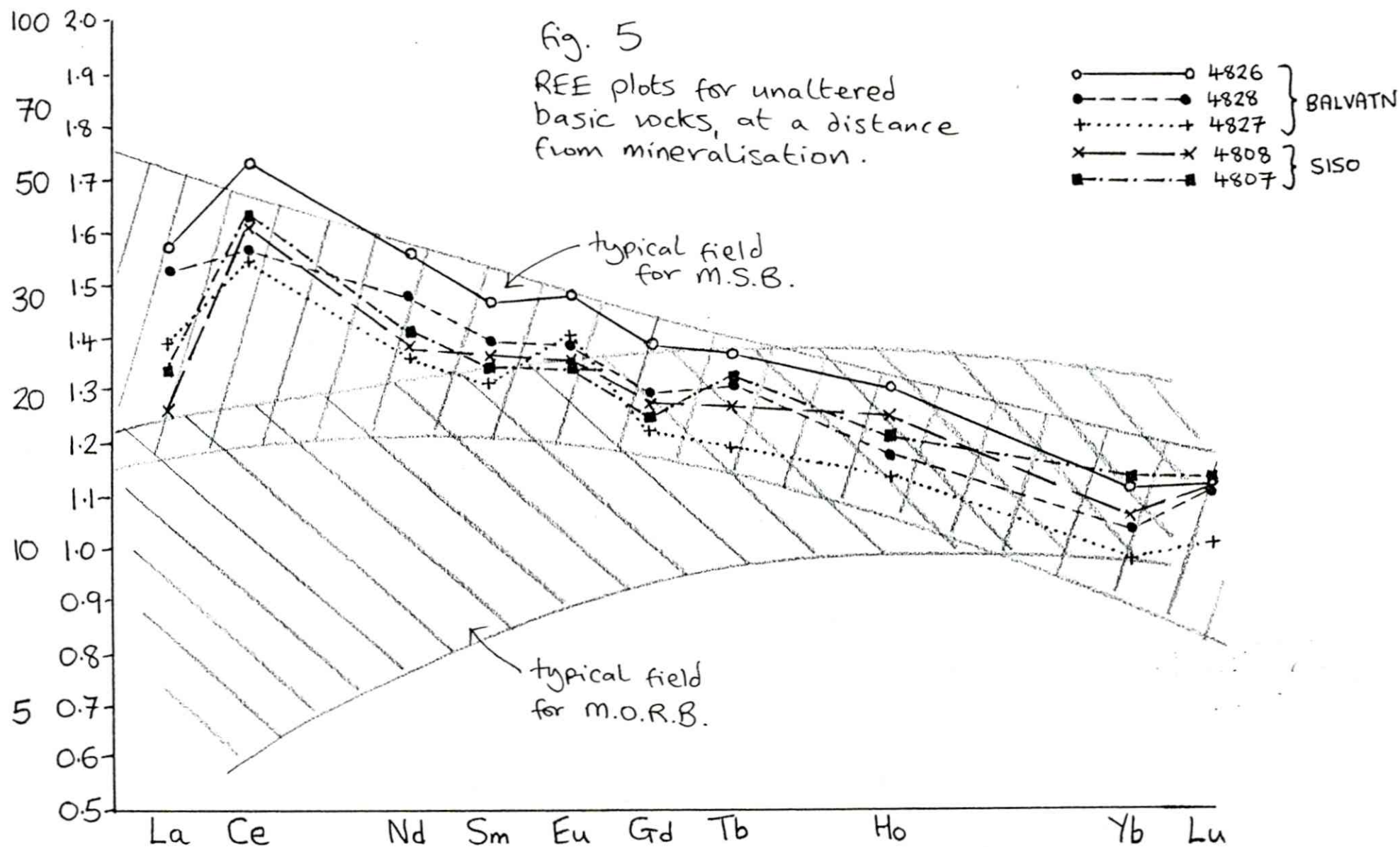


Fig 4 Triangular discriminant plot Zr-Ti-Y for volcanics from Sulitjelma. Clustering within OFB field is seen.





Sulphide Mineralogy and Petrography: A Brief Synopsis

Reflected light microscope, microprobe, and S.E.M. techniques have been used to investigate the sulphide minerals present in the Sulitjelma ores, and together with the chemical analyses of 90 sulphide mineral separates, have been used to discover how trace elements are distributed in the ores. Sulphide and sulphosalt parageneses are described and photographed on a routine basis.

The sulphide mineralogy at Sulitjelma is dominated by pyrite, pyrrhotite, chalcopyrite and sphalerite, although 16 other sulphides, sulphosalts and associated minerals have also been observed, but in much smaller concentrations.

Pyrite

Pyrite is the dominant iron-sulphide in the Giken II deposit. It occurs as fractured and crushed crystals and as deformed euhedral crystals displaying durchwebung textures and may grow to considerable size (several cm.), and appear twisted and rotated. Very often, these will contain silicate inclusion traces which may curve according to deformation of fracture zones. The large deformed pyrites are more common in the disseminated ores than the massive ores and commonly co-exist with euhedral pyrites that have recrystallised after tectonic movement of the ore zone. These euhedral pyrites, termed 'metablastic' are commonly twinned and annealed to form triple junctions at 120° . Inclusions of chalcopyrite, pyrrhotite and magnetite are common within

the pyrite crystals. Further interesting textures are seen in some ores from Mons Petter Mine, where small rounded pyrite grains are observed in a matrix of magnetite. This texture is unique to this locality.

Pyrrhotite

Pyrrhotite is the dominant iron-sulphide phase in the ores of Sagmo Mine, where it may be primary in origin, rather than a metamorphic manifestation of earlier pyrite. Its favoured formation over pyrite may have been induced by different f_{S_2} and temperature conditions at a site distant to the pyritic bodies of Giken, Charlotta, Mons Petter and Hankabakken.

Where pyrrhotite is found in Giken II mine, it is restricted to concentrations in ores which are interpreted as being re-mobilised and are located in the roof of the main orebody. Pyrrhotite is rare in the massive ores of Giken (often only as inclusions within pyrite) and effectively absent in the disseminated ores. Deformation twinning is commonly seen. A tectonoclastic texture is seen in the South Ore field area, in which rounded quartz and mica fragments up to 1 cm in diameter, are found rolled in a mass of pyrrhotite.

Chalcopyrite

Chalcopyrite is found in the massive ores of Giken II as an interstitial matrix to the pyrite metablasts. It also commonly occurs within the fractures in deformed pyrite crystals, often intergrown with sphalerite. Very rarely, an

isolated chalcopyrite crystal may be found. Masses of massive chalcopyrite, often containing high concentrations of Ag and Au minerals and containing exsolution lamellae of cubanite, occur irregularly throughout the orebody. Additionally, chalcopyrite is found as small rounded inclusions within pyrite, often with cubanite.

Sphalerite

Like chalcopyrite, sphalerite occurs in the matrix of the ores around the pyrite crystals, but only rarely is it found as inclusions within pyrite. Both chalcopyrite and sphalerite are often found restricted to certain distinct bands within the ore.

Other minerals

The following have been observed:

Galena PbS

Molybdenite MoS_2

Arsenopyrite FeAsS

Gudmundite FeSbS

Bornite Cu_5FeS_4

Cubanite CuFe_2S_3 as exsolution lamellae in chalcopyrite

Bismuthinite Bi_2S_3 Within galena

Tetrahedrite $(\text{Cu,Fe})_{12}\text{Sb}_4\text{S}_{13}$

Freibergite $(\text{Cu,Ag,Fe})_{12}\text{Sb}_4\text{S}_{13}$ contains 17% Ag

Electrum (Ag,Au) with Au:Ag ratios of 50:50 to 80:20

Argentite Ag_2S

Wehrlite (Bi-Ag telluride) ??

Breihauptite NiSb

Aurostibite AuSb_2

Hessite - Empressite (Ag Tellurides)

Niccolite NiAs

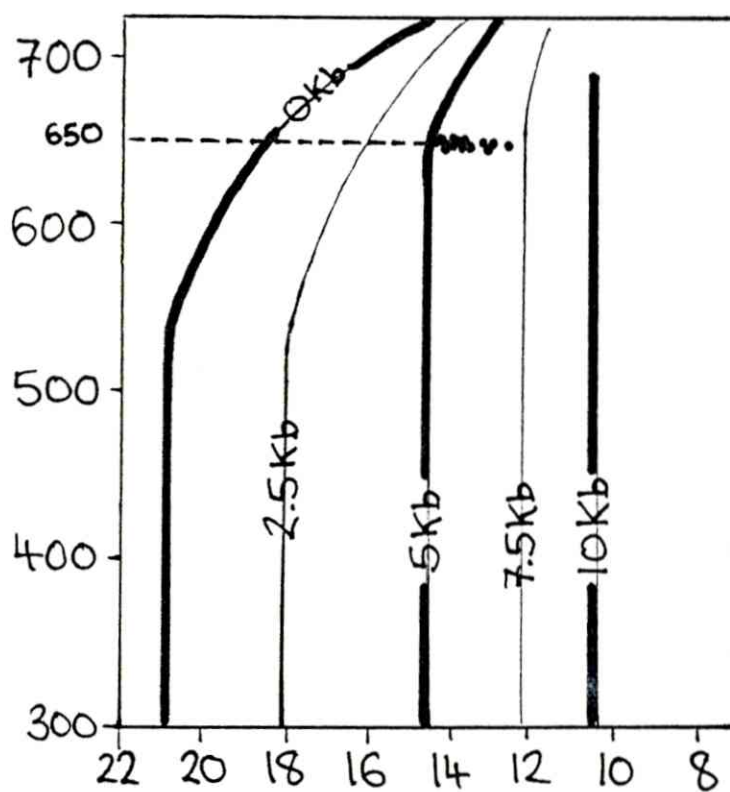
The rare minerals are typically found within fractures in pyrite and there is an association of Ag, Au with Sb, Pb minerals, and also with sphalerite. Freibergite is commonly observed and is probably the major source of Ag in the ores. Antimony parageneses have been described from Sulitjelma by Ramdohr, who suggests that they represent a late modification to a pre-existing Pb-paragenesis. It seems likely that Ag and Au are also important constituents of this paragenesis with the concentrations of Ag-Sb-Au minerals resulting from processes as described by Ramdohr. Certainly, the mineral Breihauptite is relatively common in the ores and although always hosted within pyrrhotite, is seen to be replacing pre-existing galena.

Compositions of these rare minerals are being systematically studied using the microprobe and S.E.M. It is anticipated that more samples will have to be collected to get a better grip on the distribution of minor minerals throughout the ores.

Sphalerite Geobarometry

50 analyses of sphalerite, co-existing with pyrite and pyrrhotite have been made on the microprobe. Use of the sphalerite geobarometer of Scott (1979) infers maximum pressures of metamorphism of 8 kBar (see attached diagram.)

Temperature °C



Mol % FeS in Sphalerite

Sphalerite Geobarometry

The FeS content of sphalerites from Sulitjelma are plotted at a temperature of 650° c on the diagram of Scott (1979). Pressures of 5 - 7 kB are indicated.

Silicate Mineralogy and Petrography

The aims of my work have been:

1. The identification of silicate phases and the calculation of typical modal mineralogies of the main lithologies (unaltered metavolcanics, altered volcanics, chlorite-schist horizons, potassic zones, meta-sediments, acid-volcanics and keratophyres, and meta-intrusives.
2. To determine the influence of mineralogy upon chemistry. Which silicate minerals control the distribution of which major and trace elements?
3. Identification of evidence for the sequence of reactions that took place to produce the present-day silicate assemblages, and to find out what the original assemblages were. Also it is important to consider at what stage did certain key reactions take place:

Reactions induced by hydrothermal activity;

e.g. (Na-Ca) Plagioclase + SiO_2 + Na \longrightarrow (Na) Plag. + Qz

Reactions induced by prograde metamorphism;

e.g. Chlorite + Calcite \longrightarrow Actinolite + Quartz

Reactions induced by retrograde metamorphism;

e.g. Ca-amphibole + Epidote \longrightarrow Chlorite + Quartz + CaO
4. To gain information on the metamorphic conditions from mineralogical studies of assemblages.

e.g. P-T conditions implied by K-Al silicates.
5. To assess the influence on the silicate mineralogy by sulphides.

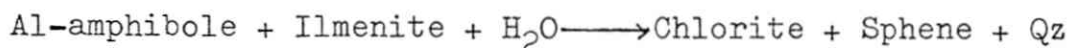
e.g. on the (Fe/Fe+Mg) ratio in chlorites and biotites.

The silicate mineralogy is considered here in terms of the major elements, whose distribution is governed by the silicate minerals.

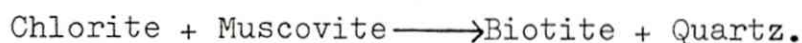
Titanium

Host Minerals: Sphene (Ubiquitous in all lithologies, often over 5% by mode. Ilmenite (much less common than sphene.) Hornblende (0.8% TiO_2) and Biotite (1.6% TiO_2), which is the major source of Ti in the potassic schists.

Reactions to form sphene may include:



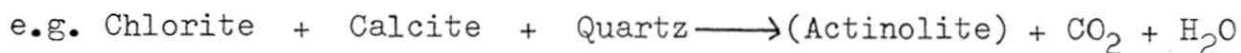
whilst Ti-Biotite is formed by:



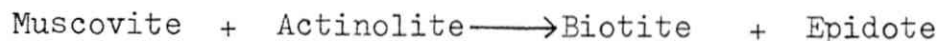
Sphene may have been formed during the hydrothermal stage of genesis, by a reaction of Ilmenite and Ca^{++} under low f_{CO_2} conditions.

Calcium

Prograde reactions incorporate Ca into amphiboles:



and into epidote-clinozoisite minerals:



Epidote occurs as worn porphyroblasts which are often zoned.

There is some evidence of retrograde reaction:



There is evidence to suggest that this CaO has entered plagioclase. Epidote bearing rocks have higher An contents of plagioclase.

Sodium

Plagioclase (Albite) is the main host for Na. In most samples the composition of plagioclase is between Ab₉₅ and Ab₁₀₀, the albitisation process having happened during initial Na-spilitisation.

Potassium

Main minerals: Biotite and its pre-cursor, muscovite.

Reactions to form biotite:

Muscovite + (Al-amphibole) \longrightarrow Biotite + Epidote

Chlorite + Muscovite \longrightarrow Biotite + Quartz

K is enriched into the rock by K-metasomatism,

Chlorite + Al + K \longrightarrow Serisite + (Fe,Mg) + H₂O

Some evidence of retrograde reactions are seen:

Biotite + H⁺ \longrightarrow Chlorite + (Fe,Mg) + K⁺ + Qz

Further reactions can take place to produce new K bearing minerals:

Ca-amphibole + Muscovite \longrightarrow Garnet + Epidote

Chlorite + Garnet + Muscovite \longrightarrow Biotite + Staurolite + Qz

Biotite + Staurolite + Qz \longrightarrow Kyanite + Biotite + Muscovite

Garnets and K-Al silicates are only very minor constituents of the Sulitjelma rocks. Kyanite is the only K-Al silicate seen. Two types of garnets are seen:

1. Zoned Fe-Mg (Almandine) garnets (see fig. 1)
2. Spessartine Mn garnets (greater than 50% Spessartine).

These are restricted to cherty exhalite bands.

Trace elements

Ba is found to be about 1.0% in muscovites from Sulitjelma.

Iron and Magnesium

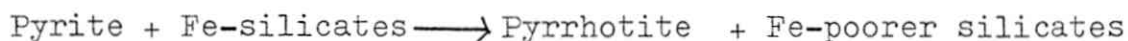
Host minerals: Amphibole, Chlorite and Biotite.

Figs. 2,3 and 4 show the compositions of amphiboles, chlorites and biotites respectively. The compositions are influenced by bulk rock composition and apparently, the distance from mineralisation.

It has been established that there is a correlation between $(\text{Fe}/\text{Fe}+\text{Mg})$ in chlorite and distance from mineralisation (see fig. 5). It is suggested that use of this ratio can be of use in exploration.

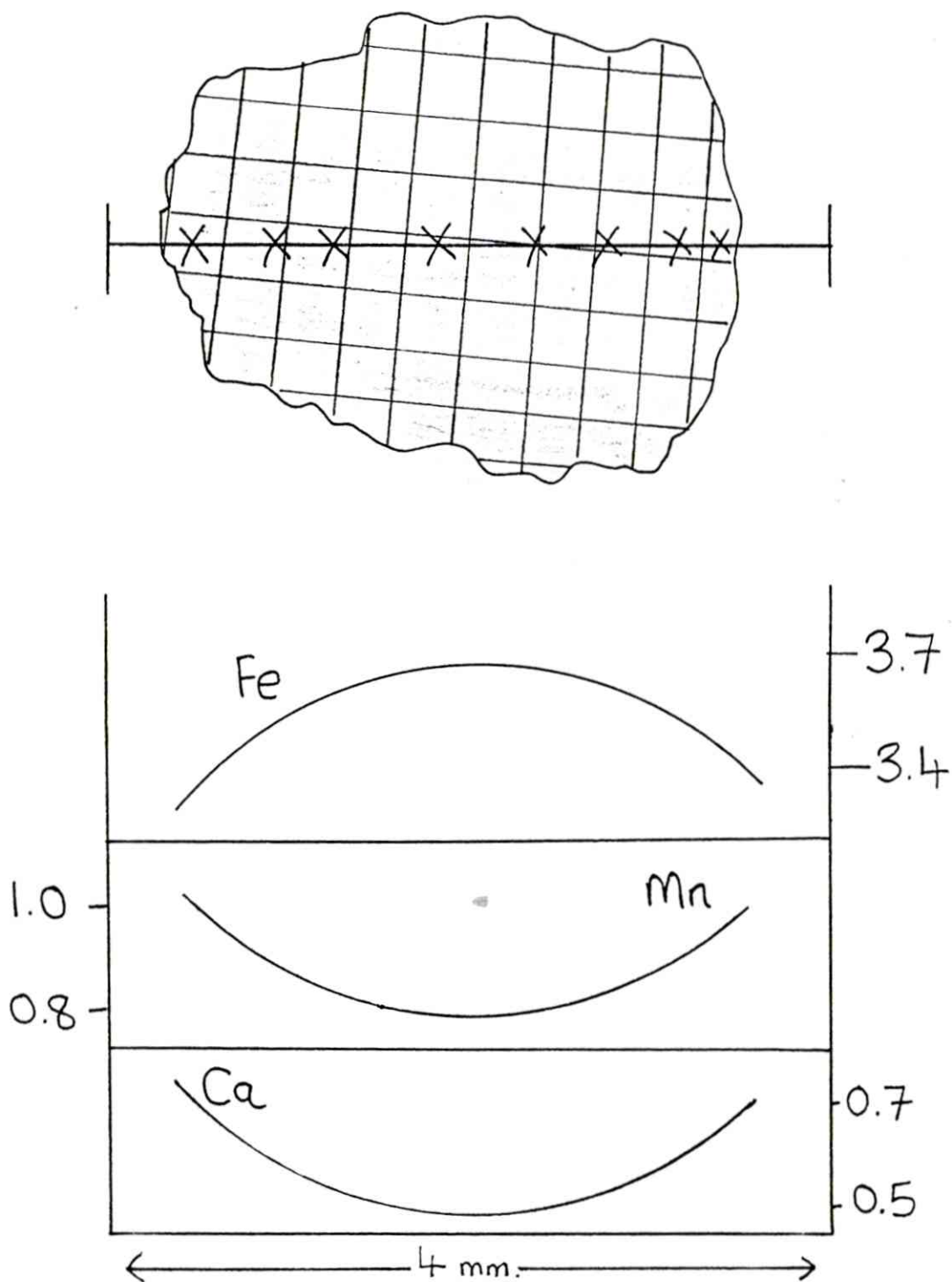
It has been further shown, that there is good correlation between $(\text{Fe}/\text{Fe}+\text{Mg})_{\text{chlorite}}$ and $(\text{Fe}/\text{Fe}+\text{Mg})_{\text{biotite}}$ where the two minerals co-exist, except that the ratio is always higher for biotite than for chlorite (see fig. 6) The two minerals are obviously co-genetic.

The influence of sulphides upon silicate mineralogy has been considered with respect to sulphur fugacities and the relative quantities of pyrite and pyrrhotite in the ores. The isogradic reaction of Thompson (1972) below, is suggested to explain the difference between the mineralogies of the two sulphide deposits studied (Pyrite + Biotite at Giken II) and (Pyrrhotite + Serisite at Sagmo).



Much more work remains to be done to clarify the sequence of metamorphic reactions at Sulitjelma and more in depth microscope and microprobe studies will have to be carried out.

fig. 1

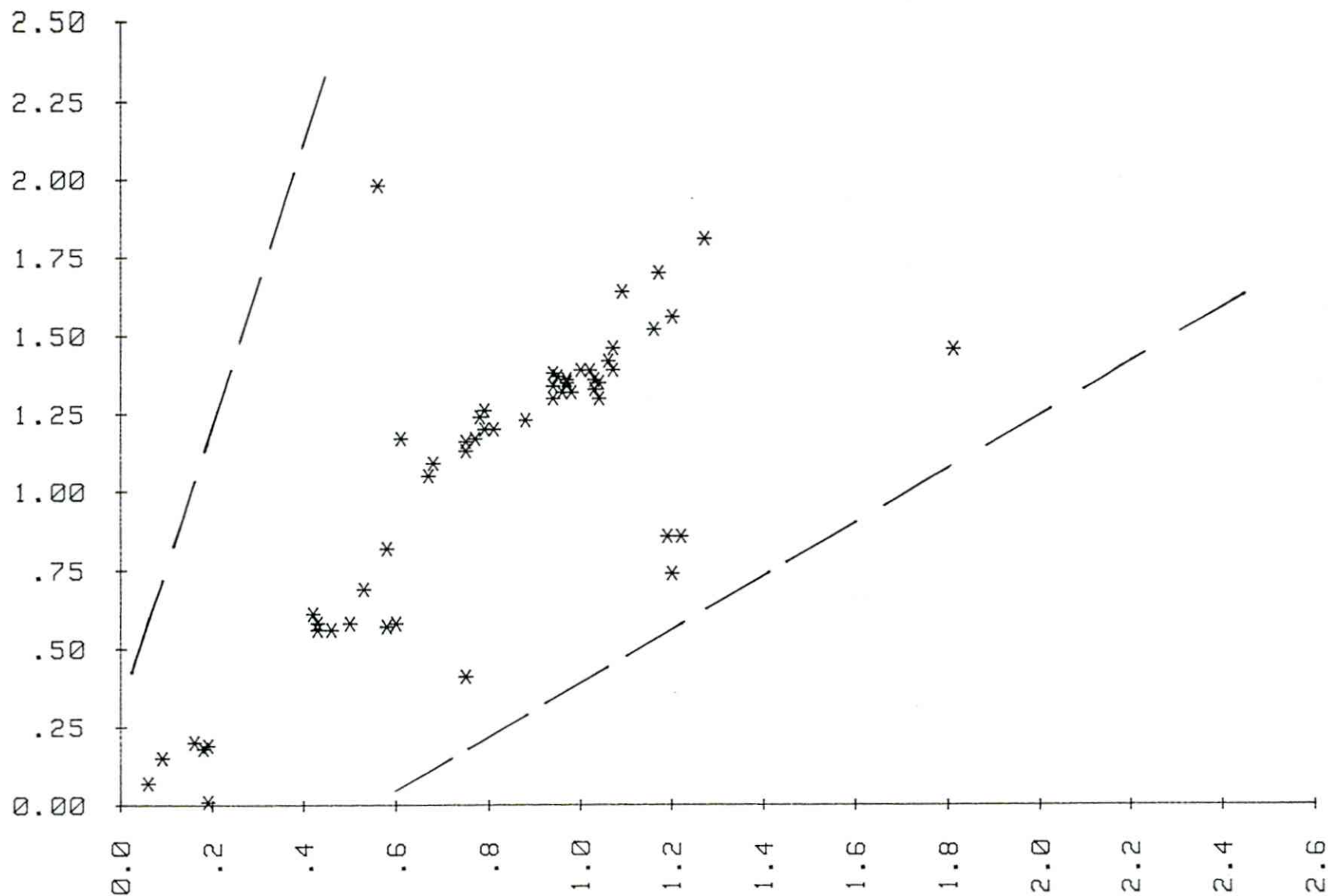


Schematic profile across a garnet crystal showing reverse zoning expressed in mol % Fe, Mn and Ca across the crystal.

fig. 2

AMPHIBOLE COMPOSITIONS

ATOM. PROP. [AL]4

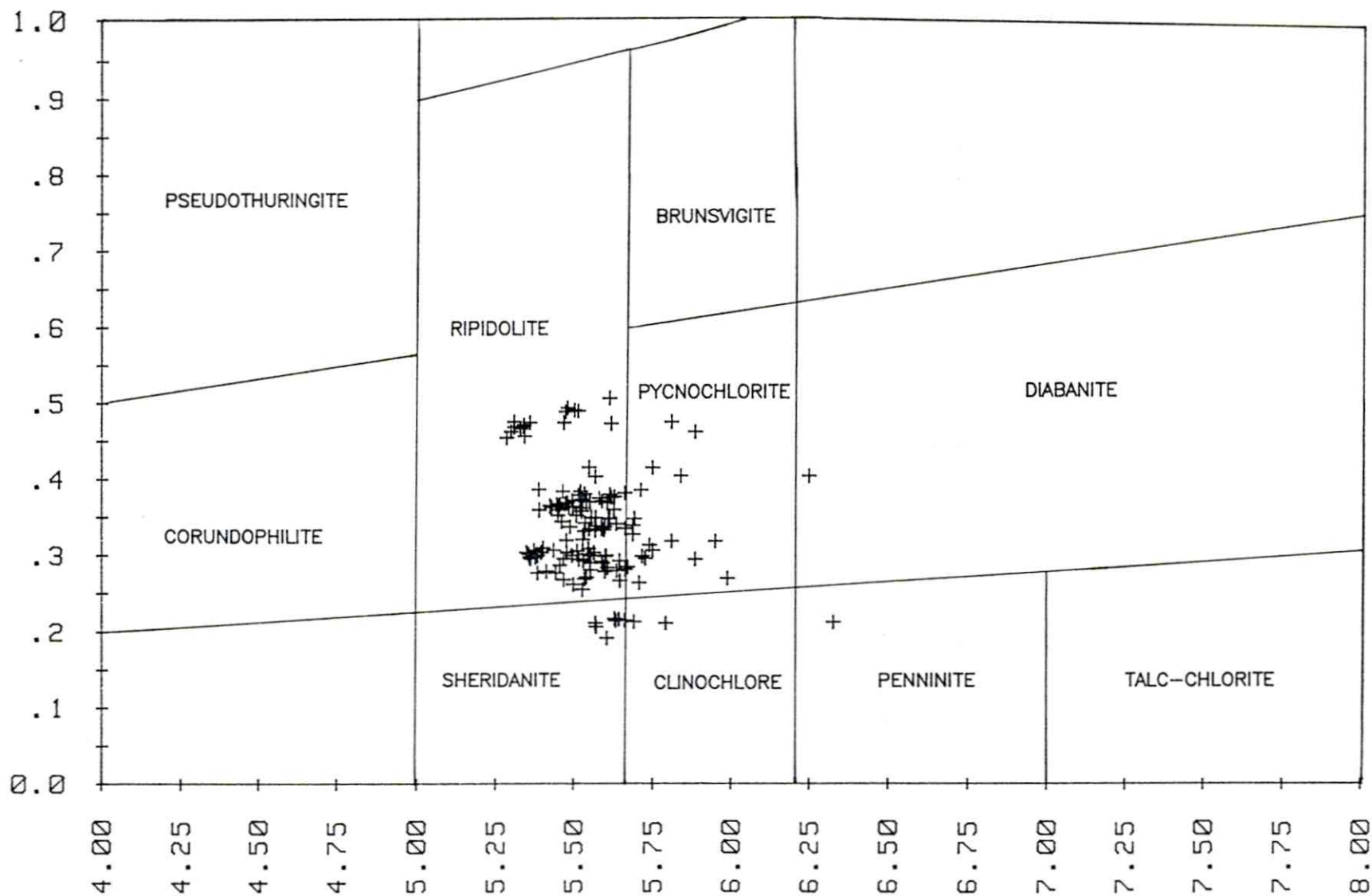


A.P. [AL]6 + TI

fig. 3

CHLORITE COMPOSITIONS

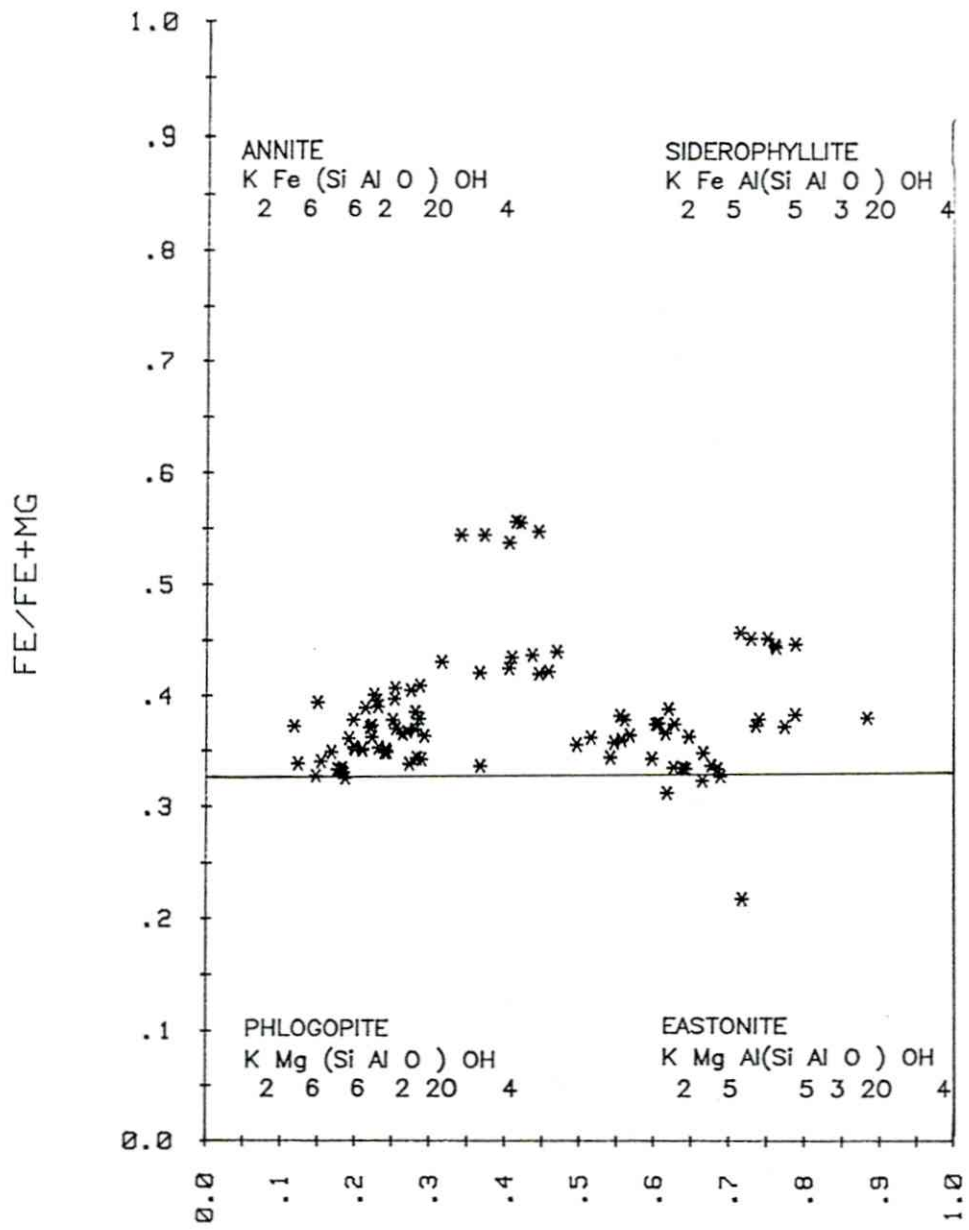
FE/FE+MG RATIO



NUMBER OF SI CATIONS

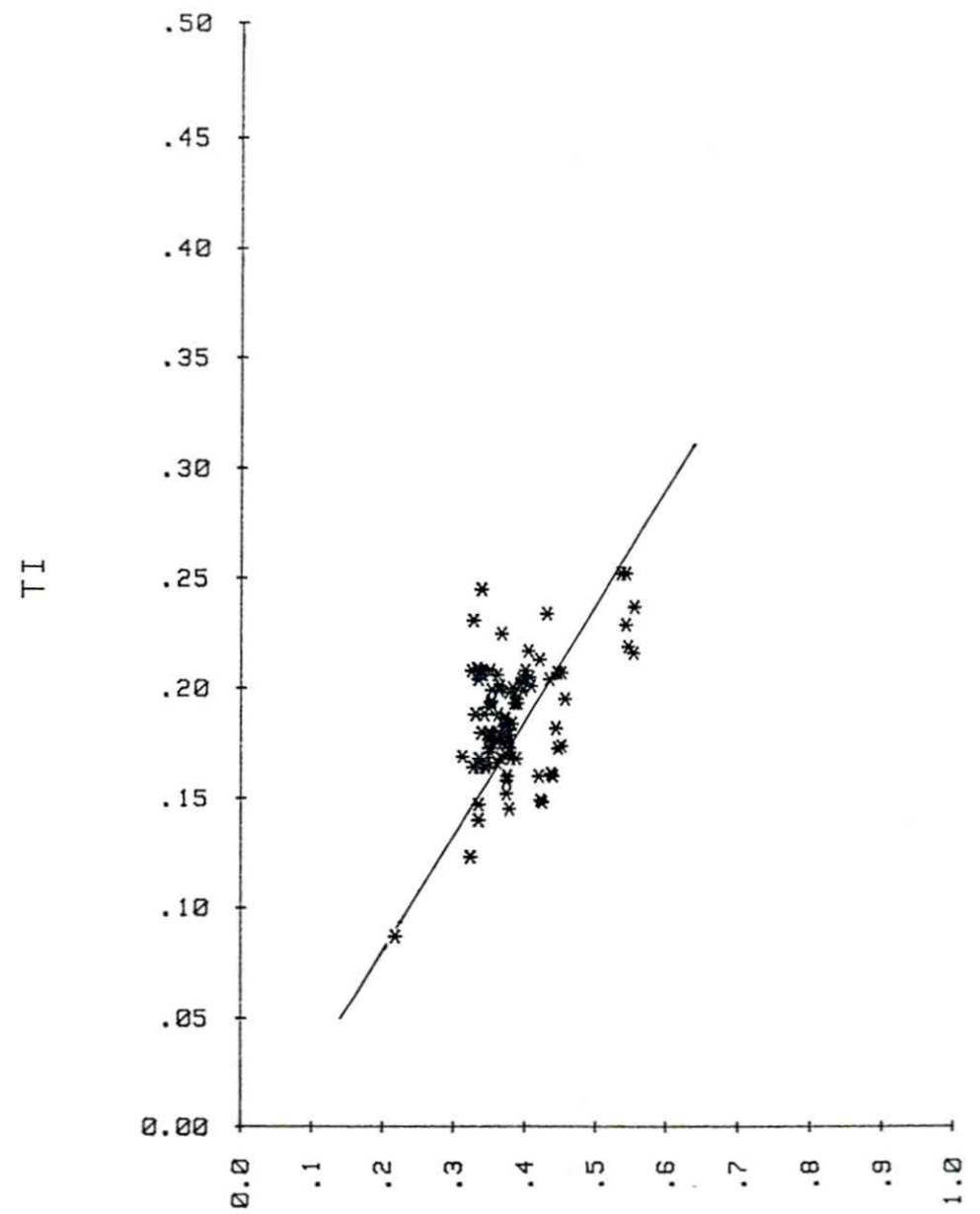
794

BIOTITE COMPOSITIONS

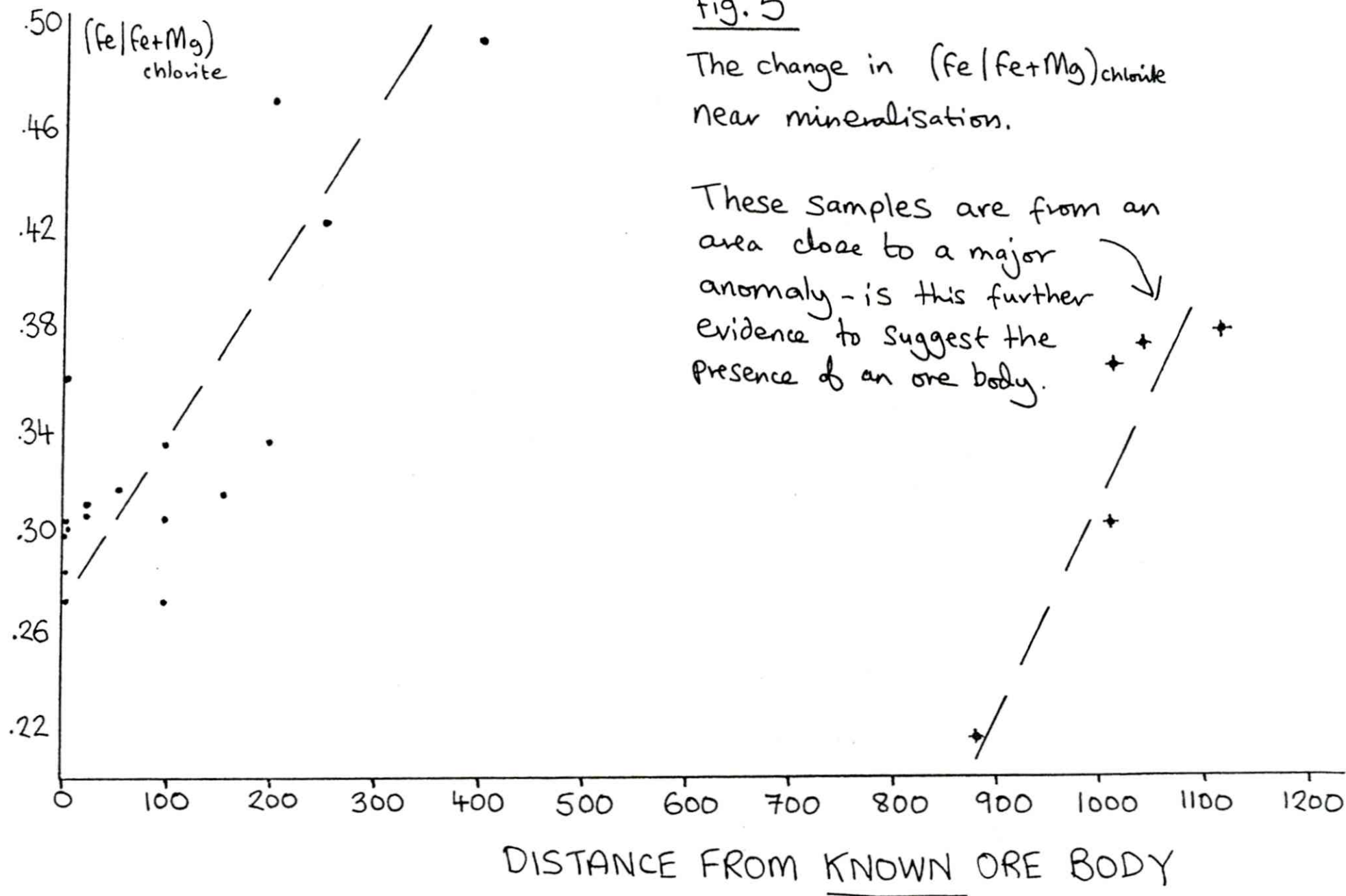


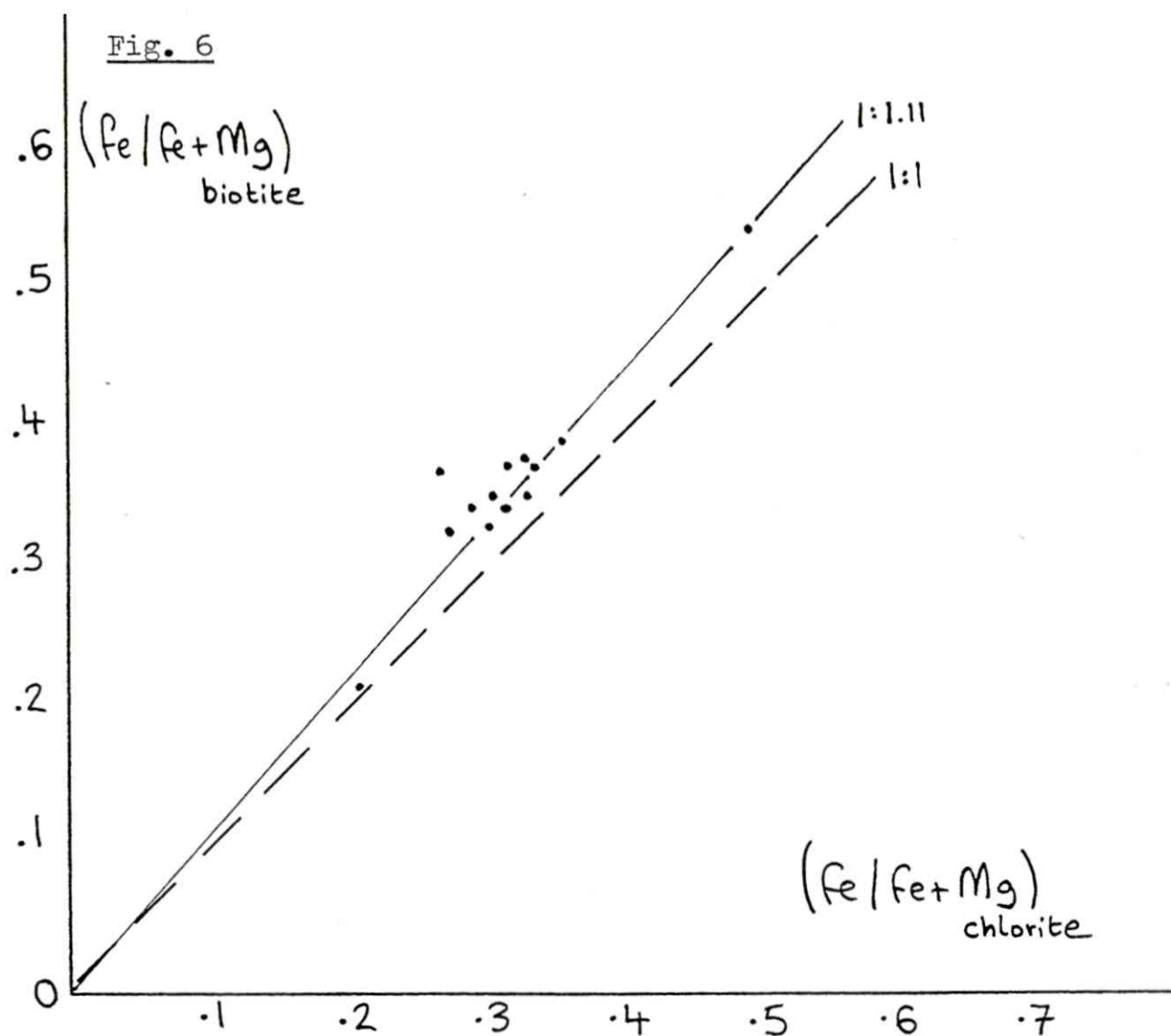
AL vi

BIOTITE COMPOSITIONS (AP)



FE/(FE+MG)





$(\text{Fe}/\text{Fe}+\text{Mg})_{\text{biotite}}$ plotted against $(\text{Fe}/\text{Fe}+\text{Mg})_{\text{chlorite}}$ in co-existing mineral pairs.

Biotite is concentrated in biotite relative to chlorite, and is expressed by the curve in the above diagram with a slope of 1:1.11

TIME PLAN1985/1986NIGEL COOK

1985

MONTH	WEEK
APRIL	17
MAY	18
	19
	20
	21
	22
JUNE	23
	24
	25
	26
JULY	27
	28
	29
	30
AUGUST	31
	32
	33
	34
	35
SEPT.	36
	37
	38
	39
OCTOBER	40
	41
	42
	43
	44
NOVEMBER	
DECEMBER	
JAN. 1986	
FEB. 1986	
MAR. 1986	
APRIL 1986	
MAY 1986	
JUNE 1986	

To Sulitjelma

Computer work:
Interpretation of data,
Constructing diagrams, maps.

Underground work, re-visiting
sites, some additional
sampling of potassic zone.
Photography.

Cartographic work: Planning
layout of fair copy maps.

Field work: Re-visiting some
sites, photography.
Collection of small amount of
reference samples
(Supervisor to assist 2/3
weeks to be fixed.)

Return London

Petrographic work:
Microscopy
S.E.M. (about 4 sessions)
Probe (about 15-20 sessions)
Final data interpretation.
Photography of samples for
reference.

Start writing first chapter
(Regional geology)

Literature work: Sorting
out references.

Writing Up

(Possibly 2/3 weeks in Norway working on final
diagrams and maps during Spring.)

FINISH WRITING UP, present thesis.