THE GEOLOGY OF THE TANTALITE VALLEY MAFIC-ULTRAMAFIC COMPLEX AND THE KUMKUM METAMORPHIC-IGNEOUS MASSIF NEAR WARMBAD, SOUTH WEST AFRICA (NAMIBIA)

BY

KEVIN GRANT KARTUN B.Sc (HONS) (CAPE TOWN)

V. 2.

Thesis submitted in fulfillment of the requirements for the degree of Doctor of Philosophy

University of Cape Town

March, 1979

Volume 2

Appendices

Figures

Tables

TABLE OF CONTENTS

TABLES

MINERAL ANALYSES - SAMPLES FROM TANTALITE VALLEY AND KUMKUM (TABLE 43)

TANTALITE VALLEY

KUMKUM

PAGE

MAJOR AND TRACE ELEMENT ANALYSES (TABLE 44)

AVERAGE MAJOR AND TRACE ELEMENT COMPOSITIONS FOR ROCKS FROM THE TANTALITE VALLEY - KUMKUM AREA (TABLE 45)

Appendix 1 — Determinative Mineralogy

Modal proportions of minerals present in thin section were estimated from visual comparison charts. Although this method is not as accurate as point counting, it is possible to analyse a large number of thin sections in this way. Plagioclase compositions were determined using the standard methods outlined in Kerr (1959) and results, in some cases, were supplemented by electron microprobe determinations. The proportions of plagioclase and K-feldspar present in a number of samples was checked by staining slabs of rock with amaranth and cobaltinitrite after the method of Laniz et al (1964). Identification of a number of minerals present in slides was checked using the electron microprobe. Several samples were examined under the ore microscope and the proportions of the various sulphide and oxide phases present were estimated as before. These results are included in the modal analysis tables. The rocks were also checked for magnetism using a compass needle to see whether magnetite is present. The identification of most of the opaque minerals found in the slides in subjective and depends on shape and colour criteria as well as rock associations.

Appendix 2 Mineral Analyses

These were obtained using a Cambridge Microscan 5 electron microprobe in the Department of Geochemistry, University of Cape Town. For a detailed account of operating procedure, precision and accuracy of the technique see Reid (1977). Calibration was achieved using a variety of natural standards whose compositions are known from wet chemical or X-ray fluorescence methods.

Each analysis presented represents the average result obtained from several grains or is representative of the composition of the mineral as a whole as shown by a qualitative point scan of a slide. A finely focussed (1-2μ diameter) beam was used for all elements. The totals obtained for minerals such as olivine, pyroxene, etc were required to be 100$\pm$ 1% before an analysis was accepted. Applying these constraints it was hoped that the analyses obtained were as reliable and accurate as possible.

In the tables of these analyses total iron is generally reported as FeO (ie FeO*). Only in the case of pyroxenes, spinellids and ilmenite has the proportion of Fe_2O_3 present been estimated by assuming ideal stoichiometry.

The analyses were carried out by the author, by Dr A C Moore and by A P Le Roex.

Appendix 2 - continued

An estimation of the precision of the analytical technique is given in Table (a) after Reid (1977)

TABLE (a)

Oxide	$\bar{X}$	S.D.	ERR	DL
SiO_2	41,97	0,08	0,08	0,06
TiO_2	3,92	0,08	0,10	0,07
Al_2O_3	13,51	0,06	0,06	0,04
FeO	6,82	0,15	0,16	0,10
MgO	16,34	0,07	0,10	0,05
CaO	12,10	0,07	0,08	0,05
Na_2O	2,71	0,12	0,14	0,09
K_2O	1,18	0,06	0,10	0,07
TOTAL	98,55	0,20		

$\bar{X}$ = Mean of 10 replicate analyses of the same spot within a pargasitic hornblende in a peridotite from the Swartkop complex

S.D. = Standard deviation about the mean

ERR = 2 σ error (95 percent confidence limits) due to counting statistics

DL = Theoretical detection limit (99 percent confidence)

All quantities expressed in weight percentage of the oxide

Appendix 3 Major and Trace Element Analyses:

Major element analyses were mainly carried out in the Department of Geochemistry, University of Cape Town, although some twenty analyses were done by courtesy of the Geological Survey in Pretoria. The method employed was X-ray fluorescence spectrometry (XRF) and samples were analysed in the form of fusion discs. This served for all major elements except Na and S, which were determined by XRF on powder briquettes The proportion of ferrous iron present was obtained by titration of a solution containing 0,5 grams of sample against a standard solution of potassium dichromate. H_2O^+ and CO_2 were determined by means of a gas chromatograph apparatus at the University of Cape Town, otherwise where loss on ignition (L.O.I.) values are quoted, these have been corrected for the presence of sulphur and iron oxidation and are equivalent to the sum of CO_2 and H_2O^+.

The quantity H_2O^- represents weight lost from the sample at 110°C.

Determinations of trace element concentrations and mass absorption coefficients was carried out in the Geochemistry Department, University of Cape Town, using XRF on powder briquettes.

The data reduction for major and trace elements was achieved using computer programs devised by the staff of the Geochemistry Department, University of Cape Town.

For a more detailed account on the method employed, standards used, precision and detection limit of the technique when applied to major and trace element determination, the reader is referred to Reid (1977).

Analyses and data reduction done at the University of Cape Town were by Miss J Barr, Dr A C Moore and the author.

Appendix 3 - continued

Estimates of the precision and detection limits for major oxides are given in Table (b) after Reid (1977). Precision is expressed as a percentage of the average concentration. Detection limits expressed as weight percent of oxide.

Na on a pressed powder briquette; all other major elements on Norrish fusion discs.

TABLE (b)

Oxide	Average	Precision	Detection Limit
Fe_2O_3	5	0,3	0,04
MnO	0,20	2,5	0,006
TiO_2	0,5	0,4	0,004
CaO	5,0	0,3	0,01
K_2O	2,5	0,8	0,002
SiO_2	55	0,5	0,05
Al_2O_3	15	0,5	0,03
MgO	4,0	1,0	0,05
Na_2O	3,0	1,3	0,08

Counting errors and detection limits for trace elements analysed by XRF are given in Table (c) after Reid (1977). All data are in ppm.

TABLE (c)

Element		SD(100)	SD(10)	DL
Ba	G	2,0	2,0	3
	B	6,2	4,0	7
Rb	G	0,6	0,4	0,8
	B	0,6	0,5	1,0
Zr	G	1,0	0,9	2,0
	B	1,4	1,2	2,6
Nb	G	1,2	1,1	2,3
	B	1,6	1,4	2,9
Y	G	1,0	0,9	1,9
	B	1,2	1,1	2,2
Zn	G	0,8	0,5	1,0
	B	1,0	0,7	1,0
Sr	G	0,6	0,4	0,7
	B	0,6	0,5	0,9
Cu	G	1,0	0,8	1,7
	B	1,2	1,0	2,0
Co	G	3,4	3,2	7
	B	4,4	4,2	9
Ni	G	1,2	1,0	2,1
	B	1,6	1,2	2,6
Cr	G	1,6	1,2	2,5
	B	2,0	1,5	3,1
V	G	2,6	2,2	4,8
	B	3,0	2,8	5,6

Appendix 3 - continued

SD(100) = 2 σ error (95 percent confidence) at 100 ppm

SD(10) = 2 σ error at 10 ppm

DL = Detection limit at 99 percent confidence

G = Granitic matrix

B = Basaltic matrix

Appendix 4 C.I.P.W. norms

These were computed from the major element analyses, recalculated to 100% volatile free and assuming an Fe_2O_3/FeO ratio of 0,2, using the program, NEWNORM, which is available in the Geochemistry Department at the University of Cape Town. Also calculated, among other things, are D.I. and M.I. (both in weight percent) where D.I. is the differentiation index of Thornton and Tuttle (1960) and is the sum of the normative minerals, quartz, orthoclase, albite, nepheline, leucite and kaliophyllite and M.I., the mafic index, which is the result of dividing weight percent FeO by the sum of the weight percents of FeO and MgO.

Appendix 5 — Key to Bulk Rock Analyses

A. Tantalite Valley Area:

1. Amphibolites

AM76 ‡	Anorthite ($An_{94,70}$) - Fe-pargasitic hornblende-sphene-opaque oxides.
AM77 ‡	Magnesian hornblende- bytownite ($An_{82,4}$) - quartz-sphene.
AM113 ‡	Hornblende-quartz-sphene-plagioclase.
AM157 ‡	Biotite-magnesian hornblende-scheelite-sphene.

(Metasomatic)

2. Mottled Metagabbro

TV288 ‡	Plagioclase (An_{43}) - hornblende-quartz-biotite-sphene-opaque minerals.
TV294 ‡	Plagioclase (An_{36}) - hornblende-biotite-quartz-sphene-opaque minerals.
TV275A*	Plagioclase (An_{44}) - hornblende-biotite-sphene-opaque minerals-quartz.

TV298*	Hornblende-plagioclase (An_{60})-biotite-opaque minerals-sphene-quartz.
JWVB46 (TV46)	Labradorite (42,3%)-quartz (28,2%)-actinolite (16,8%) cummingtonite (10,3%) - ilmenite (2,4%).

3. Metagabbro

TV277*	Plagioclase-hornblende-biotite-opaque minerals.
TV42 *	Plagioclase (An_{60}) - hornblende-biotite-sphene-opaque minerals.
TV182*	Plagioclase (An_{49}) - hornblende-biotite-sphene.
TV8 *	Plagioclase (An_{57}) - hornblende-biotite-sphene-opaque minerals.
TV77 *	Plagioclase (An_{76}) - actinolitic hornblende-biotite-sphene-opaque minerals.
TV265*	Actinolitic hornblende-plagioclase (An_{46}) - biotite-sphene-opaque minerals.
TV126*	Plagioclase (An_{70}) - hornblende-biotite-sphene-ilmenite-apatite.
TV217*	Hornblende-plagioclase (An_{64}) - calcite-opaque minerals-quartz.

GBW193	Plagioclase (An_{66}) (69%) - hornblende (31%) - opaque minerals - {epidote} .
JWVB20 (TV20)	Bytownite (82,1%) - cummingtonite/grunerite (25,8%) - opaque minerals (3,1%)- actinolite.
JWVB22 (TV22)	Bytownite (55,7%) - actinolite (37,2%) - anthophyllite (6,8 %)- opaque minerals (0,3%).
JWVB24 (TV24)	Actinolite (63,3%) - labradorite (34,4%) - opaque minerals (2,3%) - quartz.

4. Gabbronorite

TV210 *	Plagioclase (An_{43}) - hypersthene - augite-quartz-amphibole-biotite-magnetite.
TV205A*	Plagioclase (An_{59}) - hypersthene - olivine-augite-biotite-magnetite.
TV282 *	Plagioclase (An_{64}) - augite-olivine-hypersthene-biotite-magnetite.
TV170 *	Plagioclase (An_{50}) - augite-olivine-hypersthene- {hornblende} - magnetite-biotite-calcite.

TV199 ‡	Plagioclase (An $_{53}$) - hypersthene - {hornblende} -augite-biotite-opaque minerals-quartz.
T36 ‡	Plagioclase (An$_{55-65}$) - augite-hypersthene-opaque minerals-biotite.
GBW195	Plagioclase (An$_{60}$) (68%) - hypersthene (22%) - augite (5%)-{hornblende} (5%) - opaque minerals-apatite.
JWVB25(TV25)	Labradorite (64,7%) - bronzite (23,3%) - opaque minerals (2,1%)-biotite - {clinoamphibole} - quartz.
JWVB26(TV26)	Bytownite (70,5%) - bronzite (24,8%) - {clinoamphibole} (4,7%)-opaque minerals-diopside.

5. Satellite Body

AM123A ‡	Diopside-bronzite-plagioclase (An $_{58,3}$) - quartz-biotite-{hornblende} - opaque minerals.
AM125 ‡	Hornblende-cummingtonite-plagioclase (An$_{40}$) - biotite-opaque minerals.

6. Ultramafic Rocks

AM88A ǂ	Olivine-{chlorite} - {amphibole} - opaque minerals.
AM89B ǂ	Olivine-orthopyroxene-clinopyroxene- plagioclase (An_{50}) - phlogopite- {chlorite} - opaque minerals.
T5 ǂ	Plagioclase (An_{58}) - orthopyroxene-olivine-clinopyroxene- {hornblende} - phlogopite- {chlorite} - opaque minerals.
T6 ǂ	{Chlorite} - {actinolite}- {cummingtonite} -phlogopite-opaque minerals.
T7 ǂ	{Chlorite} - {actinolite} - olivine-opaque minerals.
T10 ǂ	Olivine-phlogopite-pentlandite (2,5%)-pyrrhotite (2%) magnetite (0,5%)- {chlorite} - {amphibole} .
T11 ǂ	Bronzite-plagioclase (An_{73})-clinopyroxene-phlogopite-opaque minerals- {chlorite} - {hornblende} .
TV45 *	Olivine-clinopyroxene- {amphibole} -phlogopite- {chlorite} -

	opaque minerals.
TV30*	{Anthophyllite} - {actinolite} -clinopyroxene-orthopyroxene-opaque minerals.
TV117*	{Actinolite} - {chlorite} - phlogopite-opaque minerals.
TV157A†	Olivine- {amphibole} - {chlorite} -phlogopite-opaque minerals.
GBW376	Olivine (69%)-plagioclase (An_{56} (31%) -phlogopite-opaque minerals- {serpentine} .
GBW374	Hypersthene (53%)-olivine (Fo_{74}) (26%)- {clinoamphibole} - plagioclase (An_{56}) (3%)- opaque minerals- {serpentine} .
GBW421	Olivine (41%)-plagioclase (An_{58} (27%) - hypersthene (26%)- {clinoamphibole} (6%)- phlogopite-opaque minerals- {chlorite} - {serpentine} loc. Sandfontein 131
GBW380	Hypersthene (52%)-olivine (28%)- plagioclase (An_{60}) (3%)- {clinoamphibole} (17%)- opaque minerals- {serpentine} loc. Sandfontein 131

7. Granitic Rocks

TV306 ‡ (Inequigranular granite gneiss)	Plagioclase (An_{46})-quartz-biotite-{epidote}-opaque minerals-sphene-hornblende-apatite-{chlorite}-zircon.
TV299 ‡ (Granodiorite)	Quartz-plagioclase (An_{30})-K-feldspar-biotite-{chlorite}-opaque minerals.
TV305 ‡ (Tonalite)	Plagioclase (An_{20})-quartz-K-feldspar-biotite-{chlorite}-{epidote}.

8. Hornfelses

8.1 Metabasite hornfels

TV9 212 ‡	Plagioclase-cummingtonite hornblende-sulphide-{chlorite} (3 cm of core).
TV13 98 ‡	Plagioclase (An_{42})-cummingtonite-{chlorite}-hornblende-sphene-{epidote}-apatite-rutile-pyrrhotite-chalcopyrite (sheared) (5 cm of core).
TV13 149 ‡	Plagioclase (An_{55})-hornblende-cummingtonite-biotite-{muscovite}-pyrrhotite-chalcopyrite

	(7 cm of core)
TV13 151 ǂ	Plagioclase (An_{63})-cummingtonite-biotite-{chlorite}-hornblende-pyrrhotite-chalcopyrite-pentlandite-pyrite (sulphides along fracture and dissem.) (7 cm of core).

8.2 <u>Pelitic hornfels</u>

TV13 165,3 ǂ	Cordierite-quartz-plagioclase (An_{45})-biotite-opaque minerals-sillimanite-{chlorite}. (5,5 cm of core).
T4 (TV4) ǂ	{Sericite}-{chlorite}-biotite-almandine-staurolite-{chloritoid}-cordierite-ilmenite-sulphide-kyanite-zincian spinel.
TV276 ǂ	Cordierite-quartz-biotite-andalusite-sillimanite-{chlorite}-staurolite-maghaemite.
T19 ǂ	Cordierite-almandine-sillimanite-biotite-staurolite-ilmenite-{chlorite}-quartz-plagioclase (An_{44}).

8.3 Pyroxene hornfels

TV226 ǂ	Bronzite-phlogopite-cordierite-ilmenite-hercynite-sulphide.

8.4 Cordierite-anthophyllite hornfels

AM170 (TV111) ǂ	Cordierite-biotite-anthophyllite- {chlorite} -quartz-ilmenite.

B. Kumkum Area:

1. Granolite

K15 ǂ	Plagioclase (An_{48})-augite-hypersthene- hornblende -magnetite.

2. Black Gneiss

K35 ǂ	Garnet-cordierite-plagioclase (An_{35})-quartz-sillimanite-microcline-biotite-ilmenite.
KK7 ǂ	Cordierite-K-feldspar-almandine-quartz-sillimanite-plagioclase (An_{12})-biotite-ilmenite-magnetite-zircon-spinel.
K101 ǂ	Garnet-cordierite-gedrite-

biotite-plagioclase (An_{27}) - quartz-magnetite-ilmenite-spinel-sillimanite-apatite-zircon-{haematite} .

GBW302 Cordierite (47%)-sillimanite (22%)-biotite (18%)-almandine (6%)-plagioclase (5%)-quartz (2%)-zircon-apatite-opaque minerals-{pinite} (loc. Kumkum Massif).

GBW98 Cordierite (50%)-sillimanite (30%)-almandine (10%)-biotite (8%)-quartz (2%)-zircon-opaque minerals-{pinite} (loc. Sandfontein 131).

GBW241 Almandine (30%)-sillimanite (27%)-K-feldspar (13%)-biotite (11%) quartz (10%)-plagioclase (9%)-zircon-apatite-opaque minerals (loc. Kumkum Massif)

3. Amphibolites

K94 ǂ Hornblende-plagioclase (An_{73})-quartz-opaque minerals-phlogopite-{chlorite}-{prehnite} - {calcite} .

K40 ǂ Plagioclase (An_{43})-hornblende-opaque minerals-biotite-{epidote} - {clinozoisite} - {chlorite} -chalcopyrite-{malachite} .

4. <u>Inequigranular granite gneiss</u>

K49‡ (KBH) — Quartz-plagioclase-microcline-biotite-{chlorite}-garnet-apatite-opaque minerals-{epidote} - {muscovite} -allanite-myrmekite.

GBW744 — Quartz (29%)-microcline (29%)-plagioclase (An_{40}) (20%)-biotite (19%)-garnet (3%)-opaque minerals-{epidote} -apatite. Eendoorn 404.

5. <u>Contaminated gabbronorite</u>

K44‡ — Hornblende-plagioclase (An_{48}) clinopyroxene - orthopyroxene-biotite-quartz-opaque minerals-apatite-zircon.

K80‡ — Hornblende-plagioclase (An_{60}) clinopyroxene - orthopyroxene- opaque minerals-quartz-biotite-apatite.

K34A ǂ — Plagioclase (An_{51})-orthopyroxene-quartz-clinopyroxene-hornblende-opaque minerals-biotite-apatite.

K63A ǂ — Plagioclase (An_{49})-orthopyroxene-clinopyroxene-quartz-biotite-opaque minerals-hornblende-apatite.

K39 ǂ — Plagioclase (An_{66})-orthopyroxene-quartz-clinopyroxene-hornblende-opaque minerals-apatite-zircon.

6. <u>Kumkum gabbronorite</u>

K28 ǂ — Olivine-plagioclase (An_{48})-clinopyroxene-orthopyroxene {hornblende} -biotite-hercynite-magnetite.

K22 ǂ — Plagioclase (An_{41})-clinopyroxene- {hornblende} -orthopyroxene-biotite-magnetite-zircon.

K30A ǂ — {Hornblende} -orthopyroxene-plagioclase (An_{81}) biotite-opaque minerals.

K37A ǂ — Plagioclase (An_{74})-diopside-

	bronzite-olivine-biotite-{hornblende} -magnetite-hercynite-apatite.
K65 ‡	Plagioclase (An_{66})-orthopyroxene-{hornblende}- olivine-clinopyroxene-biotite-hercynite-opaque minerals.
GBW225	Plagioclase (An_{52}) (50%)-augite (21%)- {clinoamphibole} (22%)-olivine (7%)-apatite-{epidote} - {chlorite} (loc. Kumkum 105.
GBW439	Plagioclase (An_{58}) (42%)-hypersthene (32%) augite (15%)-{clinoamphibole} (8%)-olivine (3%) biotite-apatite-spinel-{epidote}. (loc. Kumkum 105).

7. <u>Eselruh gabbronorite</u>

K59A ‡	{Hornblende} -diopside-olivine-orthopyroxene-plagioclase (An-88)-calcite-magnetite-hercynite-phlogopite.
K60 ‡ (≡AM230)	{Hornblende} -bronzite-biotite-plagioclase (An_{45})-opaque minerals.

K7[‡]	{Hornblende} -bronzite-plagioclase (An_{73})-diopside-phlogopite-olivine-spinel-opaque minerals.

8. Verloorkoppe gabbronorite (≡ Contaminated gabbronorite?)

GBW1	Plagioclase (An_{62}) (47%)-augite (40%)-olivine (6%) {clinoamphibole} (4%)-opaque minerals (3%)-biotite-apatite (Khais Zuid 116).

9. Einsiedler gabbronorite (≡ Kumkum gabbronorite?)

GBW7	Plagioclase (An_{60}) (51%)-augite (31%)-olivine (17%) opaque minerals (1%)-biotite-{serpentine} (Warmbad town area 145)

10. Warmbad granite

GBW458 and GBW608	Quartz-K-feldspar-plagioclase (An_{25})-muscovite-biotite-zircon-apatite±sphene + opaque minerals {chlorite} - {epidote} - {sericite}.

ǂ Analyses done in the Geochemistry Department, University of Cape Town.

* Analyses done at Geological Survey Pretoria but with traces, H_2O^+ and CO_2 determined at the University of Cape Town.

GBW - Analyses from Beukes (1973), exact locations unknown.

JWVB - Analyses from Von Backström (1976). For location of samples see Map 2.

{ } - Secondary minerals.

Appendix 6

Two pyroxene geothermometer

The thermometer of Wood and Banno (1973) is based on the diopside-enstatite miscibility gap determined by Davis and Boyd (1966), who investigated the reaction,

$(Mg_2\ Si_2\ O_6)_{opx} \rightleftharpoons$

enstatite-diopside solid solution

$(Mg_2\ Si_2\ O_6)_{cpx}$

diopside-enstatite solid solution, which at equilibrium can be expressed by,

$$\Delta G^{o}_{P,T} = -RT \ln K = -RT \ln \left\{ \frac{a^{cpx}_{Mg_2Si_2O_6}}{a^{opx}_{Mg_2Si_2O_6}} \right\}$$

The assumptions are made that (a) both ortho- and clino-pyroxene phases behave as ideal two-site solutions of $Ca\ Mg\ Si_2\ O_6$ and $Mg_2\ Si_2\ O_6$ components, and

$$a^{cpx\ or\ opx}_{Mg_2Si_2O_6} = \left(\frac{Mg^{2+}}{Ca^{2+}+Mg^{2+}+Fe^{2+}+Mn^{2+}+Na^{+}}\right)_{M2} \times \left(\frac{Mg^{2+}}{Fe^{3+}+Fe^{2+}+Al^{3+}+Ti^{4+}+Cr^{3+}+Mg^{2+}}\right)_{M1}$$

and (b) that

$\frac{Mg^{2+}}{(Mg^{2+} + Fe^{2+})}$ for M2, M1 sites and mineral are all

equal. Wood and Banno (1973), using experimental data on complex and iron-rich systems, were able to fit a curve which reproduces the experimental data to within 60°C and which is expressed by the equation:

$$T\ (^{o}K) = \frac{-10202}{\ln \frac{a^{cpx}_{Mg_2Si_2O_6}}{a^{opx}_{Mg_2Si_2O_6}} - 7{,}65\ {}^{opx}_{Fe} + 3{,}88\ (X^{opx}_{Fe})^{2} - 4{,}6} \qquad (27)$$

where $X^{opx}_{Fe} = \left(\frac{Fe^{2+}}{Fe^{2+} + Mg^{2+}} \right)_{opx}$

Wells (1977) has recalibrated the above thermometer by incorporating additional experimental data on the diopside-enstatite miscibility gap and the iron-bearing system. A curve can be fitted through most of these data to give an expression which is valid over the range 800 to 1700°C.

$$\ln K = -\frac{\Delta H^{o}}{RT} + \frac{\Delta S^{o}}{R} = \frac{-7341}{T} + 3.355 \qquad (3)$$

This equation may be modified to include the experimental data for equilibrated multi-component two pyroxene assemblages to give

$$T\ (^{o}K) = \frac{7341}{3.355 + 2.44\ X_{Fe}^{opx} - \ln K} \qquad (5)$$

which reproduces most of the experimental data to within 70°C. Discrepancies between equation (5) and equation (27) are most pronounced at low values of X_{Fe}^{opx} and at low to moderate temperatures. Generally, the pressure dependence on the amount of solid solution is negligible in the range of 1 bar to 40kbar.

Appendix 7

The Olivine-Chromite Geothermometer of Jackson (1969)

The Mg-Fe^{2+} exchange between olivine and chromite can be expressed by the equation:-

$$\tfrac{1}{2}\, Fe^{2+}_2 SiO_4 + Mg\,(Cr_\alpha\,,\, Al_\beta\,,\, Fe^{3+}_\gamma)_2\, O_4 \rightleftharpoons$$

$$\tfrac{1}{2}\, Mg_2SiO_4 + Fe^{2+}\,(Cr_\alpha\,,\, Al_\beta\,,\, Fe^{3+}_\gamma)_2\, O_4 \qquad (a)$$

where α , β and γ are the fractions of the trivalent cations in chromite, with $\alpha + \beta + \gamma = 1$. It can be shown that a thermodynamic distribution coefficient for the above equation can be simplified to:-

$$K_{D_{Mg-Fe^{2+}}} = X^{ol}_{Mg} \cdot X^{spinel}_{Fe^{2+}} \Big/ X^{ol}_{Fe^{2+}} \cdot X^{spinel}_{Mg} \qquad (b)$$

$K_{D_{Mg-Fe^{2+}}}$ is related to the standard Gibbs free energies of the products and reactants and when the experimental values for these are substituted, the expression:-

$$T = \frac{5580\alpha + 1018\beta - 1720\gamma + 2400}{0{,}90\alpha + 2{,}56\beta - 3{,}08\gamma - 1{,}47 + 1.987 \ln K_{D_{Mg-Fe^{2+}}}} \qquad (c)$$

can be derived, where T is the temperature in degrees Kelvin and α , β and γ are the mole fractions of the trivalent cations.

The main sources of error in this geothermometer are uncertainties in the free energy data, in the assumption of ideal Fe^{2+}- Mg mixing in the mineral phases and difficulties in determining the Fe^{2+}/Fe^{3+} ratios of spinel from microprobe analyses. The uncertainty for values of T obtained from equation (c) is of the order of $\pm$ 300°C.

Appendix 8

The Stroh Geobarometer for coexisting Olivine, Orthopyroxene and Spinel

Stroh (1976) has developed a geobarometer based on the equilibrium between olivine, orthopyroxene and spinel given by the equation:-

$$\underset{\text{Olivine}}{Mg_2SiO_4} + \underset{\text{Opx}_{ss}}{MgAl_2SiO_6} = \underset{\text{Spinel}}{MgAl_2O_4} + \underset{\text{Opx}_{ss}}{Mg_2Si_2O_6} \qquad (a)$$

using the experimental data of MacGregor (1974) for the system MgO - Al_2O_3 - SiO_2. Pressures are calculated from the equation:-

$$P=1 + \frac{(9116-5{,}065T_o) - RT_o \ln \dfrac{(X_{Mg})SP(X_{Al})^2\ SP(X_{Mg}^{M1})opx}{(X_{Mg})^2\ OL\ (X_{Al}^{M1})opx}}{(V^o_{MgAl_2O_4} - V^o_{Mg_2SiO_4} + \bar{V}_{MgAl_2SiO_6} - \bar{V}_{Mg_2Si_2O_6})} \qquad (b)$$

where P is the pressure in bars; T_o, which is known, is the temperature in degrees Kelvin; V^o and $\bar{V}$ are the standard and partial molar volumes respectively and are given in calories bar^{-1} and R, the gas constant, is equal to 1,9872 cals deg^{-1} mole^{-1}.

Appendix 9

Equilibria involving Garnet and Cordierite

The following equilibria relate garnet and cordierite in the presence of sillimanite and quartz:

$$3(Fe_2Al_4Si_5O_{18}\cdot 0,5H_2O) \rightleftharpoons 2(Fe_3Al_2Si_3O_{12}) +$$

Fe-cordierite almandine

$$4(Al_2SiO_5) + 5(SiO_2) + 1.5(H_2O) \qquad (1)$$

sillimanite quartz

$$3(Mg_2Al_4Si_5O_{18}\cdot 0,5H_2O) \rightleftharpoons 2(Mg_3Al_2Si_3O_{12}) +$$

Mg-cordierite pyrope

$$4(Al_2SiO_5) + 5(SiO_2) + 1.5(H_2O) \qquad (2)$$

sillimanite quartz

$$3(Fe_2Al_4Si_5O_{18}\cdot 0,5H_2O)+2(Mg_3Al_2Si_3O_{12}) \rightleftharpoons$$

Fe-cordierite pyrope

$$3(Mg_2Al_4Si_5O_{18}\cdot 0,5H_2O)+2(Fe_3Al_2Si_3O_{12}) \qquad (3)$$

Mg-cordierite almandine

The water content of the cordierite is taken to be 0,5 moles per formula unit (based on natural and artificial cordierites). The data of Holdaway and Lee (1977) yield an expression in terms of P (bars) and T(^oK) for reaction (1) using the method as set out by Chatterjee (1977):

$$\Delta G^{o}_{P,T}=31360-42T-4,0061(P-1)+6RT\ln(X^{garnet}_{Fe}/X^{cordierite}_{Fe})+1,5RT\ln f_{H_2O} \qquad (i)$$

where R=1,9872 cals deg^{-1} $mole^{-1}$ and f_{H_2O} is the fugacity of water as tabulated by Burnham et al (1969).

As expression for the exchange reaction 3:

$$\Delta G^{o}_{P,T}=-33428+12,09T-0,1814(P-1)+6RT\ln(X^{garnet}_{Fe}/X^{cordierite}_{Fe}.X^{cordierite}_{Mg}/X^{garnet}_{Mg}) \qquad (iii)$$

is derived from Thompson (1976b) but with the lowest temperature calibration point increased by 30^{o}K after the suggestion by Holdaway and Lee (1977).

Independent data for reaction 2 involving hydrous magnesium - cordierite are not readily available and an expression for reaction (2) may be generated by combining equation (i) and (iii).

An ideal ionic mixing model has been assumed for garnet and cordierite and $\Delta G^{o}_{P,T}$ = 0 at equilibrium.

The effect of fluid compositions on the equilibrium pressures may be assessed by rearranging equation (i) and assuming ideal mixing in the fluid:

$$X_{H_2O}=\frac{\exp\left\{(-31360+42T+4{,}0061(P-1))/1{,}5RT\right\} -4\ln(X_{Fe}^{garnet}/X_{Fe}^{cordierit}}{f_{H_2O,P,T}} \qquad (iv)$$

where X_{H_2O} is the mole fraction of water in the fluid, and, on the right hand side, the upper term is the f_{H_2O} calculated from equation (i) and the lower term is the fugacity of pure water at P bars and T^oK(using tables by Burnham et al., 1969).

Note:

On pages 189 and 191 it was assumed that cordierite did not undergo any significant change in composition compared to garnet under new metamorphic conditions since it was modally greatly in excess. Thus garnet core compositions and "matrix" cordierite were assumed to approximate equilibrium conditions.

To test this assumption, pelitic hornfels sample T19 containing 10% garnet and 60% cordierite was used (Table 9). If the core garnet composition, taken as the original garnet composition (Table 43, p. 183, analysis IC) is changed to form garnet of rim composition (Table 43, p. 183, analysis IR) then per mole of garnet 0,14 moles of Mg must be removed and 0,06 moles of Fe^{2+} must be added. Therefore, for a rock containing 10% garnet and 60% cordierite, per mole of cordierite, $\frac{0,14}{6}$ moles of Mg will be added and $\frac{0,06}{6}$ moles of Fe^{2+} will be subtracted from the "original" cordierite composition to give the cordierite composition observed. Therefore the "original" cordierite composition in equilibrium with the garnet core composition (using molecular proportions of cordierite, analysis 1, p. 182, Table 43) is

$$\begin{aligned} Mg &= 0{,}596 - 0{,}020 = 0{,}576 \\ Fe^{2+} &= 0{,}379 + 0{,}010 = 0{,}389 \end{aligned}$$

This is a maximum estimate since it is assumed that all ionic exchange is between garnet and cordierite. By comparing the calculated "original" cordierite composition with that used in calculations (Analysis 1, p. 182, Table 43) it can be seen that the assumption made on pages 189 and 191 is valid to a first approximation. Thus the temperature calculated using the "original" cordierite composition and garnet core composition will be slightly higher than that calculated here i.e. 660°C compared with 650°C.

Appendix 10

Plagioclase-Garnet-Al_2SiO_5-Quartz Geobarometer

Ghent (1976) and Schmid and Wood (1976) showed that the reaction:

$$\underset{\text{anorthite}}{3(CaAl_2Si_2O_8)} \rightleftharpoons \underset{\text{grossular}}{Ca_3Al_2Si_3O_{12}} + \underset{\text{sillimanite}}{2(Al_2SiO_5)} + \underset{\text{quartz}}{SiO_2} \qquad (1)$$

may be used to estimate pressure of metamorphism provided the temperature is accurately known. Under equilibrium conditions and with sillimanite as the aluminosilicate phase, the above reaction can be represented as:

$$3 \ln \left(X^{garnet}_{gross} / X^{plag}_{anorthite} \cdot \gamma^{garnet}_{gross} / \gamma^{plag}_{anorthite} \right) \qquad (i)$$

$$= \frac{5809}{T} - 16,69 + \frac{0,6566\ (P-1)}{T}$$

data for ΔH ΔS, ΔV : D. Waters (pers comm.)

where $X^{garnet}_{gross} = Ca\ /(Ca+Mg+Fe^{2+}+Mn)$, $X^{plag}_{anorthite} = \frac{Ca}{Ca + Na}$

$$\gamma^{garnet}_{gross} = \exp\ (1 - X^{garnet}_{gross})^2 . W/_{RT}, \quad W=950\ cal\ mol^{-1}$$

(Schmid and Wood 1976)

R = 1,9872, T = temperature in degrees Kelvin

$\gamma^{plagioclase}_{anorthite}$ = 1,276 (Orville 1972).

The maximum error in equilibrium pressure at any temperature is ± 1,19 kb (Schmid and Wood 1976).

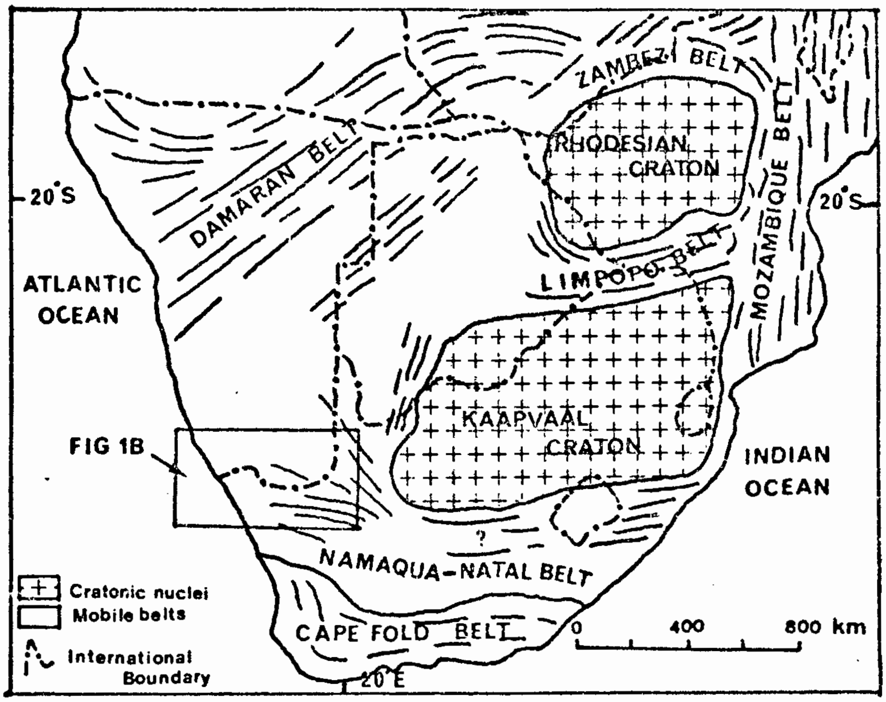


Fig 1A Regional setting of the area represented in Fig 1B and its relation to the Tectonic units in the Southern Africa Shield (after Anhaeusser et al 1968)

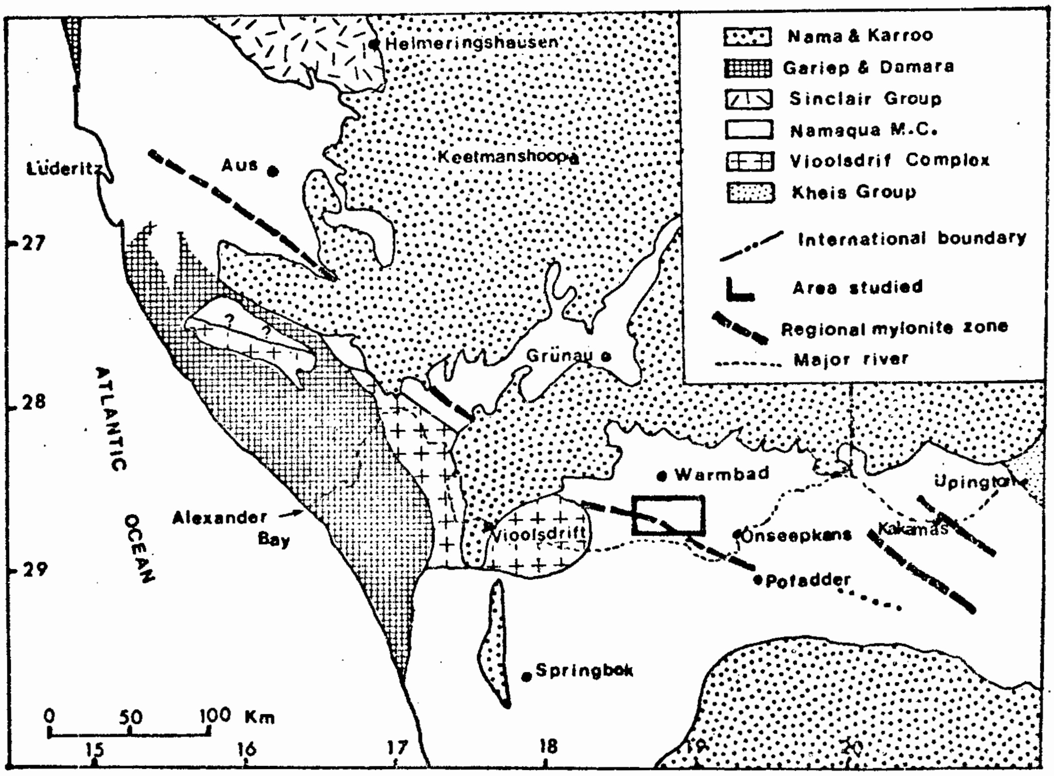
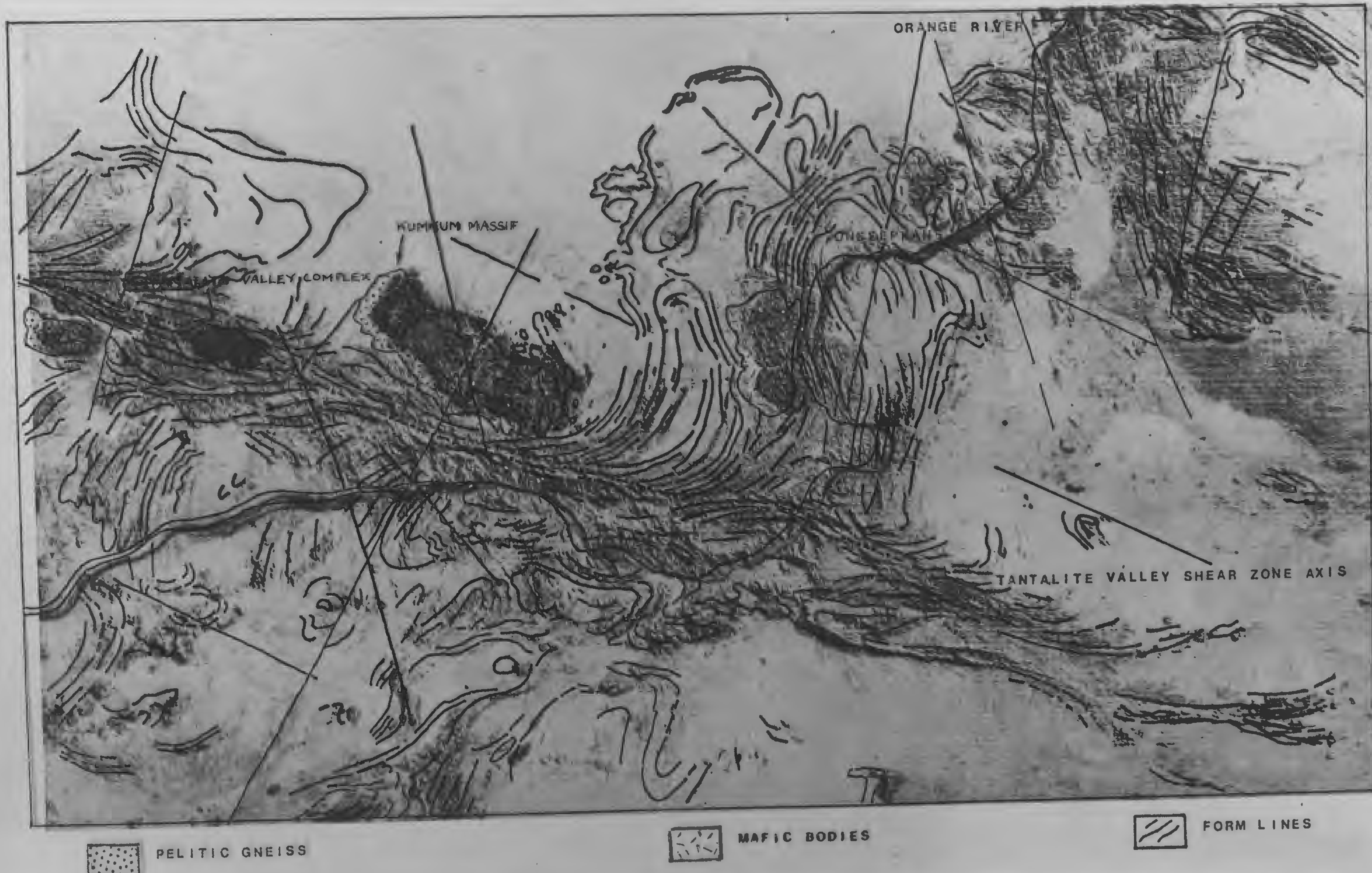


Fig 1B Location and regional setting of the study area in the Namaqua Mobile Belt

Figure 2

Portion of ERTS image No 1055 - 08053, September, 1972 showing the extent of the Tantalite Valley shear zone, its right lateral displacement and the distribution of large mafic and pelitic bodies in an area underlain mainly by rocks of the Namaqualand Metamorphic Complex.

Scale of imagery approximately 1:50 000



ORANGE RIVER
MASSIF
VALLEY COMPLEX
TANTALITE VALLEY SHEAR ZONE AXIS
PELITIC GNEISS
MAFIC BODIES
FORM LINES

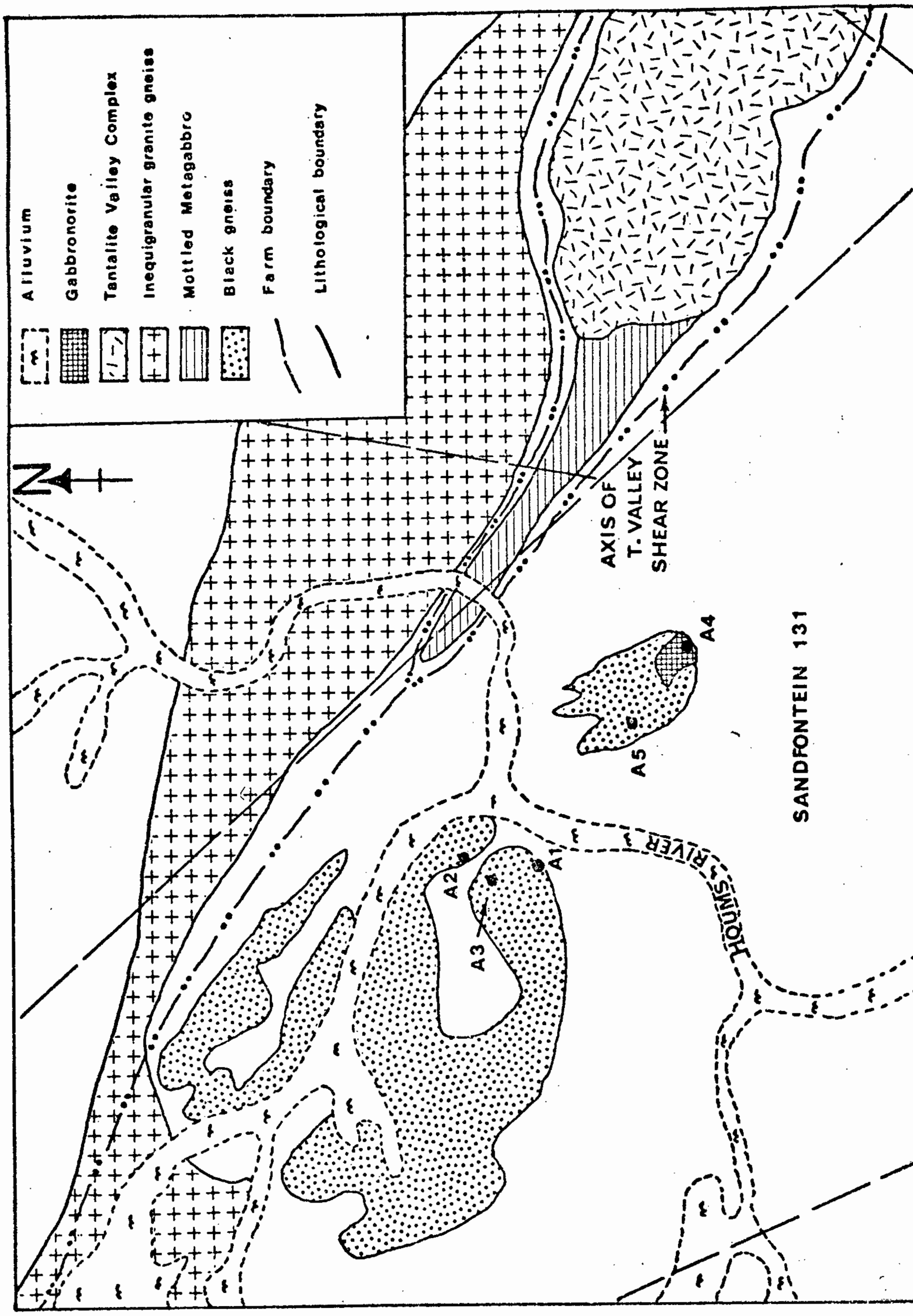


Fig 3   Samples collected on Sandfontein 131

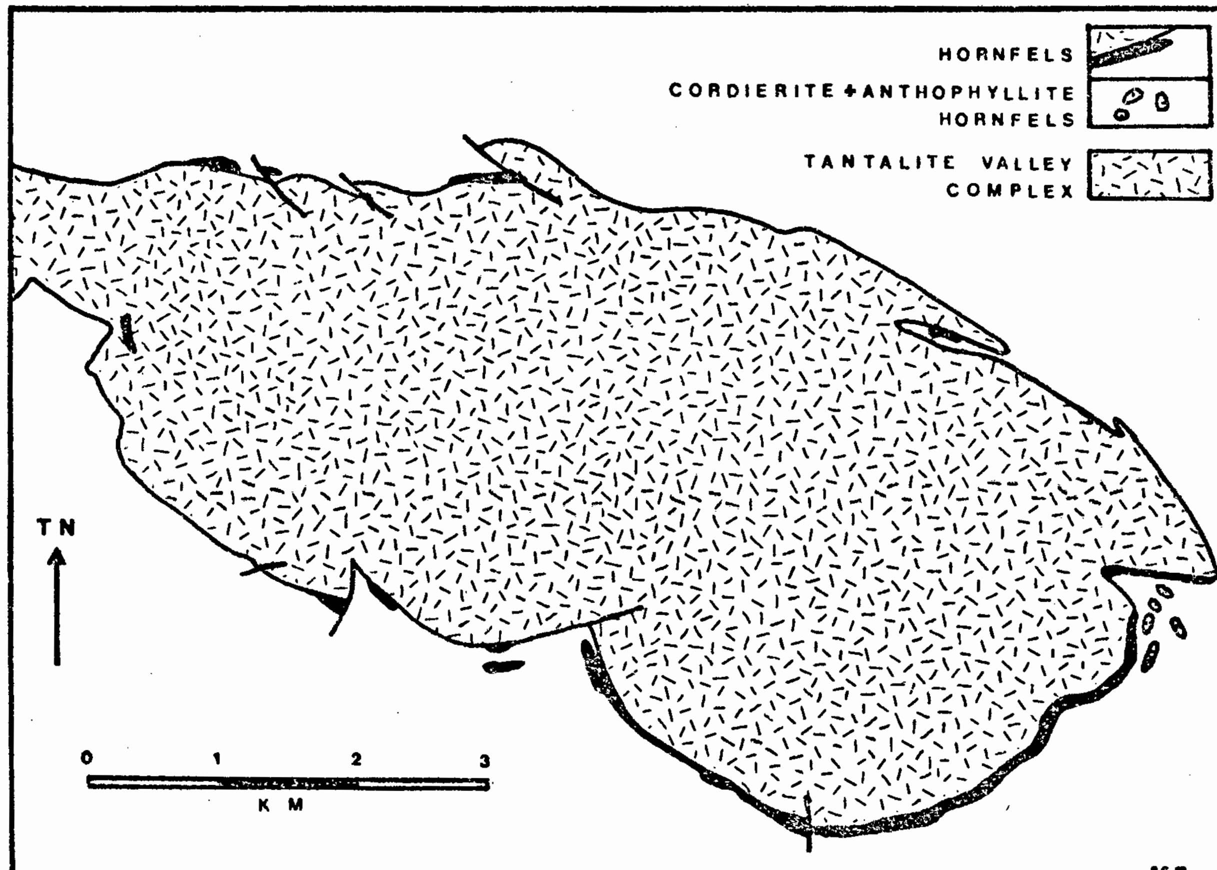


Fig 5 Map of the Tantalite Valley Complex, illustrating the areas where a recognisable aureole has been developed. See also Moore (1975)

Fig 6 - Oblique aerial photograph of the Tantalite Valley Complex; view S.E. (Photo: A.C. Moore).

Fig 7 - The Western part of the Tantalite Valley Complex showing conical hills of gabbronorite and valleys occupied by metagabbro.

Fig 8 - The eastern end of the Tantalite Valley Complex which is dominated by Signaalberg (1069 m) consisting of metagabbro. The White City pegmatite is on the extreme left.

Fig 9 - The main mafic-ultramafic plug of the Tantalite Valley Complex, which weathers reddish compared to surrounding metagabbro. Note the young discordant pegmatites.

Fig 10 - Cross-section through the Grey Gneiss Sequence looking towards the west from the eastern bank of the Girtus River. Pink Gneiss can be seen as an ochre-weathering band to the left. The mafic rocks in the foreground have many features in common with the Tantalite Valley satellite body.

Fig 11 - Amphibolite layer within the Grey Gneiss Sequence to the south of the Tantalite Valley Complex. The white hill is composed of quartz which occurs here along a prominent fracture, the trend of which is parallel to that of the Tantalite Valley Lineament.

Fig 12 - The North-western end of the Kumkum Massif, showing characteristic outcrop appearance of Black Gneiss.

Fig 13 - The main Kumkum gabbronorite body in the centre of the Kumkum Massif. The weathered, rounded boulders in the foreground are of Inequigranular granite gneiss.

Fig 14 - Inequigranular granite gneiss showing flattened xenoliths of mottled meta-gabbro. West of Tantalite Valley Complex.

Fig 15 - Tonalite intrusive into mottled meta-gabbro which is free of megacrysts. Photograph was taken to the west of the Tantalite Valley Complex (Photo. AC Moore)

Fig 16 - A characteristic outcrop of mottled metagabbro showing the uneven distribution of megacrysts in the rock

Fig 17 - The Tantalite Valley Satellite body, looking towards the south-west. The contact with the Grey Gneiss Sequence is sharp.

Fig 18 - Tonalite containing partly assimilated xenoliths of mottled metagabbro. West of Tantalite Valley Complex. Sample location AM183.

Fig 19 - Granodiorite containing abundant xenoliths of Grey Gneiss and of early, concordant pegmatite. The outcrop is situated along the eastern contact of the Tantalite Valley Complex. Sample location TV299 (Photo. AC Moore)

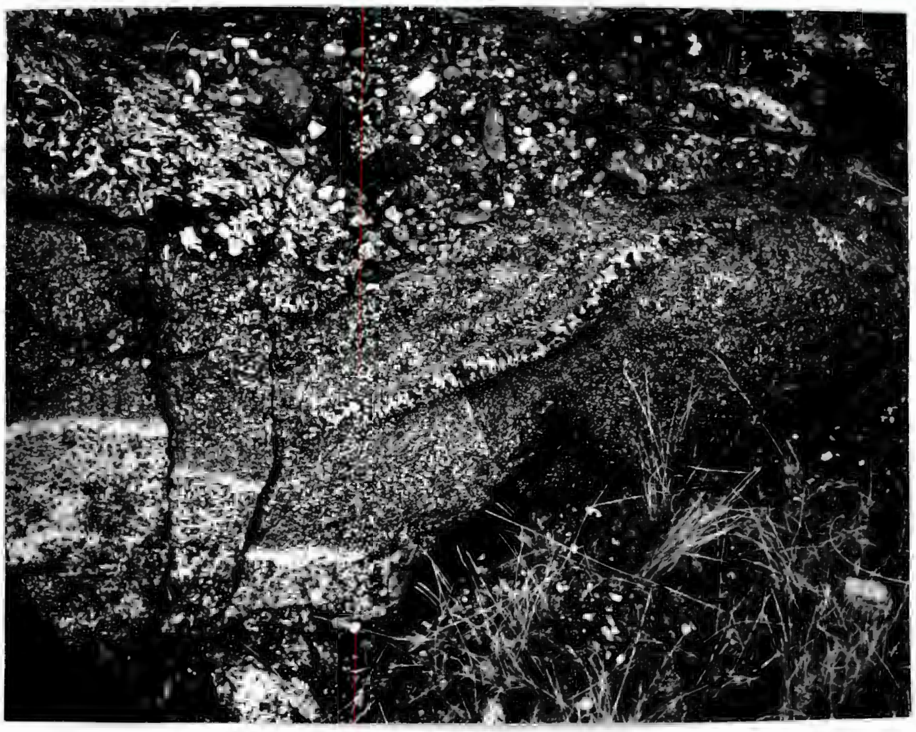


Fig 20 - Pegmatitic metagabbro schlieren in metagabbro occurring both parallel with and transgressive to the layering. Tantalite Valley Complex.

Fig 21 - Xenoliths of metagabbro and mottled metagabbro in finer-grained metagabbro, West end of Tantalite Valley Complex.

Fig 22 - Isomodal, reverse and normal graded layering in metagabbro from the south-east contact of the Tantalite Valley Complex.

Fig 23 - Isomodal leuco-and melano-cratic layers in gabbroid on the eastern bank of the Girtus River which is correlated with the Tantalite Valley Satellite Body.

Fig 24 - Typical outcrop of pelitic hornfels. Western end of the Tantalite Valley Complex.

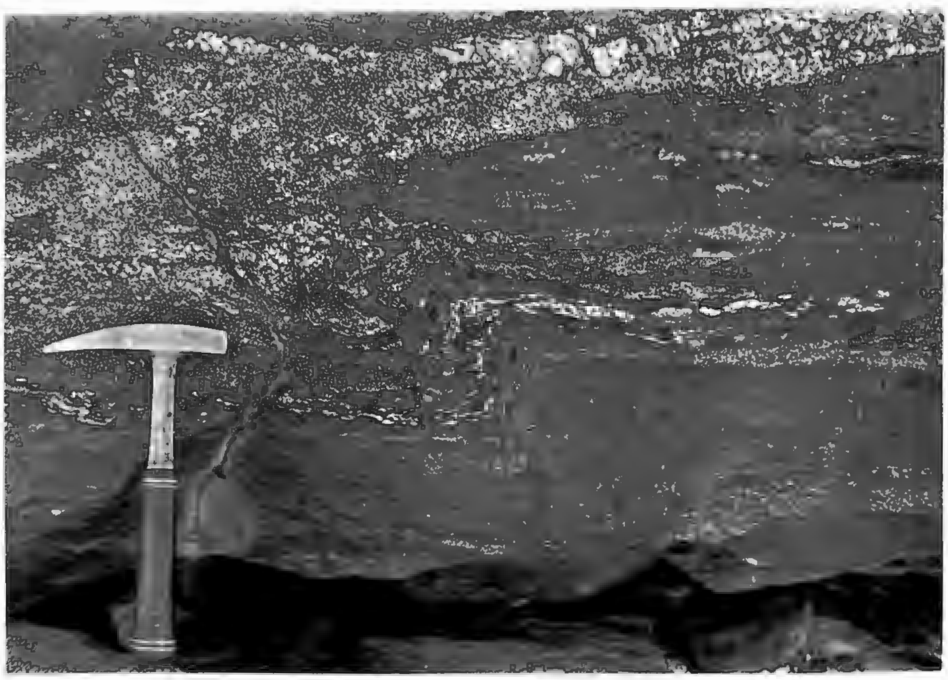


Fig 25 - Folding of sillimanite-rich layers within pelitic hornfels of Tantalite Valley (Photo. AC Moore).

Fig 26 - Isolated reddish-brown weathering outcrops (foreground) of cordierite- anthophyllite hornfels, separated by numerous pegmatites and migmatite-rich Grey Gneiss. The prominent band of dark-weathering rocks in the background represents pelitic hornfels proper..

Fig 27 - Characteristic outcrop of Augen gneiss, situated to the south of the Tantalite Valley Complex.

Fig 28 - Diatexitic migmatite (Nebulite) with disrupted layer of mafic rock still identifiable. Core of Tantalite Valley Shear Zone. (Photo. AC Moore).

Fig 29 - Folded Metatexitic (venitic) migmatite in the core of the Tantalite Valley Shear Zone. (Photo. AC Moore).

Figure 32

A: TV275A - Mottled metagabbro - Tantalite Valley. Ilmenite rimmed in turn by sphene and chloritized biotite which contains intergrowths of prehnite parallel to $\{001\}$. Note the presence of quartz and saussuritized plagioclase. pp light.

1 cm = 0,20 mm.

B: AM234 - Amphibolite - Kumkum area. Partly chloritized biotite intergrown with prehnite. Note the characteristic lens-shape of the latter and the presence of saussuritized plagioclase. pp light.

1 cm = 0,20 mm.

C: TV24 Metagabbro - Tantalite Valley. Zoned calcic amphibole with actinolitic core and hornblende margin. pp light.

1 cm = 0,20 mm.

D: TV42 Metagabbro - Tantalite Valley. Fibrous, actinolitic hornblende forming at the expense of plagioclase at the contact between amphibole and plagioclase. Crossed nicols.

1 cm = 0,20 mm.

Fig 30 - Rounded, fibrolite-muscovite-quartz nodules (see Fig 34H) embedded in Grey Gneiss <u>sensu stricto</u>. East of Tantalite Valley Complex near sample locality AM161 (Map 2).

Fig 31 - Shallow dipping, young, discordant pegmatite intrusive into ultramafic rocks. This has formed metasomatic hornblende and/or phlogopite-rich rocks (Fig 36H). Location - Tantalite Valley Scheelite prospect (Map 4).

FIG. 32

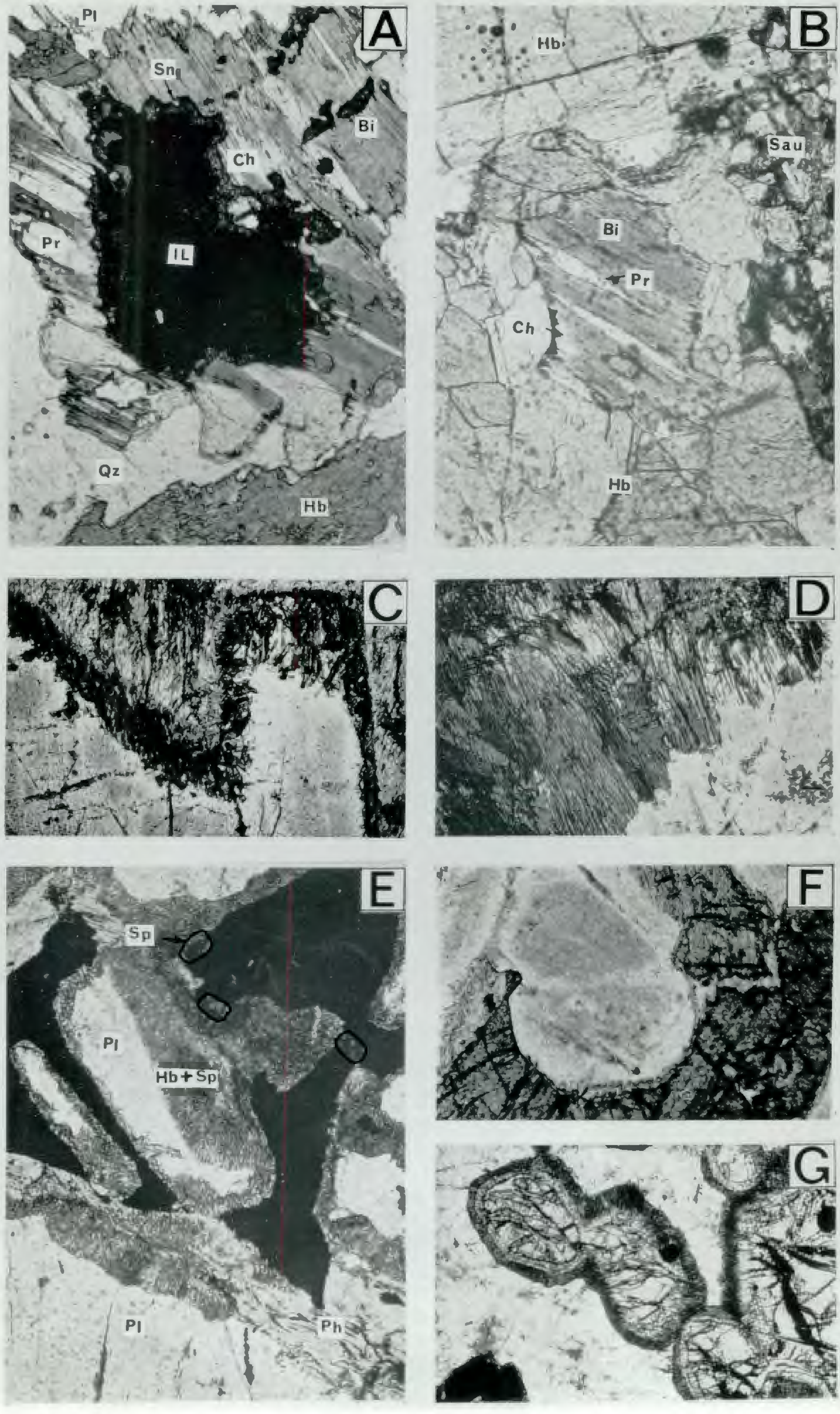


Figure 32 (cont.)

E: TV280 Olivine gabbronorite - Tantalite Valley. Intercumulus magnetite with which is associated primary green spinel is surrounded by hornblende + spinel symplectite in contact with plagioclase which it is replacing. pp light.
1 cm = 0,15 mm.

F: PW3 - Pyroxenite (norite) - Main Ultramafic body - Tantalite Valley.
Opaque mineral clouding plagioclase with the latter having clear rims in contact with orthopyroxene and other plagioclase grains. Secondary amphibole occurs around the borders of pyroxene and along plagioclase/plagioclase boundaries. pp light.
1 cm = 0,20 mm.

G: T12 - Troctolite - Tantalite Valley.
Serpentinized olivine surrounded by continuous rims of bronzite (clear) and hornblende + spinel symplectite (dark) in contact with plagioclase. Rims of amphibole also occur around euhedral opaque minerals, which are probably chromite. pp light.
1 cm = 0,20 mm.

Figure 33

A: Partial melt texture in Tantalite Valley psammitic hornfels sample AM30A. pp light (Photo. AC Moore).

1 cm = 0,62 mm

B: TV282 Olivine gabbronorite - Tantalite Valley. Part of olivine-plagioclase corona. pp light.

1 cm = 0,15 mm.

C: K37A Kumkum gabbronorite.

Relic olivine surrounded by rims of bronzite (clear) and Fe-pargasite (dark) in contact with plagioclase. pp light.

1 cm = 1,29 mm.

D: T11 Pyroxenite (norite) - Tantalite Valley.

Rutile exsolution in phlogopite. pp light.

1 cm = 0,20 mm.

E: TV49 Troctolite - Tantalite Valley.

Zoned spinel surrounded by plagioclase. Brown picotite (black) grades into green spinel-hercynite (pale grey). pp light.

1 cm = 0,20 mm.

Figure 33 (cont.)

F: T14 Troctolite - Tantalite Valley.
Serpentinized olivine surrounded by cummingtonite-thin clear zone (unidentified) and hornblende + spinel in contact with plagioclase. pp light.
1 cm = 0,20 mm.

G: TV225 Tantalite Valley orthopyroxene-bearing hornfels. Relatively coarse-grained, phlogopite-poor, cordierite-rich, orthopyroxene-bearing areas set in a finer-grained, mineralogically identical matrix. pp light.
1 cm = 3,71 mm.

H: TV276 Tantalite Valley Pelitic Hornfels.
Idioblastic staurolite is included in cordierite and biotite and there are needles of sillimanite. pp light.
1 cm = 0,20 mm.

FIG.33

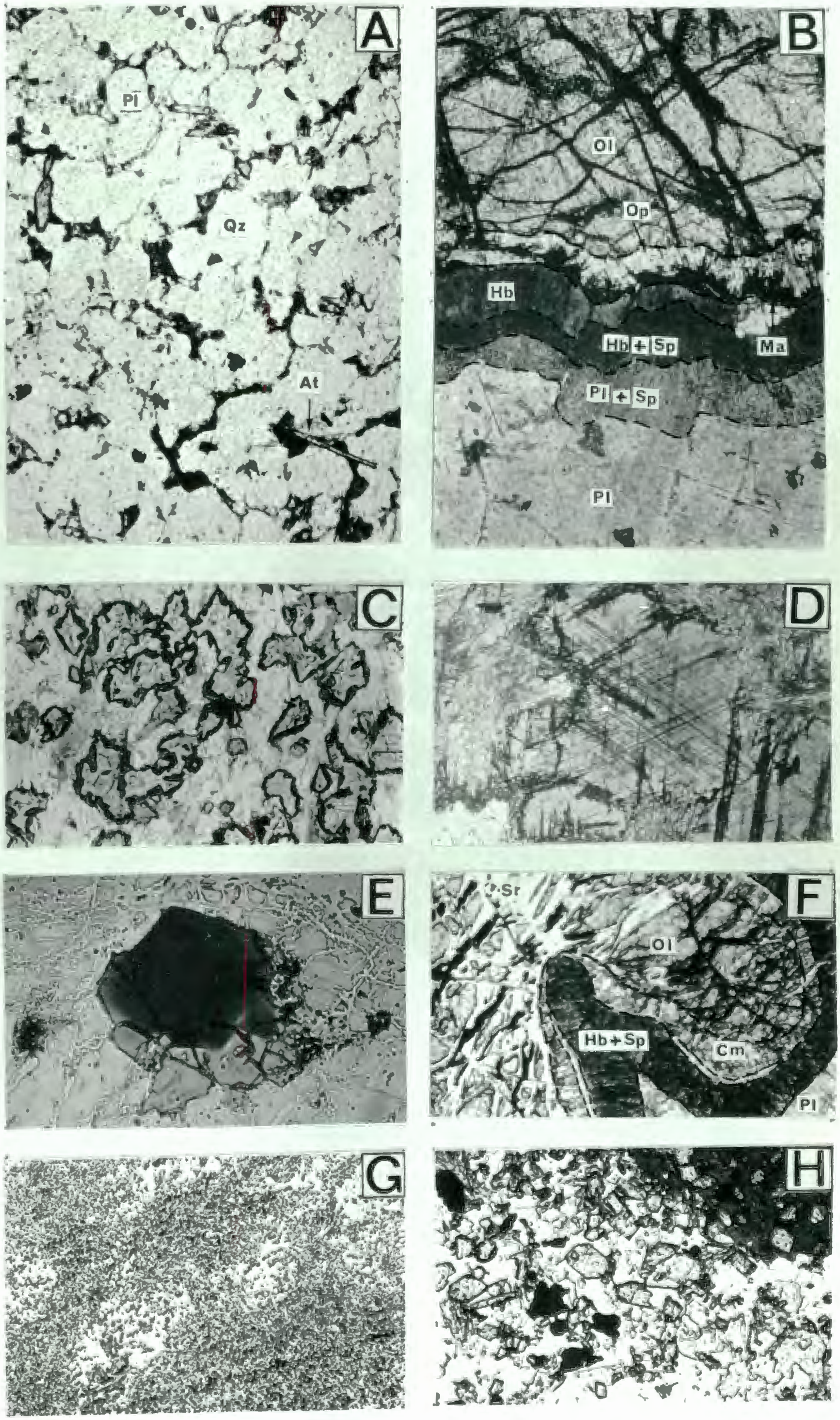


FIG. 34

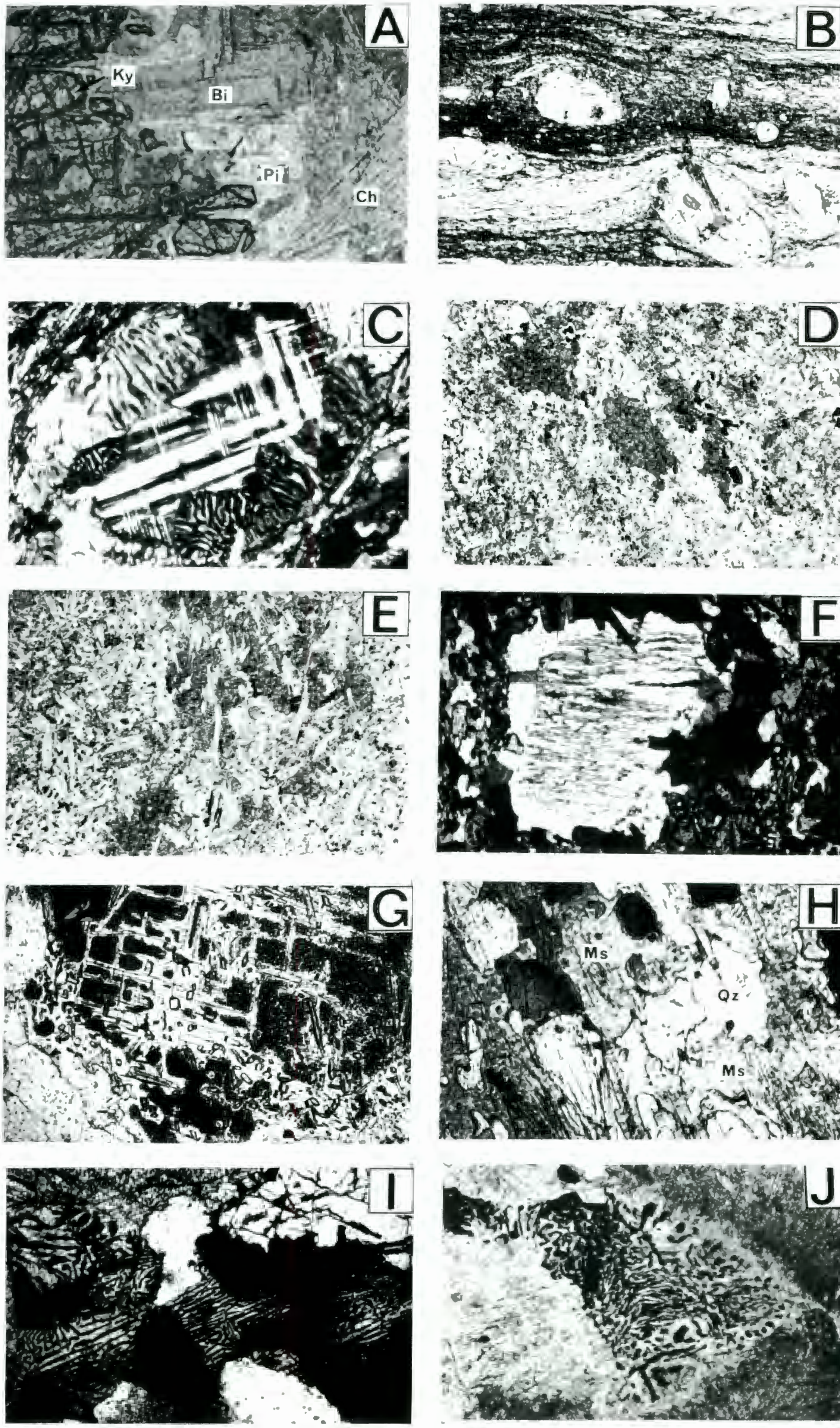


Figure 34

A: Kyanite in Pelitic Hornfels sample TV4 from Tantalite Valley. pp light.
1 cm = 0,20 mm.

B: K214A - Mylonite - Kumkum area.
Typical mylonite texture. Porphyroclasts are rotated and there is a marked difference in grain size between biotite found as inclusions and in the matrix. pp light.
1 cm = 1,86 mm.

C: K178 - Mylonite - Kumkum area.
Myrmekite developed on the margins of a microcline porphyroclast. Crossed nicols.
1 cm = 0,20 mm.

D: KK7 - Black Gneiss - Kumkum area.
Typical texture of Black Gneiss with anhedral garnet porphyroblasts in a fine-grained matrix of cordierite, feldspars, quartz, biotite and sillimanite. pp light.
1 cm = 1,86.

E: K62 - Black Gneiss - Kumkum area.
Laths of sillimanite cross-cut garnets. pp light.
1 cm = 1,43 mm.

Figure 34 (cont.)

F: K79 - Black Gneiss - Kumkum area.
Flame perthite. Crossed nicols.
1 cm = 0,20 mm.

G: KK10D Black Gneiss - Kumkum area.
Plagioclase with sillimanite aligned parallel to cleavages and dark green spinel filling the interstices of the trellis-work thus formed. pp light.
1 cm = 0,20 mm.

H: P.G.T.V. Nodule in Grey Gneiss - Tantalite Valley. A large mat of muscovite has inclusions of quartz, with which it has interlobate grain contacts. Both minerals have fibrolite inclusions. pp light.
1 cm = 0,20 mm.

I: TV173 Olivine gabbronorite - Tantalite Valley. Opaque mineral-orthopyroxene symplectite formed at the expense of olivine. The opaque mineral tends to occur parallel to the pyroxene cleavages. pp light.
1 cm = 0,20 mm.

Figure 34 (cont.)

J: TV251 Metagabbro - Tantalite Valley.
Opaque mineral-amphibole symplectite, interpreted as being an altered, pseudomorphic replacement of original olivine. pp light.
1 cm = 0,20 mm.

FIG. 35

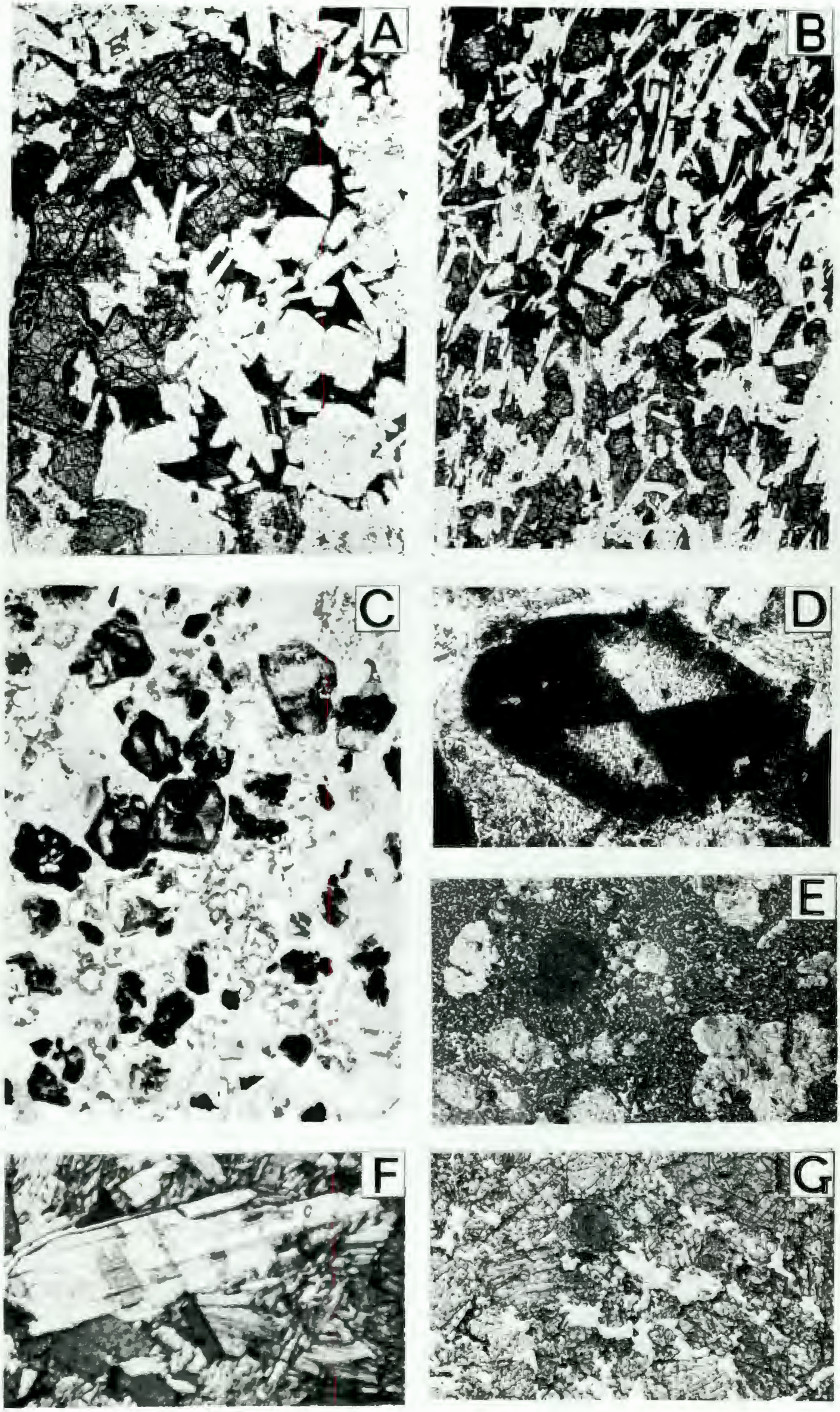


Figure 35

A: TV280 Olivine gabbronorite - Tantalite Valley. Orthocumulate texture with cumulus olivine and plagioclase and intercumulus pyroxenes. Although this rock-type is coarser grained than the Kumkum gabbronorite (see B) it is texturally and mineralogically very similar. pp light.

1 cm = 1.37 mm.

B: KK4 - Kumkum gabbronorite. Orthocumulate texture with cumulus plagioclase and olivine and intercumulus pyroxenes. Plagioclase laths define a distinct lamination. pp light.

1 cm = 1,37 mm.

C: AM204 - Eselruh gabbronorite - Kumkum area. Cumulus clinopyroxene (euhedral) showing hourglass zoning defined by opaque mineral exsolution. Note bronzite-hornblende/spinel coronas which have pseudomorphed olivine. pp light.

1 cm = 0,74 mm.

Figure 35 (cont.)

D: AM204 - Eselruh gabbronorite - Kumkum area. Cumulus clinopyroxene showing hourglass zoning on $\{100\}$. pp light.
1 cm - 0,20 mm.

E: TV275 - Mottled metagabbro - west of Tantalite Valley Complex. Texture of mottled metagabbro, showing the relationship between plagioclase megacrysts and the groundmass of hornblende and plagioclase. pp light.
1 cm = 3,71 mm

F: AM125 - Metagabbro - Tantalite Valley satellite body. Hornblende exsolved parallel to $\{10\bar{1}\}$ and $\{100\}$ in cummingtonite. pp light.
1 cm = 0,20 mm.

G: AM123A - Gabbronorite - Tantalite Valley satellite body. The rock consists predominantly of ortho-and clino-pyroxene and interstitial plagioclase. pp light.
1 cm = 2,86 mm.

Figure 36

A: KK3 - Contaminated gabbronorite - Kumkum area.
Typical equigranular interlobate texture.
pp light.
1 cm = 1,37 mm.

B: K58 - Kumkum granolite.
Typical equigranular interlobate texture.
Hornblende (dark grey) rims pyroxenes (light grey). Colourless material is plagioclase and quartz. pp light.
1 cm = 1,37 mm.

C: TV8 173 - Norite - Tantalite Valley.
Mesocumulate texture with euhedral bronzite being cumulus and plagioclase intercumulus.
pp light.
1 cm = 2,14 mm.

D: T32 - Troctolite - Tantalite Valley.
Mesocumulate texture with cumulus olivine and euhedral chromite? and intercumulus plagioclase. pp light.
1 cm = 3,00 mm.

Figure 36 (cont.)

E: TV170 Texture of cordierite-anthophyllite hornfels with decussate laths of anthophyllite and idioblastic cordierite. pp light.
1 cm = 3,57 mm.

F: K81 - Black Gneiss - Kumkum area.
Cordierite rims formed as a result of garnet breakdown. pp light.
1 cm = 0,20 mm.

G: KK7 - Black Gneiss - Kumkum area.
Opaque mineral symplectite in garnet formed as a result of the breakdown of this mineral to form cordierite. pp light.
1 cm - 0,20 mm.

H: AM157 - Metasomatic hornblendite-Tantalite Valley.
The rock is made up of decussate laths of hornblende, phlogopite and accessory amounts of scheelite. pp light.
1 cm = 2 mm.

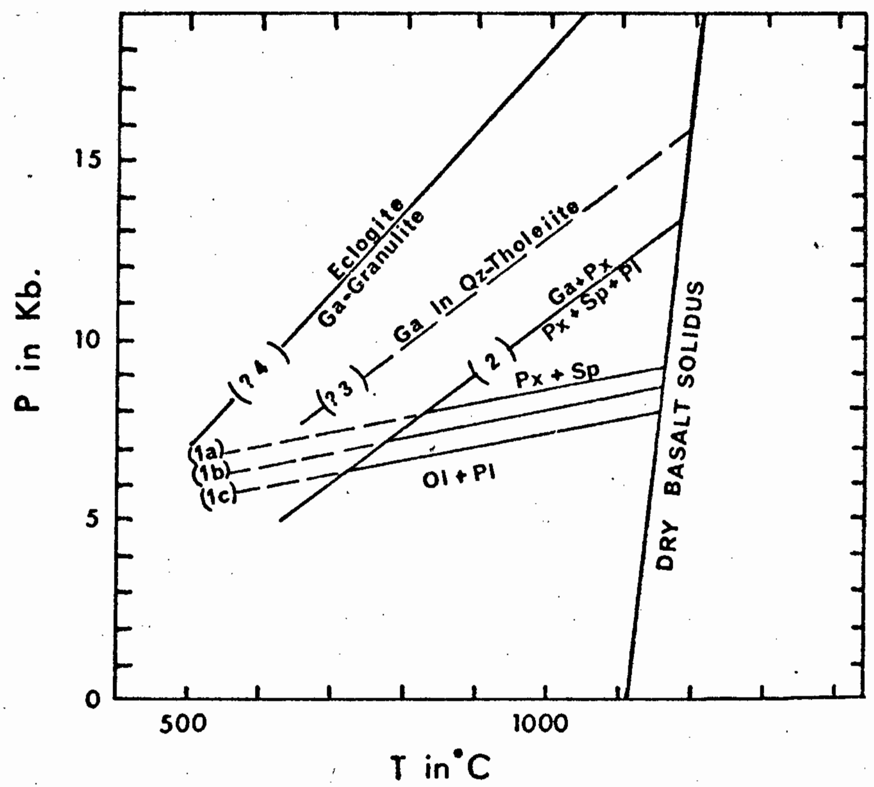


Fig 37 Experimentally determined equilibria: most are extrapolated to lower T for clarity; after Griffin & Heier (1973)

1a Reaction Mg-Ol+Pl→ Op+Cp+Sp (Green and Ringwood, 1967b)

1b Same reaction (Irving & Green 1970)

1c Same reaction but Fo-An system (Kushiro & Yoder 1966)

2 Op+Cp+Sp+Pl→ Cp+Ga. Fo-An system (Kushiro & Yoder 1966)

3 Appearance of garnet attributed to the reaction Op+Pl (±sp)→Ga±Cp±Qz (Green and Ringwood 1967b)

4 Disappearance of plagioclase in quartz-tholeiite (Green & Ringwood 1967b); position is very dependent on bulk composition

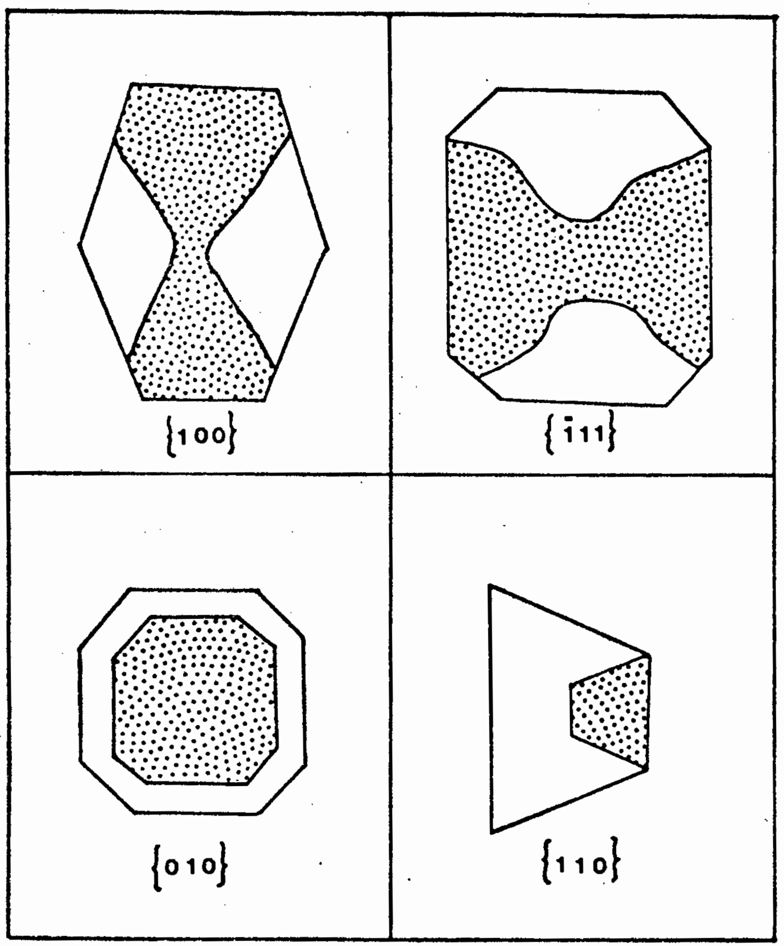


Fig 38 Sector zoning in clinopyroxenes from Eselruh gabbronorite

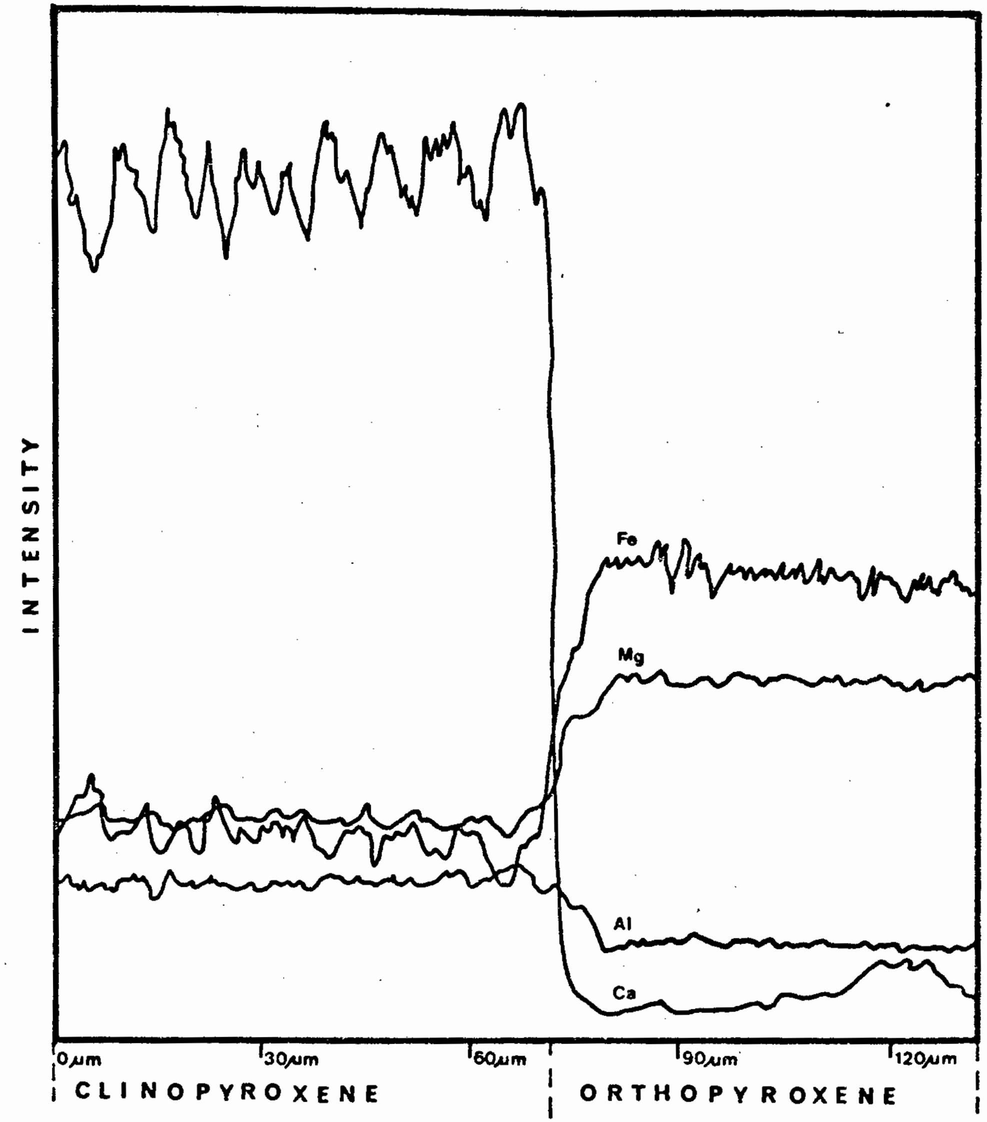


Fig 39 Qualitative scan of exsolution features in adjacent ortho- and clino-pyroxene grains from norite sample TV6 129. 15kV

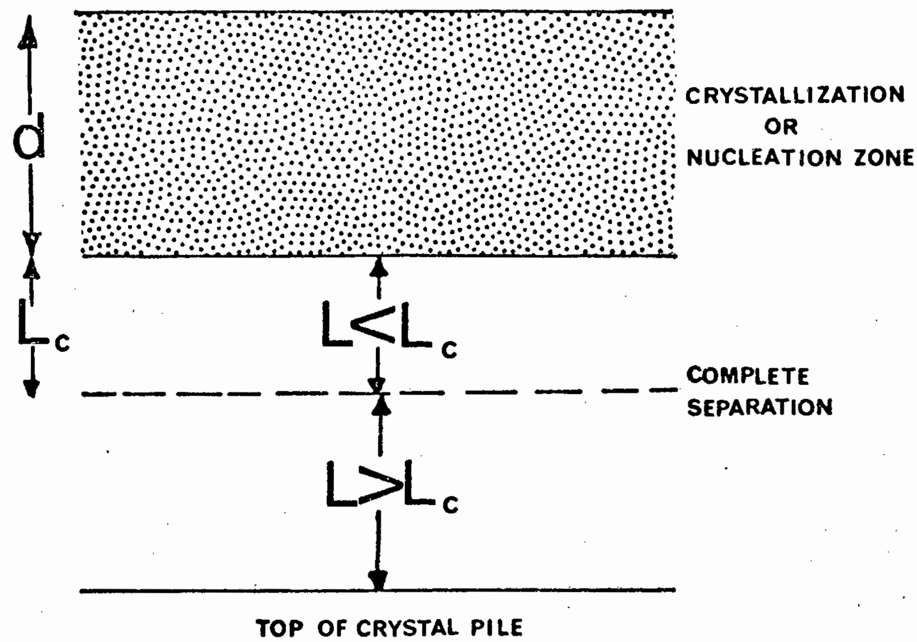


Fig 40 After Goode (1976). Crystallization model showing development of crystallization or nucleation zone (stippled) of thickness d at a distance of L above top of crystal pile. L_c represents critical distance below nucleation zone at which complete separation of pyroxene/olivine and plagioclase occurs.

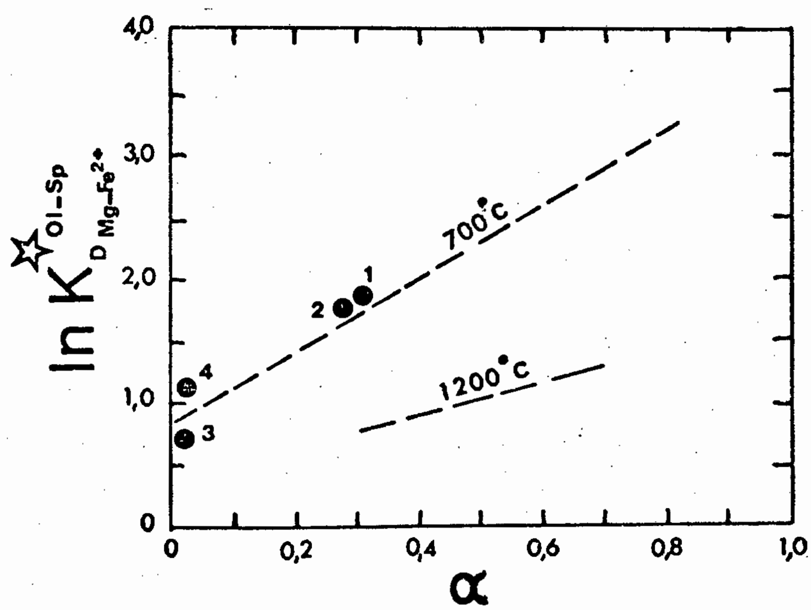


Fig 41 Plot of $\ln K_D^{*}\,{}^{ol-sp}_{Mg-Fe^{2+}}$ versus (after Evans and Frost 1975, Fig 8) for some olivine-spinel pairs from the study area. Terms explained in Table (34) and text. (1) TV49 ferritchromite-olivine (2) TV49 picotite-olivine (3) TV49 spinel-olivine (4) K37A hercynite-olivine.

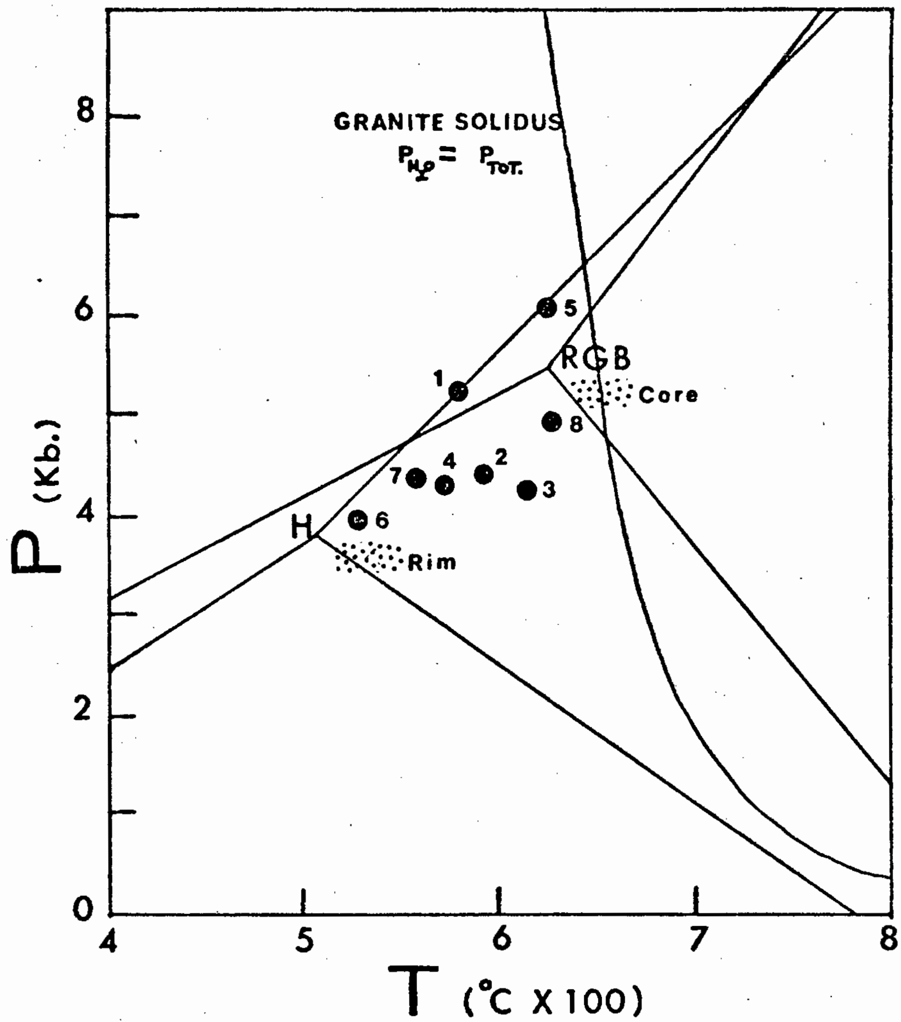


Fig 42 P-T diagram showing the results of garnet-cordierite geothermometry-geobarometry for Black Gneiss samples

1	A5	5	K66B
2	A3	6	K35 Porphyroblast Core
3	KK7	7	K35 Porphyroblast Rim
4	K19A	8	K35 Groundmass Rim

Shaded areas give the results for Tantalite Valley Hornfels sample T19. Peak of contact metamorphism is represented by "Core" and retrograde metamorphism by "Rim". "H" and "RGB represent the limits of the alumino-silicate polymorphs after Holdaway (1971) and Richardson, Gilbert and Bell (1969) respectively

Fig 43 Part of the pyroxene quadrilateral Di-Hd-En-Fs showing the pyroxene phases and their compositional variation in the mafic-ultramafic rocks of the Tantalite Valley and Kumkum areas. Below the base of the quadrilateral, the scale (Fo to Fa) shows the range of olivine compositions. Tie-lines between appropriate coexisting pyroxene pairs are drawn, as well as lines linking coexisting pyroxene and olivine pairs

Key:-

(1) - TV49 - Troctolite

(2) - (2A)-(2B)-(2C) TV6 129 - Norite - where 2A and 2B are discrete phases and 2 and 2C are exsolved phases

(3) - K4 Eselruh gabbronorite

(4) - AM123A - T.V. Satellite Body

(5) - TV 233 - Gabbronorite

(6) - TV263 - Gabbronorite

(7) - AM21C - Gabbronorite

(8) - AM41 - Gabbronorite

(9) - TV187 - Gabbronorite

(10) - K37A - Kumkum gabbronorite

(11) - K45A - Contaminated gabbronorite

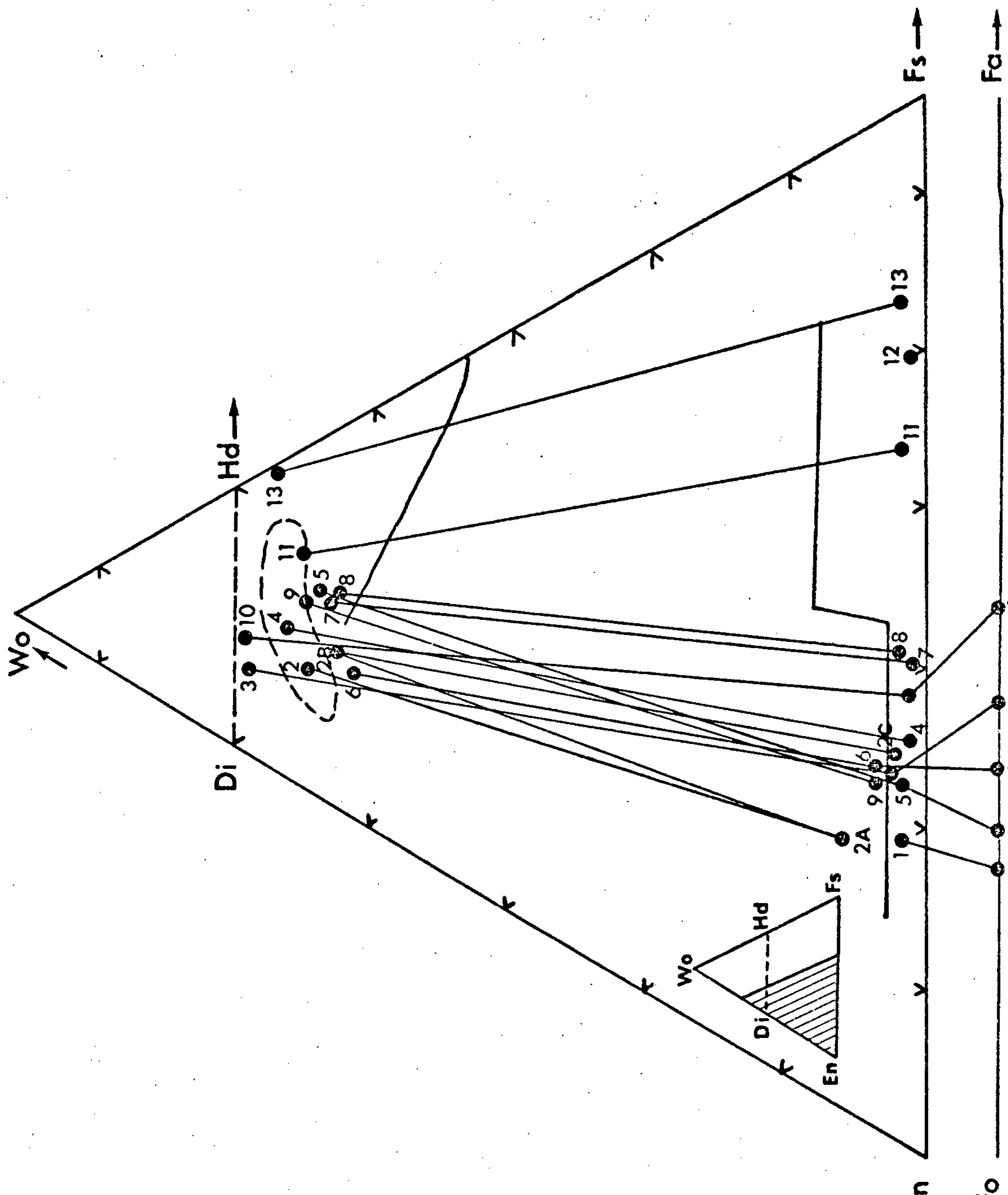
(12) - KK6 - Black Gneiss

(13) - K58 - Granolite

Note (3) - (13) are discrete phases

Field of clinopyroxenes from SE Alaskan type ultramafic rocks

Skaergaard trend



Wo
Di
Hd
En
Fs
Fo
Fa

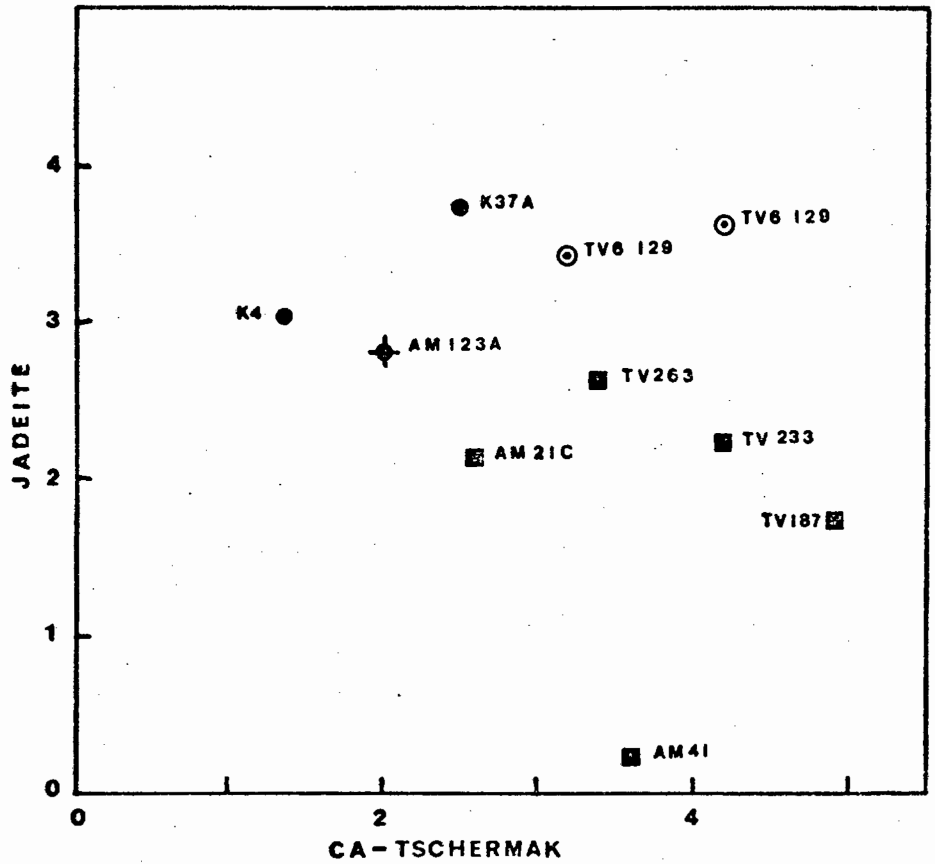


Fig 44 Plot of Jadeite versus Ca-Tschermak for clinopyroxenes from the study area. Symbols as for Fig (66) Tantalite Valley except that blacked in circles are samples from the Kumkum area

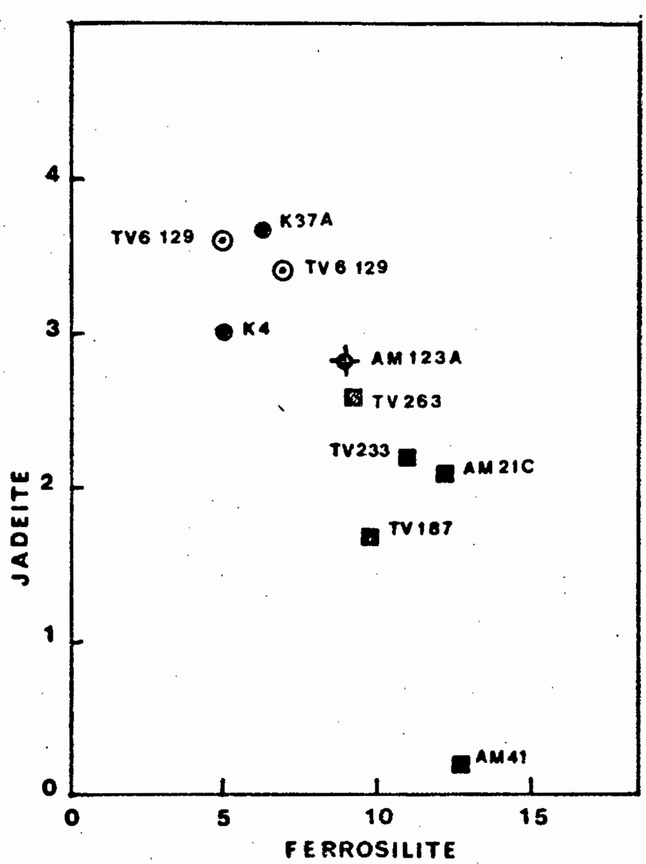


Fig 45 Plot of Jadeite versus Ferrosilite for clinopyroxenes from study area. Symbols as in Fig 44.

Fig 46 Plot of Mg-tschermakite + Ca - tschermakite versus Ferrosilite for orthopyroxenes from the study area. Symbols as for Fig 44

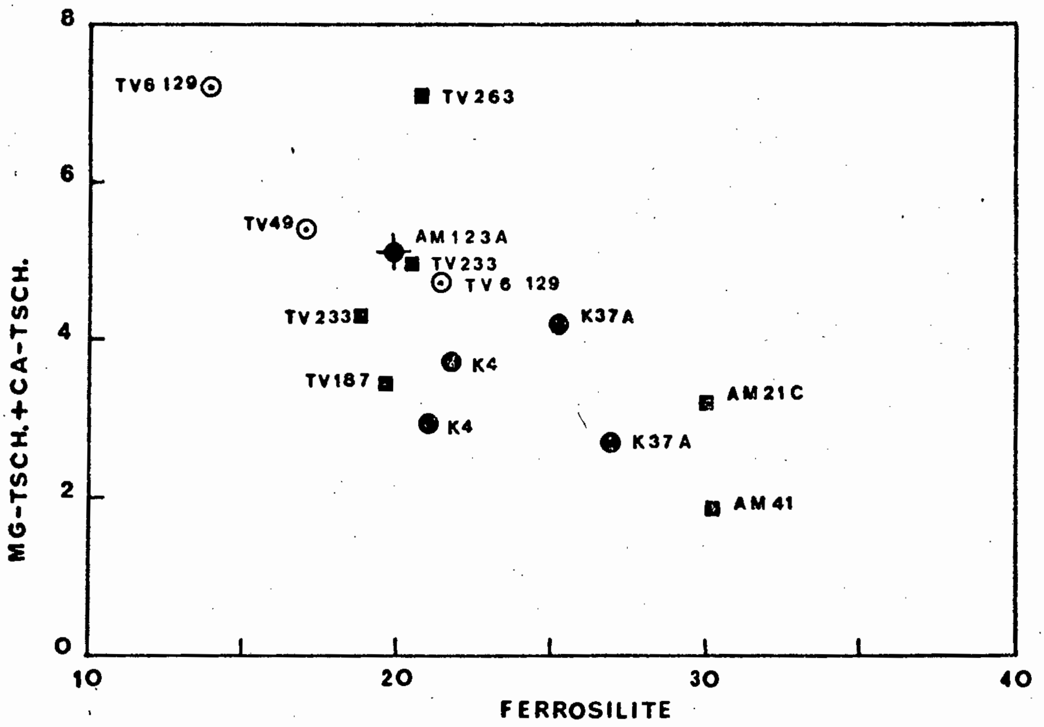
Fig 47 Plot of clinopyroxenes from some mafic and ultramafic rocks of the study area on part of a triangular diagram in terms of (Ca + Na + K): Mg: (Fe^{2+} + Fe^{3+} + Mn) atomic percent. After Le Bas (1962)

Field I clinopyroxenes from per-alkaline rocks

Field II clinopyroxenes from normal-alkaline rocks

Field III clinopyroxenes from non-alkaline rocks, including tholeiitic, high alumina and calc alkaline

Symbols as for Fig 44


MG-TSCH.+CA-TSCH.
FERROSILITE
TV6 129
TV 263
TV49
AM 123 A
TV233
TV 6 129
TV 233
K37A
K4
TV187
AM 21 C
K4
K37 A
AM 41

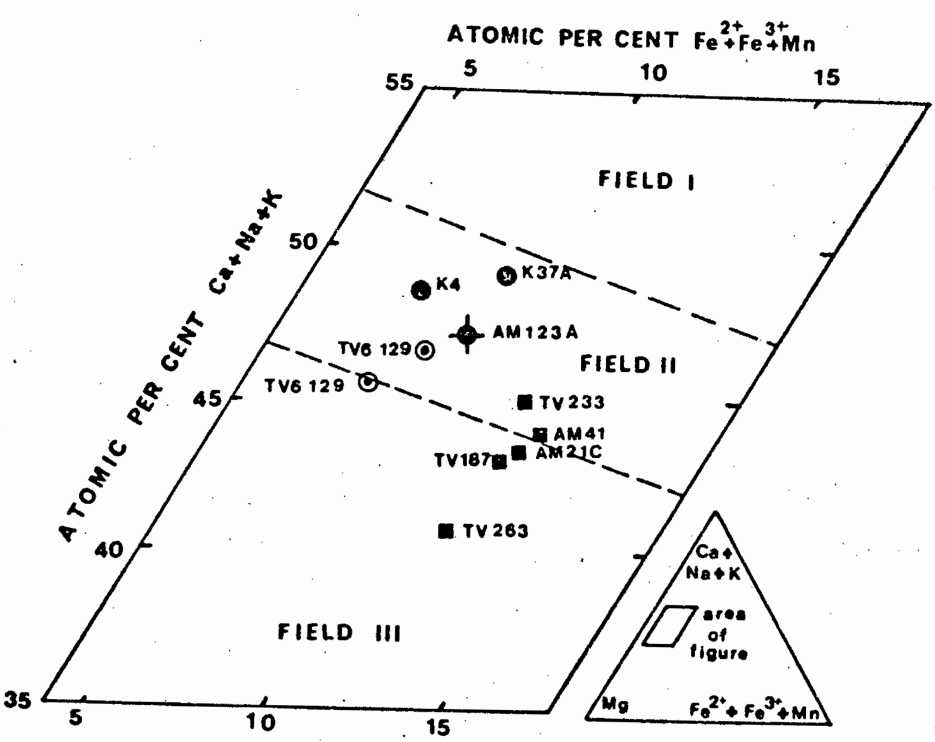
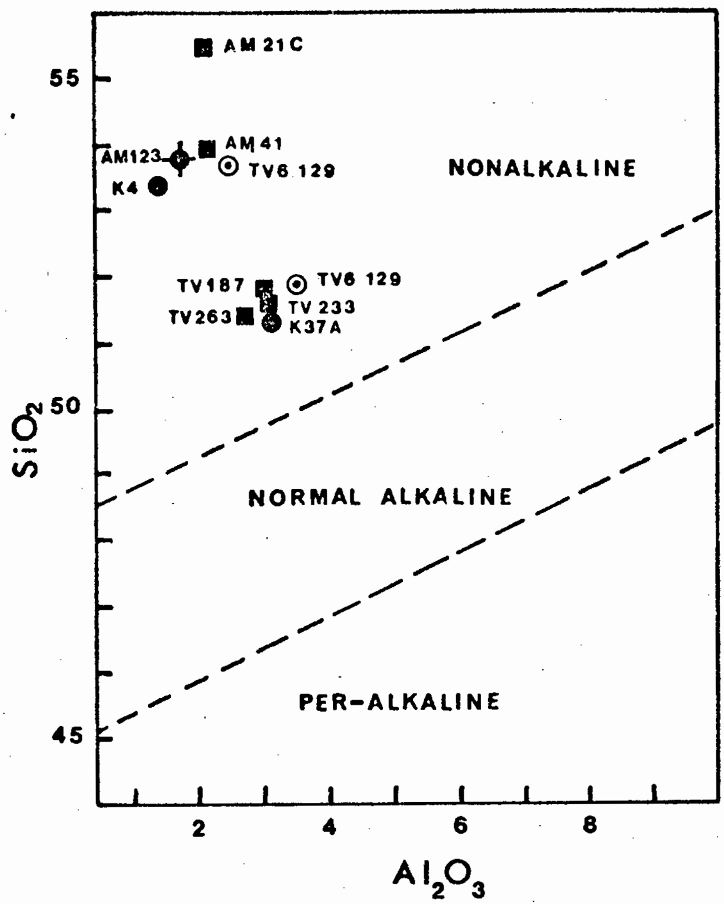

ATOMIC PER CENT Fe2++Fe3++Mn
ATOMIC PER CENT Ca+Na+K
FIELD I
FIELD II
FIELD III
K4
K37A
AM123A
TV6 129
TV6 129
TV233
AM41
AM21C
TV187
TV 263
Ca+ Na+K
area of figure
Mg
Fe2++Fe3++Mn

Fig 48 Silica/alumina plot (weight percent) of clinopyroxenes from the study area after Le Bas (1962). Symbols as in Fig 44

Fig 49 Range of analyzed plagioclase compositions in metabasites from the Tantalite Valley and Kumkum areas.

Circles - Tantalite Valley metabasites including mottled metagabbro, amphibolite, metabasite hornfels, metagabbro, gabbronorite, satellite body, mafic-ultramafic rocks.

Triangles - Kumkum metabasites including gabbronorites (Contaminated, Eselruh and Kumkum) and Granolite.


AM 21C
55
AM123
AM 41
TV6 129
NONALKALINE
K4
TV187
TV6 129
TV263
TV 233
K37A
SiO2
50
NORMAL ALKALINE
PER-ALKALINE
45
2
4
6
8
Al2O3

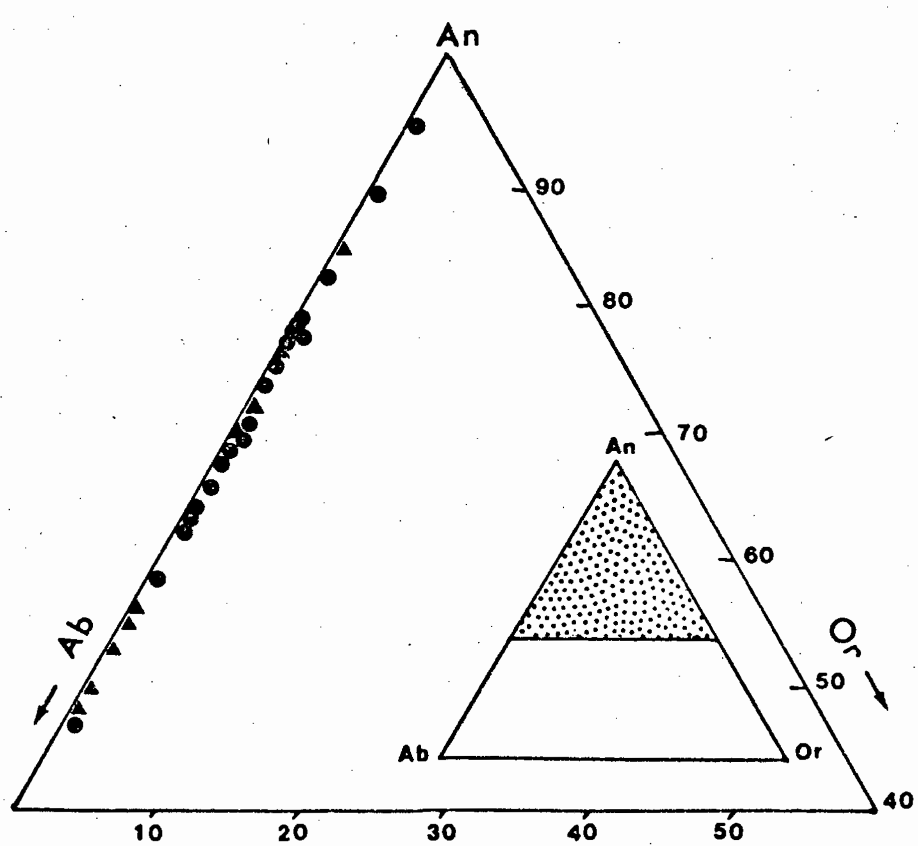

An
90
80
70
An
60
Ab
Or
50
Ab
Or
40
10
20
30
40
50

Fig 50 The nomenclature of calcic amphiboles occurring in various mafic and metabasite rocks of the Tantalite Valley and Kumkum areas after Leake's (1968) classification

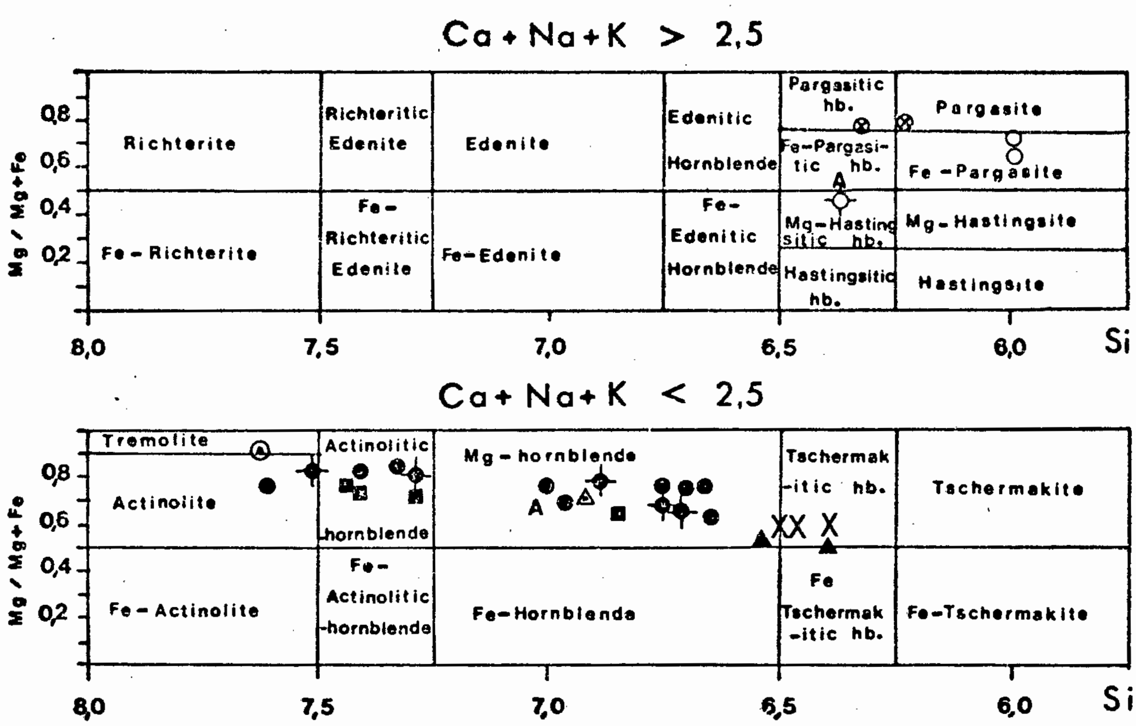
Key Tantalite Valley

(A) Amphibolites
(▲) Mottled Metagabbro
(●) Metagabbro
(⧫) Satellite Body
(◎) Ultramafic rocks
(▲) Metasomatic hornblendite
(X) Metabasite hornfels

Kumkum

(◊) Granolite
(○) Kumkum gabbronorite
(⊗) Eselruh gabbronorite

Fig 51 Plot of Si against (Ca + Na + K) for calcic amphiboles, with Atomic proportions based on 23 oxygens. Scheme after Miyashiro (1973). Symbols as for Fig 50.


Ca+Na+K > 2,5
Richterite
Richteritic Edenite
Edenite
Edenitic Hornblende
Pargasitic hb.
Pargasite
Fe-Pargasitic hb.
Fe-Pargasite
Fe-Richterite
Fe-Richteritic Edenite
Fe-Edenite
Fe-Edenitic Hornblende
Mg-Hastingsitic hb.
Mg-Hastingsite
Hastingsitic hb.
Hastingsite
Mg / Mg+Fe
Si
Ca+Na+K < 2,5
Tremolite
Actinolite
Actinolitic hornblende
Mg-hornblende
Tschermakitic hb.
Tschermakite
Fe-Actinolite
Fe-Actinolitic-hornblende
Fe-Hornblende
Fe Tschermakitic hb.
Fe-Tschermakite

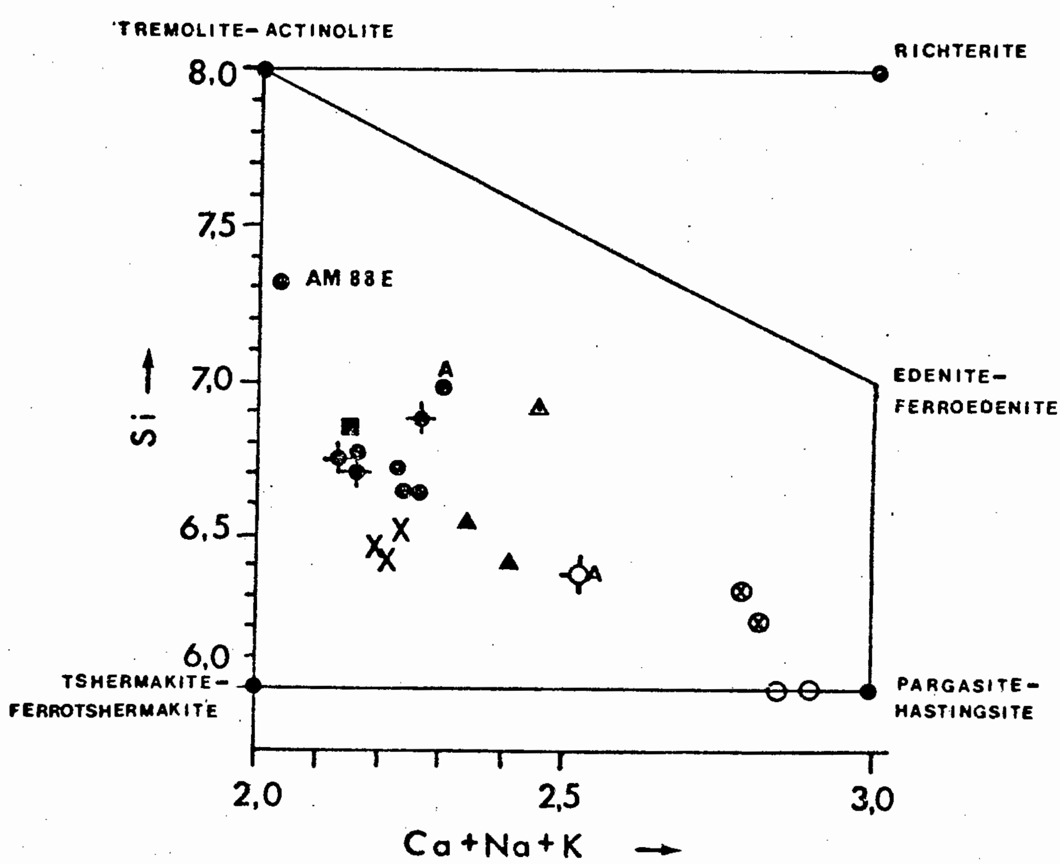
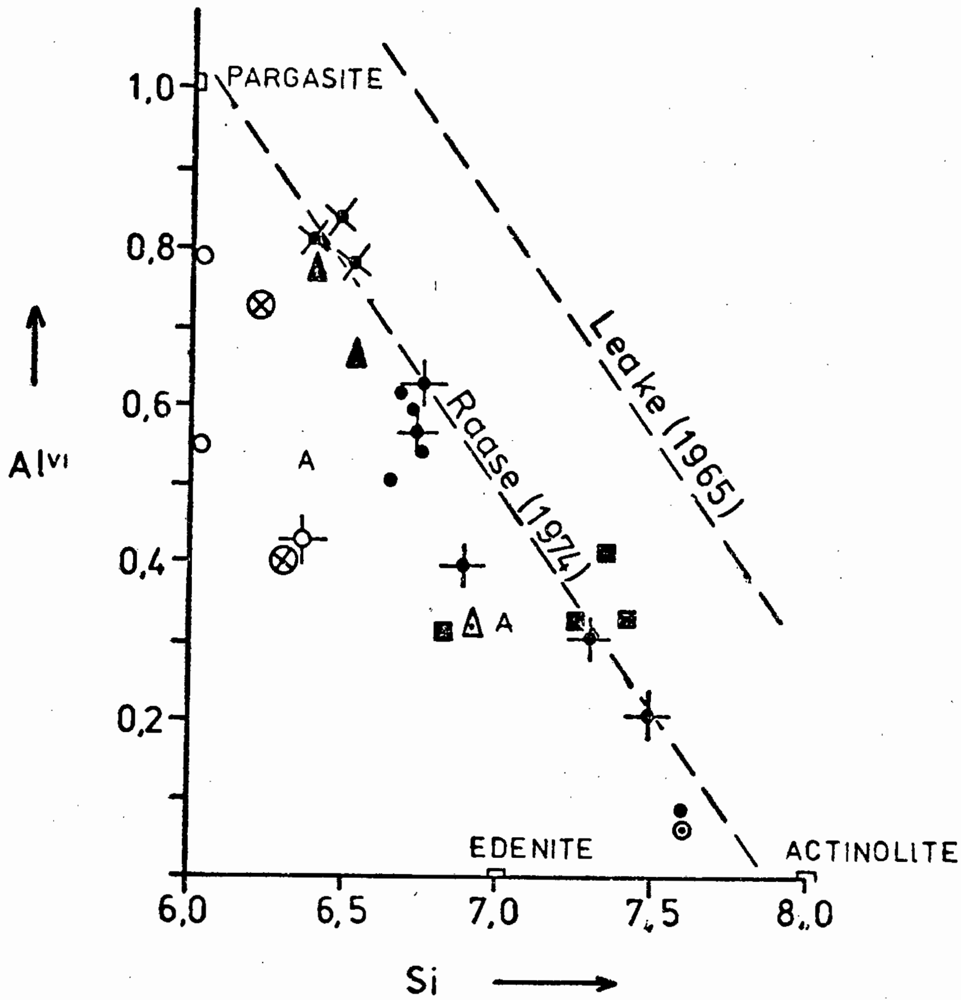

TREMOLITE-ACTINOLITE
RICHTERITE
AM 88 E
EDENITE-FERROEDENITE
TSHERMAKITE-FERROTSHERMAKITE
PARGASITE-HASTINGSITE
Si
Ca+Na+K

Fig 52 Relation between Al^{VI} and Si. (23 oxygens) contents of calcic amphiboles from the study area. Symbols as in Fig 50. Upper diagonal line (Leake 1965) indicates the maximum possible amounts of Al^{VI}. Lower diagonal line (Raase, 1974) indicates the division between hornblende from low-pressure regional metamorphic terranes (below) and high-medium pressure metamorphic terranes (above).

Fig 53 Variation of Ti versus Si in calcic amphiboles, with atomic proportions based on 23 oxygens. Fields of Igneous and Metamorphic amphiboles after Leake (1965a). Symbols as in Fig 50.


1,0
0,8
0,6
0,4
0,2
Al^{VI}
PARGASITE
Leake (1965)
Raase (1974)
EDENITE
ACTINOLITE
6,0
6,5
7,0
7,5
8,0
Si

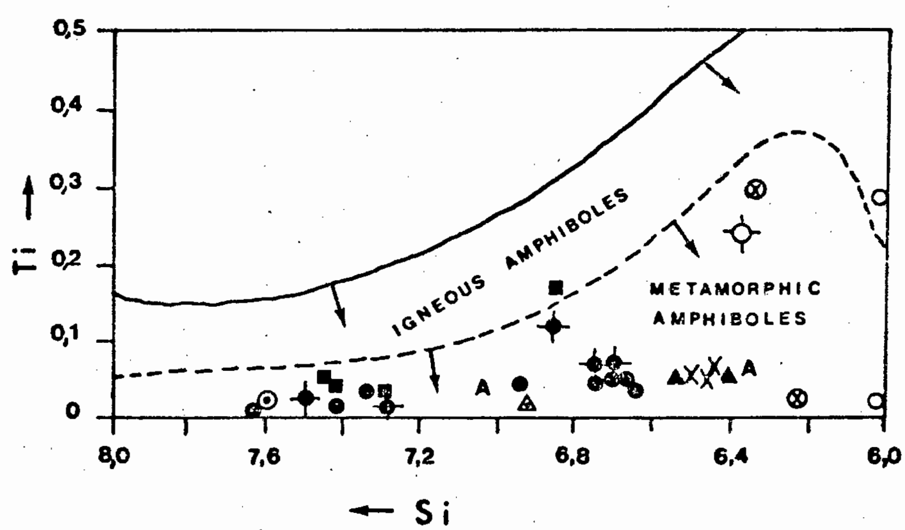

0,5
0,4
0,3
0,2
0,1
0
Ti
IGNEOUS AMPHIBOLES
METAMORPHIC AMPHIBOLES
8,0
7,6
7,2
6,8
6,4
6,0
Si

Fig 54 Distribution of Mg, total Fe and Ca between coexisting hornblende and cummingtonite

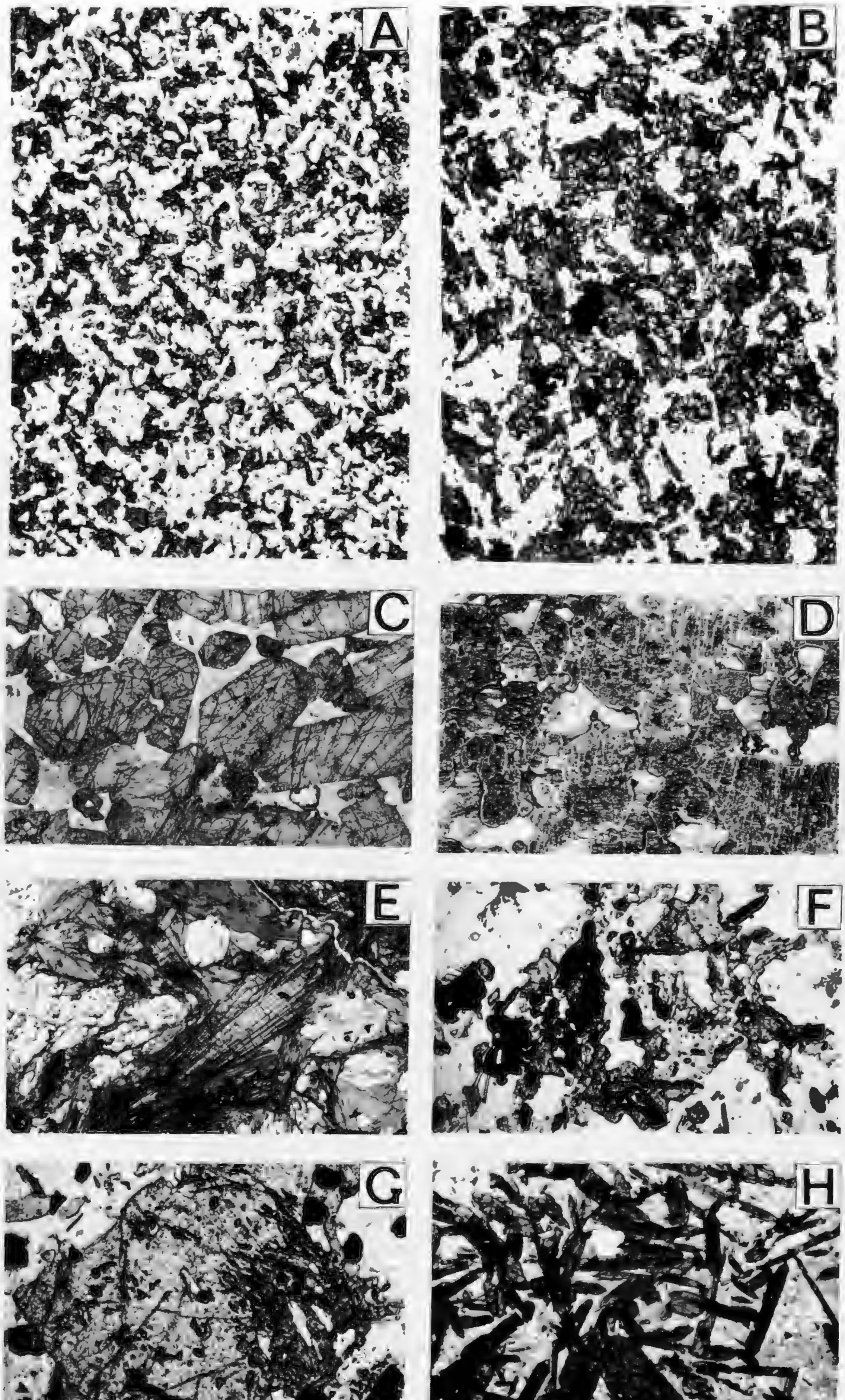
blank circles - Metabasite hornfels

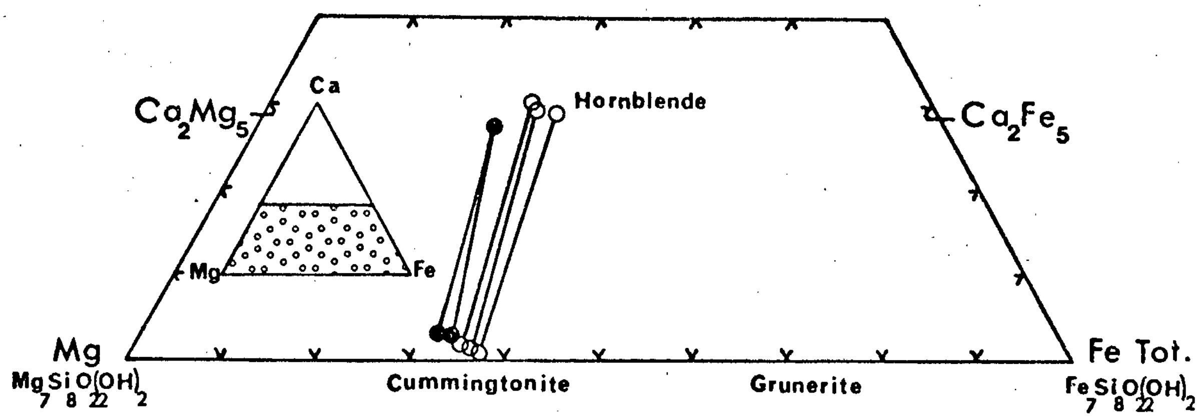
opaque circles - Metagabbro from satellite body

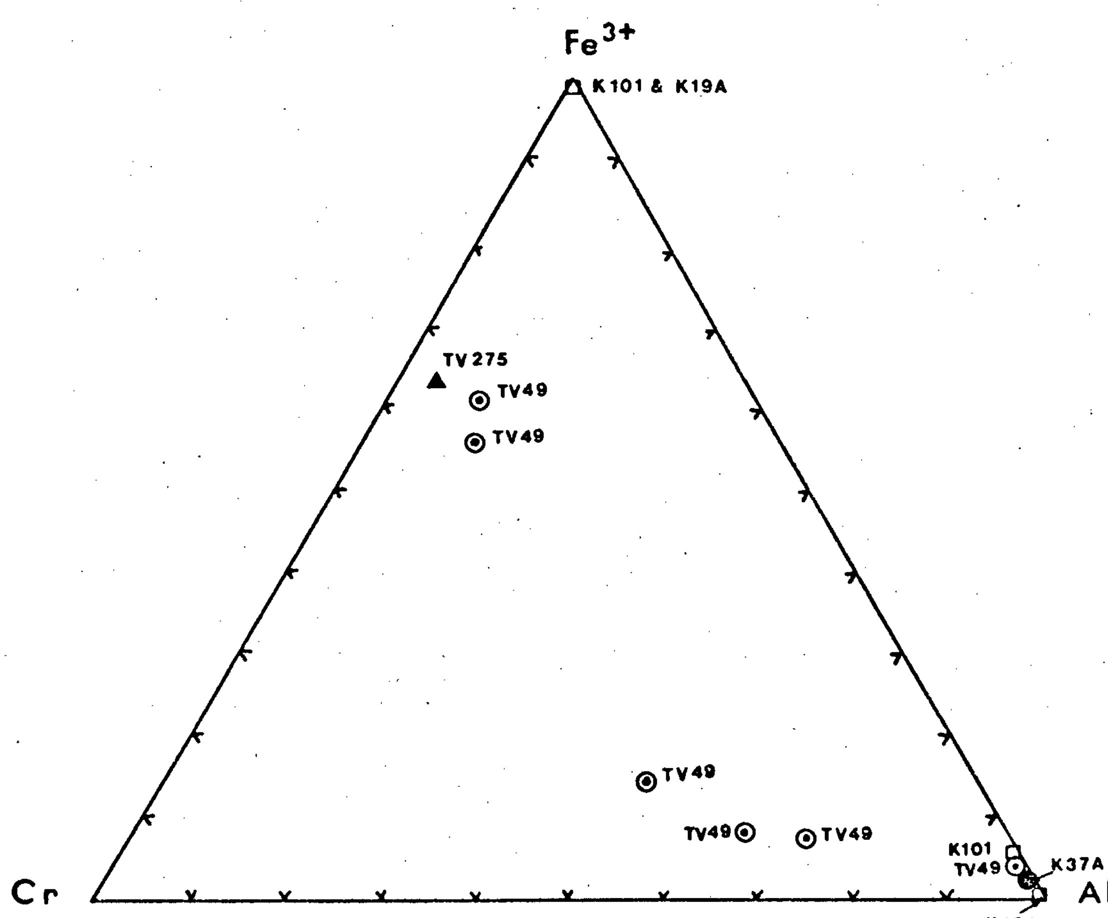
Fig 55 Cr, Al and Fe^{3+} in spinels from Tantalite Valley and the Kumkum area.

(▲) Mottled metagabbro
(◎) Troctolite
(●) Kumkum gabbronorite
(□) Black gneiss

FIG.36




Ca
Mg
Fe
Ca_2Mg_5
Ca_2Fe_5
Hornblende
Mg
$Mg_7Si_8O_{22}(OH)_2$
Cummingtonite
Grunerite
Fe Tot.
$Fe_7Si_8O_{22}(OH)_2$


Fe^{3+}
K101 & K19A
TV275
TV49
TV49
TV49
TV49
TV49
K101
TV49
K37A
K101
Cr
Al

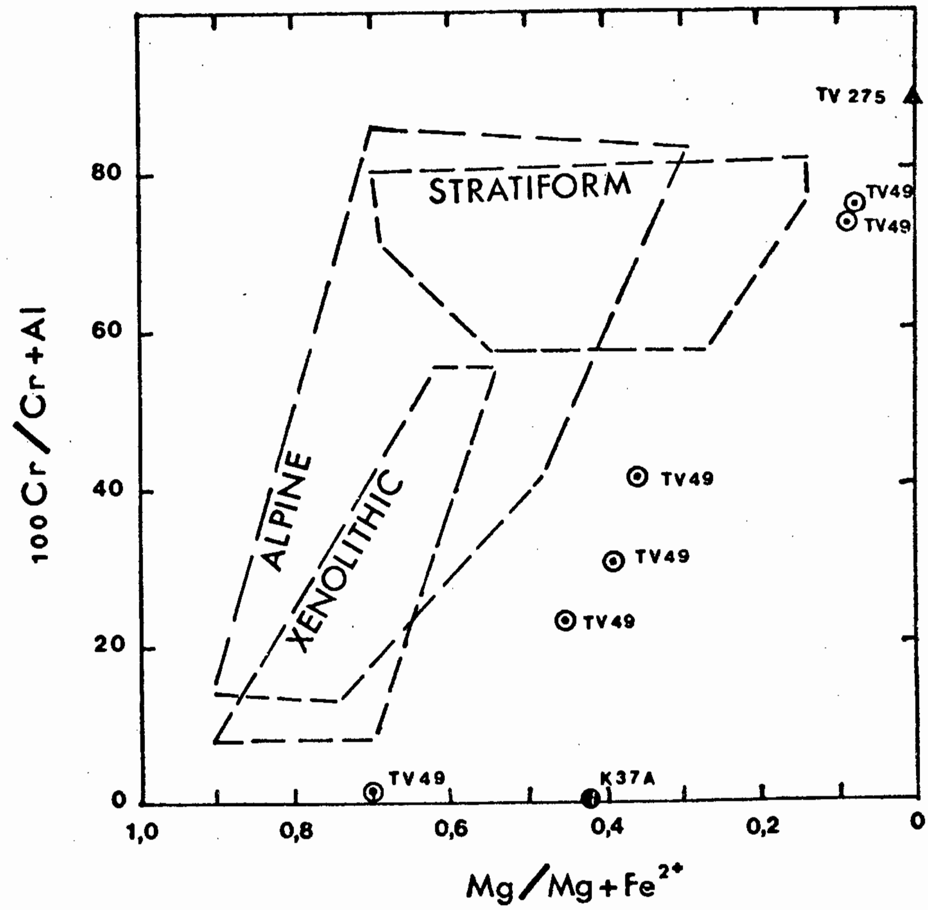


Fig 56 Correlation between 100 Cr/(Cr + Al) and X_{Mg} for the spinels from troctolite sample TV49 from Tantalite Valley. (▲) is ferritchromite from mottled metagabbro and (●) is hercynite from Kumkum gabbronorite. The fields of stratiform, alpine and xenolithic chromites are from Irvine and Findlay (1972)

Fig 57 Plot of TiO_2 against FeO (total)/MgO for biotites

Key:- Tantalite Valley

(▲) Mottled metagabbro
(☆) Pelitic hornfels
(★) Cordierite-anthophyllite hornfels
(⊗) Orthopyroxene-bearing hornfels
(■) Gabbronorite
(♦) Satellite Body
(◎) Ultramafic Rock
(◬) Metasomatic hornblendite

Kumkum

(●) Black Gneiss
(◇) Granolite
(K) Kumkum gabbronorite
(E) Eselruh gabbronorite

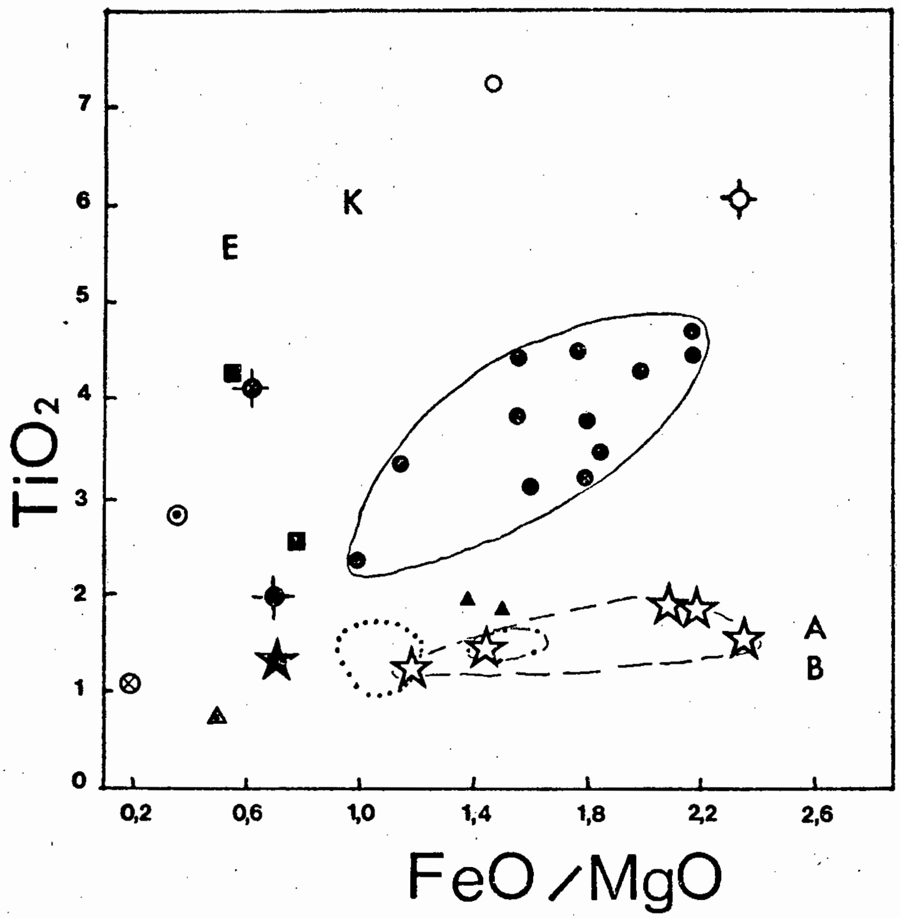
— field of biotites from Black Gneiss
- - field of biotites from Pelitic hornfels
.... field of metamorphic biotite in the Haib basaltic andesites (Reid 1977)
-.-. field of primary igneous biotite from Vioolsdrift granodiorite and adamellite (Reid 1977)

A Average bulk rock composition of Black Gneiss
B Average bulk rock composition of Pelitic Hornfels

Fig 58 Al-Mg-Fe (atom %) plot for metamorphic chlorites from Tantalite Valley

(○) Pelitic hornfels
(●) Metagabbro
(▲) Mottled metagabbro
(□) Cordierite-anthophyllite hornfels
(◎) Ultramafic rock
(▽) Psammitic hornfels
(+) Metabasite hornfels

- - - field of chlorites from Haast Schist Group Metabasites (Cooper 1972) with grade of metamorphism increasing from left to right as indicated by the arrow.
-.-. field of chlorites from the Haib basaltic andesites after Reid (1977)


TiO2
FeO / MgO
K
E
A
B
0
1
2
3
4
5
6
7
0,2
0,6
1,0
1,4
1,8
2,2
2,6

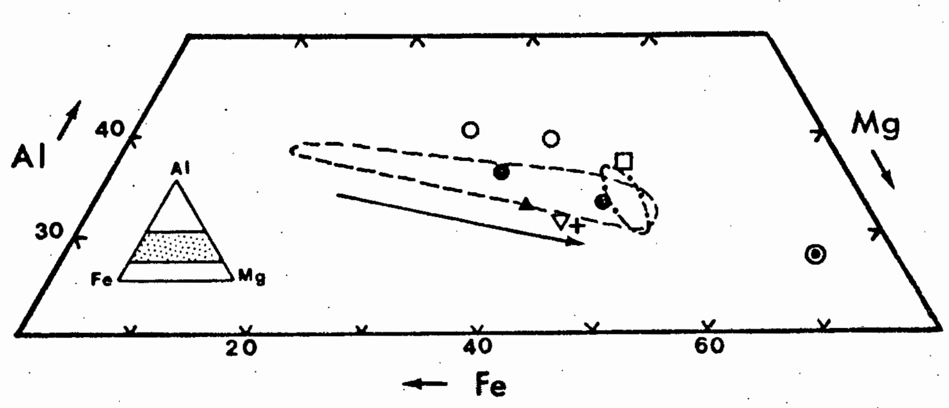

Al
Mg
Fe
40
30
20
40
60
Al
Fe
Mg

Fig 59 AFM diagram with projection through biotite for hornfelses from Tantalite Valley.
Analyses of minerals are plotted as circles and whole rocks are plotted using square symbols.
Numbers next to the symbols refer to samples as follows. 'C' and 'R' refer to analyses of core and rim zones of garnets

1 Pelitic hornfels. TV276

1A As above but corrected for 13% chlorite

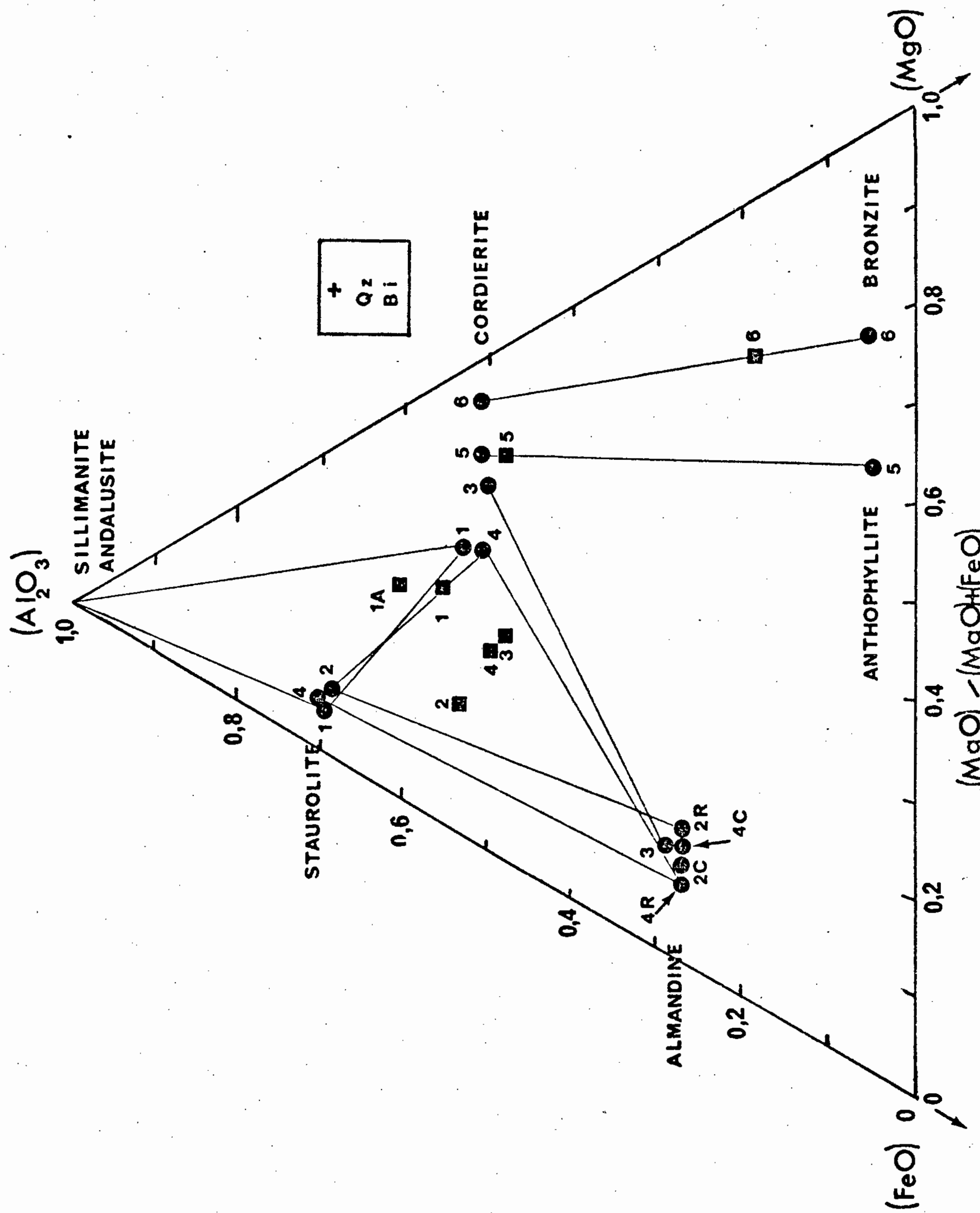
2 Pelitic hornfels TV4.

3 Pelitic hornfels TV13/165.

4 Pelitic hornfels T19.

5 Cordierite-anthophyllite hornfels. TV170.

6 Orthopyroxene-bearing hornfels TV226



(Al_2O_3)
SILLIMANITE
ANDALUSITE
CORDIERITE
BRONZITE
ANTHOPHYLLITE
STAUROLITE
ALMANDINE
+ Qz Bi
(FeO)
(MgO)
$(MgO)/(MgO)+(FeO)$

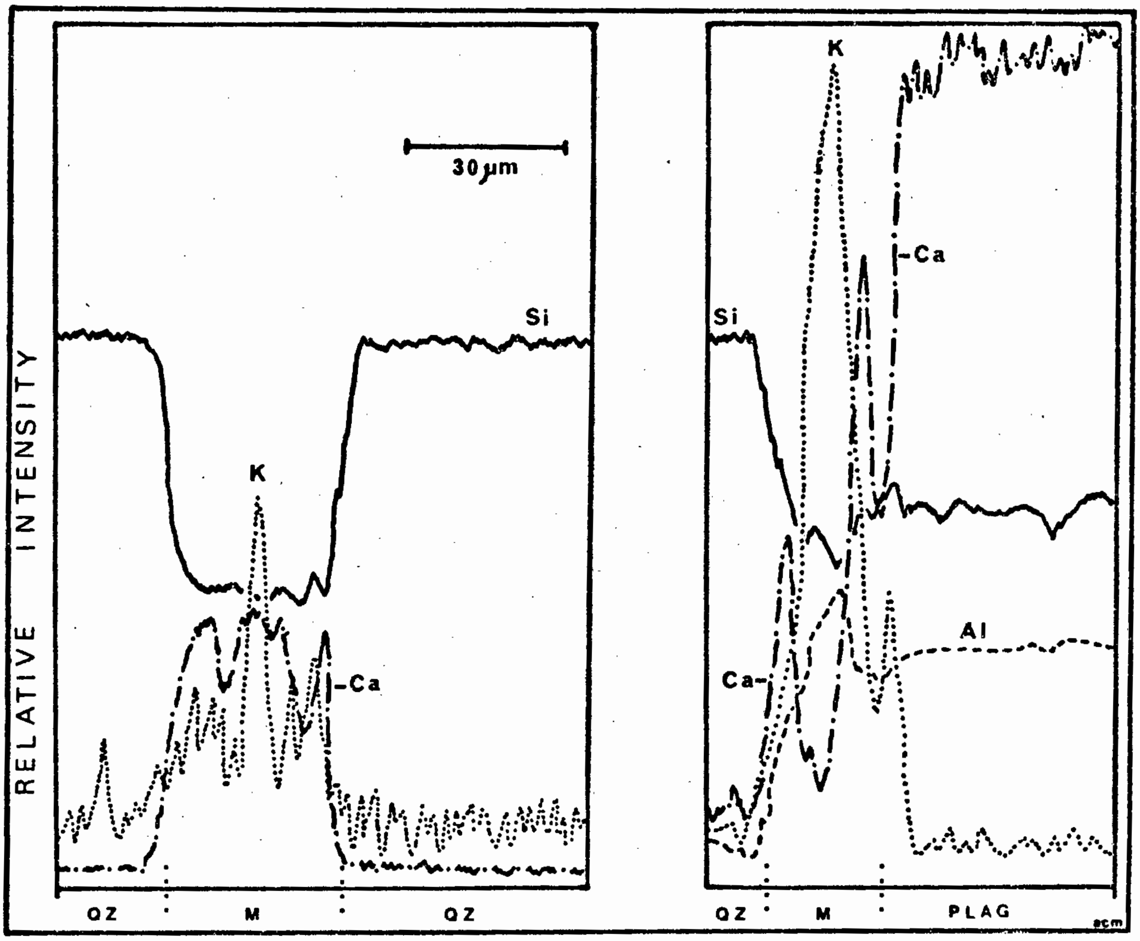


Fig 60 Electron microprobe scans across grain boundaries in Tantalite Valley psammitic hornfels sample AM30A. The left hand side is across a quartz-quartz boundary, separated by turbid material (M) and the right-hand side is across a quartz-plagioclase boundary

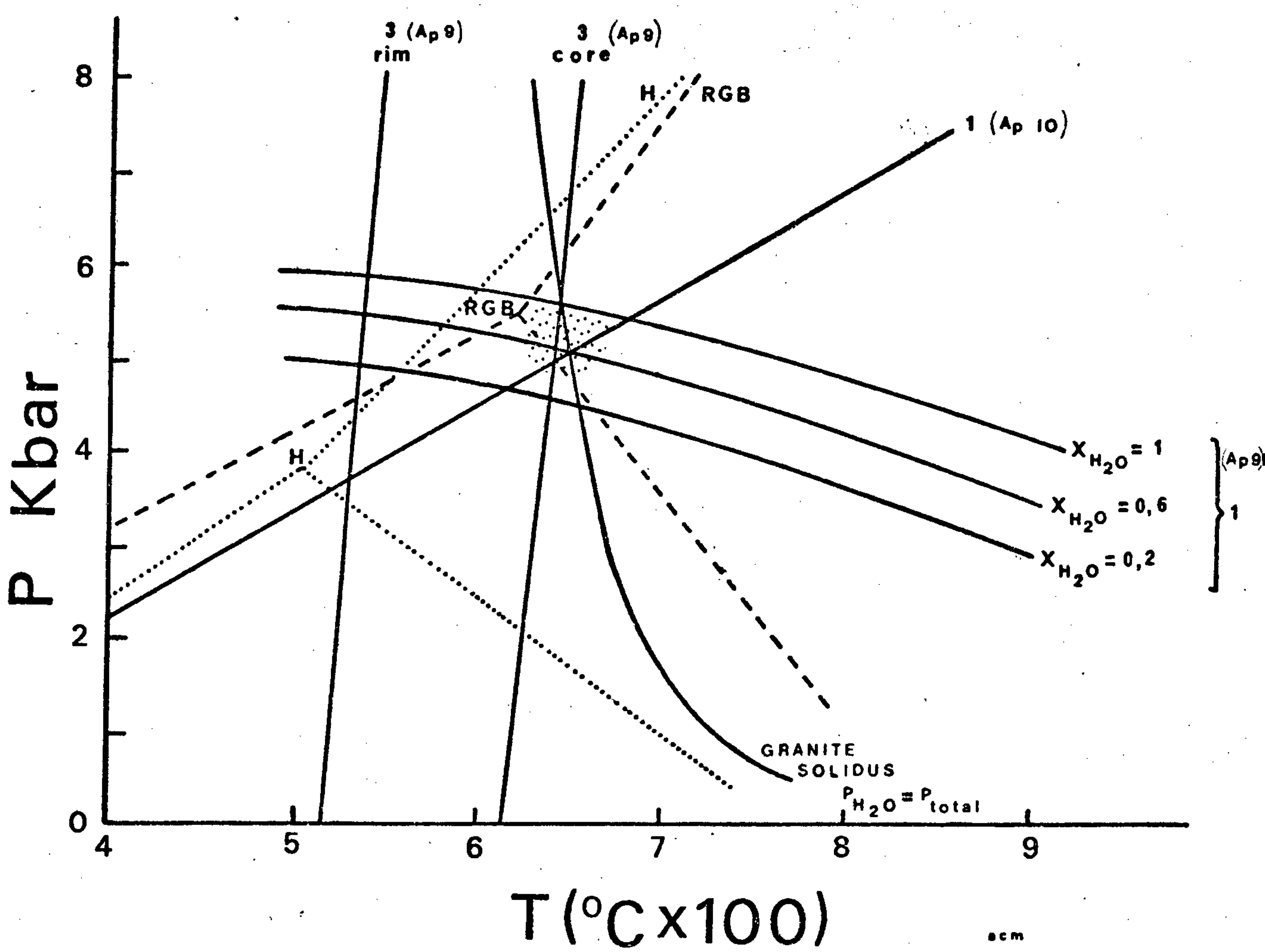


Fig 61 P-T diagram indicating the probable conditions of formation of the pelitic hornfels T19 at the peak of contact metamorphism (stippled area). Reactions calculated are numbered as in appendices 9 and 10 ie Ap9 and Ap10. Also plotted are the limits of stabilities of the alumino-silicate polymorphs after Holdaway (1971) labelled "H" and of Richardson, Gilbert and Bell (1969), labelled "RGB". The position of the saturated granite solidus is also shown (Turner 1968).

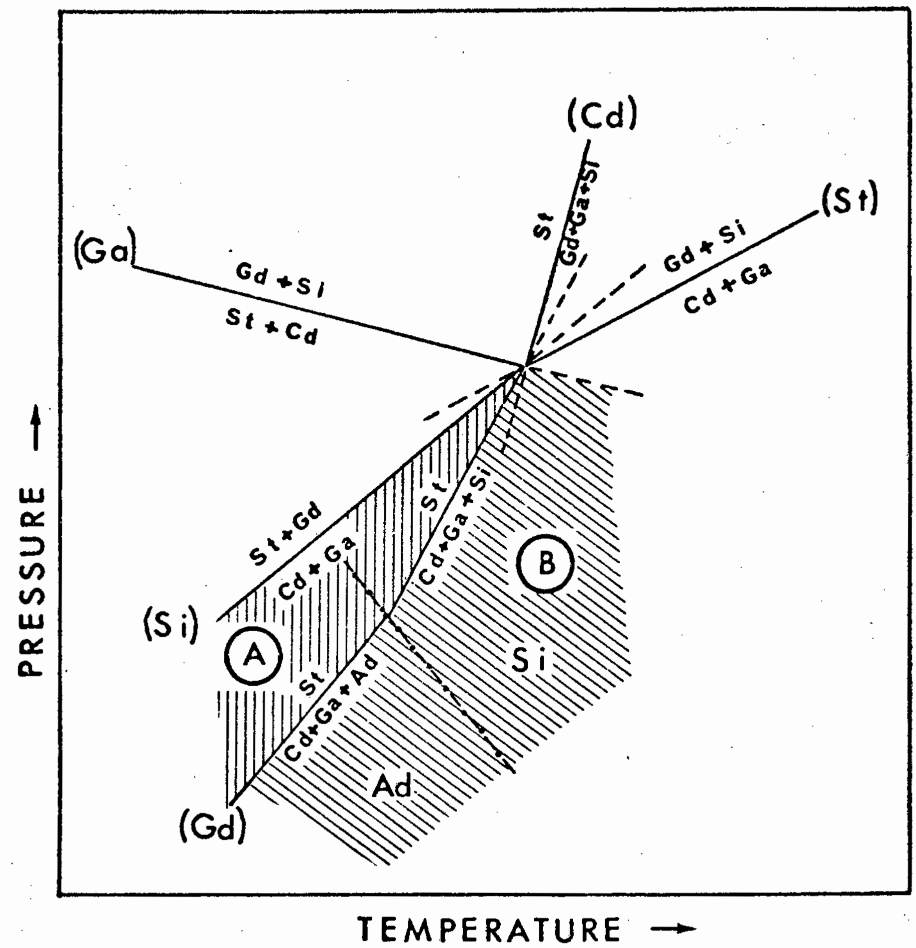


Fig 62 Schreinemakers' bundle after Robinson and Jaffe (1969, Fig 16A). Sectors A and B are explained in the text. The slope of the reaction (Gd) is taken from Robinson and Jaffe for the sillimanite zone (Si) but is probably too steep because they assumed anhydrous cordierite and the most water-rich staurolite for their calculations (Robinson and Jaffe 1969, Table 7). The slope of the reaction (Gd) in the andalusite zone (Ad) is calculated using the Case I ($PH_2O=P_{solid}$) formula of Robinson and Jaffe, an assumed molar volume of 51,5 cc for andalusite and $\underline{S}$ equal to 544 J/deg per mole of dehydration of water, plus 60 J/deg per atom of Al changing from Vl to IV co-ordination.

Fig 63 AFM diagram for Black Gneiss samples projected through K-feldspar. Mineral compositions are represented by opaque circles and rock compositions by hollow circles.

(1) KK7

(2) K19A

(3) K66B

(4) K35 Matrix Rim

(4A) K35 Porphyroblast Core

(4B) K35 Porphyroblast Rim

(5) GBW 241

(6) A3

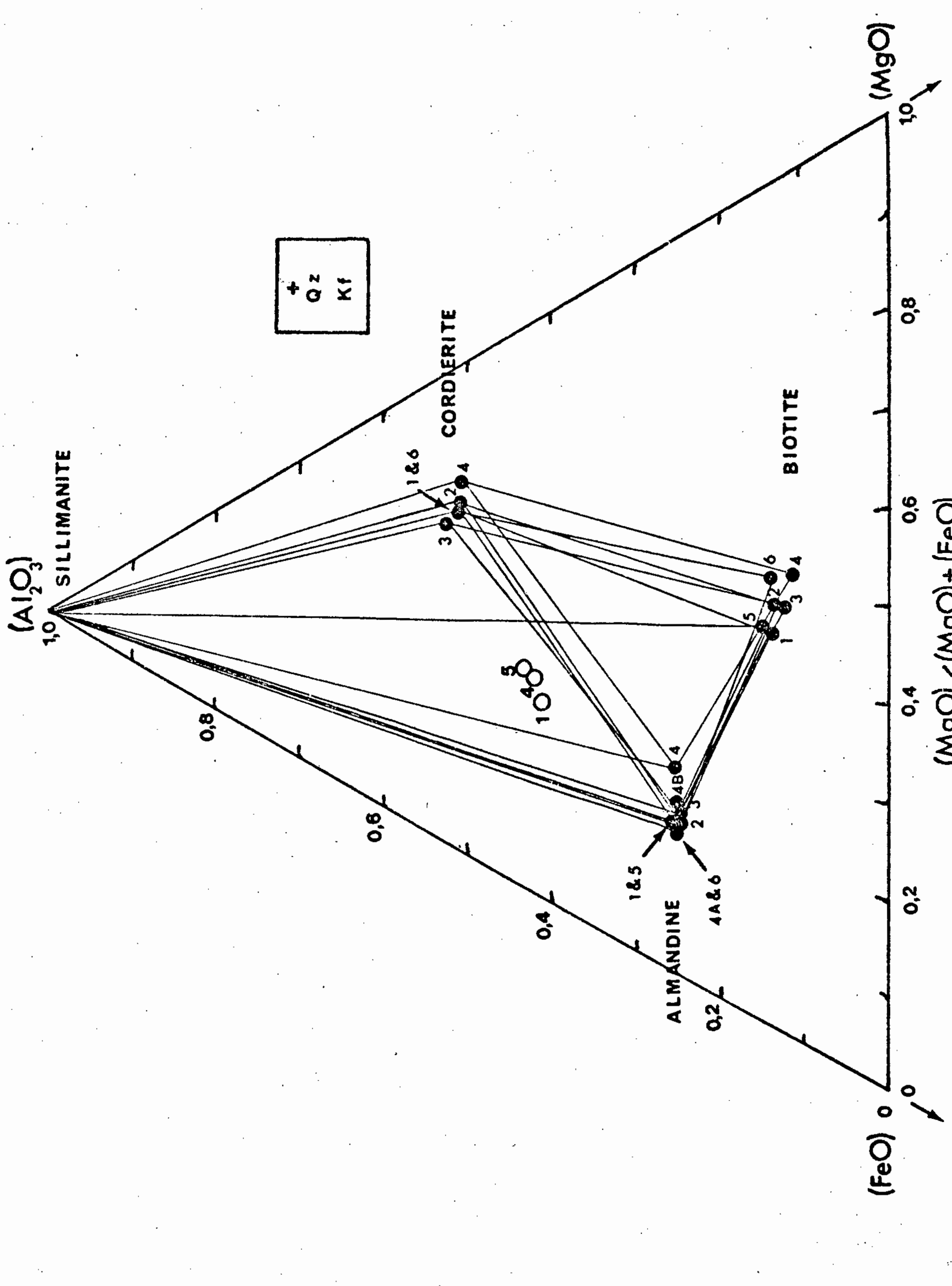

(Al2O3)
1,0
SILLIMANITE
CORDIERITE
BIOTITE
ALMANDINE
+
Qz
Kf
1&6
1&5
4A&6
4B
0,8
0,6
0,4
0,2
(FeO) 0
(MgO)
(MgO)/(MgO)+(FeO)

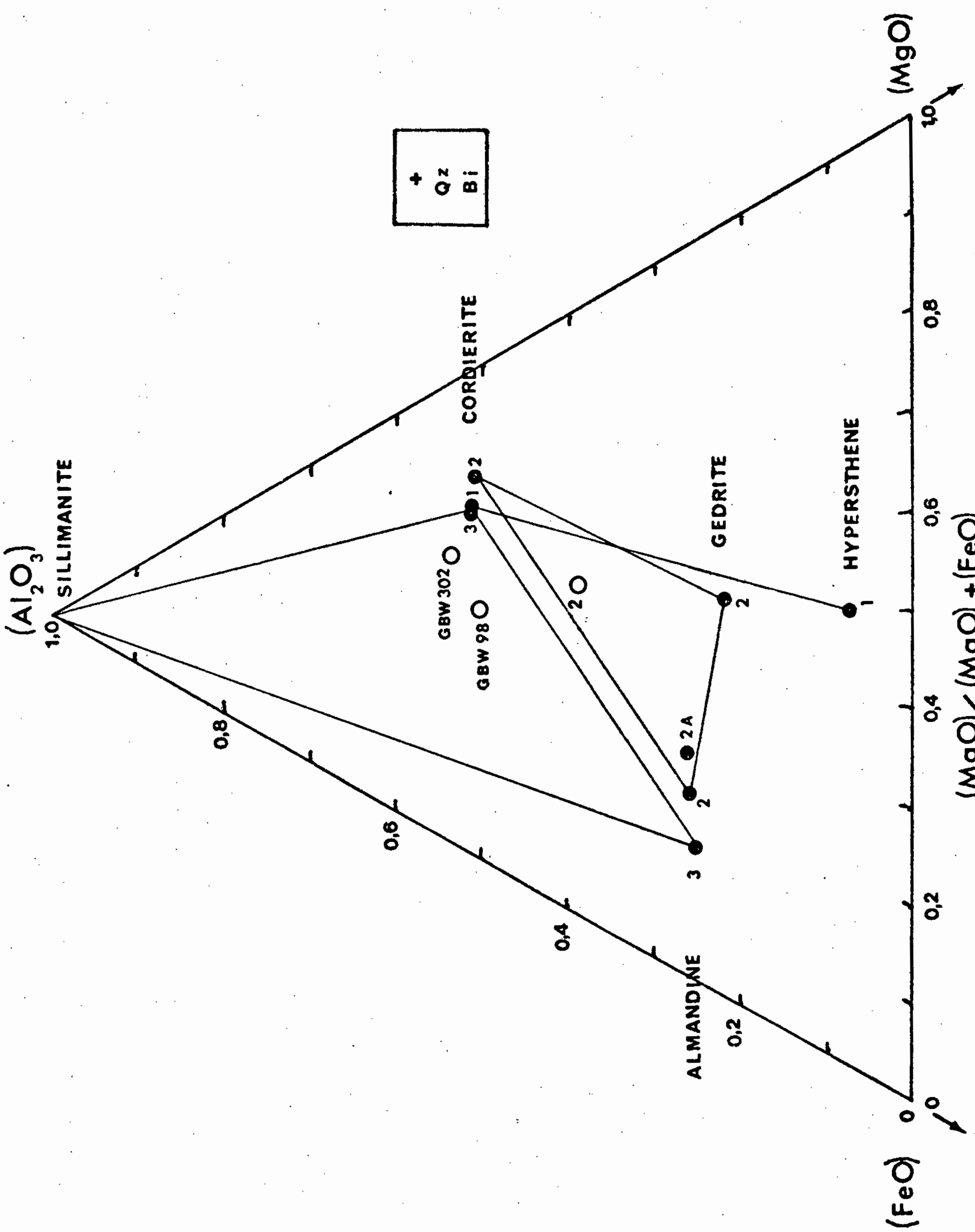
Fig 64 AFM diagram for K-feldspar free samples of Black Gneiss from the Kumkum and Sandfontein areas. Projection is through biotite. Mineral compositions are represented by opaque circles and rock compositions by hollow circles

(1) KK6

(2) K101

(2A) K101 Garnet core

(3) A5


(Al2O3)
SILLIMANITE
CORDIERITE
GEDRITE
HYPERSTHENE
ALMANDINE
(FeO)
(MgO)
(MgO) / (MgO) + (FeO)
+ Qz Bi
GBW 302
GBW 98
1,0
0,8
0,6
0,4
0,2
0

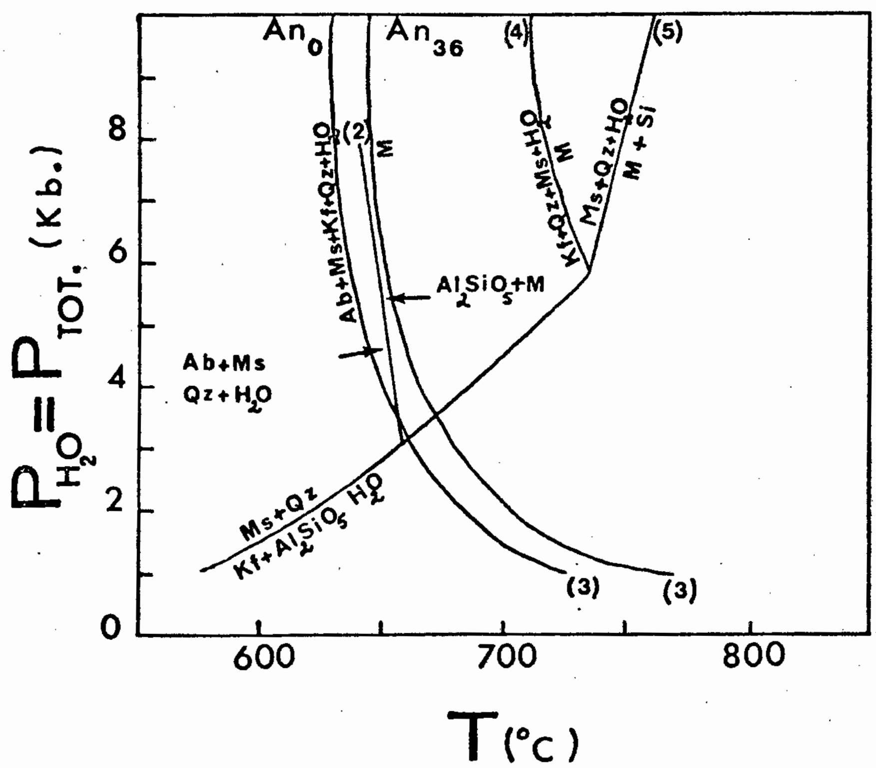


Fig 65 $P_{H_2O} = P_{tot}$ vs T diagram showing reactions involving the breakdown of muscovite with quartz after Winkler (1974, Fig 7-3). Reactions are numbered as in the text.

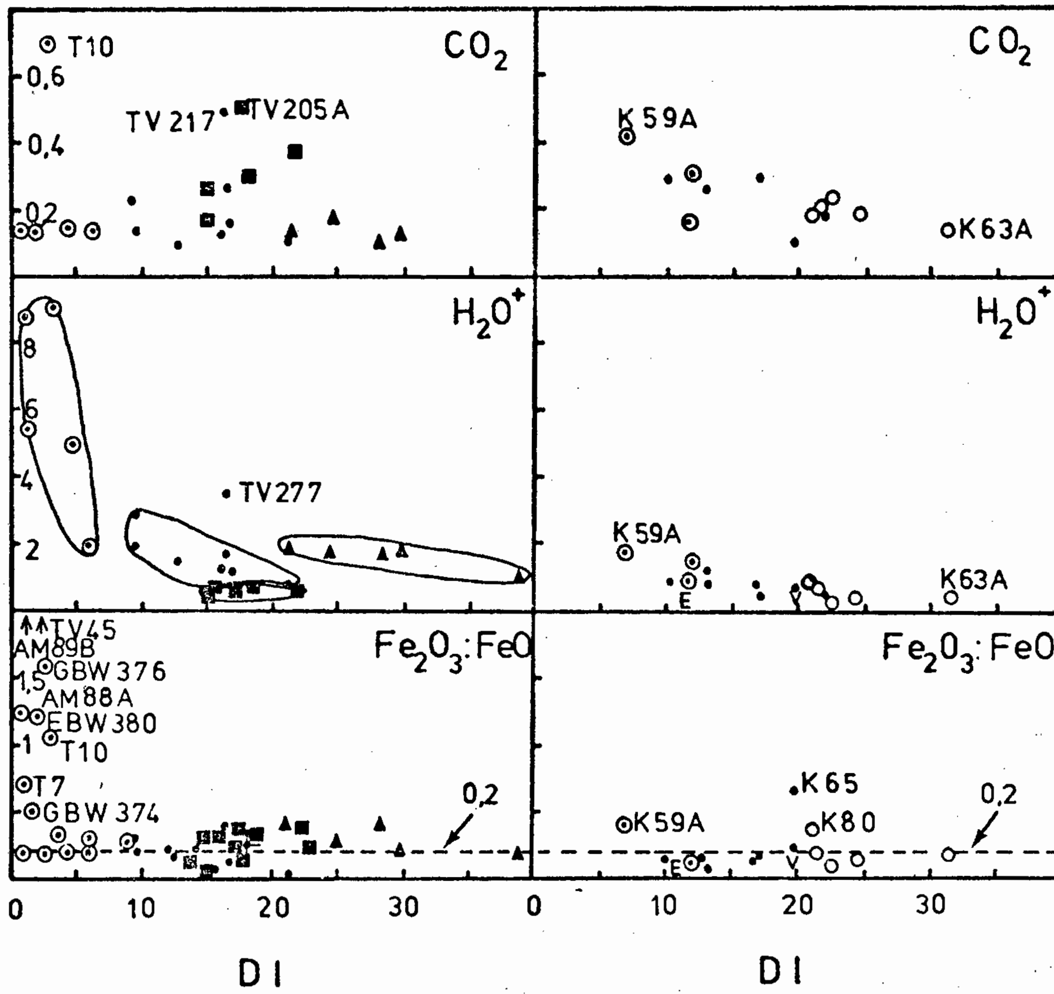


Fig 66 Plots of CO_2, H_2O^+ and Fe_2O_3: FeO against D.I. (Differentiation Index) for Tantalite Valley Rocks and Kumkum Rocks (right). Some symbols used in this and proceeding diagrams are

Key: Tantalite Valley

(A) Inequigranular granite gneiss

(▲) Mottled metagabbro

(●) Metagabbro

(■) Gabbronorite

(✦) Satellite body

(◉) Ultramafic rocks

Kumkum area

(●) Kumkum gabbronorite

(◉) Eselruh gabbronorite

(○) Contaminated gabbronorite

(E) Einsiedler gabbronorite (GBW7)

(V) Verloorkoppe gabbronorite (GBW

(⌖) Granolite

(▲) Inequigranular granite gneiss

(W) Warmbad granite (Beukes 1973)

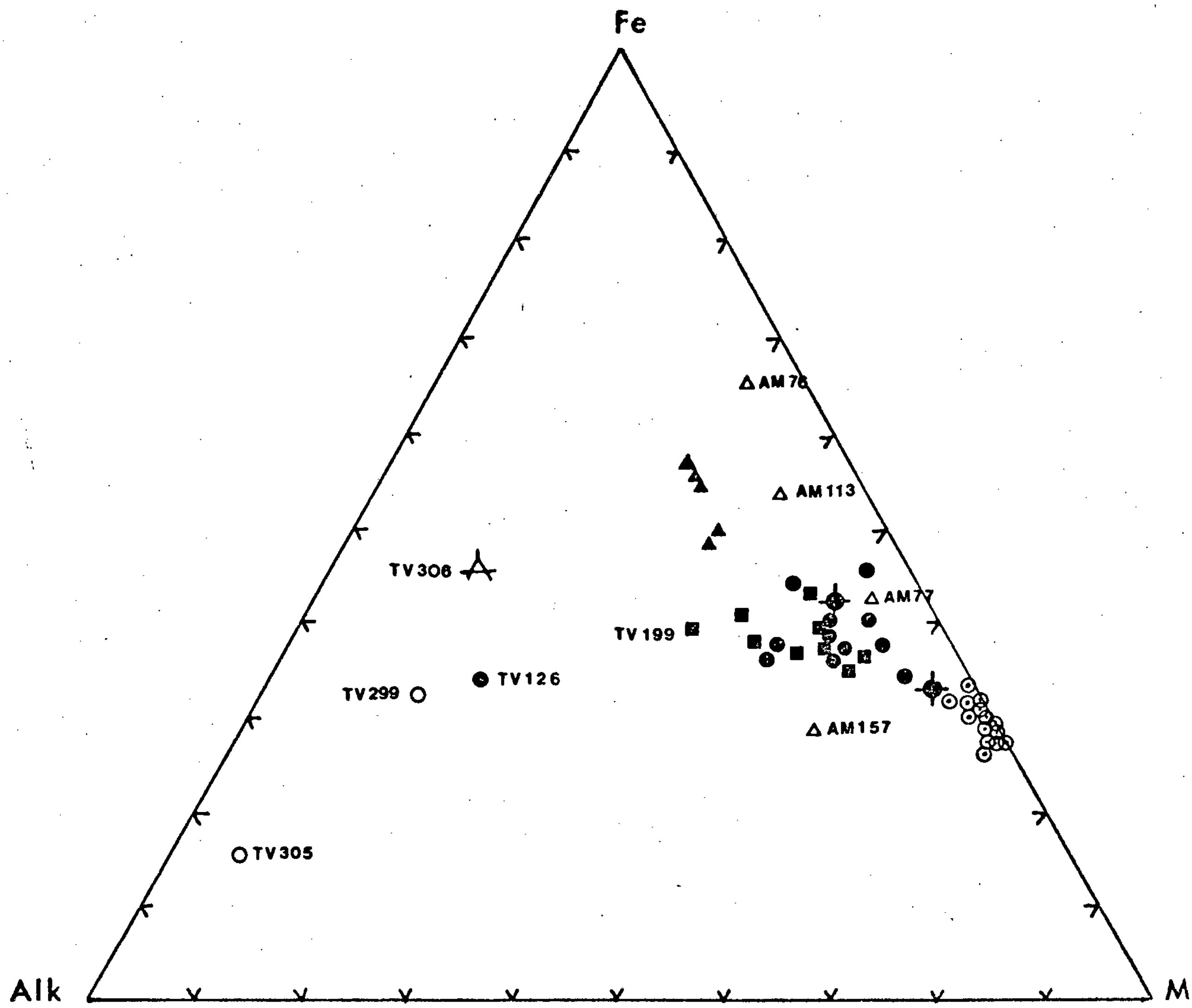


Fig 67 AFM diagram (weight %) for rocks from the Tantalite Valley area. Symbols as in Fig (66) and

(△) Amphibolites

(O) Tonalite and granodiorite

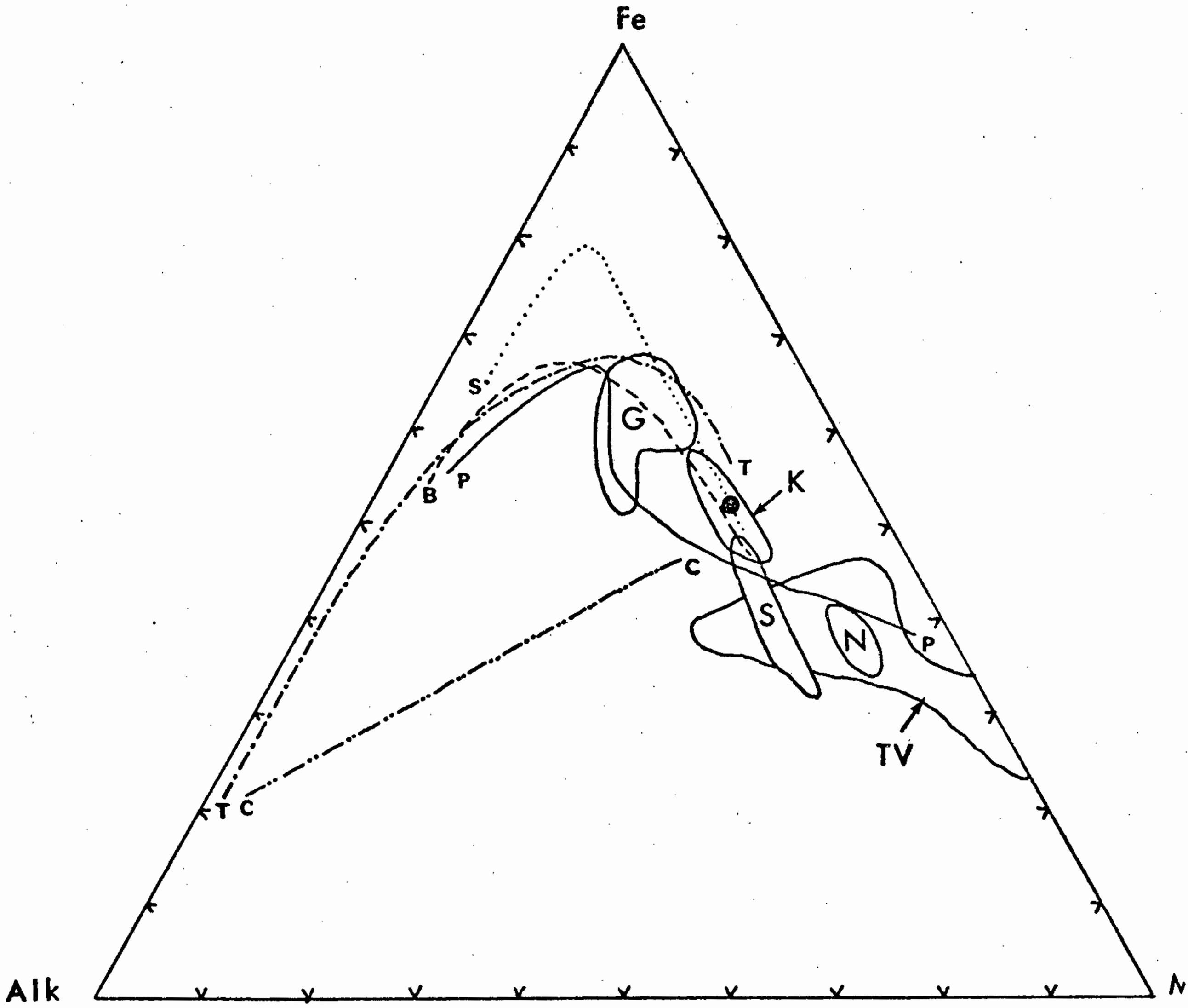


Fig 68 Alk ($Na_2O + K_2O$) - Fe (Total Fe as FeO) - M (MgO) diagram.
All oxide compositions on a volatile free basis

—··— Cascades trend (Carmichael 1964)
—·— Thingmuli trend (Carmichael 1964)
--- Birds River trend (Eales and Robey 1976)
...... Skaergaard trend (Wager and Brown 1968)
—— Palisades trend (Walker *et al* 1973)
● Average of 123 metatholeiites - W Australia (Hallberg 1972)
G Field of Gannakouriep dykes
K Karroo field represented by Tandjiesberg and Calvinia (Le Roex and Reid 1978)
S Field of Swartkop rocks (Reid 1977)
N Field of Nouzees rocks (Moore and Reid pers comm)
TV Field covered by gabbronorite, metagabbro and ultramafic rocks of Tantalite Valley

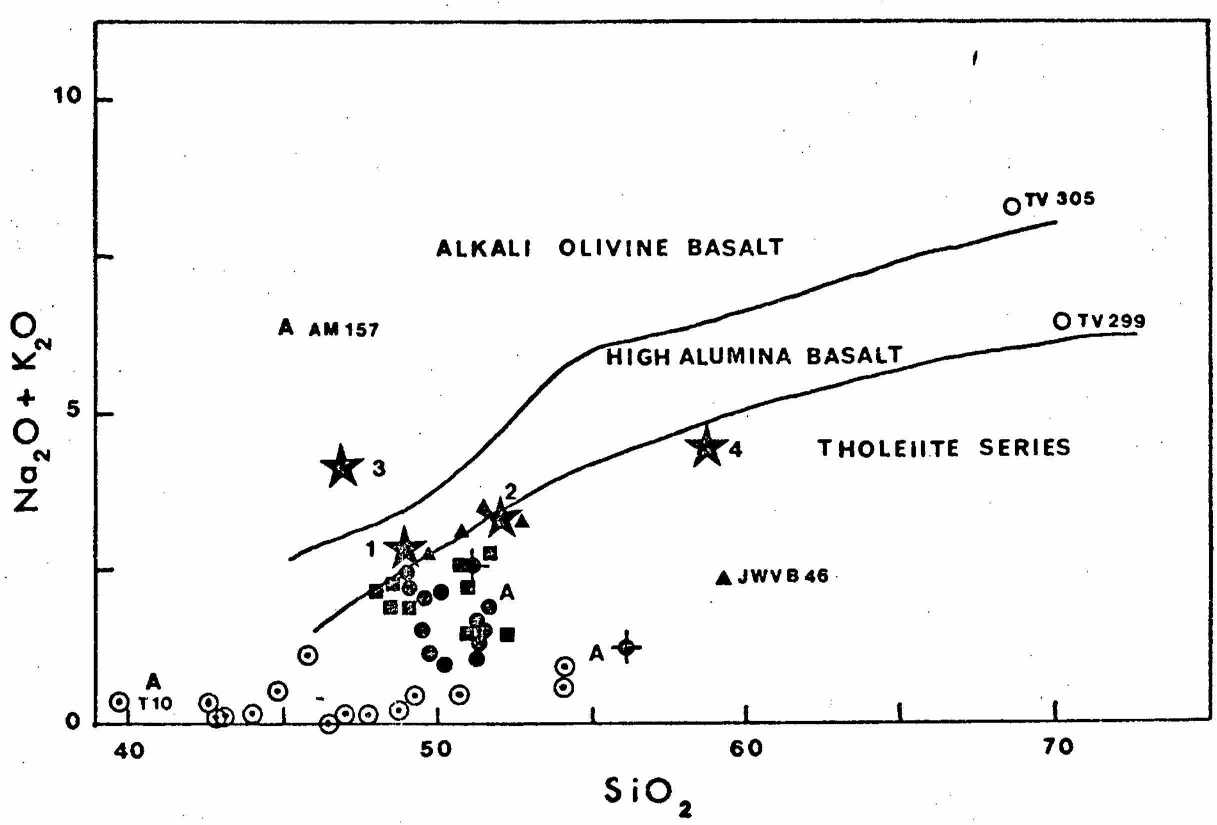


Fig 69 Plot of $(Na_2O + K_2O)$ against SiO_2 for Tantalite Valley Samples. Fields are those defined for the Japanese arc by Kuno (1968).

Symbols are the same as in Fig (66) and A represents amphibolites

(1) Oceanic tholeiitic basalts

(2) Continental tholeiitic basalts

(3) Oceanic alkali basalts

(4) Andesites of island arcs (McBirney 1969)

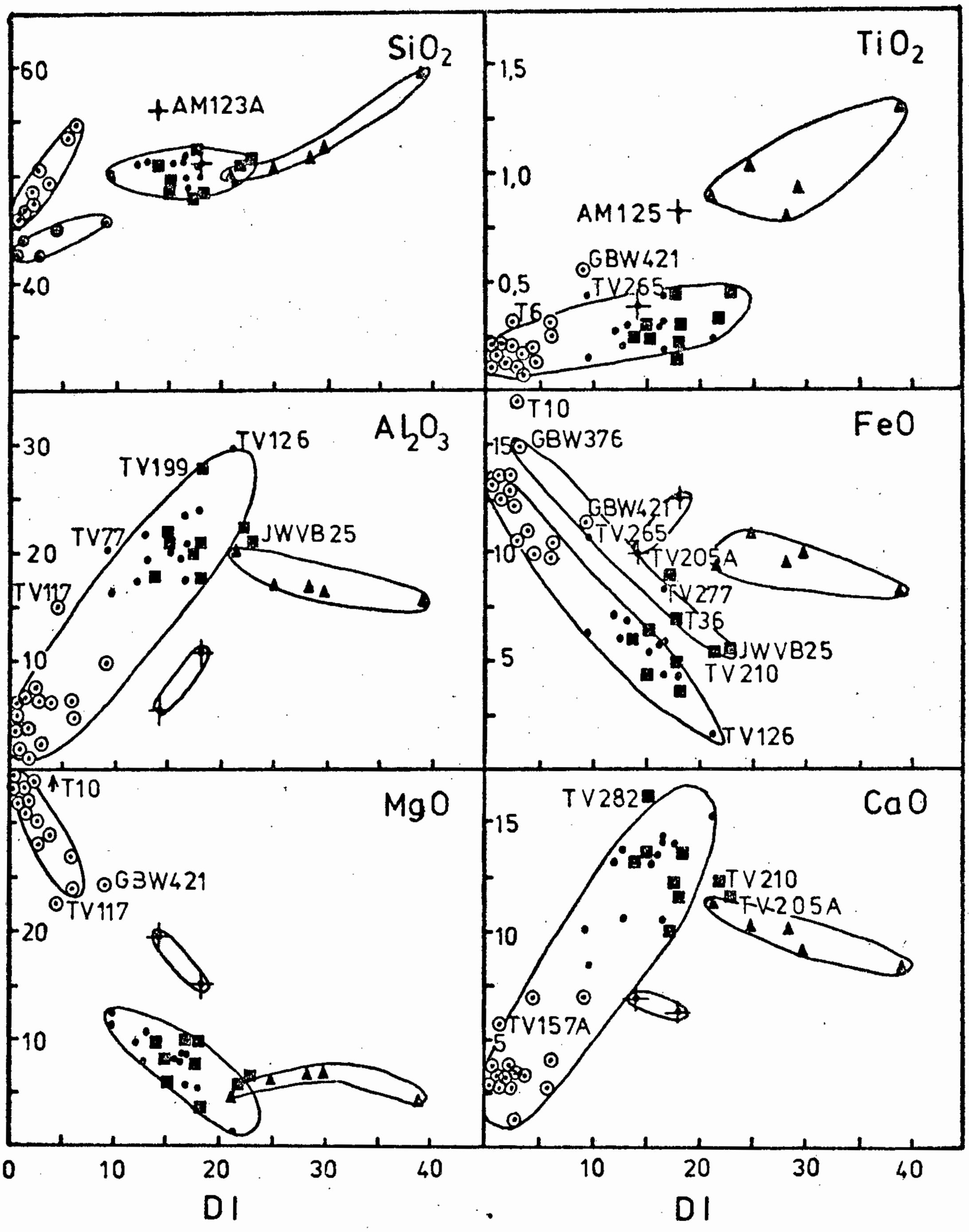


Fig 70 Plot of major oxides against D.I. for the mafic and ultramafic rocks of Tantalite Valley. Symbols are as in Fig 66. Fields define average trends.

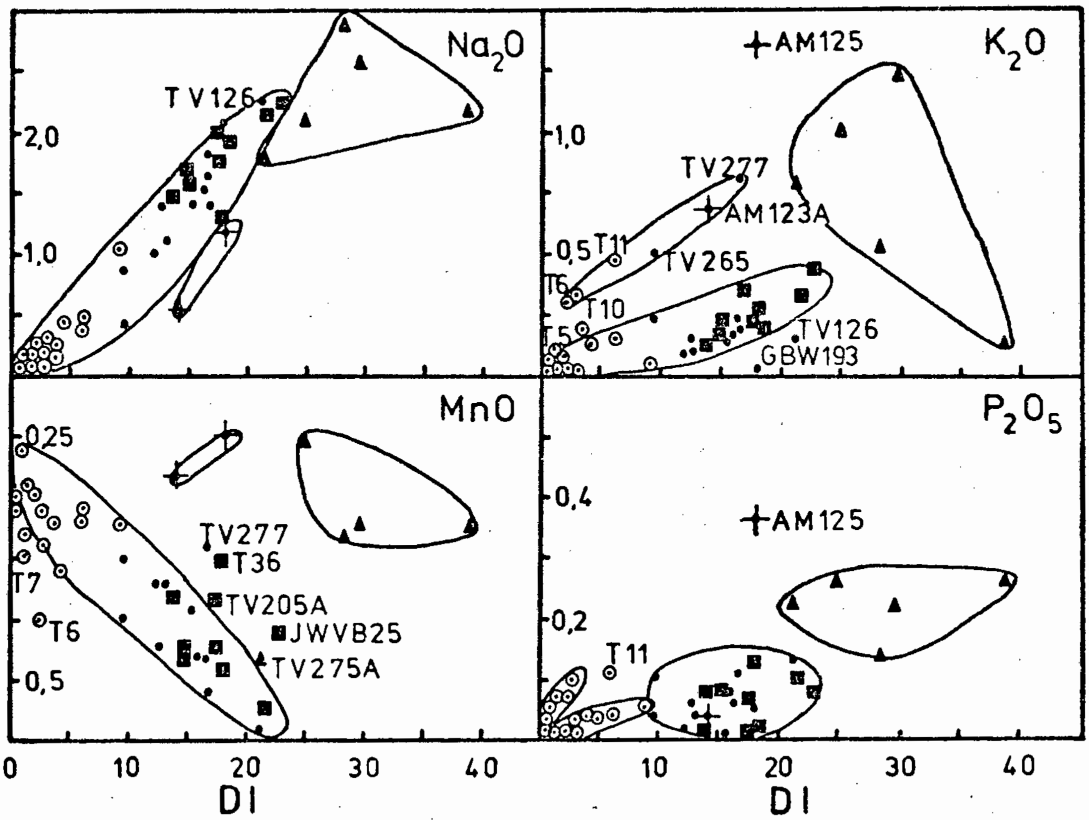


Fig 70 Plot of major oxides against D.I. (continued)

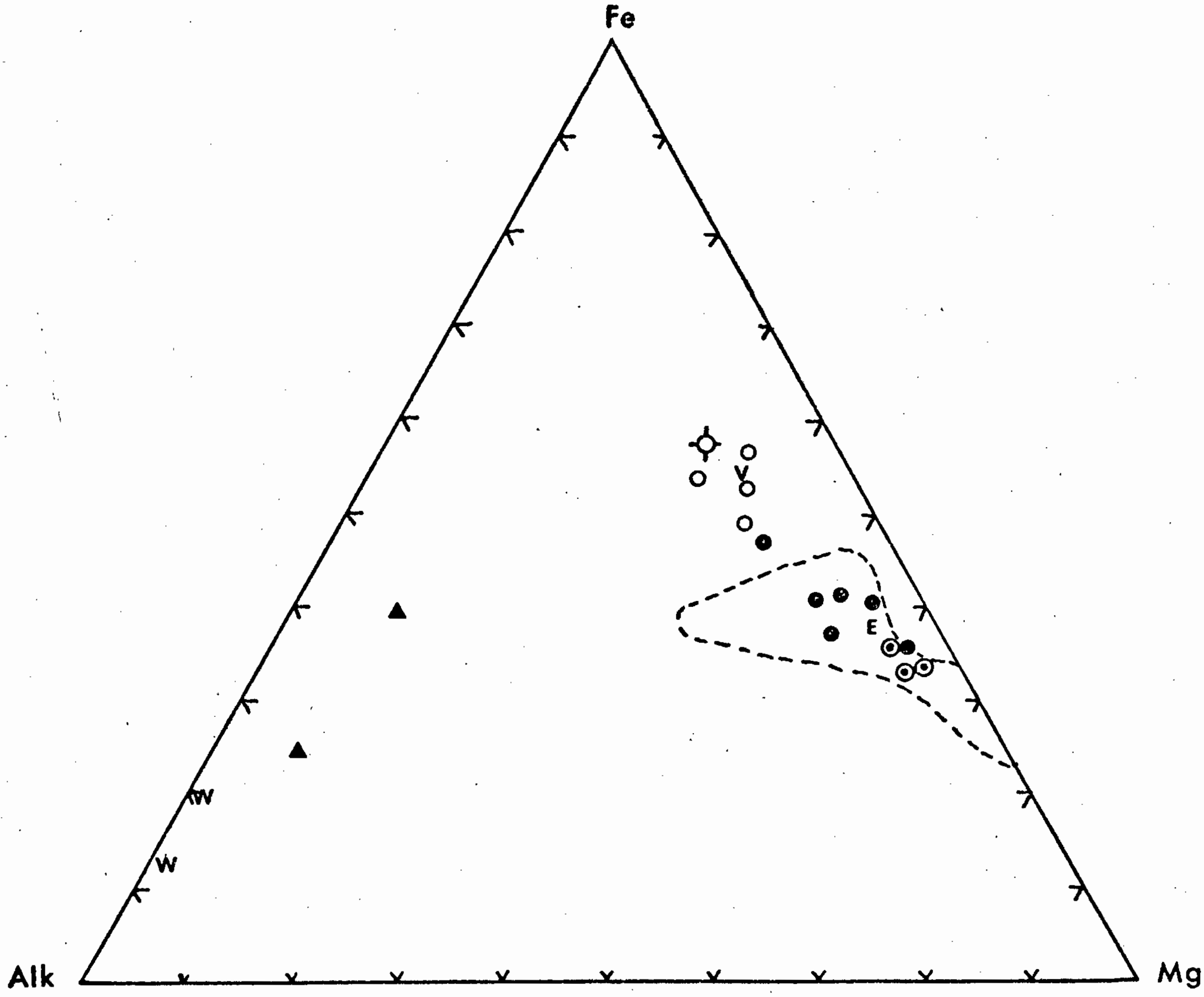


Fig 71 Alk ($Na_2O + K_2O$) - Fe (Total Fe as FeO) - Mg (MgO) plot for rocks from the Kumkum area, Symbols as in Fig 66. The field covered by gabbronorite, metagabbro and ultramafic rocks of Tantalite Valley is included

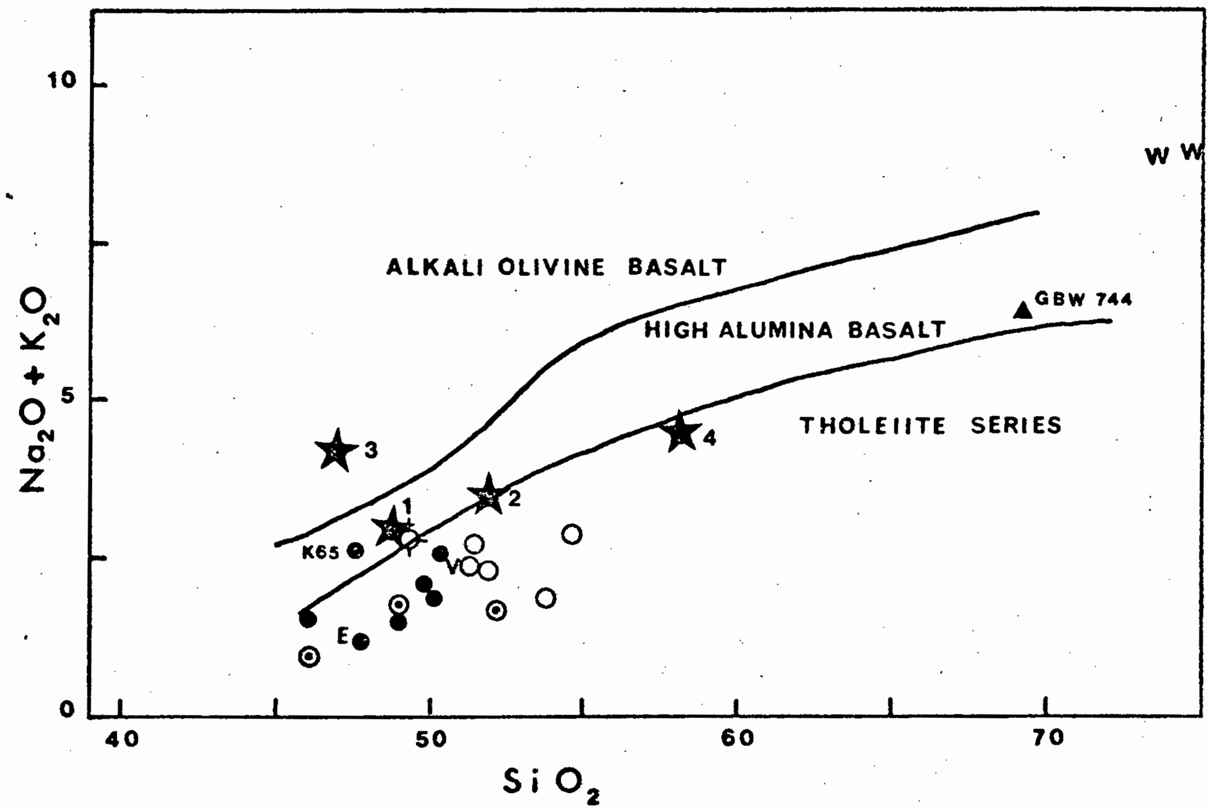


Fig 72 Plot of ($Na_2O + K_2O$) against SiO_2 for Kumkum samples,

Symbols as in Fig 66 and Fig 69. Fields are those defined for the Japanese arc by Kuno (1968).

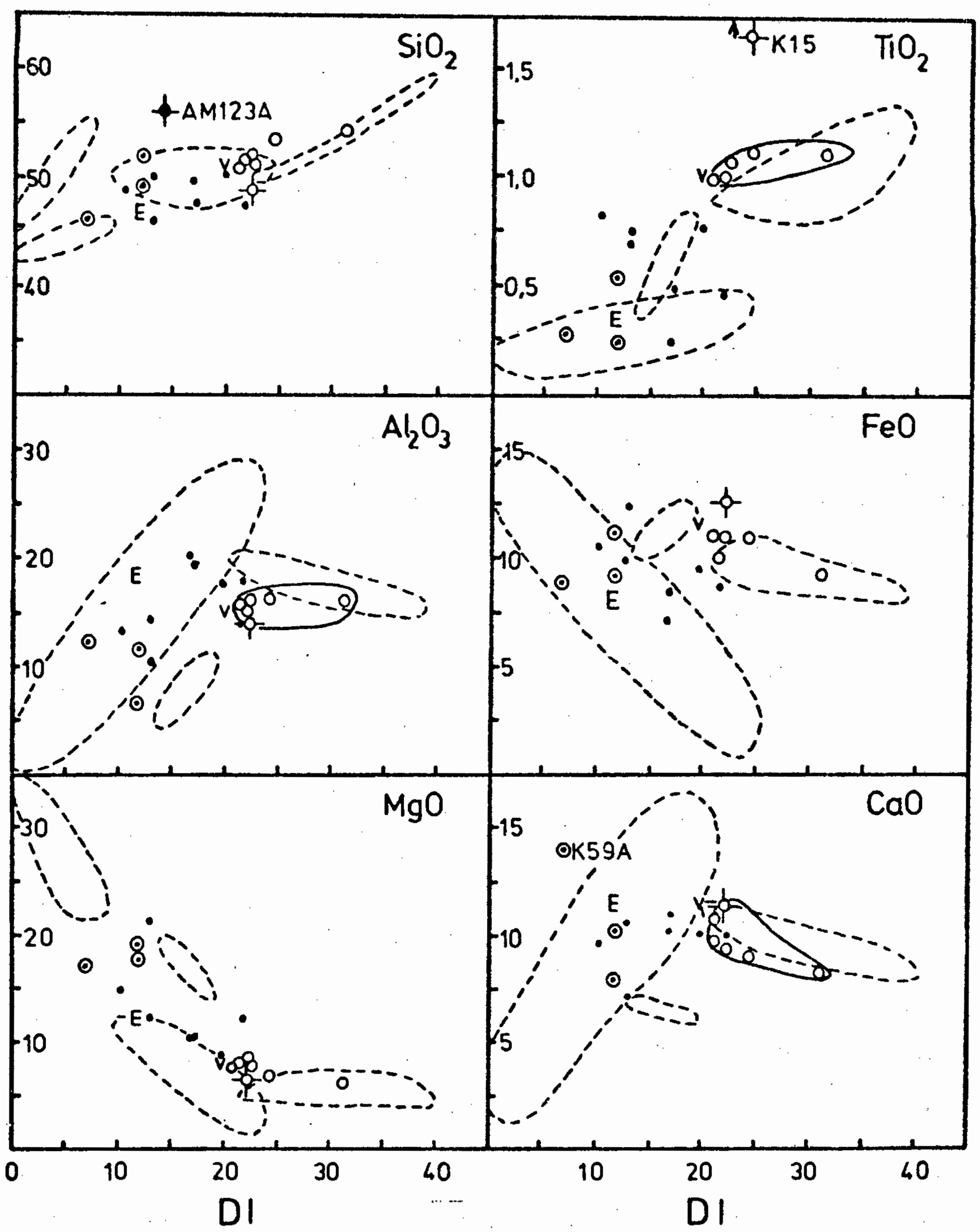


Fig 73 Plot of major oxides against D,I. for mafic rocks from the Kumkum area. Symbols as in Fig 66.

- - - fields of Tantalite Valley rocks

—— fields of Kumkum rocks

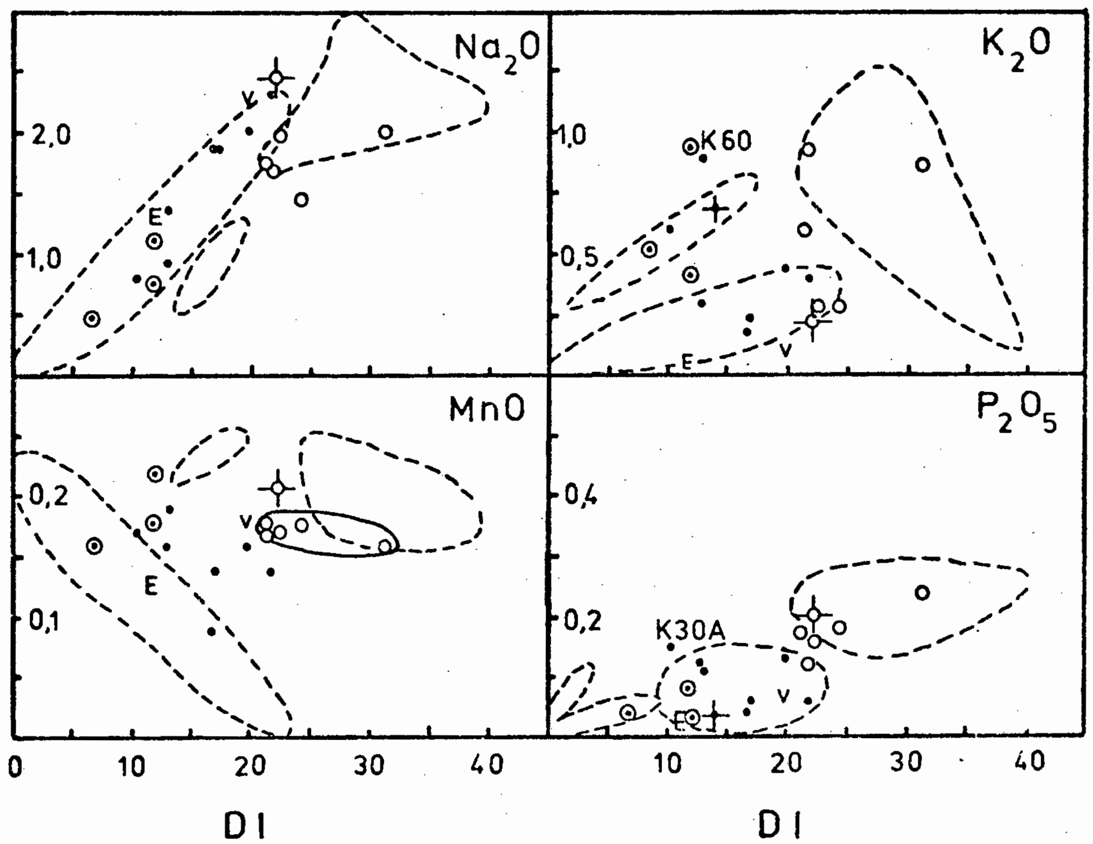


Fig 73 Plot of major oxides against D.I. (continued)

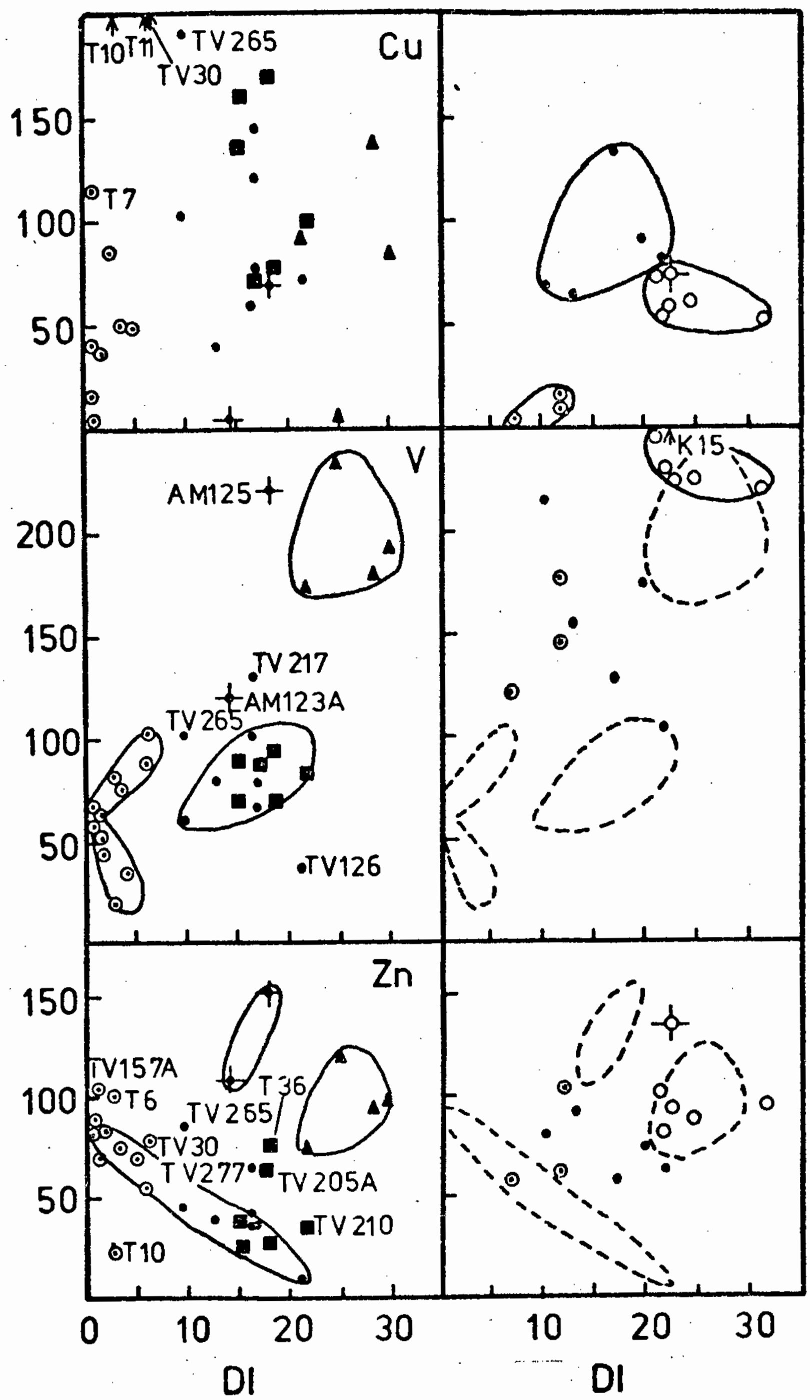


Fig 74 Plot of Cu, V and Zn against D.I. for Tantalite Valley samples (left) and Kumkum samples (right). See Fig 66 for symbols used.

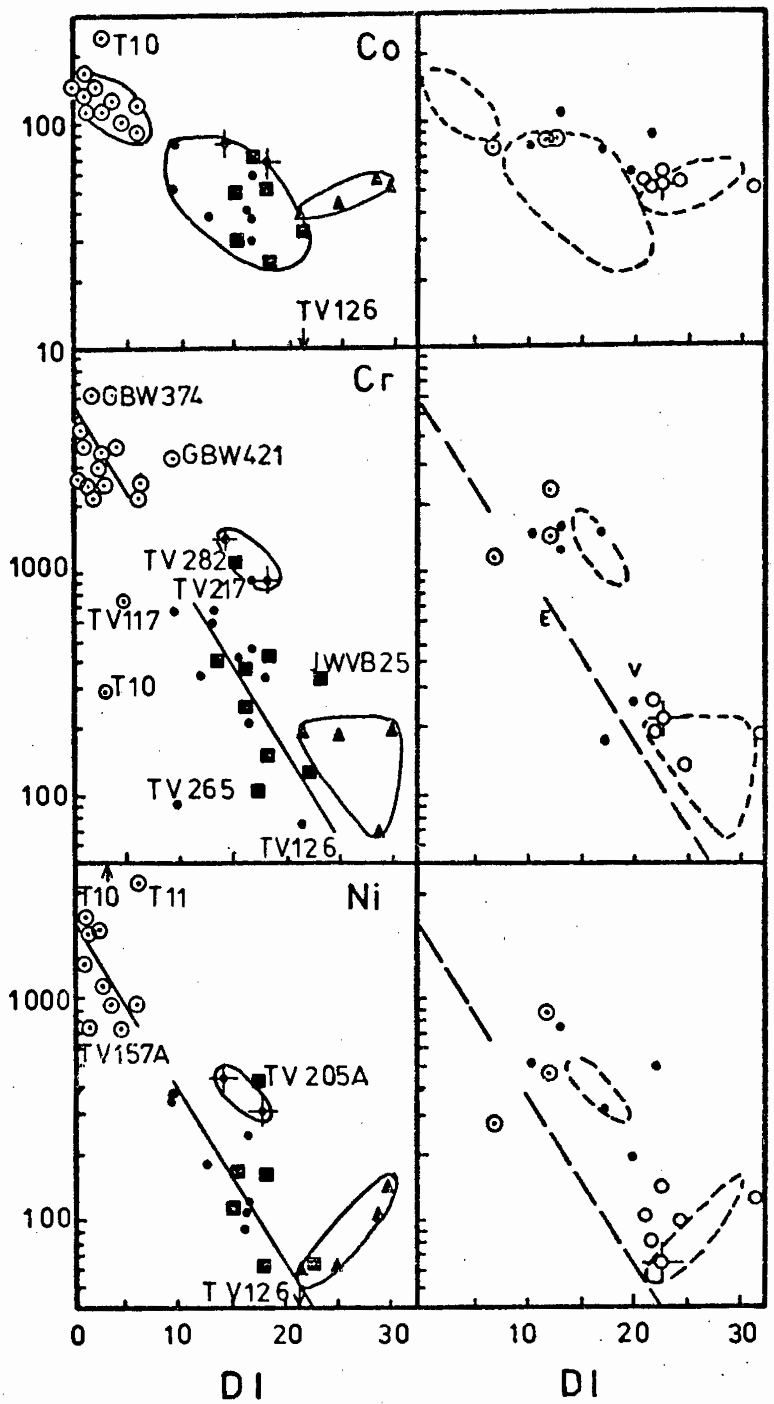


Fig 75 Plot of Co, Cr and Ni against D.I. for Tantalite Valley samples (left) and Kumkum samples (right). See Fig 66 for symbols used, Trend lines have been visually estimated.

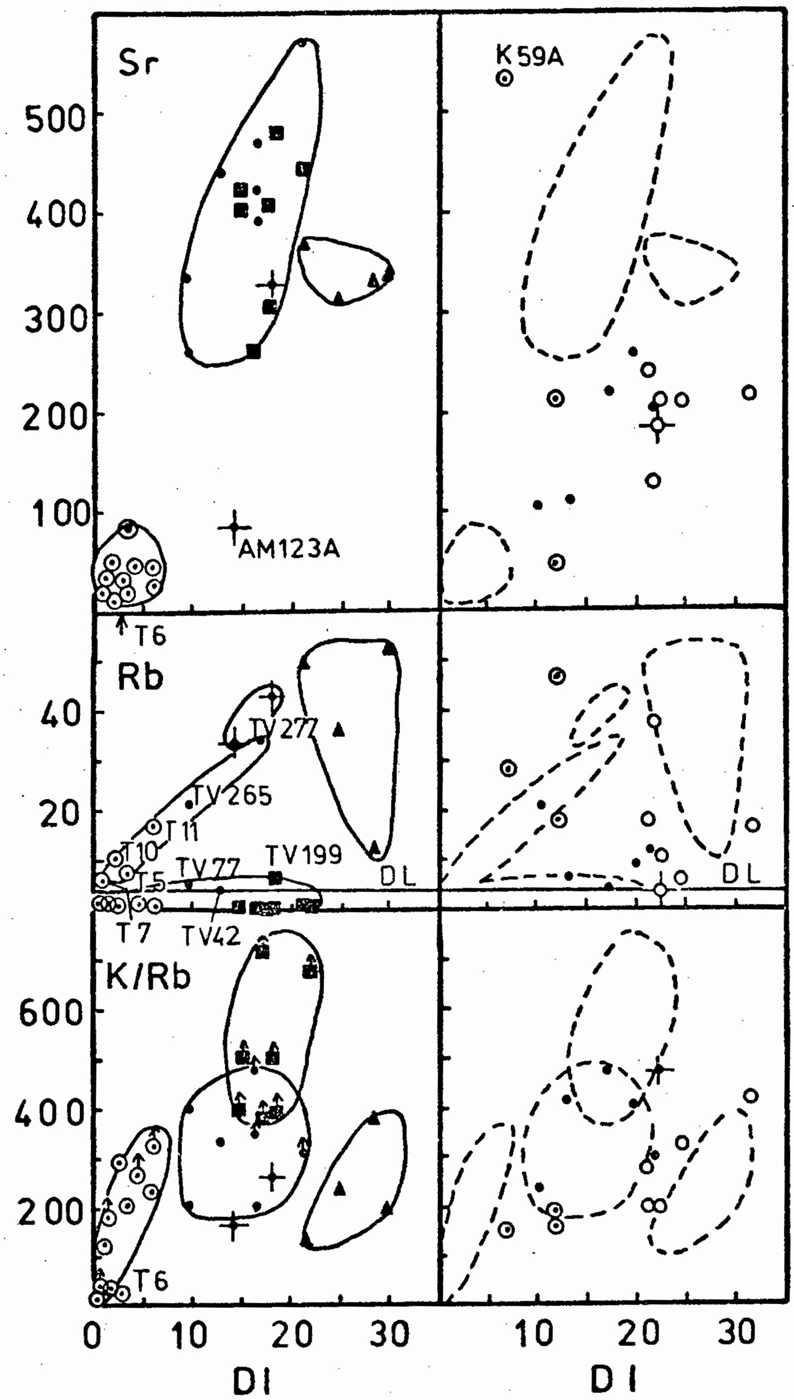


Fig 76 Plots of Sr, Rb and K/Rb against D.I. for Tantalite Valley samples (left) and Kumkum samples (right). Symbols as in Fig 66. D.L. is the detection limit. Points with arrows represent minimum values.

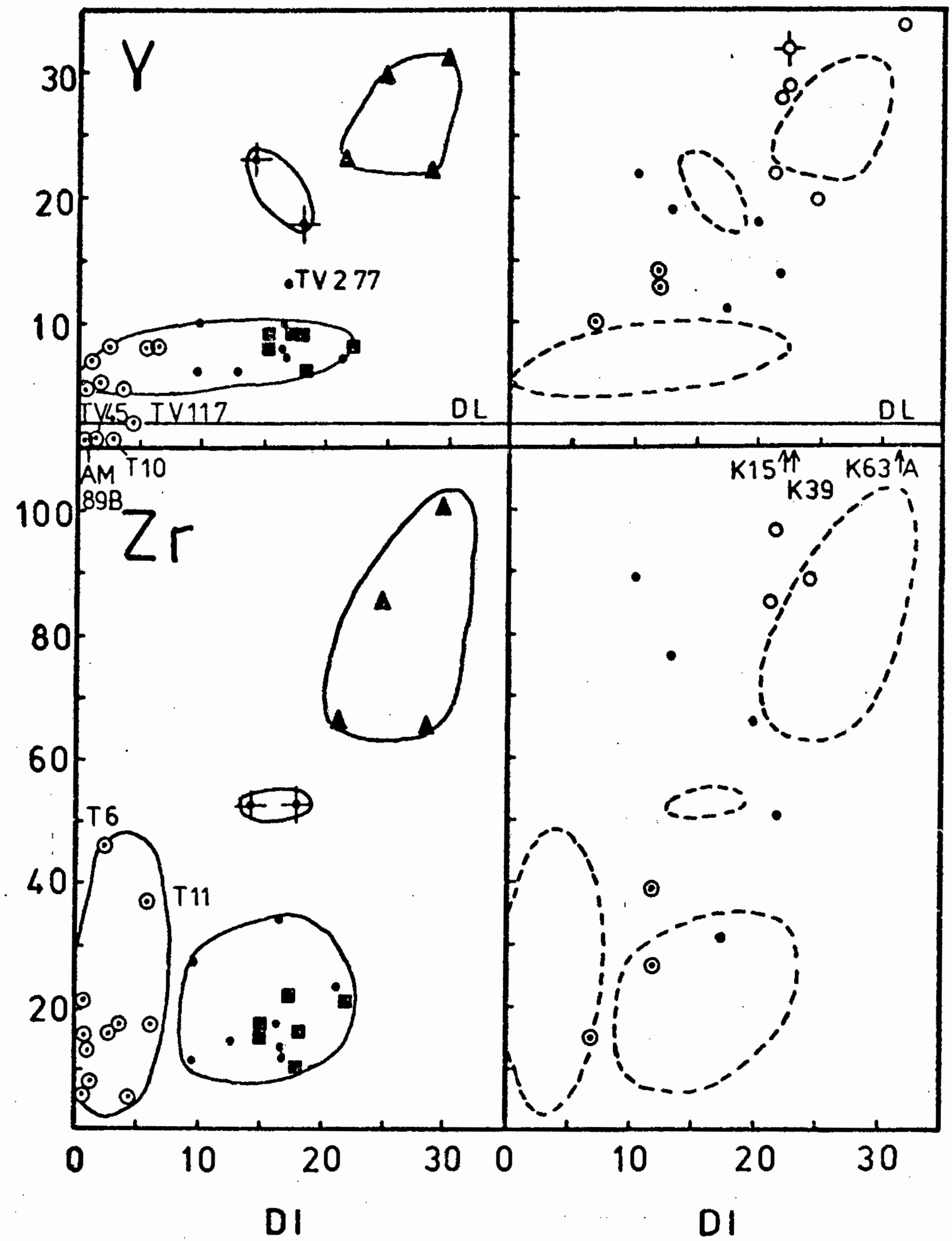


Fig 77 Plots of Y and Zr against D.I. for Tantalite Valley samples (left) and Kumkum samples (right). D.L. = Detection limit. Symbols as in Fig 66.

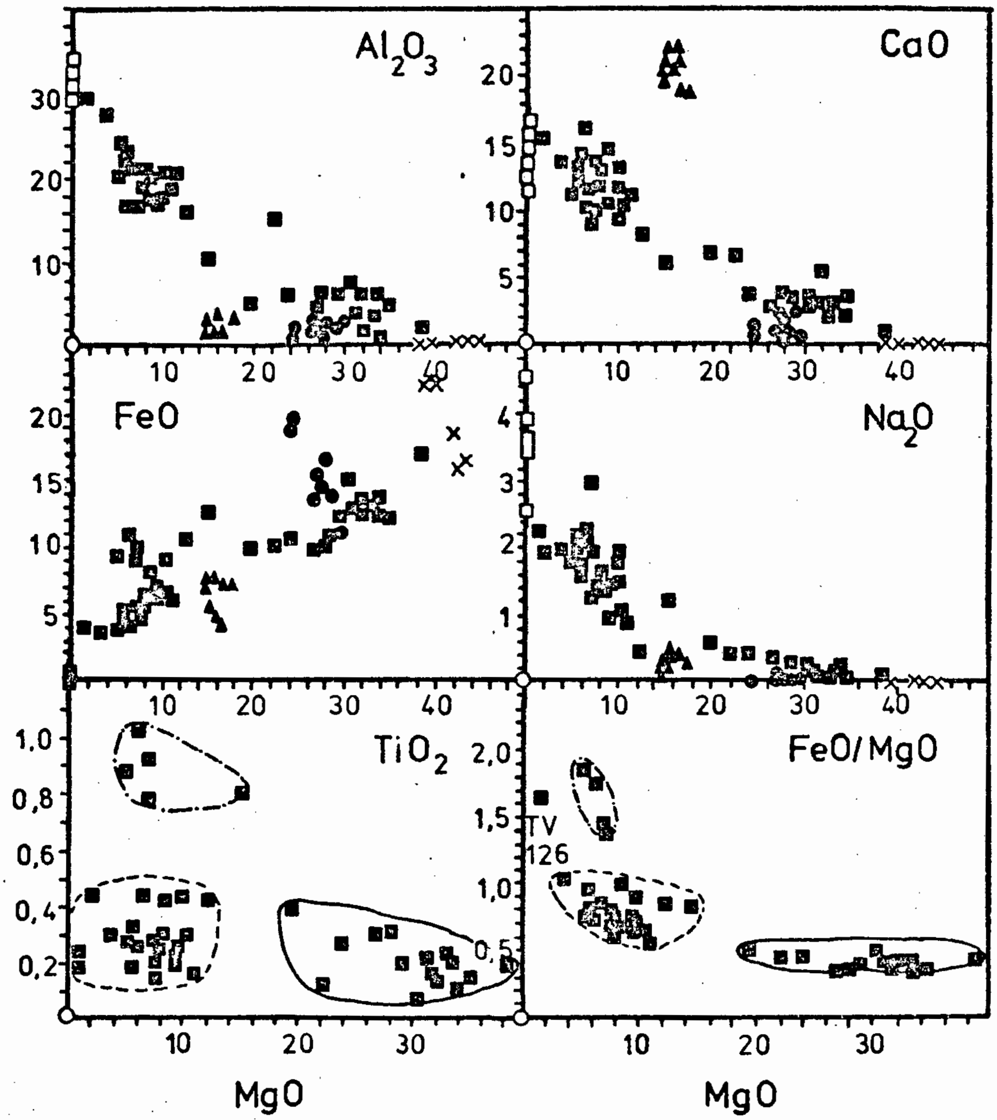


Fig 78 Plots of major elements against MgO (weight %, volatile free) for Tantalite Valley samples

Key:
- (■) Bulk rock analysis
- (□) Plagioclase
- (●) Orthopyroxene
- (▲) Clinopyroxene
- (X) Olivine

- - - field of metagabbro and gabbronorite samples

—·—· field of mottled metagabbro samples

—— field of ultramafic rocks

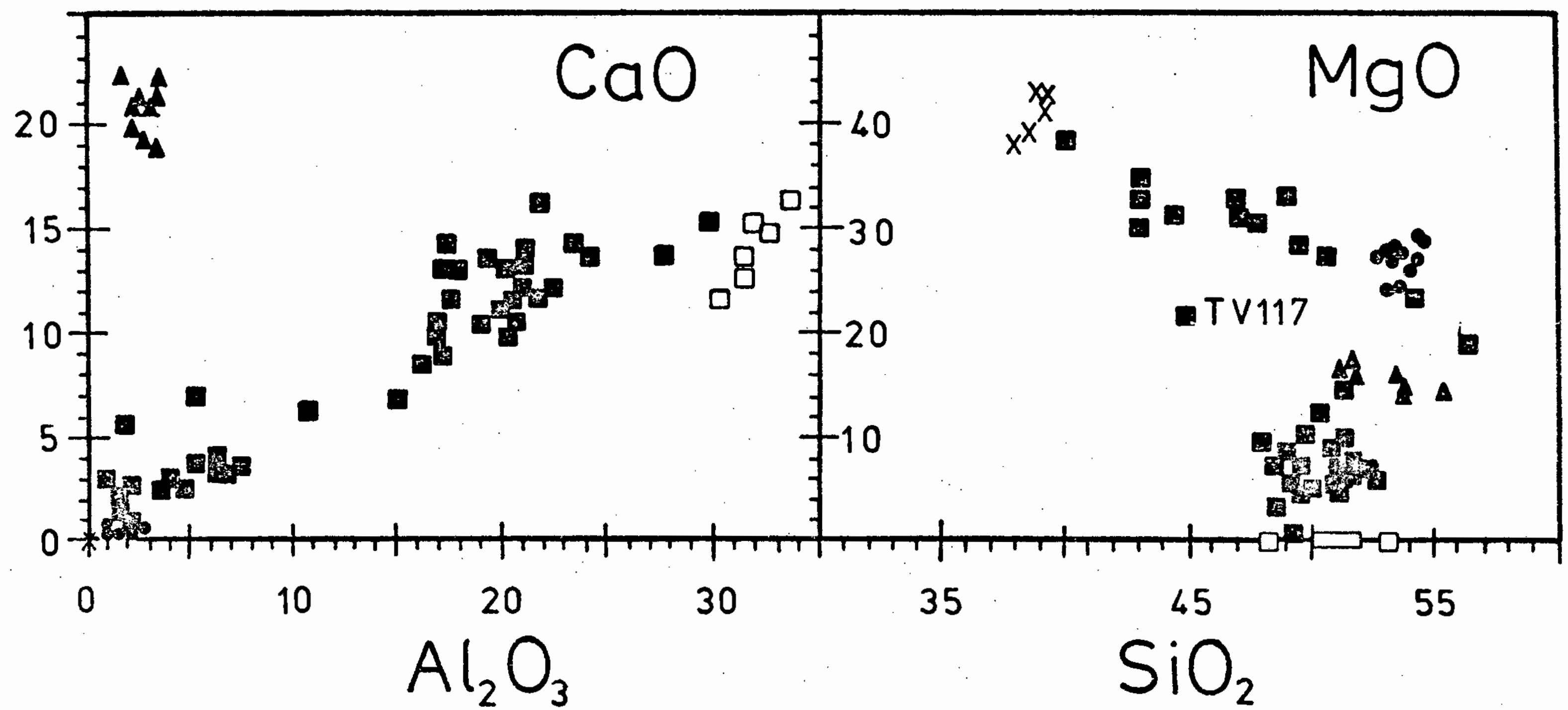


Fig 79 Plots of CaO vs Al_2O_3 and MgO vs SiO_2 for rocks of the Tantalite Valley Complex. Symbols as for Fig 78.

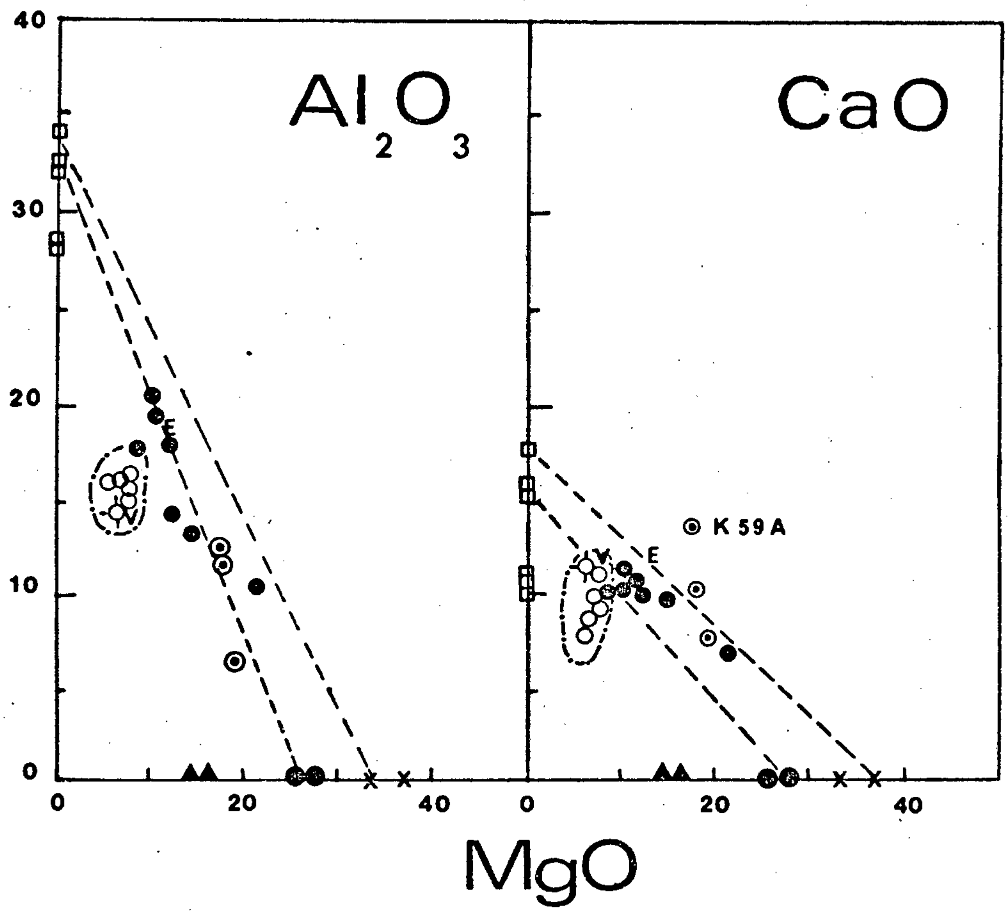


Fig 80 Plots of Al_2O_3 and CaO against MgO (weight %, volatile free) for Kumkum samples, Rock symbols as in Fig 66 Mineral symbols as in Fig 78

Note (●) Kumkum gabbronorite
(◉) Orthopyroxene

—·—· field of altered and/or contaminated rocks

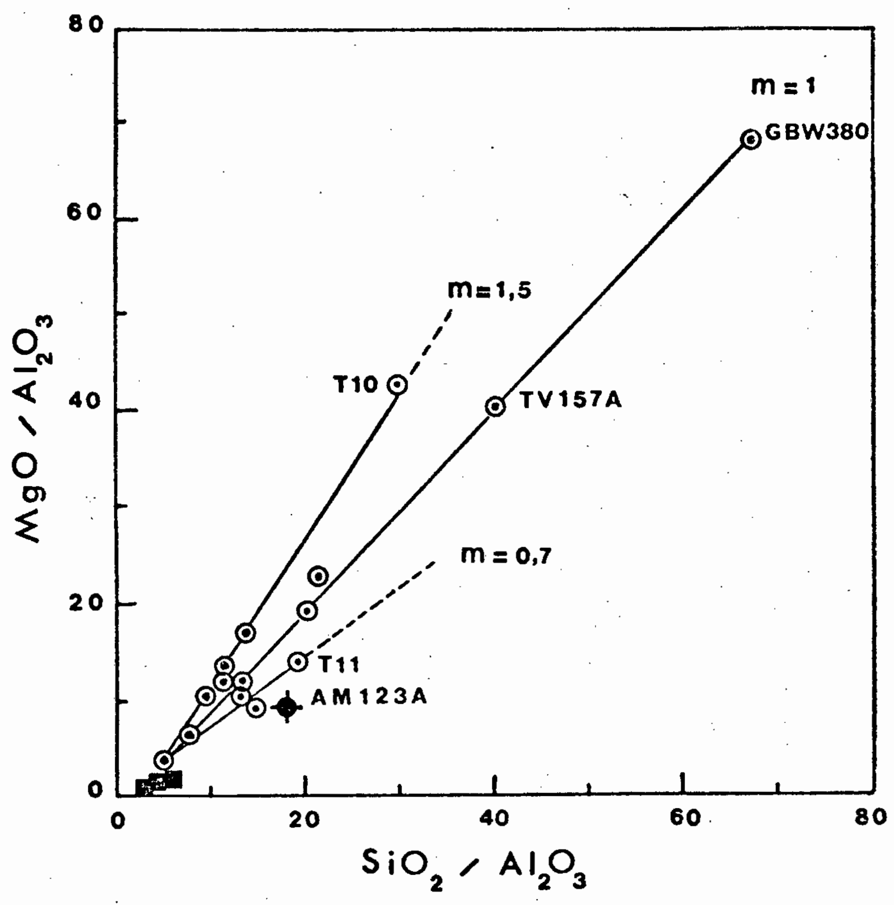


Fig 81 Plot of MgO/Al_2O_3 vs SiO_2/Al_2O_3 (vol free, molec prop) for gabbronorites (■), including satellite body (⊕) and ultramafic rocks (◎) of Tantalite Valley after Pearce (1968, 1969) m = slope

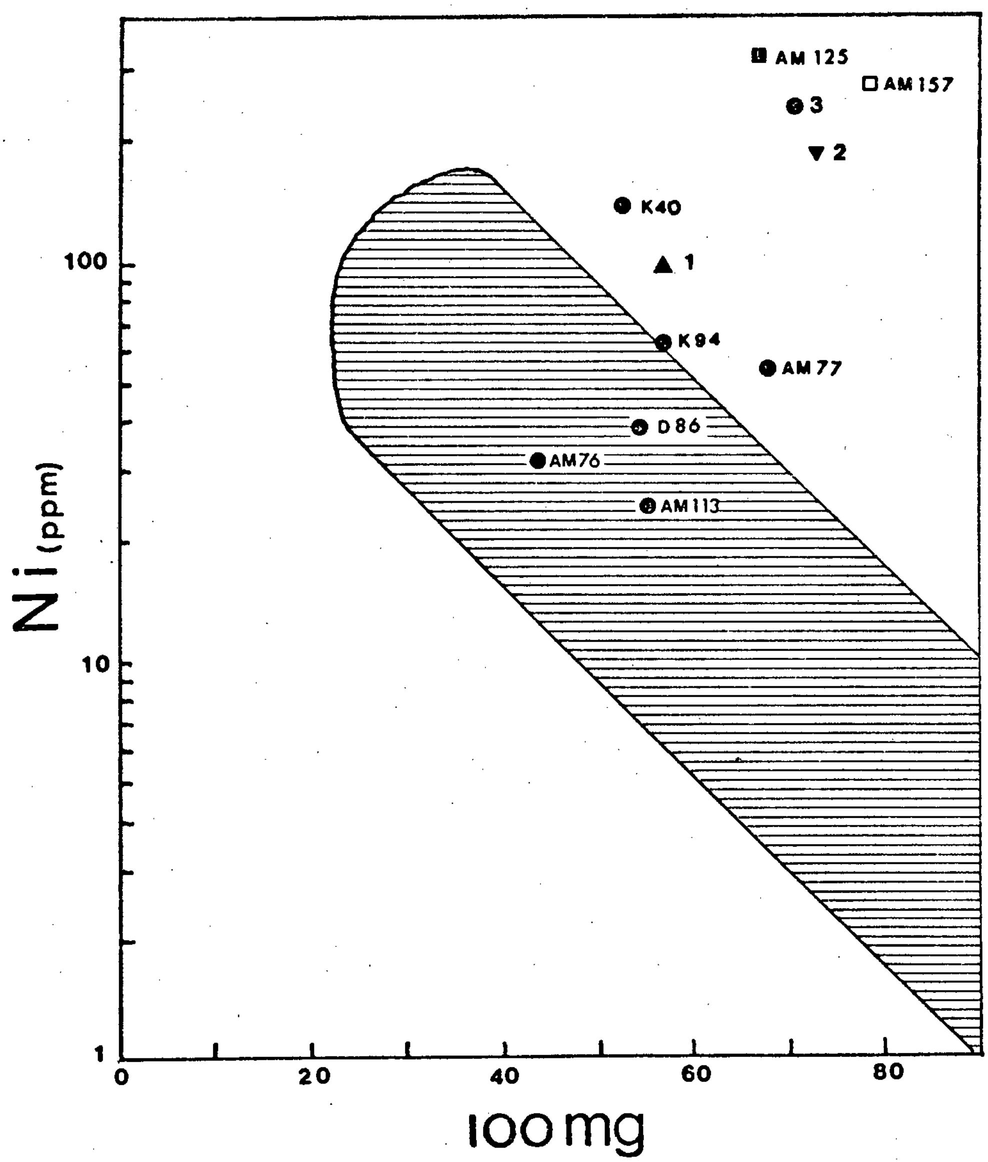


Fig 82 Plot of Ni against 100 Niggli mg after Van de Kamp (1969) for amphibolites from the Tantalite Valley and Kumkum areas. The shaded area shows the field and trend of shale-carbonate rocks.

(●) Amphibolites
(□) Metasomatic hornblendite
(■) Satellite body metagabbro
(▲1) Av mottled metagabbro
(▼2) Av metagabbro
(●3) Av orthoamphibolite (Moore 1977)

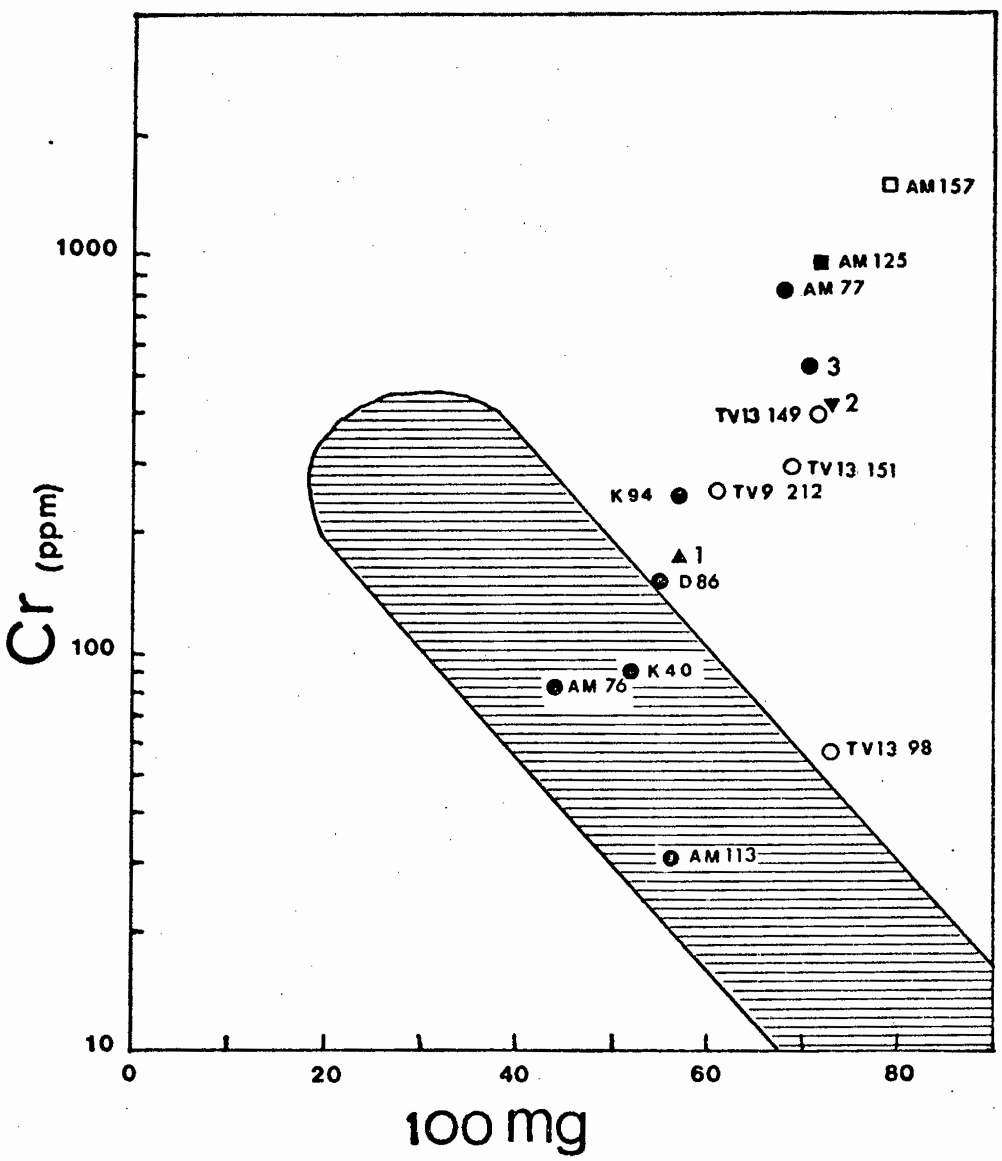


Fig 83 Plot of Cr against 100 Niggli mg after Van de Kamp (1969) for amphibolites from the Tantalite Valley and Kumkum areas. The shaded area shows the field and trend of shale-carbonate rocks. Symbols as for Fig (82) and (O) equals metabasite hornfels.

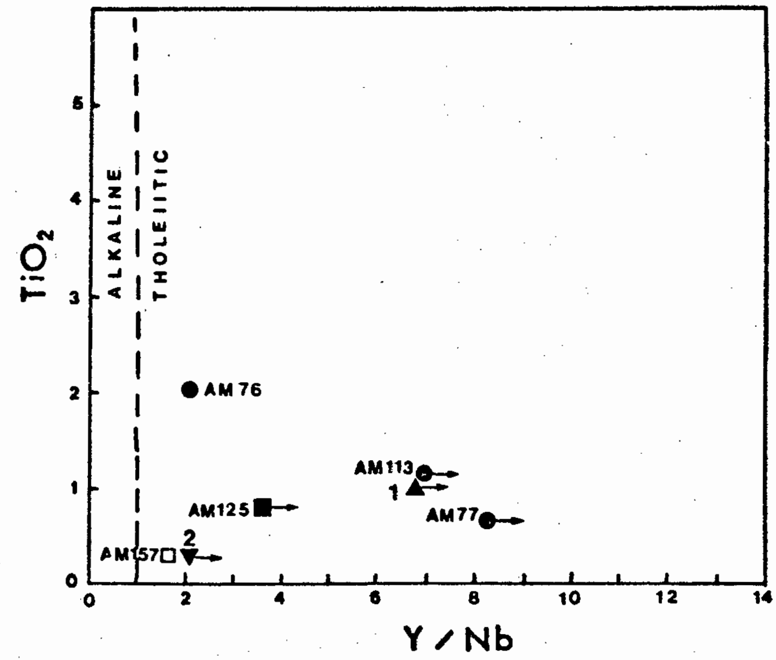


Fig 84 Plot of TiO_2 vs Y/Nb (after Winchester and Floyd 1976) for amphibolites from the study area. Symbols as in Fig 82. Boundary between alkaline and tholeiitic rocks after Pearce and Cann (1973). Points with arrows are minimum values of Y/Nb since Nb is generally below the detection limit.

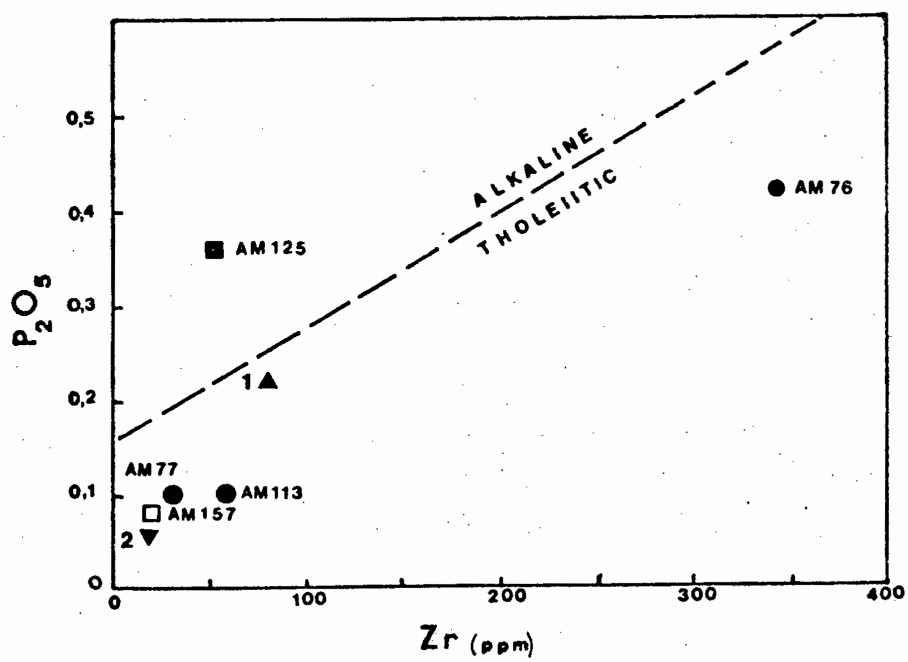


Fig 85 Plot of P_2O_5 vs Zr (after Winchester and Floyd 1976) for amphibolites from the study area. Symbols as in Fig 82.

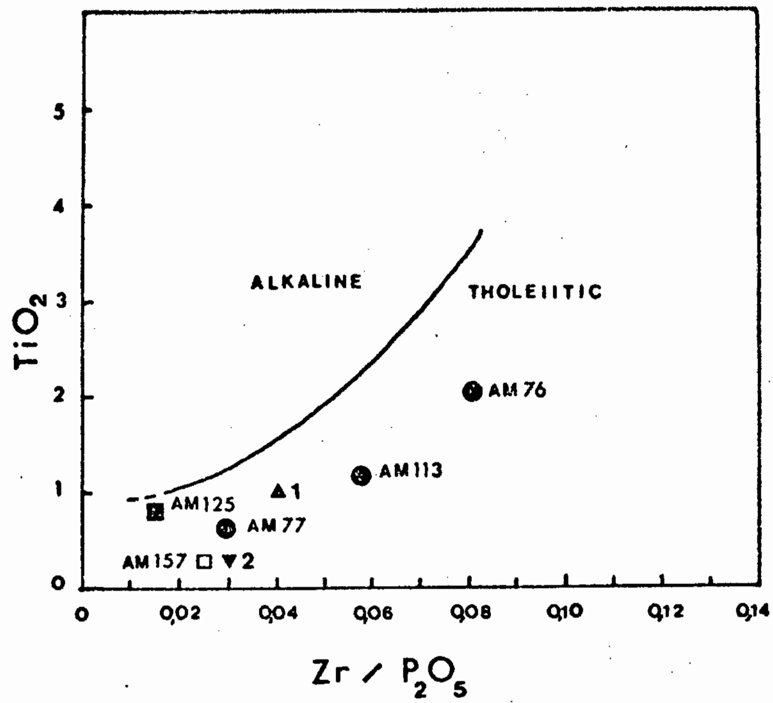


Fig 86 Plot of TiO_2 vs Zr/P_2O_5 (after Winchester and Floyd 1976) for amphibolites from the study area. Symbols as in Fig 82.

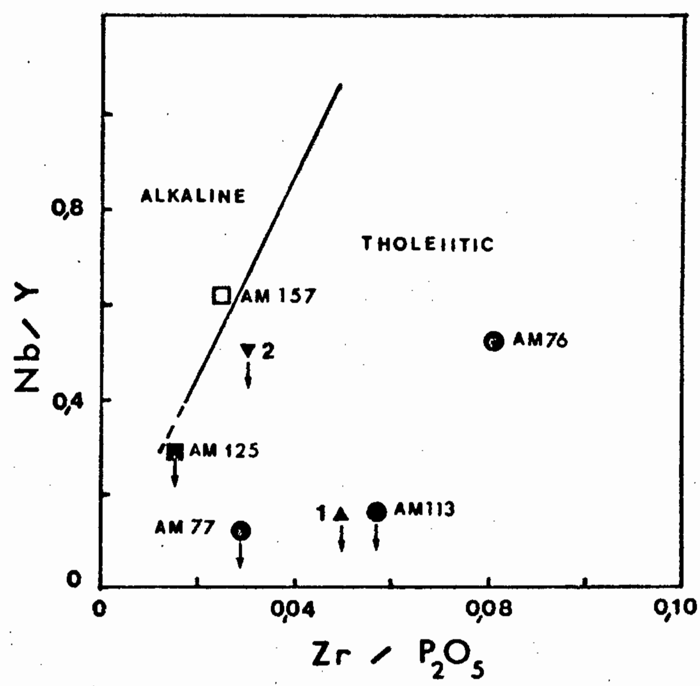


Fig 87 Plot of Nb/Y vs Zr/P_2O_5 (after Winchester and Floyd 1976) for amphibolites from the study area. Symbols as in Fig 82. Points with arrows represent maximum values of Nb/Y since Nb is usually below the detection limit.

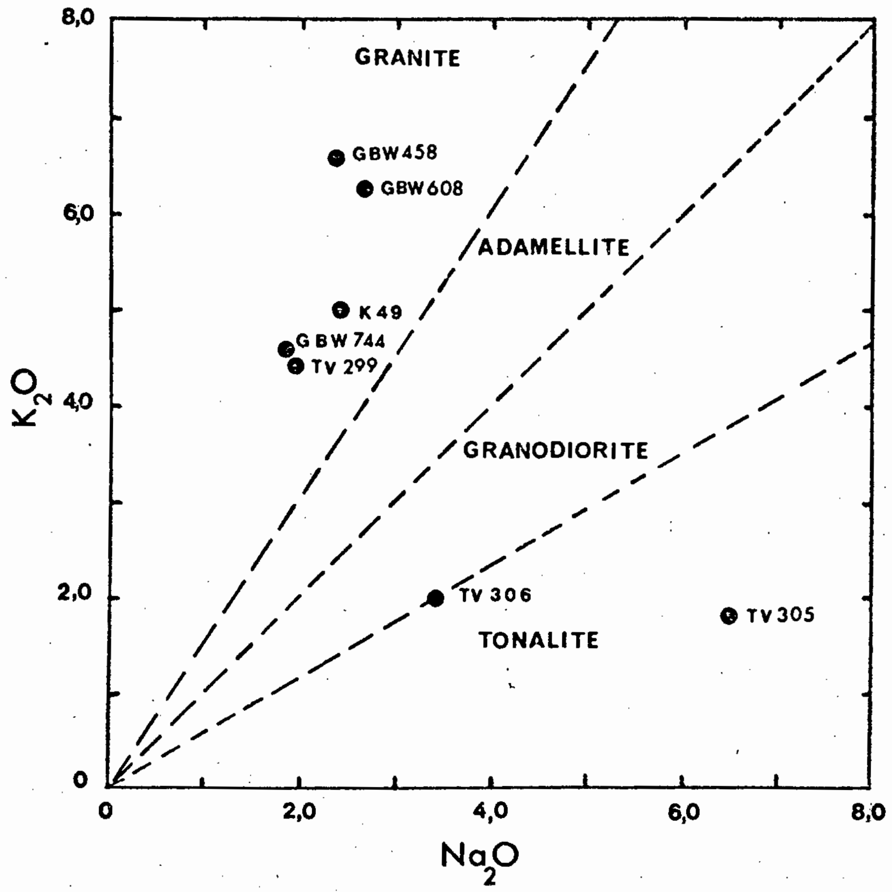


Fig 88 Plot of K_2O vs Na_2O (wt %, volatile free) for granitic rocks from the study area. A chemical classification used by Harpum (1963) and others based on the K_2O/Na_2O ratio is shown.

GBW 458, 608 - Warmbad granite
TV 305, 299 - So called granodiorite and tonalite of Tantalite Valley
GBW 744, TV 306, K49 - Inequigranular granite gneiss

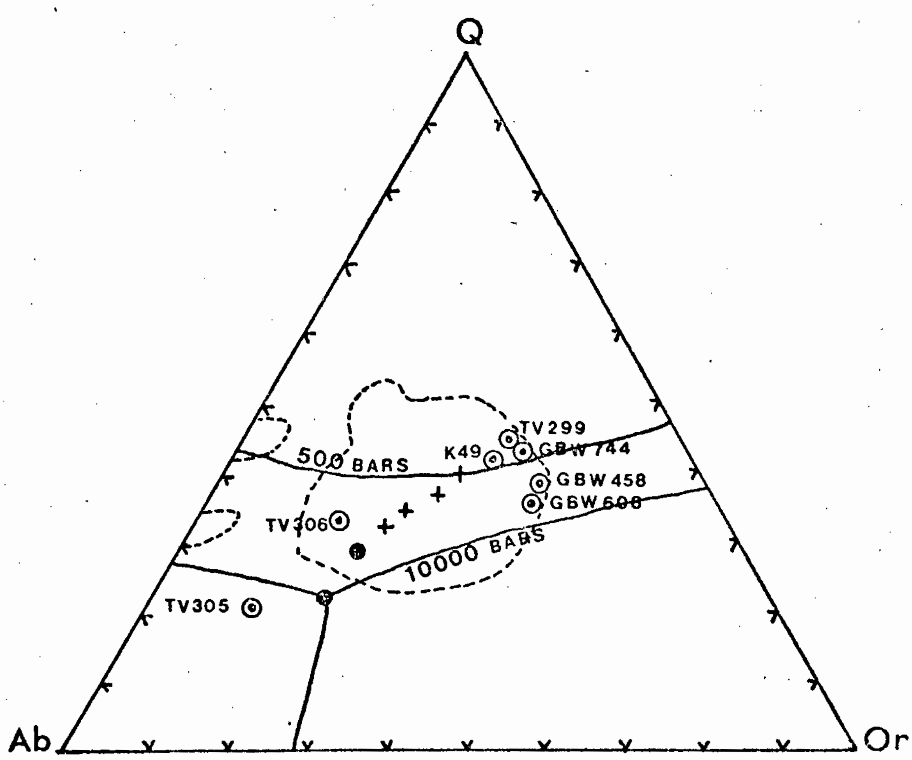


Fig 89 Compositions of granitic rocks from the Tantalite Valley - Kumkum area, plotted in terms of Ab, Or and Q (weight %). The plus signs indicate the minima for 500, 1 000, 2 000 and 3 000 bars P_{H_2O} and the full circles represent eutectic points for 5 000 and 10 000 bars P_{H_2O} (after Luth, Jahns and Tuttle 1964)

field of 83% of the world's granites (Winkler and Von Platen 1961)

ADDENDUM

Fig. 90. The chemical compositions of various metamorphic rocks from the Kumkum-Tantalite Valley area plotted on ACF and A'FK diagrams after Winkler (1974, Fig. 5 - 7)

Key:-

(1B) Clays and shales either free of carbonate or containing up to 35% carbonate; between arrows: marls containing 35-65% carbonate

(II) Greywackes

(1) Ultrabasic rocks

(2) Basaltic and andesitic rocks

(⊛) Metabasite hornfels

(▲) Amphibolite

(◎) Pelitic hornfels

(⊗) Granolite

(■) Black gneiss

(□) Pyroxene hornfels

(○) Cordierite-anthophyllite hornfels

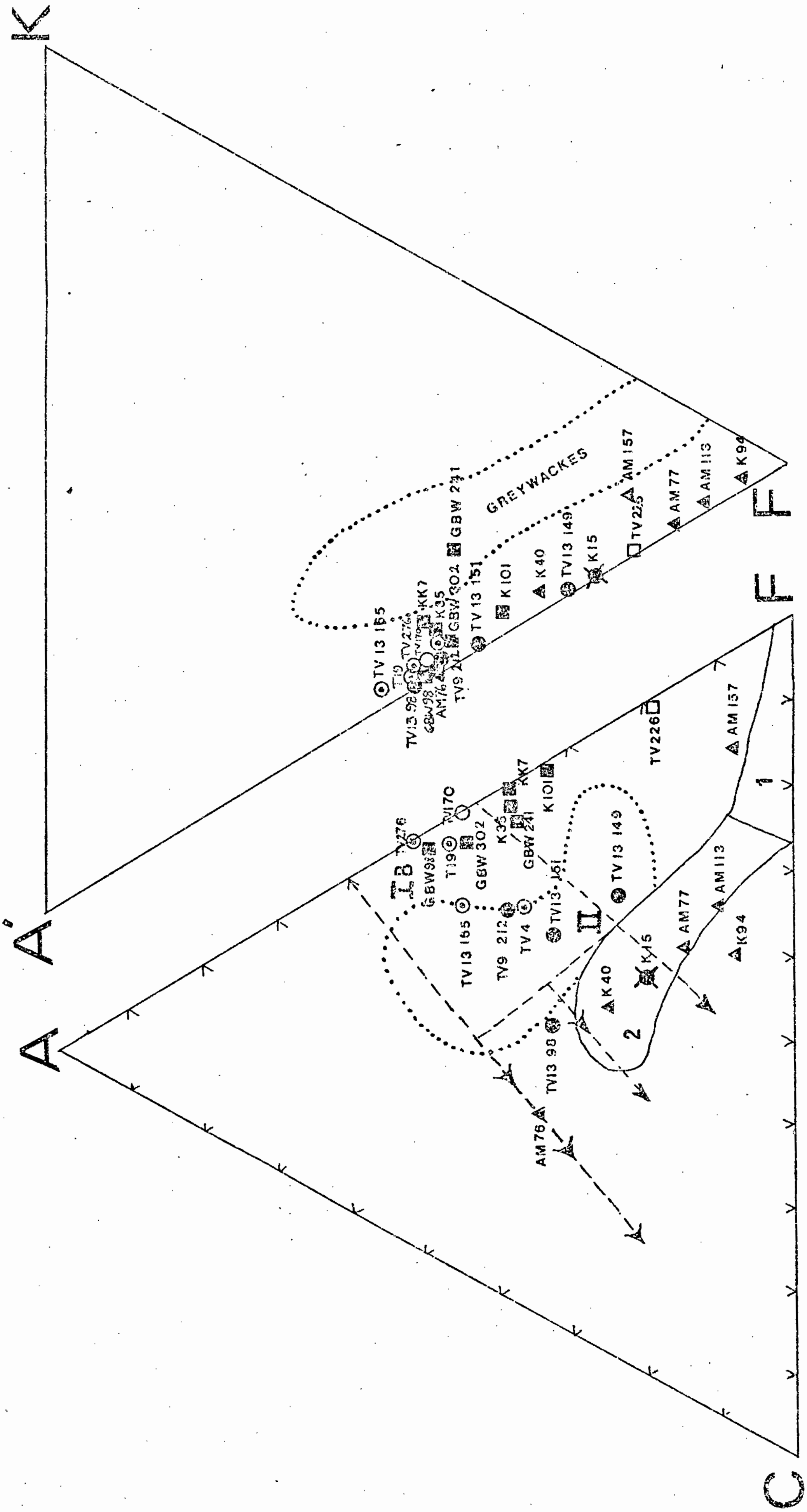

K
A'
A
C
F
F
GREYWACKES
TV13 165
TV13 98
TV276
TV170
T19
GBW98
AM76
TV9 212
TV4
K7
K35
GBW 302
GBW 241
TV13 151
K101
K40
TV13 149
K15
TV226
AM157
AM77
AM113
K94
IB
II
1
2

TABLE 1

AREAL EXTENT AND AGE RELATIONSHIPS OF THE INTRUSIVES OF THE TANTALITE VALLEY BODY.

	ROCK-TYPE	AREA IN KM^2 *	YOUNGEST
POST - T.V.C.	PEGMATITES	NOT DETERMINED	
TANTALITE VALLEY COMPLEX (T.V.C.)	MAFIC-ULTRAMAFIC ROCK	0,90 ≠	↓
	GABBRONORITE	30,38	
	TONALITE/GRANO-DIORITE	0,29	
	METAGABBRO	15,06	
PRE-T.V.C.	MOTTLED META-GABBRO (M.M)	2,40	OLDEST
	TOTAL INCL. M.M.	49,03	
	TOTAL EXCL M.M.	46,34	

* Areas determined by Fixed-arm planimeter from Map 1

≠ Main plug = 0,58 km^2, North-east plug = 0,18 km^2, Rest = 0,14 km^2.

TABLE 2.

ESTIMATED MODES (IN VOLUME %) OF SOME ROCK TYPES FOUND AS PART OF THE GREY GNEISS SEQUENCE.

SAMPLE	QZ	KF	PL	AN	GA	CD	BI	MS≠	SI*	CH	HB	OPA-QUES	OTHERS
AM154	45	15	19	(20)			10	10				1	
AM134	40		15		<0,5		18	5	5	15		1	op(1), zc, sn
AM17	65	3◊					10	20	1	<0,5			ap
AM67	19	20	13	(30)			20	25	1	<0,5		<0,5	ep(2), clay
AM25	60	20	10				7	3					
AM55	45							32		22			rutile, ep
AM288A	60		9	(20)			1	30					
AM288B	13						25	50	5	5		2	
AM122L x	56		20	(20)			3	20	1				
AM122M ‡	74						15	10	<0,5			1	
AM222	40	35	5	(20)			20	<0,5					zc, sn
KK5A	33		60				5					2	ap, zc
K96	30	44	5		7	0,5	10		3			<0,5	zc
TV338	38	2	30				10	15	5	<0,5			zc
TV331	<0,5	<0,5					15			<0,5	30	<0,5	ap, zc
TV336	15		54	(64)			20				10	0,5	cz, sn, ep
K2A						33	40		25			2	zc
AM270	20						10	5	65				
K176A	73	0,5					5	0,5	20				rutile, myrmekite, haematite, zc
GGTVA	40	<0,5	3				5	35	17			<0,5	zc
GGTVB	33	2◊	1				3	35	25				zc, ep
K175	92	<0,5	1	(31?)		2	3	1		0,5			pr

AM154 - TV338 Grey Gneiss including muscovite-rich varieties
TV331 - TV336 Hornblende-bearing Grey Gneiss
K2A - AM270 Aluminium-rich Grey Gneiss
K176A - GGTVB Sillimanite knots in Grey Gneiss
K175 Metaquartzite

* includes fibrolitic sillimanite
≠ includes primary and secondary muscovite
◊ perthitic K-feldspar
x leucoband
‡ melanocratic band

chlorite $\gamma = \beta$ green α very pale green
$\gamma = \beta$ dark green α yellow green

first generation biotite $\gamma = \beta$ dark brown α pale yellow or pale brown
second generation $\gamma = \beta$ olive green α pale orange
hornblende γ blue green β green α yellow green

TABLE 3

MINERAL ASSEMBLAGES OF CALC-SILICATE

A. Scapolite + sphene

plus (1) Diopside + garnet + calcite + plagioclase {± muscovite} (GWB269, 259)

(2) Diopside + garnet + calcite + microcline {+ muscovite} (GBW 265)

(3) Diopside + garnet (GBW 264)

(4) Diopside + garnet + calcite + {muscovite} + quartz (GBW 268)

(5) Diopside + tremolite + plagioclase + quartz + calcite (DT 1358)

(6) Garnet + plagioclase + hornblende + quartz (K 208A)

B. Diopside + hornblende + quartz + plagioclase

plus (1) ± microcline + sphene + epidote (DT 109, 83A, AM260A, K126 GBW 597, 371, 350, 49)

(2) ± sphene (DT 1683A, 1636, 77A, 1303)

C. Diopside + garnet + plagioclase

plus (1) Quartz + microcline + sphéne + epidote ± tremolite (GBW 354, 83)

(2) Sphene + epidote ± biotite (GBW 255, AM 25C)

(3) Microcline (DT 1455A)

(4) Quartz + sphene + hornblende (DT 99A)

(5) Quartz + epidote (K1)

D. Plagioclase-diopside

plus (1) Quartz + sphene + epidote ± tremolite (GBW 134, 646, 483, TV 108)

(2) Quartz + sphene + epidote + microcline (GBW 645)

(3) Quartz ± sphene (DT 170A, 1271A)

(4) Sphene + microcline (DT 1308)

E. Plagioclase-garnet-hornblende

plus (1) epidote minerals + sphene ± biotite (AM 213, K 122)

(2) epidote minerals + sphene + quartz (K 208)

F. Plagioclase-Calcic Amphibole (either hornblende or tremolite-actinolite)

plus (1) Quartz ± epidote + sphene (RUNWAY, DT 171A, GBW 23, 424)

(2) Spinel (T3)

(3) Quartz + epidote + sphene + K-feldspar + biotite (TV 335)

(4) Quartz + sphene + K-feldspar (DT 1304)

{ } secondary minerals

GBW - samples from Beukes (1973)

DT - samples from Toogood (1976)

AM, K, TV and others - samples from this work.

TABLE 4

FREQUENCY DISTRIBUTION OF CALC-SILICATE SAMPLES

CLASS	NUMBER OF SAMPLES	% OF $\sum$ FOR EACH CLASS
A 1	2	
2	1	
3	1	
4	1	15,91
5	1	
6	1	
B 1	8	27,27
2	4	
C 1	2	
2	2	
3	1	15,91
4	1	
5	1	
D 1	4	
2	1	
3	2	18,18
4	1	
E 1	2	
2	1	6,82
F 1	4	
2	1	15,91
3	1	
4	1	
	TOTAL 44 ($\sum$)	100,00

TABLE 5

MINERAL ASSEMBLAGES IN MARBLE

A. Olivine + Calcite (5 samples i.e. 50% of total)

plus

(1) {muscovite} ± chondrodite ± spinel (GBW 262, 263, 257)

(2) phlogopite + brucite + humite (AM 260B, 262/2)

B. Calcite + diopside (4 samples i.e. 40% of total)

plus

(1) microcline + garnet + chondrodite (GBW 272)

(2) microcline + garnet + quartz + {muscovite} (GBW 273)

(3) microcline + graphite + spinel (GBW 588)

(4) hornblende + plagioclase + humite (AM 290/2)

C. Calcite + tremolite (1 sample i.e. 10% of total)

plus

(1) sphene (GBW 288)

{ } secondary minerals

GBW - samples from Beukes (1973)

AM - samples from this work

TABLE 6

ESTIMATED MODES (IN VOLUME %) OF CALC-SILICATES

SAMPLE	PL	AN	GA	HB	DI	QZ	OPAQUES		EP	CZ	ZO	SN	OTHERS
AM25C	45	(45)	25		18				<0,5			<0,5	bi(1), allanite, zc
AM213	68	(65)	20	5					1	4		2	
K1	50	(46)	7		37,5	2	<0,5		3	0,5			
K122	31	(63)	5	2			<0,5	mt	<0,5	60		1	ch, bi, pr
K208	51	(75)	35	<0,5		10			2	1		1	
K208A	63	(68)	20	3		10	2	mt	<0,5	0,5		1	ch, scopolite
Runway	71	(56)		3		7	3	mt	15			1	haematite
AM260A	5	(80)		25	20	40			5			3	ms, zc, allanite
T3	70	(60)											sp, tremolite (25)
TV108	20	(63)			53	20				2		<0,5	tremolite (5)
K126	29	(41)		15	20	35						1	microcline <0,5)
TV335	50	(36)		1		25	0,5	mt	4			1	microline(3), myrmekite, bi(15) op, zc

TABLE 7

ESTIMATED MODES (IN VOLUME %) OF MARBLES

SAMPLE	OL	CC	DI	PL	HB	BRUCITE	HUMITE	PH	CH	AP
AM290/3		75	10	8	2					
AM260B	2	80				10	3	3	1	1
AM262/2	20	75				1	3	1		

Hornblende γ greyish olive-green β greenish grey α pale brownish yellow
γ deep blue green β yellow-green α pale olive-green
Epidote γ yellow-green α light green
Chlorite γ green α pale brown

Biotite $\gamma = \beta$ dark brown α pale yellow-brown
Phlogopite $\gamma = \beta$ orange-brown α neutral
Humite γ neutral α yellow

TABLE 8

MINERAL ASSEMBLAGES OF THE HORNFELS

PELITIC HORNFELS GROUP

A		all contain andalusite + sillimanite + quartz and biotite
	A1	+ staurolite ± plagioclase
	A2	± staurolite ± plagioclase + cordierite
	A3	± plagioclase + almandine
B		all contain cordierite + staurolite ± quartz and biotite
	B1	± almandine ± sillimanite
	B2	± almandine ± plagioclase
	B3	+ almandine + kyanite
C		all contain cordierite + biotite + quartz
	C1	+ andalusite ± plagioclase
	C2	+ sillimanite ± plagioclase
	C3	± plagioclase
D*		andalusite, biotite, quartz, plagioclase with or without almandine

* Beukes (1973) has identified K-feldspar in some samples consistent with this group.

PYROXENE-BEARING HORNFELS GROUP

E		all contain orthopyroxene and mica
	E1	+ cordierite ± plagioclase
	E2	+ Clinopyroxene + hornblende + plagioclase

CORDIERITE-ANTHOPHYLLITE HORNFELS GROUP

F		all contain cordierite + anthophyllite ± quartz
	F1	+ phlogopite
	F2	+ phlogopite + almandine ± K-feldspar ± plagioclase

Beukes (1973)

METABASITE HORNFELS GROUP

G		all contain amphibole + plagioclase
	G1	± garnet ± quartz ± biotite
	G2	± garnet + quartz + K-feldspar + biotite

PSAMMITIC HORNFELS GROUP

H		all contain plagioclase and quartz
	H1	+ K-feldspar + primary muscovite + garnet
	H2	+ K-feldspar + biotite + garnet
	H3	+ biotite ± anthophyllite

TABLE 9

ESTIMATED MODES (IN VOLUME %) OF PELITIC HORNFELS

SAMPLES	QZ	PL	AN	GA	BI	CH	CD	ST	SI	AD	OPAQUES	OTHERS	GROUP
TV312	24	10	(39)		15	3		3	1	37	4	ms(1) ep	A
TV276 ≠	20				13	13	25	6	9	12	2 (ma)	zc	A
AM31A	55	10	(38)		10	5	3	1	1	6	2	ms(7) zc, ep	A
AM104	20			10	30	5			10	20	3	ep (2)	A
AM272	10				10	5	38	2	30		2 (ox)	ms(3) zc	B
TV308	4				20	1	73	1			<0,5	zc	B
T19		1	(44)	10	6	3	59	3	10		2 (il)	tourmaline (4), ms(2)	B
TV104G	10	7	(40)	2	3	0,5	73	3			1 (ox)	ms	B
TV4	<0,5			10	25	15	4	6			2 (ccp) (py) (po)	ky, cc, sp(1) white mica (37), chloritoid	B
TV13 165≠	30	20	(45)	5	8	3	32		<0,5		2 (il)	tourmaline ap, ep, sn, zc	C
TV230	10				5	1	83				1 (il)	zc	C
AM170A*	5				25	10	30	3	25		2 (ox)	ep	B

* interbedded with cordierite

≠ average of three or more thin sections

Biotite γ greenish brown, reddish brown, blue green

α yellow, pale brown, pale yellowish green

Staurolite γ yellow α pale yellow, neutral

Chlorite $\gamma = \beta$ pale green α neutral

muscovite, chlorite, epidote, chloritoid and calcite are secondary

TABLE 10

ESTIMATED MODES (IN VOLUME %) OF CORDIERITE-ANTHOPHYLLITE HORNFELS

SAMPLE	CD	AT	PH	CH	QZ	IL	GA	GROUP
TV102	36	40	15	5	3	1	< 0,5	F 2
AM170	27	26	35	10	1	1	-	F 1

Small amounts of zircon, apatite, talc, calcite and tourmaline may also be present.

Anthophyllite $\gamma = \beta$ pale green, neutral α pale yellow

Phlogopite $\gamma = \beta$ greenish brown α pale yellow

Chlorite $\gamma = \beta$ green α pale green, pink.

TABLE 11

ESTIMATED MODES (IN VOLUME %) OF METABASITE HORNFELS

SAMPLE	QZ	PL	AN	GA	B1	CH	MS	CM	HB	ACT	OPAQUES	OTHERS	GROUP
TV9 219.8	20	60	(40-45)	1	5	<0,5	1	8			1	kf(4), ap, ep	G 2
TV9 240,12	15	65	(55)	3	5	1		10			1 (py)	ap	G 1
TV12 207,95	15	60	(54)		15	4					1	at(3), zc, ep (1)	G 1
AM35	15	20	(40)			0,5		10	55		0,5	sn	G
TV13 198,9	10	{30}		2	10	5	30	10	30		1 (ma)	ep(1), sn	G 1
T3(TV1-202)		69	(55)	1	2		2	25			1 (ox)		G 1
TV103		12	(43)	1	1	<0,5	3	79				sn(4), ep	G 1
AM31D		49*	(50)					20		30	1		G
AM31C		50*	(35-40)		5	3		20		20	1	ap, ep	G 1
AM31B	<0,5	60	(89)			<0,5	3	10		20	2 (ma)	ep (5), ap	G 1
TV9 215,3		29	(60)		<0,5	<0,5		40	15		10† (s)	rutile, sn kf-qz-ep veins (5)	G 1
TV9 212,5		40				<0,5		40	15		5 (s)		G
TV13 98		70	(42)			6		10	5		2 (po,) (ccp)	rutile, ap(1) sn(3), ep(3)	G
TV13 149		60	(55)		5		2	15	15		3 (po,) (ccp)	ep, ap	G 1
TV13 151		45	(63)		10	5		35	3		2x (s)	ep, ap	G 1

{ } original amount of mineral found

Hornblende γ olive green β yellow green α pale yellow green

γ deep blue green β olive-green α pale brownish yellow

Actinolite $\gamma = \beta$ green α pale green, neutral

Biotite $\gamma = \beta$ reddish brown, pale orange, greenish brown α pale brown, neutral

† includes pyrrhotite (6%), chalcopyrite (3%), pentlandite (0,5%) and pyrite (0,5%)

* antiperthitic

x includes chalcopyrite, pyrite, pyrrhotite and pentlandite

s sulphide minerals

TABLE 12

ESTIMATED MODES (IN VOLUME %) OF PYROXENE-BEARING HORNFELS

SAMPLE	GROUP	OP	PL	AN	PH	CD	HB	OTHERS
TV225	E1	20	30	(32)	18	30	-	2(ox)
TV226	E1	49	-		10	40	-	1(ox, hc, s)
TV195	E2	43	14	(55)	1	-	39	3(cp, ox)

Orthopyroxene γ green α pink
Hornblende γ olive green β green α yellow green
Phlogopite γ orange brown α yellow
hc : hercynite s : undifferentiated sulphides

TABLE 13

ESTIMATED MODES (IN VOLUME %) OF PSAMMITIC HORNFELS

SAMPLE	QZ	PL	AN	KF	OPAQUES	GA	MS	BI	CH	AT	OTHERS
TV13 182	32	20	(26)	40	$<$0,5 (py, ma)	1	5$\not{p}$		1		1 cc, ep
TV13 165,85	20	10	(45)	50	1 (py, ma)	1	1	15	2		1 (ep)
AM102	10	72	(30)	-	1 (ox)			15	1		1 (zc, sn)
AM30A *	40	40	(42)		0,5 (ox)			2	2	15	0,5 (ep)

* AM30A shows partial melt textures $\not{p}$ primary muscovite

Biotite $\gamma = \beta$ brownish yellow α pale yellow
Chlorite $\gamma = \beta$ green α grey

TABLE 14

MINERAL ASSEMBLAGES OF THE BLACK GNEISS (INCLUDING HORNFELSIC AND FELDSPATHIC VARIETIES)

A. Garnet + cordierite + hypersthene + biotite

plus

(1) quartz + K-feldspar + sillimanite + plagioclase (K237)

(2) plagioclase + spinel + sapphirine + corundum (GBW 590)

B. Cordierite + hypersthene + biotite

plus

(1) sapphirine + spinel (GBW 51)

(2) quartz + sillimanite + plagioclase (KK 6)

C. Cordierite + garnet + biotite + anthophyllite/gedrite

plus

(1) plagioclase + quartz + K-feldspar (GBW 292)

(2) plagioclase + quartz + sillimanite + spinel (K101)

D. Garnet + cordierite + sillimanite

plus

(1) quartz + biotite + plagioclase ± K-feldspar ± spinel (GBW 25, 33, 48, 198, 301 302, 345, 382, AM 202, 201, 203, K 54, 57, 62, 66B, 35, 67, 79, 81, 2, 19A, 222, 236A, KK 7, 10D, 4a, A5, 3, DJT 1464, 1649, 1509, 845, 838, 837A, 1992, 2567, 835, 56A, 890.)

(2) quartz + biotite + K-feldspar (DJT 73A, 2205)

(3) quartz + biotite (GBW 98, DJT 914, 1427, 1403A, 832A, K12)

(4) K-feldspar + quartz (DJT 1004)

(5) biotite + plagioclase + K-feldspar ± spinel (AM 223)

E. Garnet + sillimanite

plus

(1) biotite + quartz + plagioclase + K-feldspar ± spinel (GBW 241, GBW 284)

(2) quartz ± biotite (DJT 815, 36)

(3) quartz + biotite + K-feldspar (DJT 757, 2020A)

(4) quartz + biotite + plagioclase (DJT 1460F, A2)

F. Cordierite + biotite + sillimanite

plus

(1) K-feldspar + plagioclase ± quartz (DJT 2204, 2011, 2202, AM 214, K 36)

(2) spinel + corundum (GBW 54)

(3) quartz + muscovite (primary) (DJT 376)

(4) quartz ± K-feldspar (DJT 1428, 13, K114, K 38)

G. Sillimanite + biotite

plus

(1) quartz + k-feldspar ± plagioclase (DJT 1479, GBW 418)

H. Garnet + biotite

plus

(1) quartz + plagioclase + K-feldspar (K 216, 183, 236AB)

I. Cordierite + biotite

plus

(1) quartz + plagioclase (K 158, 185)

(2) quartz + K-feldspar (K 66C)

Not included in the above are samples GBW240 Plagioclase + quartz + garnet + K-feldspar + sphene + hornblende and GBW 186 Quartz + garnet + opaque minerals + diopside + plagioclase

GBW - samples from Beukes (1973) DJT - samples from Toogood (1976)
AM, K, KK and A - samples from this work.

TABLE 15

FREQUENCY DISTRIBUTION OF BLACK GNEISS SAMPLES

CLASS	NUMBER OF SAMPLES	% OF TOTAL FOR EACH CLASS
A 1	1	2,44
2	1	
B 1	1	2,44
2	1	
C 1	1	2,44
2	1	
D 1	39	59,76
2	2	
3	6	
4	1	
5	1	
E 1	2	9,76
2	2	
3	2	
4	2	
F 1	5	13,41
2	1	
3	1	
4	4	
G 1	2	2,44
H 1	3	3,66
I 1	2	3,66
2	1	
	TOTAL 82	100,01

TABLE 16

ESTIMATED MODES (IN VOLUME %) OF BLACK GNEISS; INCLUDING FELDSPATHIC AND HORNFELSIC VARIETIES.

SAMPLE	QZ	SI	GA	CD	BI	PL	AN	KF	OPAQUE	HER-CYNITE	ZC	OTHERS
AM223		23	10	25	10	<0,5		30	1,5 (ma)	0,5		
AM202	33	5	5	20	10	20	(45)	5	1,5 (ma)	0,5	< 0,5	
AM201	34	10	5	10	5	15		15	1 (ma)	<0,5	< 0,5	
AM214		15		45	10	1		10	3,5 (ma)	0,5		ms(5)
AM203	33	10	5	25	5	5		15	1,5 (ma)	0,5		
AM203A	62	15			20				1		0,5	ms(2)
K54	20	7	20	28	7	5		10	3 (ma, il)	<0,5	<0,5	
K87	30	5	15	20	3	6		20	1 (il)		<0,5	
K62	10	40	30	5	3	10			2 (il)			
K66B	22	4	5	25	10	3	(22)	30	1 (il)			
K67	7	3	5	50	6	26	(36)		3 (ma)	<0,5	< 0,5	
K79	5	7	20	30	10	20	(53)	<0,5	3 (ma)	<0,5	< 0,5	myrmekite
K81	78	4	<0,5	6	4	5	(31)	<0,5	2 (ma, il)		<0,5	myrmekite, haematite
K2	30	2	3	25	4	28	(49)	7	2 (ma, il)		<0,5	
KK6	56	2		30	3	1	(15)		<0,5 (ma)		< 0,5	hypersthene(7), hb
KK7	10	7	20	29	3	3	(12)	25	3 (ma, il)	<0,5	<0,5	
K12	17	12	30	30	10				1 (il)	<0,5	<0,5	
K19A	22	30	3	1	5	15	(31)	20	4 (il, ma)	<0,5		
K222	15	10	30	10	4	25	(50)	<0,5	4 (il, ma)	<0,5		haematite, ap
K206	69	7	3	10	7				3 (il, ma)	<0,5	<0,5	ap, limonite
K101	7	<0,5	30	20	15	10	(27)		2 (il, ma)	0,5	<0,5	haematite, ap, gd(15), picotit[illegible]
K237	40	2	4	22	2	3		25	1 (il)		<0,5	hypersthene (0,[illegible]
K236A	7	5	10	55	7	10	(50)	3	3 (il)		<0,5	myrmekite
K144	45	1		26	1			26	<0,5 (il)	< 0,5	< 0,5	
KK10D	10	<0,5	35	25	1	2		25	2 (il)	<0,5	<0,5	
A3	30	2	20	20	3	24	(38)	<0,5	1 (ma, il)			
A5	30	10	20	5	15	19,5	(38)					
A2	20	<0,5	20		25	32	(52)		3 (ma)			
K158	3			60	35	0,5			1 (il)		< 0,5	ch
K216	50		1		5	2		41	<0,5 (il)		< 0,5	ap
K66C	30			20	7			43	<0,5 (il)		< 0,5	
K183	65		1		o,5	3		30	<0,5 (il)		< 0,5	pr, ch
K185	41			50	4	4			0,5 (ma)		< 0,5	haematite
K236AB	39		2		3	50		5	1 (il)		<0,5	ap
KK4A	10	7	10	30	5	30	(40)	7	1 (il)			
K35	10	7	30	25	3	17	(35)	5	3 (il)			
K36	26	20		15	2	5		30	2 (ma)	<0,5		
K38	10	20		30	3			34	3 (ma)	<0,5	<0,5	

Black Gneiss: (Samples AM223 to K158)

Biotite $\gamma=\beta$ pale brown α orange-yellow

$\gamma=\beta$ olive-brown, reddish-brown α yellow, pale orange

Hypersthene γ green α pink

Hornblende γ brownish-green β green α yellow-green

Chlorite $\gamma=\beta$ blue-green α pale pink

Gedrite γ greyish-green β brownish-grey α pale yellow

continued/.....

TABLE 16 - continued

Feldspathic Black Gneiss: (Samples K216 to K236AB)

Biotite $\gamma = \beta$ deep orange-brown α pale yellow-brown
$\gamma = \beta$ dark brown α pale brown
$\gamma = \beta$ dark olive-brown α pale brown
Chlorite γ turquoise-green α pale green

Hornfelsic Black Gneiss from contact with the main body of Kumkum gabbronorite: (Samples KK4A to K38)

Biotite $\gamma = \beta$ deep brown α yellow

Note Beukes (1973) also reported the assemblage hypersthene + cordierite + andesine adjacent to the Kumkum body.

TABLE 17

ESTIMATED MODES (IN VOLUME %) OF TANTALITE VALLEY AND KUMKUM AMBHIBOLITE (INCLUDING HORNBLENDITE).

SAMPLE	HB	PL	AN	BI	OP	CP	SN	QZ	EP	OPAQUE	CC	CH	OTHERS
AM262	45	30	(50)	10			0,5	15		0,5			
AM260C	30	48	(40)	3			3	10	1	<0,5		5	ap, allanite
AM120	40	35	(50)					24		1			ap
AM113	75	<0,5					3	20	2	<0,5			
AM109	29	60	(40)				1	4	0,5	<0,5		5	pr, ap
AM105	60	20	(25)	10			0,5	5	2	1		2	
AM77	60	17	(82)				3	20					
AM76	35	55	(95)				4		4	2 (ma)			ap
AM58B	45	54	(30)				1		<0,5	0,5 (ma)	<0,5		concrinite
AM58B/2	50	49	(40)				1		<0,5	0,5	<0,5	<0,5	
AM57A	70	25	(38)	2			<0,5		1			<0,5	op, zc
AM57A/2	54	30		1					5	<0,5		5	op, zc
TV334	56	40	(54)				1	2		1			zc
TV113B	81	1				17	<0,5	0,5		<0,5			microcline
TV337A	83	5				10	1	1					
TV318	40	25	(28-38)	7			2	20	0,5	3			cz, zo, myrmekite
TV319	40	40	(63)	3	0,5	8				3			rutile, zo, cz, grunerite or tremolite(5,5
AM105A	99									1			
S116	99									1			
S12	83	5				<0,5	2	10	<0,5	<0,5			
AM234	70	20		0,5				<0,5	3		<0,5	4,5	pr
K50	50	49	(69)				<0,5	<0,5	1	<0,5		<0,5	pr
K264	40	34	(65)			25				<0,5	0,5		cz
K263	40	48	(45-60)			5		5		1	<0,5	<0,5	haematite
K94	50	44	(73)	<0,5				5		0,5	<0,5	<0,5	pr
K61	91							4	<0,5				zo(2)
K40	40	57	(43)	0,5					0,5	1,5 (ccp)		<0,5	
K157	35	47	(62)		7			10		1			zc, ap

Samples AM262 to S12 from Tantalite Valley
Samples AM234 to K157 from Kumkum

continued/....

TABLE 17 - continued

Hornblende γ blue-green β olive-green α yellow-green
γ olive-green β pale blue-green α pale yellow-green
γ grass-green β olive-green α yellow-green

Actinolitic hornblende $\gamma=\beta$ green α pale green

Biotite $\gamma=\beta$ brown α yellow
$\gamma=\beta$ yellow-brown α yellow

Chlorite $\gamma=\beta$ green α pink

Epidote γ honey yellow β brown α neutral
$\gamma=\beta$ yellow-green α pale yellow-green

Hypersthene γ green α pink

TABLE 18
ESTIMATED MODES (IN VOLUME %) OF KUMKUM GRANOLITE

SAMPLE	QZ	PL	AN	OP	CP	HB	B1	OPAQUES	AP	RUTILE	CH	ZC	OTHERS
AM209	10	55	(60)	20		10	4	1 (ma)	<0,5				haematite
K58	1	49	(53)	3	20	25		2 (il)		<0,5			
K13		48	(64)	15		35		2 (ma)	<0,5				
K15		53	(48)	10	30	5		2 (ma)					
K21	15	27	(54)	7	5	45	<0,5	1 (il)			<0,5		sulphide
K53A	12	43	(69)	2		40	1	2 (ma)					
K151	26	27	(70)	30		6	10	<0,5 (il)	<0,5		<0,5	<0,5	haematite
K248	10	37	(51)	25	5	15	6	2 (ma)					

Hypersthene γ green α pink
Hornblende γ olive-green β green α yellow-green
Biotite $\gamma=\beta$ dark brown α pale orange

TABLE 19

ESTIMATED MODES (IN VOLUME %) OF MOTTLED METAGABBRO

SAMPLE	PL	AN	HB	EP	CH	BI	QZ	SN	OPAQUES	AP	PR
AM149/2	54,5	(79-20)	40	2	1	1			1	0,5	
AM149/3	50		30		14		4	1	1	<0,5	<0,5
AM149/4	46		40		10		3	0,5	<0,5		<0,5
AM149/5	36	(36)	55	0,5	0,5	1	5,5	1	0,5		
AM149/6	44	(50)	40	1	5	2	4,5	2	1,5		<0,5
AM166	55	(55)	44		<0,5			<0,5	1		
TV294	46	(36)	40	2		10	1	1	0,5		
TV288	48	(43)	40	0,5	2	0,5	7	1	1		
TV275	60	(78-72)	33	0,5		4	1		1,5		<0,5
TV296	46	(48)	50	<0,5	1	1		1	1		
TV298	36	(60)	60	<0,5	<0,5	3	<0,5	0,5	1	<0,5	
TV275A	55	(44)	38	2	0,5	2	<0,5	1	1	<0,5	<0,5
TV270C	45	(56)	45			6	<0,5		4		
AM256	15	(40-25)		13		69		2	1		

Other minerals include zoisite, clinozoisite and K-feldspar (in cross-cutting veins, i.e. AM149/6) and zircon (TV288)

Hornblende γ blue-green β green α yellow-green
Biotite γ=β orange-brown α pale orange, pale brown
Chlorite γ = β pale green α pink

TABLE 20

ESTIMATED MODES (IN VOLUME %) OF INEQUIGRANULAR GRANITE GNEISS (ORTHOGNEISS) FROM TANTALITE VALLEY AND KUMKUM AREAS.

SAMPLE	QZ	KF	PL	AN	BI	HB	SN	OPAQUES	EP	AP	GA	OTHERS
AM290	32	45	5		10	5	2	<0,5	<0,5	0,5		allanite (o,5)
AM280	30	30	25	(24)	10		3	<0,5	2	<0,5		allanite
AM256	30		40	(40)	15		2	1	10	<0,5		ch(1)
AM144	38	15	25	(40)	15		2		1	1		ms, ch(3)
AM7	60	20	5	(20)	5			<0,5	1	<0,5		zc, ms(2), myrmekite (5)
KKIA	30		53	(35)	10						7	zc, myrmekite
K203	50		39	(33)	7			1,5 (ma)			2	ch, zc, pr, myrmekite
AM150	25	20	40	(10)	5		<0,5					myrmekite, ms(10) allanite
AM255A*	60	15	20	(20)	3				2			myrmekite, ch
K49(KBH)	52	15	25		5			<0,5	<0,5	0,5	0,5	allanite, ms, ch(1) myrmekite
TV306	25		42	(46)	25	0,5	1	2 (ma)	3	0,5		ch(o,5), zc

* Leucocratic phase of the Inequigranular granite gneiss

Bi γ-β dark greenish-brown α pale olive-green
γ-β dark brown α pale orange
Hornblende γ deep green β blue-green α olive to yellow-green
Chlorite γ = β turquoise green α pale brown, neutral

TABLE 21

ESTIMATED MODES (IN VOLUME %) OF TANTALITE VALLEY METAGABBRO

SAMPLE	PL	AN	HB	CM	AT	BI/PH	CH	QZ	OPAQUES	EP	SN	OTHERS
TV217	42	(64)	49					0,5	2 (il)	3		cc(3), cp(1)
TV265	30	(46)	25	36		5	3		<0,5	<0,5	0,5	pr
TV42	45	(60)	35			0,5	20		0,5	0,5	0,5	pr
TV8	61	(57)	35			1	2		0,5 (ma)		0,5	cc, zo(1)
TV126	88	(70)	10				0,5		0,5	2	1	zo(0,5), ap
TV77	48	(76)	50			1,5	0,5		<0,5		0,5	pr
TV182	50	(49)	50			1	0,5			<0,5	0,5	
TV277	74		15				10		1 (il)	1		ap
TV209	59	(41)	40				1		<0,5 (py, ma)	0,5		cc
TV16	49	(49)	50				0,5		0,5	1	<0,5	pr, rutile
TV22A	60	(55)	10		30	0,5	<0,5		<0,5 (il)	<0,5	<0,5	cc
TV270B	35	(56)	53			4	<0,5	1	1	<0,5		pr, sp, zo, tourmali
TV202	86	(54)	8				5		0,5			zo, cz
TV204	69	(49)	20				10		0,5	0,5		
TV75	60	(51)	40			<0,5	<0,5	<0,5	<0,5 (il)			
TV253	60	(73)	9			2	26		<0,5 (il)	1	0,5	pr, ap(2), zo
TV255	70	(62)	20			1	7		1 (ma)	<0,5		pr, zo, cz
TV242	79	(59)	20			0,5	0,5		0,5	<0,5		zo, cz
TV243	65	(48)	11		15	2	7		1			limonite, hercynite, haematite
TV251	69	(62)	18		7	4			1	0,5		ap, zc
AM103	53		45					1	0,5	<0,5	0,5	ap, kf-veins
AM92	60	(50-72)	30		5	5			<0,5			pr, rutile
AM149/1	60	(48-80)	35			1	<0,5		1 (il, ma)	2	1	pr, ap
AM149/7	50	(60-67)	30			2	10		1	5	2	allanite
AM32	60	(60)	35			<0,5	5		<0,5	<0,5		rutile, haematite, leucoxene
AM33	74	(45-75)	25					1	<0,5	<0,5		
AM30C	50	(55)	45						0,5			baryte vein
AM30D	50	(70)	46			2	0,5	1				rutile, baryte vein,
AM19	45		55			1	4		1		<0,5	
AM20	63	(30-45)	35			1			1	<0,5		
AM89A	59,5	(71)	40			0,5			<0,5	<0,5		rutile
AM88E	80	(40)	20						<0,5	<0,5		
AM90	78	(57)	20			1	0,5		0,5	<0,5		
AM3 60	40	(38-55)	50			0,5	3	3				ap
AM1 454	75	(44-65)	20					2	<0,5 (py)	2		cc
TV9 198,1	60	(65)		30			<0,5		4 (ccp, po, py)	5		ap, rutile
TV9 202,6	68	(65)	20	8		1			1 (py)	2		
TV12/122,06	60	(54)		2	30	5	1		2 (py)			
TV12/122,4	60	(54)			30	5	0,5		2 (py, ma)			
TV12/139,53	60	(54)			33	5			<0,5	2		tourmaline-qz veins
T1/TV1/25	53	(55)	45			1			1		1	
T2/TV1/173	20	(55-60)	30			5	40		4 (ccp po)			cc
T22	59	(30-60)	40			0,5			1			
T24	46	(25-50)	50	2					0,5			cc(2)
T29	54	(60)	45						<0,5			cc(1)

continued/.....

TABLE 21 - continued

Hornblende γ blue-green β green α yellow-green
Actinoilitic hornblende γ pale green α neutral
Biotite γ orange-brown α pale brown, pale orange
Chlorite γ green α pink

TABLE 22

ESTIMATED MODES (IN VOLUME %) OF METAGABBRO (METADOLERITE) DYKES

SAMPLE	PL	AN	HB	TREM/ACT	BI	CH	OPAQUES	OTHERS
AM103B	49	(40)	40			10	1	pr, kf-qz veins
TV12A	39	(41)	60		<0,5		1	
TV166	55	(55)		44			1	sn, ep

Hornblende γ blue-green β green α yellow-green
Biotite $\gamma = \beta$ orange-brown α pale orange

TABLE 23

ESTIMATED MODES (IN VOLUME %) OF TONALITE AND GRANODIORITE

SAMPLE	PL	AN	HB	QZ	KF	EP	SN	BI	CH	OPAQUES	OTHERS
AM183	60	(40)	5				3			1	
AM181C	40	(36-48)		32		5	2	15	5	1	
AM273(TV299)	20	(30)		40	15			15	0,5		ms(5)
AM255B	30			50	17	0,5		0,5	1		ms(2)
TV305	58	(20)		25	10	0,5	0,5	5	<0,5		zc, hercynite, rutile, ms

Biotite $\gamma = \beta$ deep olive-green α pale olive-green
Hornblende γ grass green β blue-green α pale yellow

TABLE 24

ESTIMATED MODES (IN VOLUME %) OF TANTALITE VALLEY GABBRONORITE

SAMPLE	PL	AN	CP	OP	HB	AT	BI/PH	CH	OL	QZ	OPAQUES	EP	OTHERS
TV210	60	(43)	10	20	4		1			3	1 (ma)	1	ap
TV282	48	(64)	38	2	1		2		7		2 (ma)		ap
TV205A	65	(59)	5	15			3		10		2 (ma)	<0,5	hercynite
TV170	50	(58)	35	3	3		1		5		2 (ma)		cc(1)
TV199	61	(53)	2	30	3		1	<0,5		1	1	<0,5	sn(1), ap
TV206	81	(54)	14	1	2		1				1		zo, cz
AM21C	54	(42)	20	10	10	5	<0,5				1	<0,5	
AM34A	60	(38)	20	15	5		<0,5	<0,5			<0,5	<0,5	
AM37A	70	(45-55)	15	14	0,5		0,5				<0,5		
TV263	45	(54)	4	16	1		1,5		30		2	<0,5	hercynite, cc
TV280	54	(52)	15	5			2		20		2	<0,5	hercynite, zo, cc, ap
TV222	60	(63)	28	7	1		0,5		3		0,5	<0,5	sr
TV233	50	(43-49)	2	30			0,5		15		2,5		hercynite, sr
TV187	68	(46)	26	4	1			0,5			0,5		zo
TV171	62	(66)	20	15	1,5		0,5				1	<0,5	
TV221	59	(44)	8	18			1		12		2	<0,5	sr, hercynite
TV153	66	(60)	18	12	<0,5		1,5				2		ap, zo, cz
AM298A	74	(48-60)	5	20			<0,5				0,5 (ma)	<0,5	
AM296	67	(45-58)	15	10	3		2	1		2	0,5 (il)		
AM294	65	(55-62)		10	1		3		19		2 (ma)		sr
AM293	50	(55-64)	20	20	5		3				2	<0,5	
TV179	38	(51-64)	6	20	2		1,5		30		1,5		ap(1)
T39	71	(55)	10	15	1		1	1			1		
AM2 492	65	(50-62)	5	25	2		1			0,5	0,5	0,5	
T15 (TV4/244,50)	79	(70)	15		5		3	1	2		0,5		
T16 (TV4/253,30)	85	(65)	3	10	1		0,5	<0,5			0,5		
T17 (TV4/254,35)	66	(60)	2	30						1	1		
T28	42	(55-60)	5	25	5		7	2	10		3		sr(1)
T35	40	(65)		8	40		1	10			1		
T36	79	(55-65)	10	10			<0,5				1		
T37	76	(55)	5	15	3		<0,5				1		
T38	87	(65)	6	3	1		1		1		1		
AM42	75	(60-66)	10	15							0,5		
AM41	55	(40-50)	17	25	3		<0,5		·		<0,5 (ma)		

Biotite γ dark brown, fox red, yellow brown, greenish brown α pale brown, yellow

Chlorite γ brown, olive green α neutral, green

(Secondary) Hornblende γ blue green, olive green β green α yellow green

(Primary) Hornblende $\gamma = \beta$ brownish α neutral

(Secondary) Actinolitic hornblende $\gamma = \beta$ green α neutral

TABLE 25

ESTIMATED MODES (IN VOLUME %) OF GABBRONORITE DYKES

SAMPLE	PL	AN	HB	OP	CP	BI	OPAQUES	AP
AM40	55	(40-45)	36	2		5	1	
AM34B	53	(65)		25	20		2	0,5
AM298A	65	(50-65)		20	15	1	4	

All samples intride gabbronorite

Biotite $\gamma = \beta$ reddish brown α yellow

Hornblende γ olive green β green α yellow green

TABLE 26

ESTIMATED MODES (IN VOLUME %) OF TANTALITE VALLEY SATELLITE BODY AND RELATED ROCKS.

SAMPLE	PL	AN	OP	CP	BI/PH	CH	HB	TREM -ACT	CM	QZ	OPA-QUE	OTHERS
AM123A	20	(58)	25	30	5		3	9		7	<0,5	sericite/cancrinite(1)
AM123B †	2	(30-45)			10		80		5	2	1	ap, rutile, ep
AM123C †					20		75			5		zc
AM125	15	(47)			9		45		30		1	rutile, sn
S151	15	(20?)					79	5			1	ap, zc
S150A *					3			80	15		2	

† AM123B and AM123C are from near the contact of the Satellite Body with Grey Gneiss

* occurs as a xenolith in ultramafic rock sample S150

Bronzite γ green α pink

Hornblende γ pale grey-green β dark grey-green α yellow-green

γ dark blue-green β olive-green α pale green

Actinolite-tremolite γ pale green α neutral

Phlogopite $\gamma = \beta$ dark brown α yellow-brown

$\gamma = \beta$ tan-brown α yellow

Biotite $\gamma = \beta$ deep brownish-orange α pale orange

TABLE 27

ESTIMATED MODES (IN VOLUME %) OF OLIVINE-RICH (≥ 30%) MAFIC-ULTRAMAFIC ROCKS OF TANTALITE VALLEY AND VICINITY.

SAMPLE	OL+SR	PL	AN	OP	CP	PH	CH	CM	HB * / TR-ACTIN	OPAQUES		OTHERS
TV45	45				15		17	15	5	3	cr, ma	
TV43	76	16		1	2	0,5			2	3	cr, ma	
TV36	50	25	72	15	8	0,5			<0,5	3	cr, ma	cc, ap
TV49	40	30		20	7	1			2,5	1	cr, ma	
TV18	60				<0,5		27	10		3		
AM88A	46						32	15		3	cr,ma	haematite talc 2, brucite 2
AM89B	55 (60)	7 (8)	64	10 (20)	15 (10)	1	1			4 (2)	cr, ma	brucite 5, cc, pr 2
T18	50	<0,5					10		35	5	cr, ma	
T14 (TV4/177)	36	45	60	7			3	5,5	0,5	3	cr, ma	
T13 (TV3/189)	41	33	50	10		1	5		<0,5	5	cr, ma	picotite, hercynite, cc, se/cancrinite 5
T12 (TV3/186)	50	25	60	6		3	5		2	5	cr, ma	hercynite, cc, se/cancrinite 4
T10(TV3/176)	83					10	1		1	5	po,pt,ma	
T21	70	18 (23)	60			2		<0,5	1	4	cr,ma	se/cancrinite 5
T23	40 (55)	2 (42)	55		2	3	8			3	cr,ma	cc 2, se/cancrinite 40
T25	25	54 (64)	55	<0,5	1		3	1	2	2		cancrinite 10, cc 2
T32	57	33	60			5		1	1	3		cancrinite
T20	30 (40)	(39)		(20)			25	5	25	4		cc 1, cancrinite 1[illegible]
PW1	44			30		2			3	21		
AM174/2	40	40		5		1	1			1	-	cc 1, brucite
TV157A	45						7	46		2	ma	
S75	30						25		40	3	ma	talc 2, haematite
U15	40					10			48	2	ma	haematite
U14	45					<0,5	5		48	2	ma	haematite

pt = pentlandite   cr = chromite

* Hornblende includes magmatic and secondary varieties

Numbers in brackets refer to original amount of minerals found.

Phlogopite $\gamma = \beta$ orange-brown, reddish-brown α pale brown, pale orange

Chlorite $\gamma = \beta$ blue-green α yellow-brown

Primary hornblende γ dark brown β brown α olive-brown

Secondary hornblende γ blue-green β green α yellow-green

TABLE 28

ESTIMATED MODES (IN VOLUME %) OF MAFIC-ULTRAMAFIC ROCKS OF TANTALITE VALLEY WITH < 30% OLIVINE

SAMPLE	PL	AN	OP	CP	PH	CH	OL+ SR	CM	HB/TREM -ACT	OPAQUES		OTHERS
TV117						50			50	<0,5	cr	
TV30			<0,5	2				50	47	<0,5		
TV181						38			60	0,5	cr	sn, hercynite 1, tourmaline 1
TV14						32			65	3	ma	haematite, limonite
TV41	3					52			45	0,5	cr	
TV270A					12	3		35	49	<0,5		zc, ap
T5(TV3/41)	41	58	30	5	5	2	11		4	2		
T6(TV3/54)					1	59		4	35	1	ma	
T7(TV3/61)					<0,5	60	11		25	3	ma	bowlingite 1
T8(TV3/64)					3	45	2		49	1	ma	
T9(TV3/73)	2 (50)		35	5 (10)	15	2	23 (25)	5	10	3	cr,ma	picotite, hercynite
T11(TV3/184)	6 (8)	73	75		4	2		10	<0,5	1	ma	se 2, rutile, sulphide
TV3	17,5		62	3	0,5		15		0,5	1,5		ap
T26	(15)		10 (80)	4 (5)		20			65	1		
T27			(95)			2		95	2	1	ma	haematite
T31						24		30	40	1	ma	talc 5
T33						68			30	2		
AM88B						15		20	38	2		talc 20, brucite 5
AM172					<0,5	30			70	<0,5		
AM173	5				<0,5	25			60			
T34	62	60-65		5	3	2	23	1	1	1		se/cancrinite 2
TV26	59	51	4	10			25			3	ma	
PW1B	25,5	50	54	1	3		15			1	cr,ma	ap
PW2B	10	50	85	3	0,5	0,5		<0,5	0,5	<0,5		
AM1/50	25		65		1,5	0,5	1,5		6	0,5		cc
PW3(270,45)	65	54	30,5	3	0,5				1	<0,5		
TV6/129	20	73	72	1,5	1	0,5			4,5	0,5		cc
TV6/268	15,5		82	1	0,5	0,5			0,5	0,5		
TV8/173	25	48	65	3	0,5		5		1	0,5	ma	ep
TV10/160,13	1		76		3	3			15	2		
TV10/235,10	25		60		1,5		5		6,5	2		
TV10/123,15	25	49	66		1				7	0,5	cr	hercynite 0,5
TV10/88					15	8		35	41	0,5	cr	sn
PW3/224	(21)		58		2	0,5	15	2		2	py,ccp	hercynite, cc
T30	5 (10)		45		1	1	17	14	8	2	ma	cc 1, hercynite 1, cancrinite 5
S34						15	25		58	2	ma	haematite
S11/25					24	5			70	1		scheelite ?
S150					25	20	15	20	14	3	ma	ap 3, haematite
S52					20	5		2	70	3		
U11					35				63	2		
U12					20			2	77	1		
S140B					10			60	30	<0,5		
S106					<0,5	1	10		87	2		

Numbers in brackets refer to original amount of mineral present.

continued/....

TABLE 28 - continued

Chlorite $\gamma = \beta$ deep green α pale green
$\gamma = \beta$ pale green α neutral, pale pink
Phlogopite $\gamma = \beta$ pale brown, orange-brown α neutral, pale orange
Tourmaline γ grey-blue β pale blue α neutral
Secondary hornblende γ blue-green β green α yellow-green
γ olive-green β green α pale olive-green
Tremolite-actinolite $\gamma = \beta$ green α pale green, neutral

TABLE 29

ESTIMATED MODES (IN VOLUME %) OF KUMKUM GABBRONORITE

SAMPLE	OP	CP	OL	QZ	BI/PH	HB	HER-CYNITE	PL	AN	OPAQUES	ZC	AP	OTHERS
K28	7	21	35		3	4	<0,5	30	(48)	<0,5 (ma)			
K28A				2	3	45		49	(42)	1			
K44A	29	6			2	7		55	(50)	1 (po)			
K65	20	8	10		2	10	<0,5	50	(66)	<0,5 (ma)			
K74	7	33	5		2	4	<0,5	48	(40)	0,5		<0,5	
KK4	20	20	12		0,5	4	<0,5	43	(61-71)	0,5 (ma)			
K22	5	25			2	7		60	(41)	1	<0,5		
K37A	18	20	5		3	2	1	50	(72)	1 (ma)		<0,5	
K42	<0,5	<0,5			<0,5	43		50	(36)	1			cm(5)
K44C	12	5			2	30		50	(68)	1			
K29A	10	2			<0,5	40	<0,5	47	(54)	1			
K250	30	7	5		0,5	6	<0,5	50	(65)	1 (ma)		0,5	
K255	5	20			2,5	20		50	(64)	2		<0,5	
K213	15	5	25		<0,5	6	1	46	(42)	2			
K258	30	15		0,5	4	5		44	(60)	1,5			
K240	30	20			2	3		43	(60)	1,5 (ma)		<0,5	
K30A	37				2	40		20		1			
K44D	14	3	30		1	5	<0,5	45	(61)	1 (ma)			picotite (1)
K152	30	11,5	10		2	4	0,5	40		2 (ma)			
Einsied-ler	4	16	13		1	4	<0,5	50	(58)	1			ch(<0,5) picotite (<0,5)
K273A	40	25	0,5		2	10	1	20	(44)	1		<0,5	
K253	8	20			3	4	0,5	60	(54)	3 (ma)		1	sn (<0,5)
AM242	2				5	40		52	(45-65)	1 (ma)			

Hornblende (secondary) γ olive-green β green α yellow-green
Hornblende (primary) γ orange-brown β brown α pale brown
Biotite $\gamma = \beta$ fox red, orange-brown α pale orange
Hypersthene γ green α pink

TABLE 30

ESTIMATED MODES (IN VOLUME %) CONTAMINATED GABBRONORITE

SAMPLE	OP	CP	PL	AN	BI	HB	OPAQUES	AP	ZC	QZ	HER-CYNITE	KF	OTHERS
K168	8	30	50	(40)	5	5	2	<0,5					
K162	7	23	50	(56)	10	5	3	0,5	<0,5	1			
K200	18	15	60	(54)	2	1	3 (ma)	<0,5	<0,5	1			
K153	10	32	50	(64)	3	3	2 (ma)						
K142	35		57,5	(68)	2*	5	0,5						
K242	20	10	59	(38)	3	1	2 (ma)	<0,5	<0,5	5			
K39	15	10	55	(66)	0,5	2	2	<0,5	<0,5	15			
KK1	15	15	60	(39)	2	7	1	<0,5	<0,5				
KK2A	33	7	44	(70)	3	12	1		<0,5				
KK10A	22	10	63	(65)	2	2	1	<0,5					
KK10B	10	25	61	(54)	2	1	1			<0,5			
KK11	23	7	60	(57)	2	5	3 (ma)		<0,5	<0,5	<0,5		
K41	10	1	36	(34-44)	10	35	0,5	0,5		7			sn <0,5
K45A	30	7	50	(49)	4		2 (ma)			7			
K46	5	2	23	(36)	3	<0,5	1 (ma)	<0,5		5		60	myrmekite < 0,5
K63A	20	20	50	(49)	3	<0,5	2 (il)	<0,5		5			ep <0,5
K69	31	5	60	(54)	2	1	1 (ma)						
K71	25	7	60	(56)	3	4	1 (il)	<0,5					
K75	30	5	58	(59)	3	3	1 (ma)	<0,5					
K76	7	30	55	(50)	4	3	1 (ma)	<0,5					
K80	10	15	32	(60)	2	35	3 (ma)	<0,5		3			
K44	7,5	12,5	33	(48)	6	35	0,5 (il)	<0,5	<0,5	5			
KK3	18	7	65	(54)	7	<0,5	3	<0,5	<0,5				
KK5	20	10	63	(54)	5		1			1			myrmekite <0,5
K93	20	21	50	(42)	5		2 (il)			2			myrmekite <0,5
K34	33	7	50	(57)	3	3	2 (ma)			2			myrmekite <0,5
K34A	33	7	43	(51)	0,5	5	1 (il)	<0,5		10			
K52	6	30	55	(57)	0,5	5	3 (ma)	<0,5					
K273	10	30	52	(60)	3	3	2 (po, ma)	<0,5					
K275A	5	15	64	(51)	<0,5	15	1 (il)						

* phlogopite

Biotite γ fox red, dark brown α pale orange, yellow

Hornblende γ olive-green β green α pale green, yellow-green

Hypersthene γ green α pink

TABLE 31

ESTIMATED MODES (IN VOLUME %) OF ESELRUH GABBRONORITE

	OP	CP	PL	AN	HB	OPAQUES	OL	PH	CM	AT	CC	OTHERS
AM 204	30	5	42	(50-63)	15	<0,5 (ma)	2	5				
K51	21	50	2		25			2				
K52A	35	0,5	55	(51)	7	0,5		1				hercynite (1)
K262	77	15			7	1 (ma)		<0,5				ch (<o,5)
K257	15	38	20		5	2 (ma)	15	4				hercynite, picotite (0,5)
K207	2	91			7	<0,5						
K59A	5	35	5	(88)	36	1 (ma)	15	<0,5			2	
K174	72				20	2,5 (ma)				3		zc, brucite, ch, ms
K60 (AM 230)	25	5	10	(65)	50	<0,5		10				
K7	33	2	23,5	(73)	40		0,5	1				
K4	5	25	49	(85)	10	<0,5 (ma)	0,5	<0,5	10			

Bronzite γ pale green α pink

Phlogopite γ orange α pale orange, neutral

Hornblende (primary) $\gamma = \beta$ yellow-brown α pale brown

Hornblende (secondary) γ olive-green β green α yellow-green

TABLE 32

ESTIMATED MODES (IN VOLUME %) OF METASOMATIC HORNBLENDITE

SAMPLE	HB/	PL	AN	BI/PH	CM	QZ	EP	OPAQUES	SCH	AP	ZC	SN
AM157	37			60					3			<0,5
AM155A/B	45			40	15							
S107	/			99				<0,5	<0,5			
S95	25	31*	(20)	25		2*		<0,5	5	<0,5	<0,5	

* Found in 2 cm thick vein.

/ $c \wedge \gamma$ = 23° average

SCH - Scheelite

Bi/phlogopite γ reddish brown, tan brown α pale yellow, neutral

Hornblende γ dark blue-green β grass green α yellowish green

TABLE 33

TEMPERATURE DATA ON CO-EXISTING ORTHO- AND CLINO- PYROXENE

SAMPLE NO	x_{Fe}^{opx}	$a_{Mg_2Si_2O_6}^{cpx}$	$a_{Mg_2Si_2O_6}^{opx}$	lnK Δ	T(°C) *	T(°C) ≁
1	0,223	0,119	0,528	-1,490	1068	1089
2	0,217	0,127	0,530	-1,429	1086	1108
3	0,224	0,087	0,547	-1,839	1009	1006
4	0,306	0,086	0,449	-1,653	966	1003
5	0,209	0,056	0,560	-2,303	952	917
6	0,229	0,072	0,555	-2,042	973	960
7	0,220	0,072	0,566	-2,062	978	960
8	0,196	0,074	0,573	-2,047	1003	975
9	0,304	0,104	0,452	-1,469	997	1046
10	0,175	0,100	0,583	-1,763	1073	1051
11	0,242	0,100	0,526	-1,660	1021	1037
12	0,175	0,090	0,583	-1,868	1054	1026
13	0,448	0,051	0,289	-2,927	864	776
14	0,542	0,027	0,198	-3,158	789	762
15	0,293	0,025	0,474	-1,735	808	914
16	0,237	0,023	0,541	-1,992	818	828

* Equation (27), Wood and Banno (1973), all results ± 60°C

≁ Equation (5), Wells (1977), all results ± 70°C

Δ Equation (3), Wells (1977)

Samples 1 - 12 from Tantalite Valley, 13-16 from Kumkum.

Sample 1 : TV263 - discrete op-cp grains in olivine gabbronorite.

Sample 2 : TV263 - ditto, calculation includes Fe^{3+}.

Sample 3 : TV187 - discrete op-cp grains in gabbronorite.

Sample 4 : AM41 - discrete op-cp grains in gabbronorite.

Sample 5 : AM123A - discrete op-cp grains in gabbronorite satellite body.

Sample 6 : TV233 - bronzite lamellae in augite in olivine gabbronorite.

Sample 7 : TV233 - discrete op-cp grains in olivine gabbronorite.

Sample 8 : TV233 - ditto, calculation includes Fe^{3+}.

Sample 9 : AM21C - discrete op-cp grains in gabbronorite.

Sample 10: TV6 129 - discrete op-cp grains in orthopyroxenite (norite).

Sample 11: TV6 129 - op lamellae in cp in orthopyroxenite (norite).

Sample 12: TV6 129 - cp blebs in op in orthopyroxenite (norite).

Sample 13: K45A - discrete op-cp grains in Contaminated gabbronorite.

Sample 14: K58 - discrete op-cp grains in granolite *sensu stricto*.

Sample 15: K37A - discrete op-cp grains in Kumkum gabbronorite.

Sample 16: K4 - discrete op-cp grains in Eselruh gabbronorite.

TABLE 34

TEMPERATURES OBTAINED USING THE OLIVINE-CHROMITE GEOTHERMOMETER OF JACKSON 1969

SAMPLE	$\frac{Mg}{Mg+Fe^{2+}}$ Olivine	$\frac{Fe^{2+}}{Mg+Fe^{2+}}$ Olivine	$\frac{Mg}{Mg+Fe^{2+}}$ Spinel	$\frac{Fe^{2+}}{Mg+Fe^{2+}}$ Spinel	$\frac{Cr}{Cr+Al+Fe^{3+}}$ Spinel, α	$\frac{Al}{Cr+Al+Fe^{3+}}$ Spinel, β	$\frac{Fe^{3+}}{Cr+Al+Fe^{3+}}$ Spinel, γ	$K_{D_{Mg-Fe^{2+}}}^{ol-sp}$ ≠	$\ln K_{D_{Mg-Fe^{2+}}}^{ol-sp}$	T in °C (Jackson) 1969	$\ln K_D$ *
Picotite											
TV49B											
TV49B/G	0,824	0,176	0,402	0,598	0,279	0,633	0,100	6,960	1,940	849	1,740
TV49CC											
Average											
Spinel											
TV49G/G	0,824	0,176	0,702	0,298	0,001	0,968	0,041	1,987	0,687	1 205	0,723
Ferrit-chromite											
TV49CHI (49CH)	0,824	0,176	0,078	0,922	0,298	0,108	0,603	55,460	4,016	330	1,804
Hercyn-ite											
K37A	0,663	0,337	0,416	0,584	0,000	0,969	0,031	2,762	1,016	863	1,092

≠ see Appendix (7) for definition

for definition of $\ln K_D$ * see text

TABLE 35

PHYSICAL CONDITIONS OF METAMORPHISM DERIVED FROM PARAGENESES CONTAINING GARNET AND CORDIERITE

SAMPLE	X_{Mg}^{cd}(A)	X_{Fe}^{Ga}(B)	X_{Fe}^{cd}(C)	X_{Mg}^{ga}(D)	X_{Fe}^{Bi}(E)	X_{Fe}^{Bi}(F)	$\ln\frac{(B)}{(C)}$	$\ln\frac{(A)\cdot(B)}{(C)\cdot(D)}$	$\ln\frac{(B)\cdot(E)}{(D)\cdot(F)}$	T(°C)[1]	T(°C)[2]	T(°C)[3]	P(kb)[4]	X_{H_2O} est[5]
A5	0,7084	0,7501	0,2885	0,1712	0,3952	0,3985	0,7084	2,38	1,47	590	630	577	5,20	$\leqslant$0,28
A3 LTi	0,6941	0,7696	0,3048	0,1736	0,4068	0,3617	0,9262	2,31	1,61	600	590	591	4,38	$\leqslant$0,38
A3 HTi	"	"	"	"	0,4129	0,3573	"	"	1,63	"	580	"	"	"
KK7 HTi	0,7102	0,7585	0,2877	0,2031	0,3440	0,4180	0,9694	2,22	1,12	620	760	613	4,24	$\leqslant$0,65
KK7 LTi	"	"	"	"	0,3745	0,3871	"	"	1,28	"	680	"	"	"
K19A LTi	0,7247	0,7446	0,2723	0,1816	0,3882	0,3857	1,0059	2,39	1,42	590	640	569	4,28	$\leqslant$0,23
K19A HTi	"	"	"	"	0,3704	0,4073	"	"	1,32	"	670	"	"	"
K101	0,7844	0,7114	0,2156	0,2299	0,5668	0,3083	1,1938	2,42	1,74	580	550	-	-	-
K101 CORE	"	0,6549	"	0,2984	"	"	"	2,08	1,39	650	660	-	-	-
K66B	0,6900	0,7780	0,3100	0,1894	0,4160	0,4116	0,9202	2,21	1,42	610	640	625	6,10	$\leqslant$0,62
K35P CORE	0,7730	0,7467	0,2260	0,1864	0,4553	0,3945	1,1951	2,62	1,53	535	620	526	3,96	$<$ 1
K35 P	"	0,7272	"	0,2142	"	"	1,1687	2,45	1,37	580	660	556	4,35	$<$ 1
K35G	0,7726	0,6901	0,2264	0,2660	"	"	1,1162	2,18	1,10	630	750	627	4,90	$\leqslant$0,56
T19	0,6082	0,7921	0,3867	0,0978	0,3430	0,4030	0,7169	2,55	1,93	550	520	550	4,80	$\leqslant$0,22
T19 CORE	"	0,7755	"	0,1443	"	"	0,6959	2,13	1,52	650	620	640	5,00	$<$ 1
TV13 165	0,7410	0,7212	0,2590	0,1258	0,5056	0,3267	1,0241	2,80	2,18	440	460	-	-	-

continued/....

TABLE 35 - continued

$$X^{cd}_{Mg} = \frac{Mg}{Mg + Fe^{2+} + Mn} \qquad X^{cd}_{Fe} = \frac{Fe^{2+}}{Mg + Fe^{2+} + Mn}$$

$$X^{garnet}_{Fe} = \frac{Fe^{2+}}{Mg + Fe^{2+} + Mn + Ca} \qquad X^{garnet}_{Mg} = \frac{Mg}{Mg + Fe^{2+} + Mn + Ca}$$

$$X^{Bi}_{Mg} = \frac{Mg}{Mg + Mn + Fe^{2+} + Ti + Al^{vi}} \qquad X^{Bi}_{Fe} = \frac{Fe^{2+}}{Mg + Mn + Fe^{2+} + Ti + Al^{vi}}$$

Rim compositions are used unless otherwise stated

L Ti - calculations using Low-Ti biotite

H Ti - calculations using High-Ti biotite

Key to samples is the same as in Table (36)

1 - Temperatures from Thompson (1976b), Fig 1A with the low temperature end of Thompson's curve increased by 30° following the suggestion of Holdaway & Lee (1977).

2 - Temperatures from Thömpson (1976 b), Fig 1B.

3 - Temperatures from the intersection of equation (3) (Appendix 9) and equation (1) (Appendix 10).

4 - Pressures from the intersection of equation (3) (Appendix 9) and equation (1) (Appendix 10).

5. - X_{H_2O} estimated on a plot of P versus X_{H_2O} (assuming a constant temperature) for equation (iv) (Appendix 9) and using an independently determined pressure from equation (1) (Appendix 10).

Table 36: Plagioclase - garnet - Al_2SiO_5 - quartz geobarometery using Pelitic Gneiss Samples

SAMPLE	γ^{Ga}_{gross}	X^{Gross}_{Ca}	γ^{Pl}_{An}	X^{Pl}_{An}	T(°C) used	P(bars)	Source of T data
A3	1,6904	0,0322	1,276	0,3884	580	4225	av.ga-cd,ga-bi
A5	1,6935	0,0420	1,276	0,3850	560	4971	ga-cd
A5	1,6257	0,0420	1,276	0,3850	630	5967	ga-bi
K19A	1,7212	0,0273	1,276	0,3167	560	4139	ga-cd
K19A	1,6156	0,0273	1,276	0,3167	670	5579	ga-bi
K101	1,7297	0,0288	1,276	0,2710	550	4787	av.ga-cd,ga-bi
K101 ǂ	1,6333	0,0242	1,276	0,2710	655	5544	av.ga-cd,ga-bi
KK7	1,7123	0,0090	1,276	0,1232	600	4078	ga-cd
KK7	1,5755	0,0090	1,276	0,1232	760	6064	ga-bi
K66B	1,6583	0,0253	1,276	0,2246	625	6101	av.ga-cd,ga-bi
K35P ǂ	1,7744	0,0340	1,276	0,3498	505	3814	ga-cd
K35P ǂ	1,6481	0,0340	1,276	0,3498	620	5384	ga-bi
K35P	1,7226	0,0325	1,276	0,3498	550	4268	ga-cd
K35P	1,6156	0,0325	1,276	0,3498	660	5746	ga-bi
K35G	1,6655	0,0294	1,276	0,3498	610	4686	ga-cd
K35G	1,5532	0,0294	1,276	0,3498	750	6505	ga-bi
T19 ǂ	1,6355	0,0361	1,276	0,4378	630	4836	av.ga-cd,ga-bi
T19	1,6925	0,0599	1,276	0,4378	530	5305	av.ga-cd,ga-bi

ǂ core compositions, all the rest are from rims. See appendix (10) for definition of terms.

A3 - A5 Black Gneiss, Sandfontein 131.

K19A - KK7 Black Gneiss, Kumkum area.

K66B - K35G Hornfelsic Black Gneiss, Kumkum area.

K35P Porphyroblasts, K35G - groundmass.

T19 Pelitic Hornfels, Tantalite Valley.

Table 37: Temparatures obtained from coexisting plagioclase and K-feldspar using the geothermometer of Stormer (1975)

SAMPLE	X_{Kf}^{Na}	X_{Pl}^{Na}	P assumed (kb)	T (°C)	T (°C)*
K19A	0,18	0,68	5	600	560-670
A3	0,15	0,60	5	600	580
K66B	0,15	0,77	5	550	610-640
K35	0,12	0,65	5	550	505-750

* Temp. obtained from coexisting ga-cd and ga-bi using Thompson (1976·b) Fig 1A & Fig 1B.

$$X_{Pl}^{Na} = \frac{Na}{Na + Ca}$$

$$X_{Kf}^{Na} = \frac{Na}{Na + K}$$

Table 38: End member molecules of clinopyroxenes, calculated by the method of Cawthorn and Collerson (1974). (see Key for sample numbers)

SAMPLE NO.	1	2	4	6	8	9	10	12	13	14	16	17
JADEITE $Na\ Al\ Si_2\ O_6$	2,30	3,00	3,70	2,80	2,8	0,2	2,1	2,2	1,7	2,6	3,6	3,4
ACMITE $Na\ Fe^{3+}\ Si_2\ O_6$	-	-	-	-	-	-	-	-	-	-	-	-
CA-FERRITSCH $Ca\ Fe_2^{3+}\ Si\ O_6$	3,00	2,20	3,10	4,40	0,5	0,2	0,2	1,1	3,1	3,1	4,0	0,8
CA-TI-TSCH $Ca\ Ti\ Al_2\ O_6$	0,30	0,20	2,60	0,4	0,4	1,3	1,4	1,6	0,9	1,6	1,5	0,4
CA-TSCH $Ca\ Al_2\ Si\ O_6$	0,75	1,35	2,50	0,8	2,0	3,6	2,6	4,2	4,9	3,4	4,2	3,2
WOLLASTONITE $Ca_2\ Si_2\ O_6$	42,64	44,63	41,56	39,3	42,6	40,1	39,0	38,8	36,6	34,2	38,5	39,5
ENSTATITE $Mg_2\ Si_2\ O_6$	33,05	43,63	40,26	37,8	42,2	41,8	42,6	41,3	43,1	45,9	43,3	44,9
FERROSILITE $Fe_2^{2+}\ Si_2\ O_6$	17,97	4,99	6,29	14,5	9,0	12,7	12,2	10,9	9,8	9,3	4,9	6,9

Table 39: End member molecules of orthopyroxenes, calculated by the method of Cawthorn and Collerson (1974) (see Key for sample number)

SAMPLE NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
JADEITE $Na\ Al\ Si_2\ O_6$	0,30	-	-	0,30	0,30	0,40	1,13	0,1	-	-	-	-	-	-	-	-	0,4
ACMITE $Na\ Fe^{3+}Si_2\ O_6$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CA-FERRITSCH $Ca\ Fe_2^{3+}Si\ O_6$	2,00	1,40	1,75	0,90	1,11	1,40	0,21	3,9	0,4	0,1	2,5	3,2	2,4	0,8	2,3	3,3	3,2
CA-Ti-TSCH $Ca\ Ti\ Al_2\ O_6$	0,20	0,40	-	0,70	0,10	0,80	-	-	0,6	0,6	0,5	0,6	0,6	0,8	0,5	0,3	0,8
CA-TSCH $Ca\ Al_2\ Si\ O_6$	0,60	1,70	1,79	-	-	-	-	-	1,9	0,8	-	-	3,2	7,1	-	7,2	-
MG-TSCH $Mg\ Al_2\ Si\ O_6$	0,60	2,00	1,18	2,72	4,24	0,70	12,64	5,1	-	2,4	5,0	4,3	0,2	-	5,4	-	4,7
WOLLASTONITE $Ca_2\ Si_2\ O_6$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ENSTATITE $Mg_2\ Si_2\ O_6$	44,26	72,70	74,26	68,35	69,02	53,81	39,67	70,8	67,2	66,1	72,4	73,6	74,3	74,8	75,4	78,3	70,5
FERROSILITE $Fe_2^{2+}Si_2\ O_6$	52,05	21,80	21,02	27,02	25,23	42,89	46,35	20,1	30,2	30,0	20,4	18,9	19,6	20,7	16,9	13,8	21,2
REMAINDER (Fe^{3+})				0,03	0,04	0,01	0,05										

Sample Number Key for pyroxene end members. Table 38 & 39

1. K58 Granolite
2. K4 Eselruh gabbronorite discrete
3. K4 Eselruh gabbronorite op. in ol-pl. coronas
4. K37A Kumkum gabbronorite discrete
5. K37A Kumkum gabbronorite op. in ol-pl. coronas
6. K45A Contaminated gabbronorite
7. KK6 Black Gneiss
8. AM123A Tantalite Valley Satellite Body
9. AM41 T.V. gabbronorite
10. AM21C T.V. gabbronorite
11. TV233 T.V. gabbronorite, lamellae in cp.
12. TV233 T.V. gabbronorite, discrete
13. TV187 T.V. gabbronorite
14. TV263 T.V. gabbronorite
15. TV 49 T.V. troctolite
16. TV6 129 T.V. norite, discrete
17. TV6 129 T.V. norite, lamellae in pyroxene

Table 40: Groundmass, soda-poor clinopyroxenes within the range Ca_{35-55} Mg Fe_{0-18} from mafic-ultramafic rocks from the study afrea compared with those from other igneous rocks.

LOCATION	DISPCRIPTION	FIELD (Le Bas, 1962)	Ca^* : Mg : Fe^*	Alz	TIO_2 Wt%	Al_2O_3 Wt%	Si O_2 Wt%	REFERENCE
AM123A	TV Satellite body	II	47,0:43,7: 9,3	0,95	0,13	1,75	53,80	
AM41	TV gabbronorite	II	43,9:43,0:13,0	0,40	0,47	2,19	53,87	
AM21C	TV gabbronorite	III	43,4:44,0:12,6	0,00	0,46	2,16	55,44	
TV263	TV olivine gabbronorite	III	40,5:47,1:12,4	4,40	0,58	2,89	51,37	
TV233	TV olivine gabbronorite	II	45,0:42,9:12,1	4,05	0,56	3,11	51,42	
TV187	TV gabbronorite	III	43,0:44,1:12,9	4,45	0,33	3,06	51,56	
TV6 129A	TV norite	III	45,6:47,2: 7,2	1,80	0,13	2,43	53,67	
TV6 129C	TV norite	II	46,8:45,0: 8,2	5,15	0,56	3,49	51,81	
K37A	Kumkum gabbronorite	II	48,9:41,5: 9,6	5,35	0,93	3,19	51,36	
K4	Eselruh gabbronorite	II	48,6:44,2: 7,3	2,00	0,07	1,41	53,36	
Bushveld	high alumina (Le Bas, 1962)	III	45 : 50 : 5 - 42 : 45 : 13	2,5- 3,7	0,21- 0,50	2,08- 2,80	52,47- 54,07	Hess (1949)
Stillwater	high alumina (Le Bas, 1962)	III	37 : 56 : 7 - 40 : 42 : 18	3,0- 5,4	0,24- 0,29	2,33- 3,07	51,43- 52,61	Hess (1949)
Skaergaard	high alumina (Le Bas, 1962)	III	42 : 48 : 10 - 40 : 43 : 17	4,8- 5,9	0,76- 0,97	2,92- 3,22	51,17- 51,25	Brown (1957)
Potrush dolerite	tholeiitic (Le Bas,1962)	III	43 : 43 : 14	5,0	0,50	5,23	51,05	Harris (1937)
Uwekahuna gabbro (Kilauea)	tholeiitic (Le Bas,1962)	III	40 : 49 : 11	5,3	0,72	3,14	51,62	Muir & Tilley, 1957
Nozoki dolerite (Yamagata)	calcalkaline (Le Bas, 1962)	III	41 : 45 : 14	1,6	0,50	0,73	51,80	Kuno, (1960)
Okonjeje	gabbro	II	48 : 37 : 15 - 45 : 40 : 15	7,1- 11,1	1,18- 1,25	4,28- 5,11	47,51- 49,77	Simpson (1954)
Canary Is.	syenite	I	48 : 37 : 15	12,7	3,78	5,67	45,21	Kunitz (1936)

Ca^* = Ca + Na + K

Fe^* = $Fe^{2+} + Fe^{3+}$ + Mn

Alz = $\frac{Al^{IV}}{z} \cdot 100$ (z = 2)

Table 41: Distribition coefficients for coexisting pyroxenes

SAMPLE LOCATION		K_D opx - cpx Mg - Fe	REMARKS
TV187		0,86	discrete op + cp
TV263	GABBRONORITE	0,70	discrete op + cp
AM41		0,67	discrete op + cp
AM21C	(T.VALLEY)	0,64	discrete op + cp
TV233		0,96	op lamellae in cp
TV233		1,04	discrete op + cp
TV6 129	ULTRAMAFIC	0,61	discrete op + cp
TV6 129A	AND	0,38 } 0,61	op lamellae in cp
TV6 129B	RELATED ROCKS	0,84 }	cp blebs in op
AM123A	(T.VALLEY)	0,78	discrete op + cp
Eastern Bushveld	THOL.	0,67	average, Atkins (1969)
Skaergaard	ROCKS	0,73	average, Brown (1957)
Stillwater	(GENERAL)	0,72	average, Hess (1960)
Palisades		0,78	average‡, Walker *et. al.*(1973)
K58	KUM-	0,47	discrete op + cp
K4	KUM	0,38	discrete op + cp
K37A	ROCKS	0,40	discrete op + cp
K45A		0,48	discrete op + cp
S70+		0,57	

$$K_D{}^{op-cp}_{Mg-Fe} = \frac{x^{op}_{Mg}}{1 - x^{op}_{Mg}} \cdot \frac{1 - x^{cp}_{Mg}}{x^{cp}_{Mg}} \quad \text{(Kretz, 1961, 1963)}$$

where $x^{op}_{Mg} = \frac{Mg}{Mg + Fe^{2+}}$

$$X^{cp}_{Mg} = \frac{Mg}{Mg + Fe^{2+}}$$

* Sen (1970) average for 22 basic granolites from the literature including 12 charnockites from the type area and 10 granolites

‡ Middle and Early Fractionation stage

Table 42: Coexisting Hornblende and Cummingtonite

No. of pair	X^{Hb}_{Mg}	X^{Cm}_{Mg}	$K_D{}^{Hb-Cm}_{Mg-Fe}$	Hb (atoms per formula unit) Al	Na + K	Pl.
1	0,659	0,661	0,99	1,868	0,396	An47
2	0,663	0,669	0,98	1,876	0,372	An47
3	0,602	0,637	0,86	2,365	0,422	An62
4	0,601	0,646	0,83	2,279	0,423	An62
5	0,576	0,622	0,83	2,404	0,412	An74

X^{Hb}_{Mg} = Mg /(Mg + Fe) in hornblende

X^{Cm}_{Mg} = Mg /(Mg + Fe) in cummingtonite

$$K_D{}^{Hb-Cm}_{Mg-Fe} = \frac{(Mg / Fe)\ Hb}{(Mg / Fe)\ Cm}$$

Pair 1	Hb./cm.	125/G/125/W	satellite body metagabbro
Pair 2	Hb./cm.	125PG/125PW	
Pair 3	Hb./cm.	31C/G/31C/W	metabasite hornfels
Pair 4	Hb./cm.	31CPG/31CPW	
Pair 5	Hb./cm.	31D/G/31D/W	

Table 43: Mineral Analyses - Samples from Tantalite Valley and Kumkum

Olivine Analyses: Samples from the Tantalite Valley Area

	1	2	3	4	5
SiO_2	39,05	39,30	38,22	38,53	38,97
TiO_2	0,02	0,03	0,02	0,03	N.D.
Al_2O_3	0,01	N.D.	N.D.	0,02	N.D.
Cr_2O_3	N.D.	N.D.	N.D.	N.D.	N.A.
FeO	16,41	18,71	22,16	22,15	19,89
MnO	0,20	0,31	0,31	0,33	0,35
MgO	43,13	42,03	38,86	39,47	41,39
CaO	0,06	0,05	0,04	0,03	0,06
Na_2O	N.D.	N.A.	N.A.	N.A.	N.A.
NiO	0,38	0,35	0,17	0,16	N.A.
Total	99,26	100,80	99,80	100,73	100,66

** Atomic Proportions based on selected number of oxygens **

Oxygen	4	4	4	4	4
Si	0,997	0,998	0,997	0,995	0,995
Ti	0,000	0,001	0,000	0,001	0,000
Al	0,000			0,001	0,000
Cr	-				
Fe^{2+}	0,350	0,397	0,483	0,478	0,425
Mn	0,004	0,007	0,007	0,007	0,007
Mg	1,642	1,590	1,510	1,519	1,575
Ca	0,002	0,001	0,001	0,001	0,002
Na					
Ni	0,008	0,007	0,004	0,003	
Fo	82,41	80,01	75,76	76,05	78,70
Fa	17,59	19,99	24,24	23,95	21,20

*** Sample Directory ***

1 Chrysolite, Troctolite, TV49 (AV of 3 Analyses).
2 Chrysolite, surrounded by Plagioclase, OL Gabbronorite, TV233.
3 Chrysolite, surrounded by Clinopyroxene, OL. Gabbronorite, TV263.
4 Chrysolite, surrounded by Plagioclase, OL. Gabbronorite, TV263.
5 Chrysolite, Troctolite, S75.

** N.D. = Not Detected **

N.A. = Not Analysed

Orthopyroxenes From Gabbronorites and Ultramafic Rocks of Tantalite Valley

	1	2	3	4	5
SiO_2	53,23	53,52	53,22	52,75	53,87
TiO_2	0,07	0,21	0,20	0,17	0,22
Al_2O_3	1,12	1,02	1,62	2,15	1,74
Cr_2O_3	0,14	0,03	0,08	0,09	0,06
Fe_2O_3	4,00	0,25	N.D.	1,71	1,67
FeO	13,09	19,21	19,06	13,01	12,77
MnO	0,45	0,41	0,35	0,32	0,27
MgO	27,89	24,47	24,46	27,53	27,78
CaO	0,32	0,74	0,38	0,61	1,60
Na_2O	N.D.	N.D.	N.D.	N.D.	N.D.
K_2O	N.D.	N.D.	N.D.	N.D.	N.D.
Total	100,33	99,88	99,40	98,36	100,00
** Atomic Proportions Based on Selected No. of Oxygens **					
Oxygen	6	6	6	6	6
Si	1,916	1,968	1,961	1,923	1,933
Ti	0,002	0,006	0,006	0,005	0,006
Al	0,048	0,044	0,070	0,092	0,074
Cr	0,004	0,001	0,002	0,003	0,002
Fe^3	0,114	0,007		0,049	0,047
Fe^2	0,394	0,591	0,587	0,397	0,383
Mn	0,014	0,013	0,011	0,010	0,008
Mg	1,496	1,341	1,343	1,496	1,485
Ca	0,012	0,029	0,015	0,024	0,062
	WO 0,65	WO 1,49	WO 0,77	WO 1,24	WO 3,19
	EN 78,64	EN 68,39	EN 69,04	EN 78,06	EN 76,96
	FS 20,71	FS 30,13	FS 30,19	FS 20,70	FS 19,85

1 Bronzite, G-N Satellite AM123A
2 Hypersthene, G-N,AM41
3 Hypersthene, G-N,AM21C
4 Bronzite Lamellae in Augite, O-G-N,TV233
5 Bronzite, G-N, TV187
6 Bronzite (Discrete), O-G-N, TV233
7 Bronzite, O-G-N, TV263
8 Bronzite (Discrete), OPXT, TV6 129
9 Bronzite, Troctolite, TV49
10 Bronzite Lamellae in Augite, OPXT, TV6 129

Orthopyroxenes From Gabbronorites and Ultramafic Rocks of Tantalite Valley (cont.)

	6	7	8	9	10
SiO_2	53,38	54,37	54,49	54,30	53,33
TiO_2	0,21	0,29	0,11	0,17	0,31
Al_2O_3	1,97	1,67	2,21	2,54	2,27
Cr_2O_3	0,16	0,08	0,43	0,44	0,41
Fe_2O_3	2,14	0,51	2,04	1,23	1,89
FeO	12,25	13,48	9,20	11,16	13,82
MnO	0,30	0,29	0,19	0,28	0,27
MgO	28,23	27,25	29,28	29,62	27,21
CaO	0,89	2,26	2,86	0,65	0,90
Na_2O	N.D.	N.D.	N.D.	N.D.	0,05
K_2O	N.D.	N.D.	N.D.	N.D.	0,02
Total	99,55	100,22	100,83	100,41	100,48
** Atomic Proportions Based on Selected No. of Oxygens **					
Oxygens	6	6	6	6	6
Si	1,920	1,949	1,917	1,919	1,913
Ti	0,006	0,008	0,003	0,005	0,008
Al	0,084	0,071	0,092	0,106	0,096
Cr	0,005	0,002	0,012	0,012	0,012
Fe^3	0,061	0,014	0,057	0,034	0,054
Fe^2	0,368	0,404	0,271	0,330	0,415
Mn	0,009	0,009	0,006	0,008	0,008
Mg	1,513	1,456	1,535	1,560	1,455
Ca	0,034	0,087	0,108	0,025	0,035
Na					0,003
K					0,001
	WO 1,79	WO 4,46	WO 5,63	WO 1,29	WO 1,82
	EN 78.98	EN 74,78	EN 80,22	EN 81,49	EN 76,41
	FS 19,23	FS 20,76	FS 14,14	FS 17,23	FS 21,78

Clinopyroxenes From Gabbronorites and Ultramafic Rocks of Tantalite Valley

	1	2	3	4	5	6	7	8	9
SiO_2	51,37	51,42	51,56	53,80	53,87	55,44	53,67	51,65	51,81
TiO_2	0,58	0,56	0,33	0,13	0,47	0,46	0,13	0,50	0,56
Al_2O_3	2,89	3,11	3,06	1,75	2,19	2,16	2,43	3,32	3,49
Cr_2O_3	0,09	0,18	0,19	0,31	0,11	0,13	0,53	0,72	0,71
Fe_2O_3	2,11	0,60	2,03	N.D.	N.D.	N.D.	N.D.	2,38	2,17
FeO	5,73	6,76	6,15	5,64	7,80	7,37	4,35	5,14	3,10
MnO	0,21	0,20	0,19	0,17	0,19	0,26	0,11	0,18	0,14
MgO	16,63	14,87	15,65	15,37	14,80	14,86	16,48	17,46	15,95
CaO	19,27	21,14	20,76	22,30	20,96	19,92	21,26	18,91	22,18
Na_2O	0,36	0,31	0,24	0,39	0,03	0,25	0,47	0,33	0,51
K_2O	N.D.	N.D.	N.D.	N.D.	N.D.	0,05	0,02	N.D.	N.D.
Total	99,25	99,16	100,17	99,88	100,44	100,91	99,46	100,60	100,63
** Atomic Proportions Based on Selected No. Of Oxygens **									
Oxygen	6	6	6	6	6	6	6	6	6
Si	1,901	1,916	1,901	1,977	1,975	2,007	1,963	1,882	1,886
Ti	0,016	0,016	0,009	0,004	0,013	0,013	0,004	0,014	0,015
Al	0,126	0,137	0,133	0,076	0,095	0,092	0,105	0,143	0,150
Cr	0,003	0,005	0,006	0,009	0,003	0,004	0,015	0,021	0,020
Fe^{3+}	0,062	0,018	0,059					0,069	0,063
Fe^{2+}	0,177	0,211	0,190	0,173	0,239	0,223	0,133	0,157	0,094
Mn	0,007	0,006	0,006	0,005	0,006	0,008	0,003	0,006	0,004
Mg	0,917	0,826	0,860	0,842	0,808	0,802	0,893	0,948	0,865
Ca	0,764	0,844	0,820	0,878	0,823	0,773	0,833	0,738	0,865
Na	0,026	0,022	0,017	0,028	0,002	0,018	0,033	0,023	0,036
K						0,002	0,001		
	WO 41,11 EN 49,35 FS 9,54	WO 44,88 EN 43,91 FS 11,20	WO 43,86 EN 45,99 FS 10,14	WO 46,38 EN 44,46 FS 9,16	WO 44,00 EN 43,22 FS 12,78	WO 42,99 EN 44,60 FS 12,41	WO 44,69 EN 48,18 FS 7,14	WO 40,06 EN 51,44 FS 8,50	WO 47,41 EN 47,42 FS 5,17

Clinopyroxenes From Gabbronorites and Ultramafic Rocks of Tantalite Valley.

*** Sample Directory ***

1 Augite, O-G-N, TV263

2 Augite, O-G-N, TV233

3 Augite, G-N, TV187

4 Diopside, G-N Satellite AM123A

5 Augite, G-N, AM41

6 Augite, G-N, AM21C

7 Endiopside Bleb, OPXTE, TV6 129

8 Augite, Low Fe Area, OPXTE, TV6 129

9 Diopside, Lowest Fe Area, OPXTE, TV6 129

Calcic Amphibole Analyses: Samples from Tantalite Valley

	1	2	3	4	5	6	7	8
SiO_2	53,04	34,26	51,33	55,04	47,58	42,43	47,62	47,19
Al_2O_3	6,38	27,50	6,04	2,66	7,47	12,23	8,15	11,30
TiO_2	0,27	0,03	0,46	0,13	0,33	0,55	0,10	0,48
Cr_2O_3	0,03	N.A.	N.A.	N.A.	0,27	0,03	0,38	0,66
FeO*	6,39	8,45	9,62	4,02	12,77	16,58	11,32	9,48
MnO	0,05	0,13	0,17	0,09	0,26	0,42	0,55	0,04
MgO	19,64	16,87	17,02	22,95	14,19	11,15	15,47	15,95
CaO	12,61	9,63	12,43	12,08	12,43	12,37	12,00	12,07
Na_2O	0,54	0,26	0,30	0,45	0,84	1,54	1,77	1,36
K_2O	0,04	0,06	0,16	0,09	0,48	0,49	0,49	0,08
Total	98,99	97,19	97,52	97,51	96,62	97,79	97,85	98,61

** Atomic Proportions Based on Selected number of Oxygens **

Oxygens	23	23	23	23	23	23	23	23
Si	7,326	4,921	7,319	7,624	7,030	6,368	6,927	6,704
Al	1,039	4,657	1,016	0,435	1,301	2,164	1,397	1,892
Ti	0,028	0,003	0,049	0,013	0,037	0,062	0,011	0,051
Cr	0,003				0,032	0,004	0,044	0,074
Fe^{2+}	0,738	1,015	1,147	0,466	1,578	2,081	1,377	1,126
Mn	0,006	0,016	0,021	0,011	0,033	0,053	0,068	0,005
Mg	4,043	3,612	3,617	4,737	3,125	2,494	3,353	3,377
Ca	1,867	1,482	1,899	1,792	1,968	1,989	1,870	1,837
Na	0,144	0,072	0,082	0,121	0,241	0,448	0,499	0,375
K	0,007	0,011	0,029	0,016	0,090	0,094	0,091	0,014

Calcic Amphibole Analyses: Samples from Tantalite Valley contd

	9	10	11	12	13	14	15	16
SiO_2	47,65	52,34	47,36	46,94	42,81	44,26	44,61	44,61
Al_2O_3	10,71	4,07	9,06	11,52	13,63	13,72	13,26	10,54
TiO_2	0,49	0,10	0,40	0,40	0,40	0,46	0,47	0,32
Cr_2O_3	0,65	0,18	0,38	0,70	0,03	0,04	0,08	0,03
FeO*	9,39	9,09	11,17	9,66	15,06	14,33	14,43	14,64
MnO	0,05	0,08	0,09	0,05	0,27	0,18	0,14	0,18
MgO	16,54	19,24	14,02	15,83	11,49	12,16	12,22	13,14
CaO	11,93	12,60	12,45	12,13	11,25	11,26	11,62	11,90
Na_2O	1,23	0,48	1,15	1,42	1,31	1,35	1,39	1,01
K_2O	0,09	0,04	0,08	0,10	0,17	0,21	0,16	0,30
Total	98,73	98,22	96,16	98,75	96,42	97,97	98,38	96,67

** Atomic Proportions Based on Selected number of Oxygens **

Oxygens	23	23	23	23	23	23	23	23
Si	6,752	7,405	6,955	6,671	6,405	6,472	6,504	6,651
Al	1,789	0,679	1,568	1,930	2,404	2,365	2,279	1,852
Ti	0,052	0,011	0,044	0,043	0,045	0,051	0,052	0,036
Cr	0,073	0,020	0,044	0,079	0,004	0,005	0,009	0,004
Fe^{2+}	1,113	1,076	1,372	1,148	1,884	1,753	1,759	1,825
Mn	0,006	0,010	0,011	0,006	0,034	0,022	0,017	0,023
Mg	3,493	4,057	3,069	3,353	2,562	2,650	2,655	2,920
Ca	1,811	1,910	1,959	1,847	1,803	1,764	1,815	1,901
Na	0,338	0,132	0,327	0,391	0,380	0,383	0,393	0,292
K	0,016	0,007	0,015	0,018	0,032	0,039	0,030	0,057

Calcic Amphibole Analyses: Samples from Tantalite Valley contd.

	17	18	19	20	21	22	23	24
SiO_2	53,06	44,96	46,14	48,46	51,53	53,55	50,36	52.42
Al_2O_3	2,71	10,62	10,88	9,09	6,12	4,24	6,07	5,55
TiO_2	0,12	0,58	0,62	1,08	0,17	0,30	0,25	0,52
Cr_2O_3	0,14	0,25	0,19	1,03	N.D.	0,19	N.D.	0,08
FeO*	10,25	12,63	12,51	7,88	8,52	7,19	10,97	9,09
MnO	0,21	0,18	0,19	0,09	0,14	0,12	0,21	0,10
MgO	18,20	13,69	13,82	16,80	18,61	19,56	15,99	17,31
CaO	11,95	11,04	11,25	12,29	11,62	12,00	12,34	12,39
Na_2O	0,29	1,25	1,20	1,11	0,78	0,51	0,57	0,11
K_2O	0,02	0,18	0,17	0,53	0,26	0,21	0,16	0,22
Total	96,95	95,38	96,97	98,36	97,76	97,87	96,93	97,79
** Atomic Proportions Based on Selected number of Oxygens **								
Oxygens	23	23	23	23	23	23	23	23
Si	7,616	6,709	6,750	6,875	7,293	7,509	7,289	7,418
Al	0,459	1,868	1,876	1,520	1,021	0,701	1,036	0,926
Ti	0,013	0,065	0,068	0,115	0,018	0,032	0,027	0,055
Cr	0,016	0,029	0,022	0,116		0,021		0,009
Fe^{2+}	1,231	1,576	1,531	0,935	1,009	0,843	1,328	1,076
Mn	0,026	0,023	0,024	0,011	0,017	0,014	0,026	0,012
Mg	3,893	3,044	3,013	3,552	3,926	4,088	3,449	3,651
Ca	1,838	1,765	1,763	1,868	1,762	1,803	1,914	1,879
Na	0,081	0,362	0,340	0,305	0,214	0,139	0,160	0,030
K	0,004	0,034	0,032	0,096	0,047	0,038	0,030	0,040

Calcic Amphibole Analyses: Samples from Tantalite Valley contd

	25	26	27	28
SiO_2	52,65	46,46	43,19	43,16
Al_2O_3	6,02	8,46	11,97	13,61
TiO_2	0,57	1,55	0,45	0,42
Cr_2O_3	0,06	0,17	0,08	0,93
FeO*	8,87	13,08	16,70	16,59
MnO	0,12	0,13	0,27	0,21
MgO	17,64	13,91	10,32	9,42
CaO	11,32	12,36	11,67	12,16
Na_2O	0,10	0,10	1,23	1,34
K_2O	0,20	0,89	0,41	0,46
Total	97,55	97,11	96,29	98,30

** Atomic Proportions Based on Selected number of Oxygens **

Oxygens	23	23	23	23
Si	7,428	6,846	6,542	6,411
Al	1,001	1,469	2,137	2,383
Ti	0,060	0,172	0,051	0,047
Cr	0,007	0,020	0,010	0,109
Fe^{2+}	1,047	1,612	2,115	2,061
Mn	0,014	0,016	0,035	0,026
Mg	3,709	3,054	2,330	2,085
Ca	1,711	1,951	1,894	1,936
Na	0,027	0,029	0,361	0,386
K	0,036	0,167	0,079	0,087

Calcic Amphibole Analyses: Samples from Tantalite Valley

1 Actinolitic Hornblende, Metagabbro, AM88E
2 Calcic Amphibole from Symplectite part of OL;Plag, Corona, Troct. TV49
3 MG-Hornblende, Metagabbro, AM89A
4 Tremolite, Troctolite, S75
5 MG-Hornblende, Amphibolite, AM77
6 FE-Pargasitic Hornblende, Amphibolite, AM76, (AV of 2 analyses)
7 MG-Hornblende, Metasomatic Hornblendite, AM157 (AV of 2 analyses)
8 MG-Hornblende, Core, Metagabbro, AM32 (AV of 2 analyses)
9 MG-Hornblende, Rim, Metagabbro, AM32
10 Actinolitic Hornblende, Fibrous, Metagabbro, AM32
11 MG-Hornblende, Rim-New Area, Metagabbro, AM32
12 MG-Hornblende, Cross-cutting lath, Metagabbro, AM32
13 Tshermakitic-HB, Metabasite Hornfels, AM31D/G
14 Tshermakitic-HB, Metabasite Hornfels, AM31C/G
15 Tshermakitic-HB, Metabasite Hornfels, AM31C PG
16 MG-Hornblende, Margin, Metagabbro, AM90
17 Actinolite, Core, Metagabbro, AM90
18 MG-Hornblende, Metagabbro from Satellite Body, AM125/G
19 MG-Hornblende, Metagabbro from Satellite Body, AM125 PG
20 MG-Hornblende Gabbronorite Satellite Body, AM123A
21 Actinolitic Hornblende, Gabbronorite Satellite Body, AM123A
22 Actinolite, Gabbronorite Satellite Body, AM123A
23 Actinolitic Hornblende, Gabbronorite, AM21C
24 Actinolitic Hornblende, around OPX, Gabbronorite, AM41
25 Actinolitic Hornblende, New Area, Gabbronorite, AM41
26 MG-Hornblende, Primary?, Gabbronorite, AM41
27 MG-Hornblende, Mottled Metagabbro, AM149/2
28 MG-Hornblende, Mottled Metagabbro, TV275

** N.D. = Not Detected **
N.A. = Not Analysed
FeO* = Total Iron as FeO

Cummingtonite Analyses: Samples from Tantalite Valley

	1	2	3	4	5	6	7	8
SiO_2	54,93	54,21	52,25	54,71	54,77	52,94	54,52	52,54
TiO_2	0,05	0,01	0,05	0,03	0,03	0,07	0,07	0,08
Al_2O_3	1,58	1,26	1,23	0,87	1,46	1,29	1,18	2,29
Cr_2O_3	N.A.	N.A.	N.D.	N.D.	N.D.	0,02	0,03	N.D.
FeO*	18,30	20,72	21,13	20,46	19,95	19,31	18,28	13,68
MnO	0,41	1,45	0,83	0,48	0,47	0,47	0,48	0,40
MgO	20,30	19,43	19,51	20,14	20,46	21,08	20,69	20,88
CaO	0,46	0,59	0,64	0,70	0,88	1,16	0,94	5,71
Na_2O	0,11	0,19	0,12	0,14	0,14	0,20	0,13	0,07
K_2O	N.D.	0,02	N.D.	N.D.	N.D.	N.D.	N.D.	0,42
Total	96,14	97,88	95,78	97,55	98,18	96,55	96,33	96,08

** Atomic Proportions based on selected number of oxygens **

Oxygens	23	23	23	23	23	23	23	23
Si	7,934	7,841	7,752	7,892	7,832	7,721	7,890	7,619
Al	0,270	0,214	0,215	0,148	0,246	0,222	0,201	0,391
Ti	0,005	0,001	0,006	0,003	0,003	0,008	0,008	0,009
Cr						0,002	0,003	
Fe^{2+}	2,210	2,507	2,622	2,468	2,386	2,355	2,212	1,659
Mn	0,050	0,177	0,104	0,059	0,057	0,058	0,059	0,049
Mg	4,370	4,189	4,314	4,330	4,360	4,582	4,462	4,512
Ca	0,071	0,092	0,102	0,108	0,135	0,181	0,146	0,887
Na	0,031	0,053	0,035	0,039	0,039	0,057	0,036	0,020
K	0,000	0,004	0,000	0,000	0,000	0,000	0,000	0,078

*** Sample Directory ***

1 Metabasite Hornfels, TV13 151.
2 Metabasite Hornfels, AM31B.
3 Metabasite Hornfels, AM31D.
4 Metabasite Hornfels, AM31C/W
5 Metabasite Hornfels, AM31C/PW
6 Metagabbro from satellite body, AM125/W
7 Metagabbro from satellite body, AM125/PW
8 Gabbronorite, AM21C

** N.D. = Not detected **
N.A. = Not analysed

Plagioclase Analyses: Samples From Tantalite Valley

	1	2	3	4	5
SiO_2	43,07	46,84	51,29	51,26	50,46
TiO_2	N.D.	N.D.	N.D.	N.D.	N.D.
Al_2O_3	36,94	35,07	31,32	31,56	31,94
Cr_2O_3	N.D.	N.D.	N.D.	N.D.	N.D.
FeO	0,14	0,03	0,31	0,17	0,30
MnO	N.D.	N.D.	N.D.	N.D.	N.D.
MgO	0,02	N.D.	N.D.	0,02	0,02
CaO	19,65	17,35	13,82	13,56	13,99
Na_2O	0,60	2,04	3,62	3,80	3,60
K_2O	N.D.	N.D.	0,06	0,12	0,11
Total	100,46	101,38	100,46	100,52	100,45
** Atomic Proportions Based on Selected No. of Oxygens **					
Oxygen	32	32	32	32	32
Si	7,954	8,500	9,293	9,277	9,161
Ti					
Al	8,041	7,502	6,689	6,732	6,835
Cr					
Fe^{2+}	0,022	0,005	0,047	0,026	0,046
Mn					
Mg	0,006			0,005	0,005
Ca	3,888	3,374	2,683	2,630	2,722
Na	0,215	0,718	1,272	1,333	1,267
K			0,014	0,028	0,025
	AN 94,71 AB 5,23 OR 0,06	AN 82,41 AB 17,53 OR 0,06	AN 67,61 AB 32,05 OR 0,35	AN 65,89 AB 33,41 OR 0,69	AN 67,80 AB 31,57 OR 0,63

Plagioclase Analyses: Samples From Tantalite Valley

	6	7	8	9	10	11	12
SiO_2	50,86	51,83	48,39	50,27	48,40	50,35	49,37
TiO_2	N.D.	0,06	0,04	0,04	0,05	0,05	N.D.
Al_2O_3	31,75	31,58	33,64	32,28	33,70	32,61	33,35
Cr_2O_3	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
FeO	0,24	0,11	0,24	0,18	0,04	0,25	0,03
MnO	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
MgO	0,02	N.D.	N.D.	N.D.	N.D.	N.D.	0,02
CaO	13,78	12,85	16,51	15,19	16,41	14,94	16,00
Na_2O	3,70	3,94	2,55	3,39	2,57	3,52	2,77
K_2O	0,12	0,05	0,12	0,10	N.D.	0,04	N.D.
Total	100,50	100,45	101,52	101,48	101,21	101,79	101,58
** Atomic Proportions Based on Selected No. of Oxygens **							
Oxygen	32	32	32	32	32	32	32
Si	9,218	9,353	8,759	9,064	8,770	9,045	8,894
Ti		0,008	0,005	0,005	0,007	0,007	
Al	6,783	6,717	7,177	6,860	7,197	6,905	7,082
Cr							
Fe^{2+}	0,036	0,017	0,036	0,027	0,006	0,038	0,005
Mn							
Mg	0,005						0,005
Ca	2,676	2,485	3,202	2,935	3,186	2,876	3,088
Na	1,300	1,379	0,895	1,185	0,903	1,226	0,968
K	0,028	0,012	0,028	0,023		0,009	
	AN 66,83 AB 32,47 OR 0,69	AN 64,12 AB 35,58 OR 0,30	AN 77,63 AB 21,70 OR 0,67	AN 70,84 AB 28,61 OR 0,56	AN 77,87 AB 22,07 OR 0,06	AN 69,95 AB 29,82 OR 0,22	AN 76,10 AB 23,84 OR 0,06

Plagioclase Analyses: Samples From Tantalite Valley

	13	14	15	16	17	18	19	20
SiO_2	51,58	49,17	49,14	47,15	48,19	49,89	48,24	48,48
TiO_2	N.D.	N.D.	N.D.	0,03	0,02	0,03	N.D.	0,02
Al_2O_3	31,19	33,38	33,56	34,66	33,49	32,91	34,02	33,75
Cr_2O_3	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
FeO	0,03	0,12	0,03	0,20	0,21	0,14	0,14	0,21
MnO	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
MgO	N.D.	0,02	0,02	0,02	N.D.	N.D.	0,02	N.D.
CaO	12,96	15,20	16,09	16,33	16,30	15,23	16,54	16,30
Na_2O	4,38	2,95	2,66	2,41	2,66	3,24	2,57	2,66
K_2O	0,02	N.D.	N.D.	0,05	0,02	N.D.	0,04	0,02
Total	100,20	100,88	101,54	100,87	100,92	101,48	101,60	101,47
** Atomic Proportions Based on Selected No. of Oxygens **								
Oxygen	32	32	32	32	32	32	32	32
Si	9,350	8,906	8,857	8,587	8,767	8,988	8,719	8,768
Ti				0,004	0,003	0,004		0,003
Al	6,664	7,126	7,130	7,440	7,182	6,988	7,247	7,195
Cr								
Fe^{2+}	0,005	0,018	0,005	0,030	0,032	0,021	0,021	0,032
Mn								
Mg		0,005	0,005	0,005			0,005	
Ca	2,517	2,950	3,108	3,187	3,178	2,940	3,203	3,159
Na	1,540	1,036	0,930	0,851	0,938	1,132	0,901	0,933
K	0,005			0,012	0,005		0,009	0,005
	AN 61,98	AN 73,96	AN 76,93	AN 78,70	AN 77,11	AN 72,16	AN 77,88	AN 77,11
	AB 37,91	AB 25,98	AB 23,01	AB 21,02	AB 22,77	AB 27,78	AB 21,90	AB 22,77
	OR 0,11	OR 0,06	OR 0,06	OR 0,29	OR 0,11	OR 0,06	OR 0,22	OR 0,11

Plagicclase Analyses: Samples From Tantalite Valley

	21	22	23	24	25	26	27	28
SiO_2	55,62	53,21	49,67	61,17	57,25	51,75	42,95	56,78
TiO_2	N.D.	N.D.	0,05	N.D.	0,01	0,02	N.D.	N.D.
Al_2O_3	28,01	30,34	31,87	24,86	27,19	30,04	32,30	27,47
Cr_2O_3	N.D.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
FeO	0,04	0,10	0,19	0,03	0,02	0,12	0,24	0,07
MnO	N.D.	N.D.	N.A.	N.A.	N.A.	N.D.	N.A.	N.A.
MgO	N.D.	0,05	0,41	0,01	0,02	0,04	N.D.	N.D.
CaO	9,57	11,82	14,39	6,53	8,82	13,11	22,34	9,30
Na_2O	5,85	4,56	2,98	8,14	6,69	4,19	1,48	6,61
K_2O	0,02	0,16	0,34	0,06	0,07	0,04	0,17	0,05
Total	99,15	100,27	99,90	100,80	100,05	99,31	99,47	100,28
** Atomic Proportions Based on Selected No. of Oxygens **								
Oxygens	32	32	32	32	32	32	32	32
Si	10,068	9,596	9,080	10,796	10,257	9,468	8,148	10,172
Ti			0,008	0,000	0,001	0,004		
Al	5,976	6,449	6,868	5,176	5,743	6,476	7,224	5,804
Cr								
Fe^{2+}	0,006	0,015	0,028	0,004	0,002	0,020	0,040	0,012
Mn								
Mg		0,013	0,112	0,004	0,004	0,012		
Ca	1,856	2,284	2,820	1,236	1,694	2,568	4,540	1,744
Na	2,053	1,595	1,056	2,788	2,323	1,488	0,544	2,244
K	0,005	0,037	0,080	0,012	0,012	0,008	0,040	0,008
	AN 47,42 AB 52,46 OR 0,12	AN 58,33 AB 40,73 OR 0,94	AN 71,28 AB 26,69 OR 2,02	AN 30,62 AB 69,08 OR 0,30	AN 42,05 AB 57,66 OR 0,30	AN 63,21 AB 36,56 OR 0,23	AN 88,58 AB 10,62 OR 0,80	AN 43,64 AB 56,16 OR 0,20

Plagioclase Analyses: Samples From Tantalite Valley

*** Sample Directory ***

1 Anorthite, Amphibolite AM76
2 Bytownite, Amphibolite AM77
3 Labradorite, Gabbronorite AM21C
4 Labradorite Core, Gabbronorite AM41
5 Labradorite Rim, Gabbronorite AM41
6 Labradorite (Av), Gabbronorite AM41
7 Labradorite, Olivine Gabbronorite TV263
8 Bytownite, Olivine Gabbronorite TV233
9 Bytownite, Gabbronorite TV187
10 Bytownite, Troctolite TV49
11 Labradorite, Orthopyroxenite (Norite), TV6 129
12 Bytownite, Metagabbro AM32
13 Labradorite, Metabasite Hornfels AM31C
14 Bytownite, Metabasite Hornfels AM31D
15 Bytownite, Metagabbro AM88E
16 Bytownite, Mottled Metagabbro AM149/2
17 Bytownite Core, Mottled Metagabbro, TV275
18 Bytownite Margin, Mottled Metagabbro, TV275
19 Bytownite New Area 1, Mottled Metagabbro TV275
20 Bytownite New Area 2, Mottled Metagabbro, TV275
21 Andesine, Metagabbro Sample AM125, Satellite Body
22 Labradorite, Gabbronorite Sample AM123A, Satellite Body
23 Bytownite, Metagabbro AM89A
24 Andesine, Young Peg. Intr. Metasomatic Hornblendite Sample S95
25 Andesine, Psammitic Hornfels, AM30A
26 Labradorite, Metabasite Hornfels, TV13 151
27 Bytownite, Metabasite Hornfels, AM31B
28 Andesine, Pelitic Hornfels, T19

** N.D. = Not Detected **

-- N.A. = Not Analysed

Brown Mica Analyses : Mafic and Ultramafic Rocks of Tantalite Valley

	1	2	3	4	5	6	7	8
SiO_2	36,96	37,93	37,27	35,95	36,70	40,41	40,16	38,09
TiO_2	2,54	4,12	1,83	1,95	4,28	2,81	0,71	1,97
Al_2O_3	15,87	15,44	16,87	17,10	16,02	16,21	14,54	16,23
Cr_2O_3	0,11	0,87	0,35	1,15	0,19	0,46	N.A.	N.A.
FeO	13,16	10,80	18,03	17,24	9,99	7,89	9,89	12,40
MnO	0,05	0,05	0,14	0,11	0,04	0,03	0,16	0,02
MgO	16,87	17,50	12,15	12,58	18,36	20,72	19,45	17,77
CaO	0,14	N.D.	0,15	0,09	0,04	N.D.	0,04	0,06
Na_2O	N.D.	0,16	0,27	0,09	0,12	0,18	0,26	0,25
K_2O	9,32	9,41	8,53	8,69	8,97	8,98	8,39	7,15
Total	95,02	96,28	95,59	94,95	94,71	97,69	93,59	93,93
** Atomic Proportions Based on Selected No. of Oxygens **								
Oxygens	22	22	22	22	22	22	22	22
Si	5,486	5,501	5,589	5,439	5,382	5,639	5,885	5,603
Al	2,777	2,639	2,982	3,049	2,769	2,666	2,512	2,814
Ti	0,284	0,449	0,206	0,222	0,472	0,295	0,078	0,218
Cr	0,013	0,100	0,041	0,138	0,022	0,051		
Fe^{2+}	1,634	1,310	2,261	2,181	1,225	0,921	1,212	1,525
Mn	0,006	0,006	0,018	0,014	0,005	0,004	0,020	0,003
Mg	3,732	3,782	2,715	2,836	4,013	4,309	4,248	3,894
Ca	0,022		0,024	0,015	0,006		0,006	0,009
Na		0,045	0,079	0,026	0,034	0,049	0,074	0,072
K	1,765	1,741	1,632	1,677	1,678	1,599	1,568	1,342
Sum	15,718	15,573	15,548	15,598	15,607	15,531	15,602	15,480

*** Sample Directory ***

1. Phlogopite, Gabbronorite, AM41
2. Phlogopite, Gabbronorite Satellite Body, AM123A.
3. Biotite, Mottled metagabbro, AM149/2.
4. Biotite, Mottled metagabbro, TV275.
5. Phlogopite, Gabbronorite, TV233.
6. Phlogopite, Pyroxenite (Norite), TV6 129.
7. Phlogopite, Metasomatic Hornblendite, S95.
8. Phlogopite, Metagabbro from Satellite Body, AM125.

*** N.D. - Not Detected ***
N.A. - Not Analysed

Chlorite Analyses: Samples from Tantalite Valley

	1	2	3	4	5	6	7	8	9	10
SiO_2	26,43	26,68	27,26	25,01	26,20	23,93	31,27	27,66	27,55	27,09
TiO_2	0,06	0,10	0,05	0,10	0,10	0,09	0,04	0,04	N.D.	0,08
Al_2O_3	19,23	20,99	20,27	23,53	22,66	23,90	17,81	17,99	17,83	21,49
Cr_2O_3	0,03	N.D.	0,02	N.D.	N.D.	N.D.	N.A.	N.A.	N.A.	N.A.
FeO*	24,29	23,83	19,22	19,94	15,75	25,77	6,10	21,93	21,24	12,33
MnO	0,16	0,15	0,13	N.D.	0,05	0,23	N.D.	0,15	0,12	N.D.
MgO	17,48	15,24	21,26	17,41	20,89	13,65	32,80	18,96	19,59	24,91
CaO	0,03	1,29	0,04	N.D.	0,04	N.D.	0,02	0,07	0,03	N.D.
Na_2O	N.D.	N.D.	N.D.	N.D.	N.D.	0,03	N.D.	0,07	N.A.	0,04
K_2O	0,04	N.D.	N.D.	0,02	0,12	0,02	N.D.	0,09	N.A.	0,01
Total	87,75	88,28	88,25	86,02	85,81	87,62	88,05	86,97	86,36	85,95
** Atomic Proportions Based on Selected No. of Oxygens **										
Oxygens	28	28	28	28	28	28	28	28	28	28
Si	5,542	5,543	5,516	5,210	5,352	5,061	5,912	5,774	5,769	5,427
Al	4,752	5,140	4,835	5,777	5,456	5,958	3,970	4,427	4,401	5,075
Ti	0,009	0,016	0,008	0,016	0,015	0,014	0,006	0,008		0,012
Cr	0,005		0,003							
Fe^{2+}	4,259	4,141	3,253	3,474	2,691	4,558	0,965	3,829	3,720	2,066
Mn	0,028	0,026	0,022		0,009	0,041		0,027	0,021	
Mg	5,462	4,719	6,412	5,405	6,359	4,303	9,241	5,899	6,113	7,435
Ca	0,007	0,287	0,009		0,009		0,003	0,016	0,007	
Na						0,012		0,028		0,016
K	0,011			0,005	0,031	0,005		0,024		0,002
Sum,	20,076	19,871	20,057	19,889	19,921	19,954	20,097	20,031	20,031	20,003
100 $Mg/Mg+Fe^{2+}$	56,19	53,26	66,34	60,34	70,27	48,56	90,54	60,64	62,17	78,25

Chlorite Analyses: Samples From Tantalite Valley

*** Sample Directory ***

1. Ripidolite, Mottled Metagabbro, AM 149/2
2. Ripidolite, Metagabbro, AM90
3. Ripidolite, Metagabbro, AM89A
4. Ripidolite, Pelitic Hornfels, T4
5. Ripidolite, Cordierite-Anthophyllite Hornfels, TV170
6. Ripidolite, Pelitic Hornfels, TV276
7. Clinochlore, Troctolite, S75
8. Pycnochlorite, Metabasite Hornfels, AM30A
9. Pycnochlorite, Metabasite Hornfels, AM31B
10. Sheridanite, Metabasite Hornfels, TV13 151

** N.D. = Not Detected **

N.A. = Not Analysed

Spinel Analyses: Samples from Tantalite Valley

	1	2	3	4	5	6	7	8
SiO_2	N.D	0,02	N.D.	0,02	0,04	N.D.	N.D.	0,13
Al_2O_3	42,16	36,82	63,36	5,19	4,32	27,50	54,41	2,00
TiO_2	0,03	0,04	N.D.	2,52	2,40	0,44	N.D.	0,33
Cr_2O_3	18,89	23,54	0,12	20,80	19,18	28,22	0,49	22,00
Fe_2O_3	6,85	7,24	4,24	37,84	40,86	12,36	0,00	43,65
FeO	22,76	24,25	13,83	31,30	31,62	24,48	29,09	31,90
MnO	0,39	0,51	0,10	0,65	0,60	0,66	N.D.	0,33
MgO	10,46	8,80	18,33	1,76	1,50	7,81	3,91	N.D.
Total	101,55	101,22	99,98	100,08	100,52	101,47	87,90	100,33

** Atomic Proportions Based on Selected No. of Oxygens **

Oxygens	4	4	4	4	4	4	4	4
Si	0,000	0,001	0,000	0,001	0,001	0,000	0,000	0,005
Al	1,419	1,281	1,913	0,218	0,182	0,997	2,021	0,088
Ti	0,001	0,001	0,000	0,068	0,065	0,010	0,000	0,009
Cr	0,426	0,549	0,002	0,587	0,542	0,686	0,012	0,652
Fe^{3+}	0,155	0,169	0,086	1,071	1,158	0,301	0,000	1,231
Fe^{2+}	0,543	0,598	0,296	0,935	0,946	0,629	0,767	1,000
Mn	0,009	0,013	0,002	0,020	0,018	0,017	0,000	0,010
Mg	0,445	0,387	0,700	0,094	0,080	0,358	0,184	0,000

*** Sample Directory ***

1 Brown Picotite, Troctolite, TV49
2 Picotite, included in green Spinel, Troctolite, TV49
3 Green Spinel-Hercynite, Troctolite, TV49
4 Ferritchromite included in Picotite, Troctolite, TV49
5 Ferritchromite included in Picotite, new area, Troctolite, TV49
6 Picotite, new area, Troctolite, TV49
7 Zincian Spinel, Pelitic Hornfels, T4+
8 Ferritchromite, mottled metagabbro, TV275

** N.D. = Not Detected **

+ accurate electron microprobe determinations of zinc is not possible at the University of Cape Town, but it was quantitatively detected and is present at about the 12% ZnO level

Miscellaneous Analyses : Samples From Tantalite Valley

	1	2	3	4	5
SiO_2	52,72	53,29	52,76	41,30	64,18
TiO_2	0,23	0,07	0,08	0,03	N.D.
Al_2O_3	4,38	3,92	2,49	24,21	20,19
Cr_2O_3	0,19	0,02	N.A.	0,61	N.D.
Fe_2O_3	0,00	-	-	-	-
FeO	13,62	19,97*	21,62*	0,66*	0,03*
MnO	0,22	0,40	0,77	N.D.	N.D.
MgO	27,59	20,27	18,54	0,14	0,03
CaO	0,17	0,40	0,64	26,28	N.D.
Na_2O	N.D.	0,42	0,34	0,02	0,34
K_2O	N.D.	0,01	N.D.	N.D.	15,61
Total	99,12	98,77	97,24	93,25	100,38
** Atomic Proportions Based on Selected No. of Oxygens **					
Oxygens	6	23	23	23	8
Si	1,898	7,580	7,709	6,125	2,945
Al	0,186	0,658	0,429	4,231	1,090
Ti	0,006	0,007	0,008	0,003	0,000
Cr	0,005	0,002		0,072	0,000
Fe^{3+}	0,000				
Fe^{2+}	0,410	2,376	2,641	0,082	0,001
Mn	0,007	0,048	0,096	0,000	
Mg	1,481	4,298	4,036	0,031	0,001
Ca	0,007	0,061	0,101	4,176	0,000
Na	0,000	0,115	0,096	0,005	0,030
K	0,000	0,001	0,000	0,000	0,913
$100\ Mg/Mg+Fe^{2+}$	78,34	64,40	60,45	27,43	
	WO 0,35				Ca 0,000
	En 78,04				Na 0,031
	Fs 21,62				K 0,969

*** Sample Directory ***
1. Bronzite, Pyroxene-Bearing Hornfels, TV226
2. Anthopyllite, Cordierite-Anthophyllite Hornfels, TV170 (AV of 3 Analyses
3. Anthophyllite, Psammitic Hornfels, AM30A
4. Prehnite, Mottled Metagabbro, AM 149/2 (Av of 2 Analyses)
5. K-feldspar vein intruding Metagabbro sample AM181E

** N.D. = Not Detected **
N.A. = Not Analysed
* = Total Iron as FeO

Cordierite Analyses from Tantalite Valley Hornfelses

	1	2	3	4	5
SiO_2	47,47	48,47	48,55	49,24	48,20
TiO_2	0,02	0,03	N.D.	0,02	N.D.
Al_2O_3	33,09	33,15	33,29	33,87	33,83
FeO*	8,70	8,00	4,58	2,00	6,23
MnO	0,12	0,42	0,08	0,04	N.D.
MgO	7,68	7,18	10,25	11,82	10,00
CaO	0,03	0,02	N.D.	0,06	0,01
Na_2O	0,16	0,67	0,17	0,09	N.D.
K_2O	0,26	0,02	0,01	0,02	N.D.
Total	97,53	97,96	96,93	97,16	98,27
** Atomic Proportions Based on Selected No. of Oxygens **					
Oxygens	9	9	9	9	9
Si	2,474	2,507	2,492	2,491	2,460
Al	2,033	2,021	2,014	2,020	2,036
Ti	0,001	0,001	0,000	0,001	0,000
Fe^{2+}	0,379	0,346	0,197	0,085	0,266
Mn	0,006	0,018	0,003	0,002	0,000
Mg	0,596	0,553	0,784	0,891	0,761
Ca	0,002	0,001	0,000	0,003	0,001
Na	0,016	0,067	0,017	0,009	0,000
K	0,017	0,001	0,000	0,001	0,000
$100\ Mg/Mg+Fe^{2+}$	61,13	61,56	79,92	91,29	74,10

*** Sample Directory ***
1. Pelitic Hornfels, T19 (AV. of 3 Analyses)
2. Pelitic Hornfels, TV276
3. Cordierite-Anthophyllite Hornfels, TV170
4. Pyroxene-bearing Hornfels, TV226
5. Pelitic Hornfels, TV13 165 (AV. of 3 Analyses)

** N.D. = Not Detected **

Analyses of Garnet from Tantalite Valley Pelitic Hornfels Samples

	1C	1R	2C	2R	3R
SiO_2	36,96	36,48	36,97	37,16	37,69
TiO_2	0,05	0,04	0,06	0,07	0,07
Al_2O_3	21,53	21,23	21,34	21,70	21,42
Cr_2O_3	0,01	0,05	0,05	0,04	N.A.
FeO*	34,54	35,02	35,28	34,31	32,10
MnO	1,94	2,19	0,59	0,26	3,73
MgO	3,61	2,43	3,26	4,43	3,14
CaO	1,25	2,07	3,13	2,04	2,37
Total	99,89	99,51	100,68	100,01	100,51
** Atomic Proportions Based on Selected No. of Oxygens **					
Oxygens	12	12	12	12	12
Si	2,970	2,966	2,957	2,962	3,004
Al	2,039	2,034	2,012	2,039	2,012
Ti	0,003	0,002	0,004	0,004	0,004
Cr		0,004	0,003	0,003	
Fe^{2+}	2,321	2,381	2,360	2,288	2,139
Mn	0,132	0,151	0,040	0,018	0,252
Mg	0,432	0,294	0,389	0,526	0,373
Ca	0,108	0,180	0,268	0,174	0,202
100 Mg/Mg+Fe^{2+}	15,72	11,00	14,12	18,71	14,85
** Garnet End-Members + **					
Pyrope	14,11	9,64	12,83	21,49	12,59
Almandine	78,07	79,53	76,81	69,47	72,11
Spessartine	4,31	4,94	1,34	0,74	8,47
Grossular	3,50	5,70	8,87	8,24	6,83
Uvarovite	0,01	0,19	0,14	0,06	-

*** Sample Directory ***

1C: Core Zone, Garnet Porphyroblast, T19
1R: Rim of above Garnet (AV. of 3 Analyses)
2C: Core Zone, Garnet Porphyroblast, T4
2R: Rim of Above Garnet (AV. of 2 Analyses)
3R: Rim of Garnet Porphroblast, TV13 165

** N.A. = Not Analysed **

+ Calculated following Rickwood (1968)

Brown Mica Analyses : , Hornfelses from Tantalite Valley

	1	2	3	4	5	6
SiO_2	35,08	34,82	34,87	41,60	38,18	35,68
TiO_2	1,42	1,86	1,50	1,07	1,34	1,18
Al_2O_3	19,82	19,93	20,00	15,69	17,21	19.18
FeO*	16,82	19,18	21,03	4,23	11,59	15,36
MnO	0,02	0,04	0,14	N.D.	0,05	0,05
MgO	11,71	9,16	8,95	24,34	16,47	13,34
CaO	N.D.	0,01	0,02	0,05	0,03	0,19
Na_2O	0,11	0,33	0,27	0,69	0,26	0,11
K_2O	8,57	8,18	8,80	8,59	8,04	7,22
Total	93,55	93,51	95,58	96,26	93,17	92,31
** Atomic Proportions Based on Selected No. of Oxygens **						
Oxygens	22	22	22	22	22	22
Si	5,343	5,359	5,316	5,772	5,656	5,423
Al	3,558	3,615	3,594	2,566	3,005	3,437
Ti	0,163	0,215	0,172	0,112	0,149	0,135
Fe^{2+}	2,142	2,469	2,681	0,491	1,436	1,952
Mn	0,003	0,005	0,018	0,000	0,006	0,007
Mg	2,658	2,101	2,034	5,033	3,636	3,021
Ca	0,000	0,001	0,003	0,007	0,005	0,031
Na	0,032	0,098	0,080	0,186	0,075	0,033
K	1,665	1,606	1,712	1,521	1,520	1,400
Sum	15,564	15,469	15,610	15,688	15,488	15,439
100Mg/Mg+Fe	55,37	45,97	43,13	91,11	71,69	60,75

*** Sample Directory ***

1. Biotite, Pelitic Hornfels, T4
2. Biotite, Pelitic Hornfels, T19 (Av. of 4 Analyses)
3. Biotite, Pelitic Hornfels, TV276 .
4. Phlogopite, Pyroxene-Bearing Hornfels, TV226
5. Phlogopite, Cordierite-Anthophyllite Hornfels, TV170
6. Biotite, Pelitic Hornfels, TV13 165

** N.D. - Not Detected **

Analyses of Staurolite From Tantalite Valley Pelitic Hornfels

	1	2	3	4
SiO_2	26,72	26,61	26,70	27,04
TiO_2	0,44	0,43	0,65	0,40
Al_2O_3	54,64	54,25	54,13	54,36
Cr_2O_3	0,19	0,19	N.D.	0,06
FeO*	13,12	13,62	13,98	13,68
MnO	N.D.	0,13	0,15	0,38
MgO	2,15	2,26	1,54	1,35
CaO	N.D.	0,02	N.D.	N.D.
Total	97,26	97,51	97,15	97,27
** Atomic Proportions Based on Selected No. of Oxygens **				
Oxygens	23	23	23	23
Si	3,721	3,712	3,740	3,777
Al	8,970	8,919	8,937	8,951
Ti	0,046	0,045	0,068	0,042
Cr	0,021	0,021	0,000	0,007
Fe^{2+}	1,528	1,589	1,638	1,598
Mn	0,000	0,015	0,018	0,045
Mg	0,446	0,470	0,321	0,281
Ca	0,000	0,003	0,000	0,000
100 Mg/Mg+Fe^{2+}	22,59	22,84	16,39	14,91

*** Sample Directory ***

1. Rounded Inclusions in Cordierite, T4
2. Separated grains in Grain Mount, T4
3. T19
4. TV276

** N.D. - Not Detected **

FeO* - Total Iron as FeO

Olivine Analyses : Samples From the Kumkum Area

	1	2	3
SiO_2	36,75	36,58	37,50
Al_2O_3	N.D.	N.D.	0,78
TiO_2	N.D.	N.D.	N.D.
MgO	33,23	33,31	36,76
FeO	30,10	30,08	25,20
MnO	0,43	0,38	0,34
CaO	0,02	0,05	0,07
Total	100,53	100,41	100,65
** Atomic Proportions Based on Selected No. of Oxygens **			
Oxygens	4	4	4
Si	0,989	0,986	0,983
Ti	0,000	0,000	0,000
Al	0,000	0,000	0,024
Fe	0,678	0,678	0,552
Mn	0,010	0,009	0,008
Mg	1,333	1,339	1,436
Ca	0,001	0,002	0,002
Sum	3,011	3,014	3,005
FO	0,663	0,663	0,722
FA	0,336	0,336	0,277

*** Sample Directory ***

1. Hyalosiderite, Kumkum Gabbronorite, K37A Discrete, Incl in PX
2. Hyalosiderite, Kumkum Gabbronorite, K37A, Ol-Plag Corona
3. Chrysolite, Eselruh Gabbronorite, K4

** N.D. = Not Detected **

Orthopyroxene Analyses: Samples From the Kumkum Area

	1	2	3	4	5	6	7
SiO_2	50,14	53,99	54,59	53,40	53,16	51,61	47,34
TiO_2	0,08	0,14	N.D.	0,27	0,02	0,28	0,10
Al_2O_3	0,60	1,86	1,14	1,67	2,05	0,77	5,66
Fe_2O_3	1,31	1,03	1,30	1,76	2,12	1,33	3,62
FeO	31,02	14,26	13,73	17,32	16,20	26,39	27,50
MnO	0,75	0,24	0,32	0,37	0,30	0,58	0,57
MgO	15,27	27,50	28,08	25,62	26,08	19,09	15,62
CaO	0,66	0,90	0,92	0,42	0,31	0,53	0,06
Na_2O	0,04	N.D.	N.A.	0,04	0,04	0,06	0,15
Total	99,86	99,92	100,35	100,88	100,28	100,64	100,62
** Atomic Proportions Based on Selected No. of Oxygens **							
Oxygens	6	6	6	6	6	6	6
Si	1,966	1,943	1,953	1,934	1,928	1,958	1,822
Ti	0,002	0,004	0,000	0,007	0,001	0,008	0,003
Al	0,028	0,079	0,059	0,071	0,088	0,034	0,257
Fe^{3+}	0,039	0,028	0,035	0,048	0,058	0,038	0,105
Fe^{2+}	1,017	0,429	0,411	0,525	0,492	0,837	0,885
Mn	0,025	0,007	0,010	0,011	0,009	0,019	0,019
Mg	0,893	1,475	1,497	1,384	1,410	0,080	0,896
Ca	0,028	0,035	0,035	0,016	0,012	0,022	0,002
Na	0,003	0,000	0,000	0,003	0,003	0,004	0,011
Sum	4,000	4,000	4,000	4,000	4,000	4,000	4,000
Wo	1,4	1,8	1,8	0,8	0,6	1,1	0,1
En	46,1	76,1	77,05	71,9	73,7	55,7	50,2
Fs	52,5	22,1	21,13	27,3	25,7	43,2	49,6
Mg/Mg+Fe Fe=Fetot	0,458	0,763	0,771	0,707	0,720	0,552	0,475
Mg/Mg+Fe Fe^{2+}only	0,467	0,775	0,785	0,725	0,742	0,563	0,503

** Sample Directory **

1. Ferrohypersthene, Granolite K58 (Av of 2 Analyses)
2. Bronzite, Eselruh Gabbronorite K4, Discrete
3. Bronzite, Eselruh Gabbronorite, K4, Ol-Plag. Corona
4. Bronzite, Kumkum Gabbronorite, K37A, Discrete
5. Bronzite, Kumkum Gabbronorite, K37A, Ol-Plag. Corona
6. Hypersthene, Contaminated Gabbronorite, K45A
7. Ferrohypersthene, Black Gneiss, KK6 (Av of 2 Analyses)

** N.D. = Not Detected **
N.A. = Not Analysed

Clinopyroxene Analyses: Samples From the Kumkum Area

	1	2	3	4
SiO_2	51,81	53,36	51,36	51,78
TiO_2	0,12	0,07	0,93	0,15
Al_2O_3	0,98	1,14	3,19	1,25
Fe_2O_3	2,12	1,60	2,22	3,14
FeO	11,10	3,11	3,92	8,96
MnO	0,28	0,12	0,13	0,27
MgO	11,76	15,94	14,67	13,55
CaO	22,07	23,63	23,13	21,00
Na_2O	0,31	0,42	0,52	0,38
Total	100,55	99,66	100,07	100,47
** Atomic Proportions Based on Selected No. of Oxygens **				
Oxygens	6	6	6	6
Si	1,956	1,960	1,893	1,938
Ti	0,003	0,002	0,026	0,004
Al	0,044	0,061	0,139	0,055
Fe^{3+}	0,060	0,044	0,062	0,088
Fe^{2+}	0,350	0,096	0,121	0,280
Mn	0,009	0,004	0,004	0,009
Mg	0,662	0,873	0,806	0,756
Ca	0,893	0,930	0,913	0,842
Na	0,023	0,030	0,037	0,028
Sum	4,000	4,000	4,000	4,000
Wo	46,9	49,0	49,6	44,8
En	34,7	46,0	43,8	40,2
Fs	18,4	5,0	6,6	14,9
Mg/Mg+Fe Fe=Fe tot	0,617	0,862	0,815	0,672
Mg/Mg+Fe Fe^{2+} only	0,654	0,901	0,870	0,730

*** Sample Directory ***

1. Salite, Granolite, K58 (Av of 2 Analyses)
2. Diopside, Eselruh Gabbronorite, K4
3. Diopside, Kumkum Gabbronorite, K37A
4. Avgite, Contaminated Gabbronorite, K45A

Amphibole Analyses : Samples From the Kumkum Area

	1	2	3	4	5	6
SiO_2	41,77	43,54	43,00	40,39	41,10	39,90
TiO_2	1,88	2,64	0,31	2,57	0,18	0,31
Al_2O_3	11,49	12,22	14,60	14,48	16,21	18,48
FeO	19,89	8,38	7,78	12,64	9,89	21,79
MnO	0,19	0,09	0,10	0,11	0,10	0,33
MgO	8,63	15,33	15,84	11,86	14,75	13,05
CaO	11,61	11,81	12,14	11,57	11,75	0,30
Na_2O	1,30	2,75	2,95	2,76	2,85	2,29
K_2O	1,27	0,97	0,50	1,36	1,09	0,04
Total	98,02	97,73	97,22	97,74	97,92	96,49
** Atomic Proportions Based on Selected No. of Oxygens **						
Oxygens	23	23	23	23	23	23
Si	6,369	6,317	6,234	6,011	6,001	5,980
Ti	0,215	0,288	0,034	0,288	0,019	0,035
Al	2,065	2,090	2,494	2,541	2,791	3,265
Fe^{2+}	2,536	1,016	0,944	1,574	1,208	2,731
Mn	0,024	0,011	0,013	0,013	0,012	0,042
Mg	1,960	3,314	3,421	2,631	3,209	2,915
Ca	1,897	1,836	1,886	1,845	1,839	0,048
Na	0,386	0,773	0,828	0,797	0,807	0,666
K	0,247	0,180	0,093	0,258	0,204	0,008
$\frac{Mg}{Mg+Fe}$	0,44	0,77	0,78	0,63	0,73	0,52
Ca+Na+K	2,530	2,789	2,807	2,900	2,850	0,722

*** Sample Directory ***

1. Mg-Hastingsitic HB., Granolite, K58
2. Pargasitic HB., Eselruh Gabbronorite, K4, Discrete
3. Pargasite, Eselruh Gabbronorite, K4, Ol-Plag Corona
4. Fe-Pargasite, Kumkum Gabbronorite, K37A, Discrete
5. Fe-Pargasite, Kumkum Gabbronorite, K37A, Ol-Plag Corona
6. Gedrite, Black Gneiss, K101 (Av of 2 Analyses)

Plagioclase Analyses : Samples From the Kumkum Area

	1	2	3	4	5	6	7	8
SiO_2	46,81	49,87	48,83	56,85	56,05	55,32	65,72	61,87
TiO_2	0,01	0,04	0,07	0,02	0,03	0,01	N.D.	0,01
Al_2O_3	34,40	32,50	32,62	27,79	28,47	28,83	22,47	25,12
FeO*	0,24	0,08	0,27	0,10	0,16	0,13	0,03	0,03
MgO	0,07	0,01	0,31	N.D.	N.D.	0,01	N.D.	N.D.
CaO	17,72	15,10	15,96	9,93	10,27	11,13	2,63	5,78
Na_2O	1,72	3,22	2,59	5,78	5,73	5,33	10,39	8,59
K_2O	0,03	0,06	0,04	0,42	0,23	0,23	0,10	0,05
Total	100,98	100,88	100,69	100,88	100,94	100,99	101,34	101,45
** Atomic Proportions Based on Selected No. of Oxygens **								
Oxygens	32	32	32	32	32	32	32	32
Si	8,538	9,031	8,889	10,137	10,002	9,890	11,420	10,832
Al	7,398	6,939	7,000	5,841	5,988	6,076	4,604	5,184
Ti	0,000	0,010	0,010	0,002	0,004	0,002		
Fe^{2+}	0,036	0,011	0,041	0,015	0,024	0,020	0,004	0,004
Mg	0,018	0,003	0,085			0,002		
Ca	3,463	2,930	3,113	1,897	1,964	2,131	0,492	1,084
Na	0,607	1,132	0,913	1,998	1,983	1,847	3,500	2,916
K	0,006	0,014	0,010	0,095	0,052	0,052	0,024	0,012
An	84,96	71,88	77,13	47,54	49,11	52,88	12,25	27,02
Ab	14,89	27,77	22,62	50,08	49,59	45,83	87,15	72,68
Or	0,15	0,34	0,25	2,38	1,30	1,29	0,60	0,30

*** Sample Directory **

1 Bytownite, Eselruh Gabbronorite, K4
2 Bytownite, Groundmass, Kumkum Gabbronorite, K37A
3 Bytownite, Phenocryst, Kumkum Gabbronorite, K37A
4 Andesine, Megacryst, Contaminated Gabbronorite, K45A
5 Andesine, Groundmass, Contaminated Gabbronorite, K45A
6 Labradorite, Granolite, K58
7 Oligoclase, Black Gneiss, KK7 (Av of 2 Analyses)
8 Oligoclase, Black Gneiss, K101
9 Andesine, Black Gneiss, K19A
10 Andesine, Black Gneiss, A3
11 Andesine, Black Gneiss, A5
12 Andesine, Black Gneiss, K35
13 Oligoclase, Black Gneiss, K66B
14 Oligoclase, Black Gneiss, KK6

** N.D. = Not Determined **

Plagioclase Analyses : Samples From the Kumkum Area

	9	10	11	12	13	14
SiO_2	60,09	58,75	58,85	59,19	62,35	64,61
TiO_2	0,02	N.D.	N.D.	N.D.	N.D.	N.D.
Al_2O_3	25,59	26,91	26,81	26,03	23,76	22,66
FeO	0,22	0,11	0,07	0,02	0,01	0,03
MgO	0,03	0,01	N.D.	N.D.	N.D.	N.D.
CaO	6,55	7,92	7,90	7,43	4,81	3,37
Na_2O	7,80	6,88	6,96	7,63	9,18	10,26
K_2O	0,20	0,19	0,11	0,13	0,14	N.D.
Total	100,50	100,78	100,69	100,43	100,25	100,93
** Atomic Proportions Based on Selected No. of Oxygens **						
Oxygens	32	32	32	32	32	32
Si	10,660	10,416	10,436	10,528	11,032	11,304
Al	5,352	5,624	5,604	5,460	4,956	4,676
Ti	0,004					
Fe	0,032	0,016	0,012	0,004		0,004
Mg	0,008	0,004				
Ca	1,244	1,504	1,500	1,416	0,912	0,632
Na	2,684	2,368	2,396	2,632	3,148	3,480
K	0,044	0,044	0,024	0,028	0,032	0,000
An	31,32	38,41	38,27	34,74	22,29	15,37
Ab	67,57	60,47	61,12	64,57	76,93	84,63
Or	1,11	1,12	0,61	0,69	0,78	0,00

Brown Mica Analyses : Rocks From the Kumkum Area

	1	2	3	4	5	6	7	8
SiO_2	35,17	36,86	34,88	36,12	34,48	34,84	36,54	34,46
TiO_2	6,05	5,53	6,06	7,28	4,55	3,43	2,34	4,29
Al_2O_3	16,21	15,89	14,70	14,36	18,62	19,15	17,54	17,86
FeO	13,80	9,58	22,14	17,56	19,66	18,41	14,75	19,30
MnO	0,03	0,02	0,08	0,07	N.A.	0,03	0,02	0,06
MgO	14,40	17,80	9,49	12,01	9,08	10,00	15,22	9,85
CaO	0,02	0,05	0,03	0,09	0,05	0,02	N.D.	0,04
Na_2O	0,35	0,40	0,07	N.D.	0,02	N.D.	0,54	0,24
K_2O	9,23	9,48	9,20	9,79	9,51	9,82	8,31	8,77
Total	95,26	95,60	96,63	97,27	95,97	95,70	95,26	94,86
** Atomic Proportions Based on Selected No. of Oxygens **								
Oxygens	22	22	22	22	22	22	22	22
Si	5,250	5,364	5,345	5,385	5,238	5,275	5,414	5,276
Ti	0,679	0,605	0,698	0,816	0,520	0,391	0,261	0,494
Al	2,852	2,726	2,655	2,523	3,334	3,417	3,063	3,223
Fe^{2+}	1,723	1,166	2,838	2,189	2,498	2,331	1,828	2,471
Mn	0,004	0,002	0,010	0,009		0,004	0,003	0,008
Mg	3,204	3,860	2,167	2,668	2,055	2,256	3,361	2,248
Ca	0,003	0,008	0,005	0,014	0,007	0,003		0,007
Na	0,101	0,113	0,021		0,006	0,000	0,155	0,071
K	1,758	1,760	1,799	1,862	1,843	1,897	1,571	1,713
Sum	15,57	15,60	15,54	15,47	15,50	15,57	15,66	15,51
$100\ Mg/Mg+Fe^{2+}$	65,03	76,80	43,30	54,93	45,14	49,18	64,77	47,64

Brown Mica Analyses : Rocks From the Kumkum Area (cont.)

	9	10	11	12	13	14	15
SiO_2	34,73	34,92	35,30	34,65	34,97	35,19	35,91
TiO_2	3,17	3,81	3,09	3,73	4,45	4,41	3,34
Al_2O_3	18,23	18,18	18,50	17,08	17,13	16,26	16,30
FeO	18,23	16,81	17,14	18,57	18,11	17,52	15,36
MnO	0,06	N.A.	0,02	N.D	0,03	0,03	0,07
MgO	10,30	10,90	10,82	10,34	10,27	11,35	13,70
CaO	0,03	0,02	0,03	0,03	0,01	0,05	0,01
Na_2O	0,15	0,02	N.D	0,16	0,15	0,04	0,24
K_2O	9,45	9,75	9,51	9,73	9,33	9,20	9,18
Total	94,35	94,40	94,40	94,28	94,44	94,05	94,10
** Atomic Proportions Based on Selected No. of Oxygens **							
Oxygens	22	22	22	22	22	22	22
Si	5,331	5,325	5,373	5,352	5,361	5,402	5,446
Ti	0,366	0,437	0,354	0,433	0,513	0,509	0,381
Al	3,299	3,268	3,319	3,109	3,096	2,942	2,913
Fe^{2+}	2,340	2,144	2,182	2,399	2,322	2,250	1,948
Mn	0,008		0,003		0,003	0,004	0,009
Mg	2,356	2,477	2,455	2,380	2,347	2,597	3,095
Ca	0,005	0,003	0,005	0,005	0,001	0,007	0,001
Na	0,045	0,006		0,048	0,046	0,013	0,070
K	1,851	1,897	1,847	1,917	1,824	1,802	1,775
Sum	15,60	15,56	15,54	15,64	15,51	15,523	15,639
100 $Mg/Mg+Fe^{2+}$	50,17	53,60	52,94	49,80	50,27	53,58	61,37

*** Sample Directory ***

1 Biotite, Kumkum Gabbronorite, K37A
2 Phlogopite, Eselruh Gabbronorite, K4
3 Biotite, Granolite, K58
4 Biotite, Contaminated Gabbronorite, K45A
5 Biotite, High Titanium, Black Gneiss, KK7(Av of 2 Analyses)
6 Biotite, Low Titanium, Black Gneiss, KK7
7 Biotite, Black Gneiss, K101
8 Biotite, High Titanium, Black Gneiss, K19A
9 Biotite, Low Titanium, Black Gneiss, K19A
10 Biotite, High Titanium, Black Gneiss, A3
11 Biotite, Low Titanium, Black Gneiss, A3
12 Biotite, Black Gneiss, A5
13 Biotite, Black Gneiss, K66B
14 Biotite, Black Gneiss, K35
15 Biotite, Black Gneiss, KK6

** N.A. = Not Analysed **
N.D. = Not Detected

Spinellid And Ilmenite Analyses : Rocks From The Kumkum Area

	1	2	3	4	5	6
SiO_2	0,04	N.D.	N.D.	0,03	0,03	N.D.
TiO_2	N.D.	0,03	0,58	N.D.	7,04	49,49
Al_2O_3	N.D.	60,89	0,19	58,92	60,61	0,12
Cr_2O_3	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Fe_2O_3	68,55	3,02	67,77	4,05	0,00	6,48
FeO	30,92	25,84	31,62	29,96	25,90	44,48
MnO	N.D.	0,05	0,03	0,05	0,03	N.D.
MgO	N.D.	10,34	N.D.	7,52	5,95	N.D.
CaO	N.D.	N.D.	0,03	N.A.	N.D.	0,02
Na_2O	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
K_2O	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Total	99,52	100,17	100,23	100,54	99,58	100,59
** Atomic Proportions Based on Selected No. of Oxygens **						
Oxygens	4	4	4	4	4	3
Si	0,002			0,001	0,001	
Al		1,937	0,009	1,914	1,926	0,004
Ti		0,001	0,017		0,143	0,937
Cr						
Fe^{3+}	1,997	0,061	1,957	0,084		0,123
Fe^{2+}	1,001	0,583	1,015	0,691	0,584	0,936
Mn		0,001	0,001	0,001	0,001	
Mg		0,416		0,309	0,239	
Ca			0,001			0,001
Na						
K						
Sum	3,000	3,000	3,000	3,000	2,893	2,000
	US 0,00		US 1,68			IL 93,85
	MT 100,00		MT 98,32			GK 0,00
						HM 6,15

*** Sample Directory **

1 Magnetite, Black Gneiss, K19A
2 Hercynite-Spinel, Kumkum Gabbronorite, K37A
3 Magnetite, Black Gneiss, K101
4 Hercynite-Spinel, Black Gneiss, K101
5 Hercynite-Ulvöspinel-Spinel, Black Gneiss, K101
6 Ilmenite, Black Gneiss, KK7

** N.D. = Not Detected **
N.A. = Not Analysed

$$\text{Mol \% US} = \frac{Ti^{4+} \times 100}{Fe^{3+}/2 + Ti^{4+}} \quad : \quad \text{Mol \% MT} = 100\left(\frac{0{,}5\ Fe^{3+}}{Ti^{4+} + \frac{Fe^{3+}}{2}}\right)$$

$$\text{Mol \% IL} = \frac{(Ti^{4+} - Mg^{2+})100}{Ti^{4+} + \frac{Fe^{3+}}{2}} \quad : \quad \text{Mol \% GK} = \frac{100\ Mg^{2+}}{Ti^{4+} + \frac{Fe^{3+}}{2}} \quad :$$

$$\text{Mol \% HM} = \frac{100 \times Fe^{3+}}{Fe^{3+} + 2(Ti^{4+} - Mg^{2+})}$$

Where US = Ulvöspinel, MT = Magnetite, IL = Ilmenite,
GK = Geikelite, HM = Haematite

K-Feldspar Analyses: Samples From the Kumkum Area

	1	2	3	4
SiO_2	64,11	65,02	64,55	64,02
Al_2O_3	19,14	19,39	18,77	18,88
TiO_2	0,03	N.D.	0,12	0,09
MgO	0,01	N.D.	0,03	0,01
FeO*	0,06	0,04	0,11	0,09
MnO	N.D.	N.D.	N.A.	N.A.
CaO	0,04	0,22	0,04	0,04
Na_2O	1,98	1,72	1,65	1,36
K_2O	13,86	14,17	14,24	14,58
Total	99,23	100,56	99,52	99,07
** Atomic Proportions Based on Selected No. of Oxygens **				
Oxygens	8	8	8	8
Si	2,965	2,967	2,979	2,972
Ti	0,001	0,000	0,004	0,003
Al	1,043	1,043	1,021	1,033
Fe	0,002	0,001	0,004	0,004
Mn	0,000	0,000	-	-
Mg	0,000	0,000	0,002	0,001
Ca	0,002	0,011	0,002	0,002
Na	0,178	0,152	0,148	0,122
K	0,818	0,825	0,839	0,864
Sum	5,010	5,000	5,000	5,001
Ca	0,002	0,010	0,002	0,002
Na	0,178	0,154	0,149	0,123
K	0,820	0,834	0,848	0,874

*** Sample Directory ***

1. Microcline, Black Gneiss, K19A
2. Microcline, Black Gneiss, A3
3. Microcline, Black Gneiss, K66
4. Microcline, Black Gneiss, K35

** N.A. - Not Analysed **

N.D. - Not Detected

Cordierite Analyses : Rocks From the Kumkum Area

	1	2	3	4	5	6	7	8	9
SiO_2	47,97	48,19	48,30	48,71	48,02	48,43	48,84	48,80	48,07
Al_2O_3	33,45	33,27	33,63	33,82	33,29	33,50	33,42	33,87	33,89
TiO_2	0,07	0,03	0,02	0,01	0,02	0,02	N.D.	0,02	N.D.
MgO	8,76	9,15	9,01	10,13	9,09	8,91	9,45	9,33	10,14
FeO*	6,84	6,08	6,53	5,29	6,57	7,17	6,33	6,50	4,97
MnO	0,03	0,06	0,07	0,02	0,05	N.D.	0,08	0,16	N.D.
CaO	0,04	0,02	0,03	0,14	0,03	0,02	0,02	0,01	N.D.
Na_2O	0,07	N.D.	0,01	N.D.	N.D.	0,12	0,11	0,10	0,15
K_2O	0,54	N.D.	N.D.	N.D.	0,04	0,01	0,04	0,08	0,01
Total	97,77	96,79	97,60	98,10	97,11	98,18	98,25	98,87	97,24

** Atomic Proportions Based on Selected No. of Oxygens **

Oxygens	9	9	9	9	9	9	9	9	9
Si	2,478	2,492	2,483	2,478	2,483	2,483	2,492	2,480	2,465
Al	2,028	2,028	2,038	2,028	2,029	2,025	2,011	2,029	2,049
Ti	0,003	0,001	0,001	0,000	0,001	0,001	0,000	0,001	0,000
Fe^{2+}	0,296	0,263	0,281	0,225	0,284	0,307	0,270	0,276	0,213
Mn	0,001	0,003	0,003	0,001	0,002	0,000	0,003	0,007	0,000
Mg	0,674	0,705	0,690	0,768	0,701	0,681	0,719	0,706	0,775
Ca	0,002	0,001	0,002	0,007	0,002	0,001	0,001	0,000	0,000
Na	0,007	0,000	0,001	0,000	0,000	0,012	0,011	0,010	0,015
K	0,036	0,000	0,000	0,000	0,003	0,001	0,003	0,005	0,001
$100\ Mg/Mg+Fe^{2+}$	69,48	72,83	71,06	77,34	71,17	68,93	72,70	71,89	78,44

Cordierite Analyses : Rocks From the Kumkum Area

*** Sample Directory ***

1 Rim, Black Gneiss, A3 (Av of 3 Analyses)

2 Rim, Discrete Grain, Black Gneiss, A3

3 Rim, Breakdown Product of Garnet, Black Gneiss, A5 (Av of 3 Analyses)

4 Rim, Black Gneiss, K35

5 Rim, Black Gneiss, KK7 (Av of 3 Analyses)

6 Rim, Black Gneiss, K66B (Av of 2 Analyses)

7 Rim, Breakdown product of Garnet, Black Gneiss, K19A (Av of 2 Analyses)

8 Rim, Black Gneiss, KK6 (Av of 2 Analyses)

9 Rim, Black Gneiss, K101

** N.D. = Not Detected **

FeO* = Total Iron as FeO

Garnet Analyses : Samples From the Kumkum Area

	1	2	3	4	5	6	7	8
SiO_2	37,19	37,01	37,46	37,47	38,01	37,13	37,50	37,36
Al_2O_3	21,36	21,58	21,58	21,71	21,84	21,34	21,49	21,54
TiO_2	0,02	0,02	0,02	0,04	0,06	0,02	0,03	0,05
MgO	4,44	5,01	4,32	5,18	6,91	4,80	5,46	4,63
FeO*	35,05	34,93	33,77	34,48	31,97	34,29	33,04	33,83
MnO	1,11	1,05	1,63	1,32	0,67	1,49	1,18	2,09
CaO	1,14	1,00	1,48	0,31	1,06	1,22	1,15	0,97
Total	100,31	100,60	100,26	100,51	100,51	100,30	99,84	100,47
** Atomic Proportions Based on Selected No. of Oxygens **								
Oxygens	12	12	12	12	12	12	12	12
Si	2,970	2,944	2,982	2,970	2,972	2,962	2,979	2,971
Al	2,010	2,024	2,025	2,029	2,013	2,006	2,013	2,019
Ti	0,001	0,001	0,001	0,002	0,004	0,001	0,002	0,003
Fe^{2+}	2,341	2,324	2,248	2,286	2,091	2,287	2,196	2,251
Mn	0,075	0,071	0,110	0,089	0,044	0,101	0,079	0,141
Mg	0,528	0,594	0,513	0,612	0,806	0,571	0,647	0,549
Ca	0,098	0,085	0,126	0,027	0,089	0,104	0,098	0,083
$100\ Mg/Mg+Fe^{2+}$	18,40	20,36	18,58	21,12	27,82	19,98	22,76	19,61
** Garnet End-Members† **								
Pyrope	17,21	19,59	17,18	20,60	27,09	19,27	21,69	18,48
Almandine	76,90	74,90	74,88	75,55	68,45	73,79	72,39	73,99
Spessartine	2,61	2,39	3,71	2,98	1,47	3,40	2,65	4,73
Grossular	3,29	3,12	4,23	0,87	2,99	3,54	3,27	2,80

Garnet Analyses : Samples From the Kumkum Area (cont.)

	9	10	11
SiO_2	36,99	38,06	37,63
Al_2O_3	21,73	22,22	22,14
TiO_2	0,06	0,04	0,03
MgO	4,85	7,92	6,11
FeO*	35,52	30,94	33,14
MnO	0,34	1,05	1,42
CaO	0,89	0,89	1,05
Total	100,37	101,11	101,52
** Atomic Proportions Based on Selected No. of Oxygens **			
Oxygens	12	12	12
Si	2,946	2,947	2,940
Al	2,041	2,028	2,039
Ti	0,004	0,002	0,002
Fe^{2+}	2,366	2,004	2,165
Mn	0,023	0,069	0,094
Mg	0,576	0,913	0,711
Ca	0,076	0,074	0,088
100 $Mg/Mg+Fe^{2+}$	19,58	31,30	24,72
** Garnet End-Members† **			
Pyrope	19,54	31,03	24,20
Almandine	77,10	64,14	69,62
Spessartine	0,78	2,32	3,21
Grossular	2,58	2,51	2,97

Garnet Analyses : Rocks From the Kumkum Area

*** Sample Directory ***

1 Rim, Black Gneiss, A3 (Av of 3 Analyses)
2 Core, Black Gneiss, A3
3 Rim, Black Gneiss, A5 (Av of 3 Analyses)
4 Rim, Black Gneiss, KK7 (Av of 3 Analyses)
5 Rim, Groundmass, Black Gneiss, K35
6 Core, Porphyroblast, Black Gneiss, K35
7 Rim, Porphyroblast, Black Gneiss, K35
8 Rim, Black Gneiss, K19A, (Av of 2 Analyses)
9 Rim, Black Gneiss, K66B (Av of 2 Analyses)
10 Core, Black Gneiss, K101
11 Rim, Black Gneiss, K101 (Av of 2 Analyses)

** FeO* = Total Iron as FeO **

† Calculated using the method of Rickwood (1968)

Table 44: Major (in Wt%) and trace element (in p.p.m.) analyses of rocks from the Tantalite valley and Kumkum areas

AMPHIBOLITES

	AM76	AM77	AM113	AM157	K94	K40	NAM-ORTHO	D86 PARA
SiO_2	40,33	54,03	51,24	41,47	47,97	42,43	54,02	47,32
TiO_2	2,00	0,62	1,13	0,26	1,11	1,02	0,67	0,56
Al_2O_3	22,95	9,73	6,98	11,21	4,79	17,66	15,13	24,29
Fe_2O_3	5,79	2,73	4,36	1,76	2,67	5,48	0,90	1,79
FeO	4,72	6,33	10,63	8,05	7,91	8,16	6,75	4,33
MnO	0,20	0,21	0,20	0,34	0,32	0,14	0,25	0,10
MgO	4,50	10,95	10,45	18,19	7,94	8,21	9,53	4,24
CaO	17,34	12,07	10,93	4,68	11,12	12,16	10,62	13,91
Na_2O	0,61	0,70	1,46	0,72	1,16	1,34	0,69	2,01
K_2O	0,16	0,36	0,69	5,20	0,38	0,99	0,17	1,11
P_2O_5	0,42	0,10	0,10	0,07	0,11	0,07	0,28	0,06
S	(0,00)	(0,02)	(0,02)	(0,03)				
CO_2					0,08	0,08		
H_2O^+					1,16	1,77		
H_2O^-	0,73	1,23	0,08	0,13	0,13	0,20	0,08	0,05
LOI	0,57	0,80	2,12	4,57			0,50	1,36
Sum	100,32	99,86	100,37	96,65$^+$	96,85	99,71	99,59	101,13
Ba							30	117
Sr	1759	140	54	42	119	606	302	230
Rb	<5	4	9	990	7	27	6	64
Y	52	41	34	42			18	14
Zr	341	29	57	20			92	42
Nb	27	<5	<5	26			3	1
Zn	97	93	148	633	133	69	210	44
Cu	b.d.l.	79	40	b.d.l.	b.d.l.	738	11	2
Ni	30	53	24	270	62	134	240	38
Co	32	50	73	75	29	73	42	28
Cr	84	812	31	1448	252	90	519	150
V	226	246	535	87	175	400	168	130
WO_3^+				3,51%				
Fe_2O_3/FeO	1,23	0,43	0,41	0,22	0,34	0,67		
K/Rb	>266	768	646	47	451	311		
Nb/Y	0,519	$<0,122$	$<0,147$	0,619				
Zr/P_2O_5	0,081	0,029	0,057	0,025				
Y/Nb	1,926	$>8,200$	$>6,800$	1,615				
Rb/Sr	$<0,003$	0,029	0,167	23,571	0,059	0,045		
A %	34,27	14,47	9,72	7,70	7,48	24,71		
C	41,04	31,63	28,86	11,63	35,70	30,32		
F	24,69	53,89	61,42	80,67	56,82	44,97		
A' %	46,59	13,97	9,70	13,64	4,51	30,62		
K	0,50	0,89	1,58	7,65	1,21	2,21		
F	52,91	85,14	88,72	78,71	94,28	67,17		
Fig 90	marl with 35-65% carbonate	Basaltic rocks	Basaltic rocks	Ultra-basic	marl with 35-65% carbonate	Basaltic rocks		

NAMORTHO - average of 8 orthoamphibolite analyses from the Namiesberg, Bushmanland (Moore 1977)

D86 PARA - Lower amphibolite (para-) from the Namiesberg (Moore 1977)

b.d.l. = below detection limit

METABASITE HORNFELS FROM TANTALITE VALLEY

	TV9 212	TV13 98	TV13 149	TV13 151
SiO_2	35,18	50,71	45,76	43,93
TiO_2	0,20	2,22	0,13	0,19
Al_2O_3	13,29	21,06	15,69	18,10
Fe_2O_3	20,10	1,57	4,96	7,73
FeO	7,88	3,20	7,82	6,43
MnO	0,26	0,08	0,19	0,14
MgO	7,14	5,09	11,32	8,05
CaO	5,38	9,66	8,28	7,43
Na_2O	0,81	3,48	0,81	1,46
K_2O	0,65	0,23	0,28	0,37
P_2O_5	0,02	0,74	0,01	0,05
L.O.I.		1,88		
CO_2	0,32		0,13	0,16
H_2O^+	4,64		2,52	2,22
H_2O^-	0,12	0,05	0,67	0,91
Sum	95,99	99,97	98,57	97,17
S(%)	2,72	0,20	1,13	1,91
Zn	63	38	92	74
Cu	2106	766	1733	3330
Ni	10041	255	1750	2795
Co	239	65	133	170
Cr	253	57	396	295
V	112	70	50	60
Fe_2O_3/FeO	2,55	0,49	0,63	1,20
A %	37,97	32,57	23,84	31,97
C	15,36	31,99	20,79	21,13
F	46,67	35,44	55,37	46,90
A′%	44,96	48,35	28,58	40,44
K	1,28	0,71	0,54	0,79
F	53,77	50,93	70,88	58,77
Fig 90	greywacke	marls with 35-65% carbonate	greywacke	greywacke
Niggli <u>mg</u>	0,61	0,73	0,72	0,69

Pelitic hornfels (TV276, TV4, TV13 165, T19) orthopyroxene-bearing hornfels (TV226) and cordierite-anthophyllite hornfels (TV170) from Tantalite Valley

	TV276	TV4	TV13 165	T19	TV226	TV170	A	B
SiO_2	52,79	39,12	54,65	42,29	45,99	48,64	59,93	63,51
TiO_2	0,87	1,63	1,06	1,74	0,71	0,42	0,85	0,79
Al_2O_3	23,49	26,44	21,62	28,20	16,29	28,52	16,62	17,35
Fe_2O_3	5,13	1,40	4,28	4,14	2,00	0,81	3,03	2,00
FeO	8,29	12,77	6,22	12,83	8,98	4,98	3,18	4,71
MnO	0,17	0,28	0,10	0,71	0,17	0,08	-	-
MgO	4,40	5,43	4,61	5,20	22,97	10,67	2,63	2,31
CaO	0,24	5,80	2,77	1,03	0,73	0,16	21,8	1,24
Na_2O	0,39	0,76	1,70	0,61	0,33	0,58	1,73	1,96
K_2O	1,10	2,31	0,66	0,55	0,34	0,84	3,54	3,35
P_2O_5	0,03	0,03	0,03	0,01	0,30	0,01	-	-
H_2O^+	2,90	2,52	2,42	2,07	0,77	3,39	4,34	2,42
H_2O^-	0,11	0,22	0,22	0,25	0,13	0,12	-	-
CO_2	0,15	0,11	n.a.	0,09	0,11	0,10	2,31	0,22
Sum	100,06	98,82	100,34	99,72	99,82	99,32	100,34	99,86
S(%)	0,16	0,35	0,00	0,00	0,00	n.a.	-	-
Zn	107	725	200	115	375	30		
Cu	70	620	45	3	2	2		
Ni	95	425	75	170	375	15		
Nb	8	10	6	30	4	7		
Zr	280	105	330	320	95	620		
Y	15	10	20	85	10	25		
Rb	75	55	20	30	15	25		
Sr	35	390	290	70	10	25		
Co	35	50	35	35	50	10		
Cr	230	310	200	430	1040	20		
V	150	230	160	200	135	30		
Ba	195	1185			535	165		
Sc	20	28			25	10		

A = Worldwide average of clays, shales and slates : 85 analyses (except CO_2, 43 analyses) Shaw (1956)

B = Worldwide average of pelitic phyllites, shists and gneisses : 70 analyses (except CO_2, 19 analyses). Shaw (1956)

n.a. = not analysed

A	51,06	36,92	44,44	46,03	18,60	45,00
C	-	15,38	11,11	3,17	1,16	-
F	48,94	47,69	44,44	50,79	80,23	55,00
A'	47,83	43,10	52,27	48,44	19,77	46,03
K	2,17	3,45	2,27	1,56	-	1,59
F	50,00	53,45	45,45	50,00	80,23	52,38

BLACK GNEISS

	K35	KK7	K101	GBW302	GBW98	GBW241
SiO_2	53,18	62,37	39,05	45,60	43,70	57,07
TiO_2	1,50	1,03	0,97	2,49	1,35	1,41
Al_2O_3	22,66	17,86	23,66	28,76	30,14	20,51
Fe_2O_3	0,94	3,29	5,21	1,00	3,75	0,61
FeO	10,93	7,34	13,69	9,10	11,14	9,06
MnO	0,23	0,15	0,26	0,21	0,39	0,18
MgO	4,12	2,92	10,67	7,29	6,23	3,29
CaO	0,96	0,20	0,68	1,30	0,54	1,01
Na_2O	1,26	1,04	0,57	0,91	0,44	1,52
K_2O	2,58	2,35	2,34	1,44	0,50	4,47
P_2O_5	0,06	0,02	0,29	0,06	0,05	0,11
Cr_2O_3	-	-	-	0,06	0,07	0,04
L.O.I.	-	-	-	1,27	1,37	1,16
CO_2	0,18	0,12	0,10	-	-	-
H_2O^+	0,57	1,38	2,10	-	-	-
H_2O^-	0,14	0,18	0,33	0,10	0,10	0,07
Sum	99,31	100,25	99,92	99,59	99,77	100,51
A %	38	38	33	44	49	37
C	3	1	1	4	2	5
F	59	61	66	52	49	58
A´%	42	42	35	42	48	31
K	5	6	3	3	1	13
F	52	52	61	55	51	56
A_{Kf}	0,42	0,41	-	-	-	0,43
M_{Kf}	0,38	0,34	-	-	-	0,39
A_{bi}	-	-	0,39	0,53	0,50	-
M_{bi}	-	-	0,54	0,63	0,50	-

BLACK GNEISS

	K35	KK7	K101	Average Shale*
Co	36	35	44	20
Cr	158	160	107	100
V	215	120	177	130
Ni	78	62	12	70
Cu	30	22	b.d.l.	50
Zn	127	154	160	100
Rb	79	39	116	140
Sr	99	78	16	300
Ba	1094	1160		700
Sc	31	12		15
Zr	236	332		160
Y	47	8		25
Nb	21	< 4		11

* Turekian and Wedepohl (1961) and Taylor (1965)

TANTALITE VALLEY MOTTLED METAGABBRO

	TV294	TV288	TV275A	TV298	JWVB46
SiO_2	49,66	50,96	48,81	50,28	58,20
TiO_2	1,00	0,90	0,87	0,77	1,23
Al_2O_3	16,58	16,23	20,13	16,56	15,42
Fe_2O_3	2,31	1,86	2,67	2,81	1,19
FeO	8,50	8,04	6,78	6,78	6,99
MnO	0,24	0,18	0,07	0,17	0,18
MgO	5,98	6,56	4,88	6,64	4,06
CaO	10,09	8,88	11,34	9,88	8,21
Na_2O	2,04	2,51	1,79	2,90	2,10
K_2O	0,98	1,22	0,78	0,53	0,14
P_2O_5	0,25	0,21	0,23	0,14	0,25
Cr_2O_3					(0,03)
LOI					1,11
CO_2	0,18	0,13	0,15	0,11	
H_2O^+	1,82	1,82	1,90	1,74	
H_2O^-	0,05	0,05	0,42	0,19	0,08
Sum	99,68	99,55	100,82	99,50	99,16
Sr	313	337	366	333	
Rb	36	53	50	12	
Y	30	31	23	22	
Zr	86	101	67	66	
Nb	7	7	< 5	< 5	
Zn	120	98	74	94	
Cu	6	85	90	138	
Ni	64	151	59	108	
Co	44	53	40	55	
Cr	183	194	193	66	205
V	233	192	173	180	
K/Rb	231	196	131	374	

TANTALITE VALLEY METAGABBRO

	TV277	TV42	TV182	TV8	TV77	TV265	TV126	TV217	GBW193	JWVB20	JWVB22	JWVB24
SiO_2	47,09	48,78	50,12	49,14	48,27	48,92	48,33	50,33	49,05	50,59	50,51	50,72
TiO_2	0,41	0,20	0,27	0,19	0,15	0,42	0,24	0,29	0,27	0,20	0,29	0,26
Al_2O_3	19,85	20,79	19,04	23,24	19,61	15,89	29,28	17,04	23,52	19,89	18,94	17,27
Fe_2O_3	2,25	0,75	1,43	1,25	1,10	2,39	0,01	0,45	1,02	0,27	0,78	1,18
FeO	6,10	5,25	4,38	3,30	5,00	8,30	1,70	5,26	3,26	5,12	6,06	5,97
MnO	0,15	0,08	0,07	0,04	0,10	0,15	0,01	0,07	0,07	0,11	0,13	0,13
MgO	8,09	7,50	7,56	5,47	10,56	11,94	1,03	8,19	5,30	7,78	10,18	9,37
CaO	10,12	13,55	13,20	14,04	10,87	8,21	15,10	13,93	13,63	13,12	10,44	13,10
Na_2O	1,36	1,39	1,52	1,80	0,85	0,43	2,21	1,61	2,06	1,40	1,08	1,01
K_2O	0,79	0,16	0,17	0,18	0,23	0,50	0,15	0,22	0,03	0,16	0,10	0,09
P_2O_5	0,11	0,06	0,08	0,06	0,04	0,10	0,13	0,06	0,05	0,01	0,04	0,02
Cr_2O_3									(0,05)	(0,06)	(0,10)	(0,05)
LOI									1,51	1,44	1,71	1,60
CO_2	0,16	0,10	0,13	0,26	0,23	0,14	0,11	0,49				
H_2O^+	3,58	1,46	1,30	1,39	1,92	2,87	0,78	1,62				
H_2O^-	0,00	0,26	0,24	0,08	0,00	0,00	0,25	0,21	0,15	0,11	0,15	0,05
Sum	100,06	100,33	99,51	100,44	98,93	100,26	99,33	99,77	99,92	100,20	100,41	100,77
Sr	391	440	263	471	333	261	572	424				
Rb	34	4	<4	<4	5	21	<4	<4				
Y	13	6	8	7	6	10	7	10				
Zr	34	14	17	12	11	27	23	13				
Nb	<5	<4	<4	<4	<4	<5	<4	<4				
Zn	65	39	42	36	45	86	9	36				
Cu	121	39	59	78	103	191	72	145				
Ni	246	177	90	110	353	374	17	120				
Co	58	39	40	30	51	83	6	39				
Cr	251	592	207	449	684	91	74	936	342	410	684	342
V	79	80	103	67	61	102	37	129				
K/Rb	200	332	>353	>374	398	202	>311	>477				

TANTALITE VALLEY GABBRONORITE

	TV210	TV205A	TV282	TV170	TV199	T36	GBW195	JWVB25	JWVB26
SiO_2	50,39	47,73	48,26	48,18	47,63	50,86	51,77	50,83	50,83
TiO_2	0,32	0,43	0,26	0,25	0,29	0,21	0,15	0,43	0,25
Al_2O_3	22,16	20,31	21,35	20,94	27,17	17,63	20,71	21,11	17,89
Fe_2O_3	1,62	2,39	1,09	0,31	0,94	1,50	0,56	1,09	0,78
FeO	3,96	6,80	3,34	5,88	2,74	5,71	4,40	4,45	5,45
MnO	0,03	0,12	0,07	0,07	0,06	0,15	0,08	0,09	0,12
MgO	5,53	9,61	5,86	7,95	3,44	9,58	7,47	6,35	9,46
CaO	12,16	9,97	15,93	13,31	13,58	11,69	12,18	11,58	13,25
Na_2O	2,15	1,79	1,63	1,63	1,92	1,95	1,30	2,23	1,50
K_2O	0,33	0,35	0,19	0,24	0,27	0,24	0,24	0,44	0,13
P_2O_5	0,10	0,07	0,08	0,08	0,02	0,13	0,01	0,08	0,01
Cr_2O_3							(0,24)	(0,05)	(0,06)
LOI						0,68	0,00	1,16	0,71
CO_2	0,38	0,50	0,18	0,27	0,30				
H_2O^+	0,76	0,74	0,65	0,76	0,83				
H_2O^-	0,21	0,17	0,19	0,24	0,14	0,01	0,15	0,12	0,08
Sum	100,10	100,98	99,26	100,11	99,33	100,34	99,02	100,01	100,52
Ba					123				
Sr	446	409	406	424	483	307			
Rb	<4	<4	<4	<4	6	<4			
Y	8	9	9	8	6	9			
Zr	21	22	15	17	16	10			
Nb	<4	<5	<4	<4	<4	<4			
Zn	35	65	25	39	29	75			
Cu	101	73	137	161	78	171			
Ni	60	433	113	168	64	163			
Co	33	72	29	50	23	52			
Cr	125	106	1125	370	150	435	1642	342	411
V	84	90	89	71	71	93			
Sc					13				
K/Rb	>685	>726	>394	>498	387	>498			

ULTRAMAFIC ROCKS FROM TANTALITE VALLEY AREA

	AM88A	AM89B	T5	T6	T7	T10	T11	GBW376	GBW374
SiO_2	42,12	37,62	47,32	47,45	39,51	34,38	52,39	38,77	44,63
TiO_2	0,20	0,11	0,19	0,29	0,19	0,16	0,29	0,07	0,20
Al_2O_3	3,32	4,56	6,03	6,07	5,81	1,95	4,65	6,69	3,78
Fe_2O_3	6,96	9,05	2,70	1,68	5,33	7,97	1,60	8,94	4,32
FeO	5,62	2,90	8,12	8,28	7,64	7,57	8,20	5,62	8,42
MnO	0,18	0,17	0,17	0,09	0,14	0,14	0,18	0,17	0,20
MgO	29,81	30,16	27,54	26,03	30,51	33,16	25,90	27,39	28,99
CaO	2,33	3,31	3,24	3,25	2,94	0,89	2,58	3,15	2,82
Na_2O	0,02	0,04	0,28	0,09	0,08	0,10	0,38	0,28	0,16
K_2O	0,01	0,02	0,19	0,29	0,03	0,28	0,45	0,02	0,03
P_2O_5	0,03	0,01	0,04	0,09	0,05	0,02	0,11	0,00	0,07
Cr_2O_3								(0,36)	(0,90)
LOI	8,02	10,18	3,90	6,05	7,33		2,23	8,56	6,17
CO_2						0,70			
H_2O^+						9,07			
H_2O^-	0,25	0,37	0,13	0,17	0,21	0,28	0,23	0,29	0,15
Sum	98,87	98,50	99,85	99,83	99,77	96,67	99,19	99,95	99,94
Ba									
Sr	21	51	85	15	18	31	48		
Rb	< 4	< 4	8	86	6	9	17		
Y	5	< 3	5	8	5	< 4	8		
Zr	21	6	17	46	15	16	37		
Nb	< 4	< 4	< 4	< 4	< 4	< 4	< 4		
Zn	88	84	75	102	83	23	54		
Cu	41	16	50	86	115	4091	3050		
Ni	1417	2231	957	1116	1995	9495	3364		
Co	146	146	129	114	169	250	124		
Cr	2728	4433	3514	3510	3698	302	2478	2463	6158
V	67	63	75	84	63	20	89		
Sc									
S(%)	0,05	0,04	0,03	0,11	1,08	0,35			
K/Rb	> 20,75	> 41,5	207,5	29,92	41,5	295,11	229,47		

ULTRAMAFIC ROCKS FROM TANTALITE VALLEY AREA CONTD.

	TV45	TV30	TV117	TV157A	GBW421	GBW380
SiO_2	39,89	52,69	42,80	43,84	44,41	45,74
TiO_2	0,13	0,26	0,11	0,16	0,52	0,10
Al_2O_3	5,77	6,08	14,33	1,86	9,55	1,15
Fe_2O_3	9,93	2,41	1,74	2,05	2,50	6,83
FeO	3,20	8,10	8,00	10,24	8,82	5,65
MnO	0,15	0,18	0,13	0,22	0,17	0,21
MgO	28,68	23,08	21,10	29,56	23,17	31,38
CaO	2,75	3,93	6,54	5,31	6,62	2,55
Na_2O	0,10	0,45	0,42	0,11	1,03	0,22
K_2O	0,08	0,16	0,12	0,03	0,05	0,03
P_2O_5	0,06	0,04	0,04	0,01	0,05	0,00
Cr_2O_3					(0,47)	(0,45)
LOI					2,41	5,66
CO_2	0,16	0,14	0,15	0,16		
H_2O^+	8,85	1,93	4,98	5,74		
H_2O^-	0,00	0,00	0,00	0,16	0,09	0,19
Sum	99,75	99,45	100,46	99,45	99,39	99,71
Ba				23		
Sr	47	27	47	35		
Rb	<4	<4	<4	<4		
Y	<4	8	4	7		
Zr	8	17	5	13		
Nb	<4	<4	<4	<4		
Zn	69	79	70	104		
Cu	38	584	49	1		
Ni	1992	942	735	744		
Co	154	92	106	120		
Cr	2317	2403	764	2434	3216	3079
V	44	104	36	54		
Sc				29		
S(%)						
K/Rb	$>186,75$	>332	$>269,75$	125	-	-

KUMKUM GRANOLITE (K15), TANTALITE VALLEY SATELLITE BODY (AM123A, AM125), VERLOORKOPPE GABBRONORITE (GBW1) and EINSIEDLER GABBRONORITE (GBW7)

	K15+	AM123A	AM125	GBW1	GBW7
SiO_2	48,40	55,63	50,05	50,05	46,73
TiO_2	1,86	0,38	0,79	0,94	0,35
Al_2O_3	14,37	5,21	10,48	14,32	18,41
Fe_2O_3	3,46	1,54	2,50	1,54	0,48
FeO	9,41	8,49	9,98	10,06	7,63
MnO	0,21	0,22	0,24	0,18	0,13
MgO	6,66	19,23	14,47	7,84	12,35
CaO	11,46	6,89	6,25	11,43	11,56
Na_2O	2,47	0,54	1,18	2,27	1,33
K_2O	0,23	0,67	1,31	0,08	0,04
P_2O_5	0,20	0,04	0,35	0,06	0,02
Cr_2O_3				(0,05)	(0,09)
LOI		1,11	2,71	0,46	0,47
CO_2	0,13				
H_2O^+	0,44				
H_2O^-	0,14	0,09	0,12	0,09	0,11
Sum	99,84	100,04	100,43	99,32	99,61
Ba	93				
Sr	190	86	329		
Rb	4	34	43		
Y	32	23	18		
Zr	124	53	53		
Nb	< 5	< 4	< 5		
Zn	135	108	152		
Cu	76	4	70		
Ni	67	442	321		
Co	54	83	68		
Cr	222	1469	957	342	616
V	328	121	221		
Sc	49				
K/Rb	447	166	259		

\+ K15 - A% 19,44 A'% 25,24

C 32,26 K 0,59

F 48,30 F 74,17

ESELRUH GABBRONORITE

	K59A	K60	K7
SiO_2	45,37	51,01	48,15
TiO_2	0,27	0,52	0,23
Al_2O_3	12,21	6,62	11,39
Fe_2O_3	2,68	1,46	1,29
FeO	6,31	9,56	7,85
MnO	0,16	0,22	0,18
MgO	16,85	18,73	17,17
CaO	13,63	7,91	10,01
Na_2O	0,46	0,75	1,10
K_2O	0,51	0,92	0,41
P_2O_5	0,04	0,08	0,03
CO_2	0,42	0,32	0,17
H_2O^+	1,69	1,42	0,86
H_2O^-	0,17	0,14	0,10
Sum	100,76	99,63	98,94
Ba	114	328	133
Sr	533	214	46
Rb	28	47	19
Y	10	14	13
Zr	15	39	27
Nb	< 5	< 5	< 5
Zn	58	104	63
Cu	< 2	17	8
Ni	276	466	861
Co	78	84	84
Cr	1145	1436	2257
V	120	177	146
Sc	49	43	33
K/Rb	154	166	183

KUMKUM GABBRONORITE

	K28	K22	K30A	K37A	K65	GBW225	GBW439
SiO_2	45,37	50,10	47,98	47,43	47,31	49,20	49,48
TiO_2	0,74	0,75	0,80	0,48	0,46	0,23	0,67
Al_2O_3	10,42	17,55	13,12	19,30	17,95	19,90	14,17
Fe_2O_3	1,07	1,67	1,22	1,17	3,59	0,87	1,37
FeO	11,32	8,00	9,31	7,27	5,41	6,20	8,44
MnO	0,19	0,16	0,17	0,14	0,14	0,09	0,16
MgO	20,91	8,38	14,41	10,28	11,95	10,10	12,00
CaO	7,02	10,09	9,51	10,88	9,88	9,97	10,48
Na_2O	1,34	2,05	0,80	1,86	2,31	1,85	0,92
K_2O	0,30	0,44	0,59	0,23	0,40	0,18	0,89
P_2O_5	0,11	0,13	0,15	0,06	0,06	0,04	0,12
Cr_2O_3						(0,22)	(0,18)
LOI						0,76	0,21
CO_2	0,26	0,10	0,29	0,29	0,18		
H_2O^+	0,79	0,46	0,79	0,54	0,53		
H_2O^-	0,13	0,14	0,07	0,11	0,15	0,07	0,04
Sum	99,97	100,02	99,21	100,04	100,32	99,46	99,95
Ba	137	208	183	109	140		
Sr	112	257	105	220	203		
Rb	6	9	21	4	11		
Y	19	18	22	11	14		
Zr	77	66	89	31	51		
Nb	<5	<5	<5	<4	<4		
Zn	92	75	81	58	64		
Cu	64	90	68	133	81		
Ni	755	195	515	320	505		
Co	109	60	79	75	79		
Cr	1556	249	1438	170	135	1505	1232
V	156	174	215	128	104		
Sc	25	31	37	23	19		
K/Rb	415	406	237	477	302		

CONTAMINATED GABBRONORITE

	K44	K80	K34A	K63A	K39
SiO_2	50,60	50,70	53,51	54,01	51,93
TiO_2	0,89	0,98	1,11	1,13	1,07
Al_2O_3	15,31	15,61	16,13	16,05	16,46
Fe_2O_3	1,51	3,10	1,41	1,68	1,34
FeO	8,44	8,21	9,66	8,45	9,82
MnO	0,17	0,18	0,18	0,16	0,19
MgO	7,70	7,69	6,69	6,04	7,47
CaO	10,89	9,71	8,94	8,20	9,42
Na_2O	1,69	1,69	1,46	2,05	1,56
K_2O	0,91	0,60	0,28	0,86	0,26
P_2O_5	0,12	0,17	0,18	0,24	0,18
Cr_2O_3	-	-	-	-	-
NiO	-	-	-	-	-
CO_2	0,20	0,19	0,19	0,14	0,18
H_2O^+	0,73	0,78	0,35	0,43	0,30
H_2O^-	0,18	0,24	0,22	0,17	0,22
Sum	99,34	99,85	100,31	99,60	100,40
Ba	240	248	518	884	228
Sr	128	239	210	217	212
Rb	38	18	7	17	11
Y	28	22	20	34	29
Zr	97	85	89	172	122
Nb	< 5	< 5	< 4	8	< 5
Zn	83	102	90	96	95
Cu	54	75	62	52	57
Ni	83	108	102	130	146
Co	52	54	54	51	57
Cr	198	266	138	125	184
V	229	249	224	219	224
Sc	44	42	36	30	35
K/Rb	203	281	332	425	204

GRANITIC ROCKS

	K49	TV306	GBW744	TV299	TV305	GBW458	GBW608
SiO_2	71,69	62,34	68,41	69,21	67,76	73,97	72,54
TiO_2	0,34	0,82	0,98	0,43	0,19	0,19	0,25
Al_2O_3	13,57	16,50	14,40	14,50	17,53	13,47	13,62
Fe_2O_3	0,56	2,09	0,70	1,16	0,20	0,00	0,97
FeO	2,13	4,21	4,18	2,80	1,46	1,29	1,30
MnO	0,07	0,09	0,06	0,12	0,03	0,02	0,03
MgO	0,89	1,85	1,33	1,77	0,71	0,19	0,16
CaO	1,22	4,34	2,20	2,24	2,54	1,04	0,92
Na_2O	2,38	3,42	1,86	1,89	6,39	2,34	2,64
K_2O	4,89	1,95	4,46	4,33	1,78	6,49	6,13
P_2O_5	0,12	0,20	0,10	0,05	0,08	0,06	0,05
LOI			1,19			0,47	0,78
CO_2	0,23	0,08		0,09	0,09		
H_2O^+	1,19	1,15		1,07	0,46		
H_2O^-	0,25	0,22	0,06	0,16	0,07	0,13	0,01
Sum	99,53	99,26	99,93	99,82	99,29	99,66	99,41
Ba				1459	1178		
Sr	133	407		135	639		
Rb	159	64		115	33		
Y				20	4		
Zr				253	108		
Nb				8	b.d.l.		
Zn	35	72		128	32		
Cu	10	63		14	3		
Ni	7	16		11	9		
Co	2	12		8	5		
Cr	12	28		21	15		
V	25	85		31	25		
Sc				15	4		
K/Rb	261	258		318	453		

Key: K49, TV306, GBW744 - Inequigranular granite gneiss
TV299, TV305 - Tonalite and granodiorite - Tantalite Valley
GBW458, GBW608 - Warmbad granite

TABLE 45: AVERAGE MAJOR (in Wt %) AND TRACE ELEMENT (in p.p.m.) COMPOSITIONS FOR MAFIC AND ULTRAMAFIC ROCKS FROM THE KUMKUM - TANTALITE VALLEY AREA

TANTALITE VALLEY MOTTLED METAGABBRO : MAJORS

	Range Min	- Max	S	$\bar{X}$	n
SiO_2	48,81	- 58,20	3,78	51,58	5
TiO_2	0,77	- 1,23	0,17	0,95	5
Al_2O_3	15,42	- 20,13	1,82	16,98	5
Fe_2O_3	1,19	- 2,81	0,66	2,17	5
FeO	6,78	- 8,50	0,80	7,42	5
MnO	0,07	- 0,24	0,06	0,17	5
MgO	4,06	- 6,68	1,12	5,62	5
CaO	8,21	- 11,34	1,20	9,68	5
Na_2O	1,79	- 2,90	0,44	2,27	5
K_2O	0,14	- 1,22	0,42	0,73	5
P_2O_5	0,14	- 0,25	0,05	0,22	5
CO_2	0,11	- 0,18	0,03	0,14	4
H_2O^+	1,74	- 1,90	0,06	1,82	4
H_2O^-	0,05	- 0,42	0,16	0,16	5
Total				99,91	

TANTALITE VALLEY MOTTLED METAGABBRO : TRACES

	Range Min	- Max	S	$\bar{X}$	n
Zn	74	- 120	18,86	97	4
Cn	6	- 138	54,66	80	4
Ni	64	- 151	43,05	96	4
Co	40	- 55	7,16	48	4
Cr	66	- 205	57,66	168	5
V	173	- 233	26,84	195	4
Sr	313	- 366	21,85	337	4
Rb	12	- 53	18,70	38	4
Y	22	- 31	4,65	27	4
Zr	66	- 101	16,75	80	4
Nb	<5	- 7	-	<4	4

TANTALITE VALLEY METAGABBRO : MAJORS

	Range Min	-	Max	S	$\bar{X}$	n
SiO_2	47,09	-	50,72	1,14	49,32	12
TiO_2	0,15	-	0,42	0,08	0,27	12
Al_2O_3	15,89	-	29,28	3,61	20,36	12
Fe_2O_3	0,01	-	2,39	0,72	1,07	12
FeO	1,70	-	8,30	1,69	4,98	12
MnO	0,01	-	0,15	0,04	0,09	12
MgO	1,03	-	11,94	2,87	7,75	12
CaO	8,21	-	15,10	2,04	12,44	12
Na_2O	0,43	-	2,21	0,51	1,39	12
K_2O	0,03	-	0,79	0,21	0,23	12
P_2O_5	0,01	-	0,13	0,04	0,06	12
CO_2	0,10	-	0,49	0,13	0,20	8
H_2O^+	0,78	-	3,58	0,92	1,87	8
H_2O^-	0,00	-	0,26	0,10	0,13	12
Total					100,16	

TANTALITE VALLEY METAGABBRO : TRACES

	Range Min	-	Max	S	$\bar{X}$	n
Zn	9	-	86	22,63	45	8
Cu	39	-	145	49,88	101	8
Ni	17	-	374	128,08	186	8
Co	6	-	83	22,26	43	8
Cr	91	-	936	261,15	422	12
V	37	-	129	28,67	82	8
Sr	261	-	572	106,37	394	8
Rb	<4	-	34	12,68	8	8
Y	6	-	13	2,45	8	8
Zr	11	-	34	8,31	19	8
Nb		<5		-	<4	8

TANTALITE VALLEY GABBRONORITE : MAJORS

	Range Min	-	Max	S	$\bar{X}$	n
SiO_2	47,63	-	51,77	1,63	49,61	9
TiO_2	0,15	-	0,43	0,09	0,29	9
Al_2O_3	17,63	-	27,17	2,76	21,03	9
Fe_2O_3	0,31	-	2,39	0,62	1,14	9
FeO	2,74	-	6,80	1,31	4,75	9
MnO	0,03	-	0,15	0,04	0,09	9
MgO	3,44	-	9,61	2,14	7,25	9
CaO	9,97	-	15,93	1,66	12,63	9
Na_2O	1,30	-	2,23	0,30	1,79	9
K_2O	0,13	-	0,44	0,09	0,27	9
P_2O_5	0,01	-	0,13	0,04	0,06	9
CO_2	0,18	-	0,50	0,12	0,33	5
H_2O^+	0,65	-	0,83	0,06	0,75	5
H_2O^-	0,01	-	0,24	0,07	0,15	9
Total					100,14	

TANTALITE VALLEY GABBRONORITE : TRACES

	Range Min	-	Max	S	$\bar{X}$	n
Zn	25	-	75	20,45	45	6
Cu	73	-	171	42,20	120	6
Ni	60	-	433	138,38	167	6
Co	23	-	72	18,26	43	6
Cr	106	-	1642	519,91	523	9
V	71	-	93	9,74	83	6
Sr	307	-	483	59,01	413	6
Rb	$<$ 4	-	6	-	$<$ 4	6
Y	6	-	9	1,17	8	6
Zr	10	-	22	4,36	17	6
Nb		$<$ 5		-	$<$ 4	6

TANTALITE VALLEY ULTRAMAFIC ROCKS : MAJORS

	Range Min	-	Max	S	$\bar{X}$	n
SiO_2	34,38	-	52,69	5,16	43,57	15
TiO_2	0,07	-	0,52	0,11	0,20	15
Al_2O_3	1,15	-	14,33	3,28	5,44	15
Fe_2O_3	1,60	-	9,93	3,08	4,93	15
FeO	2,90	-	10,24	2,07	7,09	15
MnO	0,09	-	0,22	0,03	0,17	15
MgO	21,10	-	33,16	3,37	27,76	15
CaO	0,89	-	6,62	1,56	3,48	15
Na_2O	0,02	-	1,03	0,26	0,25	15
K_2O	0,01	-	0,45	0,13	0,12	15
P_2O_5	0,00	-	0,11	0,03	0,04	15
LOI	2,23	-	10,18	2,61	6,05	10
H_2O^+	1,93	-	9,07	2,96	6,11	5
H_2O^-	0,00	-	0,37	0,11	0,17	15
Total					99,27	

TANTALITE VALLEY ULTRAMAFIC ROCKS : TRACES

	Ranges Min	-	Max	S	$\bar{X}$	n
Zn	23	-	104	22,58	76	11
Cu	1	-	584	181,4	109	9 *
Ni	735	-	2231	584	1348	9 *
Co	92	-	248	42,05	141	11
Cr	302	-	6158	1389	2900	15 ‡
V	20	-	104	24,44	64	11
Sr	15	-	85	20,08	39	11
Rb	$<$ 4	-	86	25,34	11	11
Y	$<$ 3	-	8	3,24	5	11
Zr	6	-	46	12,67	18	11
Nb		$<$ 4		-	$<$ 4	11

* Excluding T10 and T11

‡ Including T10

ESELRUH GABBRONORITE : MAJORS (n = 3)

	Range Min	-	Max	S	$\bar{X}$
SiO_2	45,37	-	51,01	2,82	48,18
TiO_2	0,23	-	0,52	0,16	0,34
Al_2O_3	6,62	-	12,21	3,02	10,07
Fe_2O_3	1,29	-	2,68	0,76	1,81
FeO	6,31	-	9,56	1,63	7,91
MnO	0,16	-	0,22	0,03	0,19
MgO	16,85	-	18,73	1,01	17,58
CaO	7,91	-	13,63	2,89	10,52
Na_2O	0,46	-	1,10	0,32	0,77
K_2O	0,41	-	0,92	0,27	0,61
P_2O_5	0,03	-	0,08	0,03	0,05
CO_2	0,17	-	0,42	0,13	0,30
H_2O^+	0,86	-	1,69	0,42	1,32
H_2O^-	0,10	-	0,17	0,04	0,14
Total					99,79

ESELRUH GABBRONORITE : TRACES (n = 3)

	Range Min	-	Max	S	$\bar{X}$
Zn	58	-	104	25,24	75
Cu	<2	-	17	8,02	7
Ni	276	-	861	298,43	534
Co	78	-	84	3,46	82
Cr	1145	-	2257	576,67	1613
V	120	-	177	28,54	148
Sr	46	-	533	247,37	264
Rb	19	-	47	14,29	31
Y	10	-	14	2,08	12
Zr	15	-	39	12,00	27
Nb		<5		-	<5
Ba	114	-	328	118,45	192
Sc	33	-	49	8,08	42

KUMKUM GABBRONORITE : MAJORS

	Range Min	-	Max	S	$\bar{X}$	n
SiO_2	45,37	-	50,10	1,62	48,12	7
TiO_2	0,23	-	0,80	0,21	0,59	7
Al_2O_3	10,42	-	19,90	3,54	16,06	7
Fe_2O_3	0,87	-	3,59	0,93	1,57	7
FeO	5,41	-	11,32	1,98	7,99	7
MnO	0,09	-	0,19	0,03	0,15	7
MgO	8,38	-	20,91	4,13	12,58	7
CaO	7,02	-	10,88	1,26	9,69	7
Na_2O	0,80	-	2,31	0,58	1,59	7
K_2O	0,18	-	0,89	0,24	0,43	7
P_2O_5	0,04	-	0,15	0,04	0,10	7
CO_2	0,10	-	0,29	0,08	0,22	5
H_2O^+	0,46	-	0,79	0,16	0,62	5
H_2O^-	0,04	-	0,15	0,04	0,10	7
Total					99,81	

KUMKUM GABBRONORITE : TRACES

	Range Min	-	Max	S	$\bar{X}$	n
Zn	58	-	92	13,51	74	5
Cu	64	-	133	27,62	87	5
Ni	195	-	755	213,24	458	5
Co	60	-	109	17,80	80	5
Cr	135	-	1556	675,52	898	7
V	104	-	215	42,69	155	5
Sr	105	-	257	67,65	179	5
Rb	4	-	21	6,61	10	5
Y	11	-	22	4,32	17	5
Zr	31	-	89	22,63	63	5
Nb		< 5		-	< 5	5
Ba	109	-	208	39,55	155	5
Sc	19	-	37	7,07	27	5

CONTAMINATED GABBRONORITE : MAJORS (n = 5)

	Range Min	-	Max	S	$\bar{X}$
SiO_2	50,60	-	54,01	1,57	52,15
TiO_2	0,89	-	1,13	0,10	1,04
Al_2O_3	15,31	-	16,46	0,45	15,91
Fe_2O_3	1,34	-	3,10	0,73	1,81
FeO	8,21	-	9,82	0,76	8,92
MnO	0,16	-	0,19	0,01	0,18
MgO	6,04	-	7,70	0,73	7,12
CaO	8,20	-	10,89	1,00	9,43
Na_2O	1,46	-	2,05	0,22	1,69
K_2O	0,26	-	0,91	0,31	0,58
P_2O_5	0,12	-	0,24	0,04	0,18
CO_2	0,14	-	0,20	0,02	0,18
H_2O^+	0,30	-	0,78	0,22	0,52
H_2O^-	0,17	-	0,24	0,03	0,21
Total					99,92

CONTAMINATED GABBRONORITE : TRACES (n = 5)

	Range Min	-	Max	S	$\bar{X}$
Zn	83	-	102	7,12	93
Cu	52	-	75	9,19	60
Ni	83	-	146	24,60	114
Co	51	-	57	2,30	54
Cr	125	-	266	55,90	182
V	219	-	249	11,73	229
Sr	128	-	239	42,52	201
Rb	7	-	38	11,95	18
Y	20	-	34	5,64	27
Zr	85	-	172	35,98	113
Nb	< 4	-	8	-	< 4
Ba	240	-	884	284,47	424
Sc	30	-	44	5,64	37

Table 46: Some average analyses of gabbroic and basaltic rocks

	O.G.	G	A.T.	T
SiO_2	46,83	48,36	49,34	50,83
TiO_2	0,97	1,32	1,49	2,03
Al_2O_3	17,38	16,84	17,04	14,07
Fe_2O_3			1,99	2,88
FeO	10,08*	10,21*	6,82	9,06
MnO	0,14	0,18	0,17	0,18
MgO	10,03	8,06	7,19	6,34
CaO	11,36	11,07	11,72	10,42
Na_2O	2,03	2,26	2,73	2,23
K_2O	0,40	0,56	0,16	0,82
P_2O_5			0,16	0,23
H_2O^+				0,91
Total	99,22	98,86	98,81	100,00

* Total iron as FeO

O.G. - Average olivine gabbro (Nockolds, 1954, p1020)

G - Average gabbro (Nockolds, 1954, p1020)

A.T. - Average Abyssal tholeiite (Engel *et al*, 1965)

T - Average tholeiite (Nockölds, 1954, p1021)

TABLE 47: C.I.P.W. NORMS, CALCULATED VOLATILE FREE; Fe_2O_3 : FeO = 0,2 FOR ROCKS FROM THE KUMKUM- TANTALITE VALLEY AREA

AMPHIBOLITES

	AM76	AM77	AM113	AM157	K94	K40
QZ		9,44	2,05		10,11	
CO						
OR		2,19	4,14	7,21	2,60	5,97
PL	59,99	28,92	23,25	13,04	19,38	45,59
(AB)		6,09	12,61		11,51	5,39
(AN)	59,99	22,82	10,64	13,04	7,88	40,20
LC	0,74			20,57		
NE	2,84			3,58		3,36
DI	17,84	30,44	35,97	9,35	45,60	17,36
(WO)	9,00	15,76	18,34	4,88	23,31	8,81
(EN)	4,43	10,24	10,17	3,42	13,31	4,65
(FS)	4,40	4,44	7,47	1,05	8,98	3,89
HY		25,26	28,33		16,47	
(EN)		17,63	16,33		9,83	
(FS)		7,63	12,00		6,64	
OL	10,10			42,95		21,95
(FO)	4,82			32,12		11,42
(FA)	5,28			10,82		10,53
MT	2,46	2,20	3,64	2,58	2,96	3,29
CS	0,79					
IL	3,84	1,20	2,18	0,53	2,47	1,98
HM						
SP						
AP	0,99	0,24	0,24	0,19	0,31	0,17
CC						
Wt% ALK	5,03	5,09	7,85	17,46	7,71	9,75
FE	65,72	42,64	54,01	28,90	52,51	55,81
MG	29,25	52,27	38,14	53,63	39,79	34,44
DI Wt%	3,58	17,72	18,79	31,36	24,21	14,72
M.I.	70,0	45,3	58,9	35,0	57,1	62,4

METABASITE HORNFELS - TANTALITE VALLEY

	TV9 212	TV13 98	TV13 149	TV13 51
QZ		2,49		
CO	1,67			2,03
OR	4,20	1,36	1,71	2,30
PL	36,77	72,03	47,46	52,12
(AB)	7,53	30,04	7,19	13,20
(AN)	29,24	42,00	40,27	38,91
LC				
NE				
DI		1,57	2,26	
(WO)		0,82	1,16	
(EN)		0,60	0,68	
(FS)		0,14	0,42	
HY	12,25	15,26	39,18	31,92
(EN)	3,98	12,32	24,15	16,43
(FS)	8,27	2,94	15,02	15,49
OL	35,91		5,61	7,03
(FO)	10,91		3,33	3,45
(FA)	24,99		2,28	3,58
MT	7,02	1,16	3,18	3,51
CM				
IL	0,42	4,29	0,27	0,38
HM				
SP				
AP	0,05	1,78	0,02	0,12
CC				
Wt% ALK	4,16	27,47	4,36	7,79
FE	75,45	34,81	50,19	57,95
MG	20,39	37,72	45,45	34,25
DI Wt%	11,73	33,88	8,91	15,50
M.I.	79,7	48,4	53,0	63,8

TANTALITE VALLEY MOTTLED METAGABBRO

	TV294	TV288	TV275A	TV298	JWVB46
QZ	1,28	0,65	1,39		20,02
CO					
OR	5,91	7,39	4,67	3,19	0,83
PL	51,68	51,92	60,75	56,60	51,04
(AB)	17,68	21,75	15,40	25,22	18,11
(AN)	34,00	30,18	45,35	31,39	32,93
LC					
NE					
DI	12,83	11,10	8,55	14,75	5,74
(WO)	6,49	5,65	4,32	7,52	2,90
(EN)	3,29	3,08	2,15	4,16	1,45
(FS)	3,05	2,37	2,08	3,07	1,39
HY	23,04	24,20	20,02	18,12	17,38
(EN)	11,97	13,66	10,20	10,42	8,86
(FS)	11,07	10,54	9,82	7,70	8,51
OL				3,02	
(FO)				1,67	
(FA)				1,36	
MT	2,67	2,45	2,29	2,35	2,02
CM					
IL	1,94	1,75	1,67	1,50	2,39
HM					
SP					
AP	0,62	0,52	0,54	0,33	0,62
CC					
Wt% ALK	15,27	18,48	15,30	17,56	15,43
FE	54,45	49,01	55,63	48,45	56,56
MG	30,29	32,51	29,07	33,98	28,01
DI Wt%	24,87	29,78	21,45	28,41	38,96
M.I.	64,4	60,1	65,9	59,1	66,8

TANTALITE VALLEY METAGABBRO

	TV277	TV42	TV182	TV8	TV77	TV265	TV126	TV217	GBW193	JWVB 20	JWVB 22	JWVB 24
QZ			2,26	0,32	0,71	2,97	1,45	1,28	0,12	2,56	3,27	2,96
CO												
OR	4,85	0,95	1,00	1,06	1,42	3,01	0,89	1,36	0,18	0,95	0,59	0,53
PL	59,42	62,70	58,75	70,93	58,07	44,83	89,86	53,60	73,58	60,18	56,62	51,32
(AB)	11,93	11,93	13,12	15,40	7,45	3,72	19,04	13,96	17,77	12,02	9,31	8,63
(AN)	47,49	50,77	45,64	55,53	50,62	41,10	70,82	39,64	55,81	48,16	47,21	42,69
LC												
NE												
DI	3,20	13,76	16,72	11,80	3,87	0,09	3,80	24,80	10,22	14,28	4,07	18,35
(WO)	1,64	7,12	8,67	6,11	2,02	0,05	1,93	12,89	5,29	7,41	2,11	9,51
(EN)	1,00	4,61	5,71	3,95	1,40	0,03	1,04	8,66	3,46	4,95	1,43	6,23
(FS)	0,55	2,03	2,34	1,75	0,45	0,01	0,83	3,26	1,47	1,91	0,53	2,61
HY	25,12	20,48	19,07	14,21	34,03	45,33	2,84	16,87	14,20	20,37	33,25	24,55
(EN)	16,19	14,22	13,54	9,85	25,77	30,55	1,58	12,26	9,97	14,70	24,30	17,31
(FS)	8,93	6,26	5,54	4,36	8,26	14,78	1,26	4,61	4,23	5,67	8,95	7,25
OL	4,20	0,12										
(FO)	2,61	0,08										
(FA)	1,59	0,04										
MT	2,07	1,48	1,42	1,10	1,52	2,64	0,43	1,44	1,04	1,33	1,68	1,74
CM												
IL	0,82	0,38	0,53	0,36	0,28	0,82	0,46	0,57	0,51	0,38	0,55	0,49
HM												
SP												
AP	0,26	0,14	0,19	0,14	0,09	0,24	0,31	0,14	0,12	0,02	0,09	0,05
CC												
Wt% ALK	11,61	10,26	11,21	16,53	6,11	3,93	45,89	11,60	17,99	10,53	6,49	6,25
FE	44,66	40,00	38,40	37,69	34,37	45,24	34,03	36,54	36,49	36,87	37,68	40,57
MG	43,73	49,74	50,39	45,79	59,52	50,83	20,08	51,85	45,52	52,60	55,84	53,18
DI Wt%	16,78	12,88	16,38	16,78	9,57	9,71	21,38	16,60	18,06	15,52	13,17	12,13
M.I.	50,8	44,4	43,5	45,4	36,6	47,2	62,4	41,1	44,7	40,9	40,2	43,3

TANTALITE VALLEY GABBRONORITE

	TV210	TV205A	TV282	TV170	TV199	T36	GBW195	JWVB25	JWVB26
QZ	1,47						5,29	1,18	0,47
CO									
OR	1,95	2,07	1,12	1,42	1,65	1,42	1,42	2,66	0,77
PL	68,92	61,78	65,44	63,67	82,57	55,35	61,66	66,01	54,55
(AB)	18,45	15,23	14,05	13,96	16,58	16,58	11,08	19,12	12,69
(AN)	50,47	46,55	51,39	49,70	65,98	38,76	50,57	46,89	41,86
LC									
NE									
DI	8,06	2,15	23,10	13,38	2,11	14,97	8,42	8,70	19,27
(WO)	4,15	1,11	11,99	6,93	1,08	7,76	4,38	4,50	10,02
(EN)	2,57	0,69	7,95	4,52	0,66	5,09	2,96	2,90	6,79
(FS)	1,34	0,35	3,16	1,93	0,36	2,12	1,09	1,31	2,46
HY	17,33	18,84	5,48	12,42	11,13	23,47	21,71	19,04	22,93
(EN)	11,38	12,48	3,92	8,71	7,19	16,57	15,87	13,12	16,84
(FS)	5,95	6,36	1,56	3,71	3,94	6,90	5,83	5,92	6,09
OL		11,89	3,04	6,99	1,01	2,32			
(FO)		7,61	2,11	4,76	0,63	1,59			
(FA)		4,28	0,93	2,24	0,38	0,73			
MT	1,35	2,20	1,09	1,54	0,90	1,74	1,22	1,35	1,52
CM									
IL	0,61	0,82	0,54	0,47	0,57	0,40	0,28	0,84	0,47
HM									
SP									
AP	0,24	0,17	0,19	0,19	0,05	0,31	0,02	0,19	0,02
CC									
Wt% ALK	18,33	10,27	15,03	11,62	23,65	11,57	10,95	18,40	9,37
FE	40,76	43,65	36,39	38,97	39,28	37,87	35,62	37,95	36,09
MG	40,91	46,08	48,58	49,42	37,06	50,55	53,43	43,65	54,54
DI Wt%	21,87	17,30	15,17	15,38	18,24	18,00	17,80	22,97	13,94
M.I.	50,2	48,9	43,1	43,8	51,7	42,9	39,9	46,6	39,7

TANTALITE VALLEY ULTRAMAFIC ROCKS

	AM88A	AM89B	T5	T6	T7	T10	T11
QZ							
CO					0,44		
OR	0,06	0,12	1,18	1,83	0,18	1,89	2,78
PL	10,04	14,27	17,72	17,16	16,26	5,67	13,29
(AB)	0,17	0,42	2,45	0,85	0,76	1,02	3,30
(AN)	9,87	13,85	15,27	16,32	15,50	4,66	9,99
LC							
NE							
DI	2,14	3,76	0,98	0,19		0,26	2,02
(WO)	1,12	1,98	0,52	0,10		0,14	1,06
(EN)	0,83	1,47	0,38	0,08		0,10	0,79
(FS)	0,19	0,31	0,08	0,02		0,02	0,17
HY	43,53	18,30	52,33	61,95	22,81	5,74	76,05
(EN)	35,48	15,13	42,89	51,24	18,53	4,58	62,87
(FS)	8,05	3,17	9,34	10,71	4,28	1,16	13,18
OL	39,98	59,36	24,60	15,48	56,14	81,23	2,61
(FO)	31,98	48,21	19,83	12,58	44,75	63,53	2,12
(FA)	8,00	11,15	4,76	2,90	11,39	17,70	0,49
MT	3,22	3,09	2,71	2,57	3,32	4,18	2,45
CM							
IL	0,42	0,25	0,38	0,59	0,40	0,34	0,57
HM							
SP							
AP	0,07	0,02	0,09	0,24	0,12	0,05	0,26
CC							
Wt% ALK	0,60	0,15	1,21	1,06	0,26	0,79	2,28
FE	28,83	27,10	27,70	27,36	29,24	30,88	26,84
MG	71,10	72,76	71,09	71,58	70,50	68,33	70,88
DI Wt%	0,23	0,54	3,64	2,68	0,94	2,91	6,08
M.I.	29,7	28,4	28,2	27,7	29,8	31,9	27,5

TANTALITE VALLEY ULTRAMAFIC ROCKS CONTD.

	TV45	TV30	TV117	TV157A	GBW421	GBW380	GBW376	GBW374
QZ		1,34						
CO	0,74		1,79				0,52	
OR	0,53	0,95	0,77	0,18	0,30	0,18	0,12	0,18
PL	15,51	18,38	37,49	5,82	30,97	4,18	19,79	11,61
(AB)	0,93	3,89	3,72	1,02	8,97	1,95	2,62	1,44
(AN)	14,57	14,49	33,77	4,80	22,00	2,24	17,17	10,17
LC								
NE								
DI		4,22		18,58	9,22	8,94		3,43
(WO)		2,21		9,75	4,83	4,70		1,80
(EN)		1,60		7,15	3,48	3,49		1,31
(FS)		0,40		1,68	0,91	0,76		0,32
HY	30,82	71,85	26,41	30,40	17,10	47,63	21,07	47,14
(EN)	24,82	57,42	20,98	24,63	13,54	39,15	16,38	37,96
(FS)	6,00	14,42	5,43	5,78	3,55	8,48	4,69	9,18
OL	47,83		30,74	41,50	38,41	35,25	53,95	33,60
(FO)	37,77		23,92	32,97	29,80	28,46	41,00	26,53
(FA)	10,05		6,82	8,53	8,61	6,79	12,95	7,07
MT	3,29	2,60	2,46	3,18	2,81	3,09	3,68	3,23
CM								
IL	0,27	0,51	0,23	0,32	1,03	0,21	0,15	0,40
HM								
SP								
AP	0,17	0,09	0,09	0,02	0,12			0,17
CC								
Wt% ALK	0,44	1,77	1,73	0,33	3,03	0,56	0,72	0,45
FW	29,95	30,61	31,00	29,27	31,71	27,50	33,41	30,02
MG	69,61	67,62	67,26	70,40	65,26	71,94	65,87	69,53
DI Wt%	1,46	6,18	4,49	1,19	9,26	2,12	2,74	1,62
MI	31,4	31,3	31,6	29,4	32,8	28,5	34,7	30,5

KUMKUM GRANOLITE (K15), TANTALITE VALLEY SATELLITE BODY (AM123A, AM125) VERLOORKOPPE GABBRONORITE (GBW1) and EINSIEDLER GABBRONORITE (GBW7)

	K15	AM123A	AM125	GBW1	GBW7
QZ		5,57			
CO					
OR	1,36	4,02	7,92	0,47	0,24
PL	48,78	14,56	30,15	48,47	55,93
(AB)	21,07	4,65	10,24	19,46	11,34
(AN)	27,71	9,90	19,92	29,00	44,59
LC					
NE					
DI	23,37	19,50	7,66	22,97	10,58
(WO)	11,83	10,19	3,96	11,69	5,50
(EN)	6,05	7,23	2,54	6,38	3,73
(FS)	5,49	2,08	1,16	4,90	1,34
HY	16,04	53,10	45,32	22,42	13,81
(EN)	8,41	41,24	31,10	12,68	10,15
(FS)	7,63	11,86	14,21	9,74	3,66
OL	3,19		3,47	0,92	16,81
(FO)	1,60		2,31	0,50	12,03
(FA)	1,60		1,16	0,42	4,78
MT	3,10	2,45	3,07	2,84	2,00
CM					
IL	3,57	0,72	1,54	1,80	0,66
HM					
SP					
AP	0,47	0,09	0,85	0,14	0,05
CC					
Wt% ALK	12,20	3,99	8,47	10,77	6,24
FE	57,65	32,93	42,30	53,30	37,42
MG	30,15	63,08	49,24	35,93	56,35
D.I. Wt%	22,43	14,25	18,16	19,93	11,58
M.I.	65,9	34,3	46,3	59,7	39,6

ESELRUH GABBRONORITE

	K59A	K60	K7
QZ			
CO			
OR	3,07	5,55	2,48
PL	34,17	18,76	35,00
(AB)	3,98	6,52	9,48
(AN)	30,19	12,24	25,52
LC			
NE			
DI	30,53	21,91	20,01
(WO)	15,95	11,43	10,45
(EN)	11,29	7,94	7,37
(FS)	3,28	2,54	2,19
HY	1,26	43,21	20,99
(EN)	0,98	32,73	16,18
(FS)	0,28	10,48	4,81
OL	28,08	6,68	18,75
(FO)	21,26	4,94	14,13
(FA)	6,81	1,74	4,63
MT	2,17	2,73	2,26
CM			
IL	0,51	1,01	0,46
HM			
SP			
AP	0,09	0,19	0,07
CC			
Wt% ALK	3,65	5,32	5,41
FE	33,21	35,13	32,92
MG	63,14	59,56	61,67
D.I.Wt%	7,05	12,07	11,96
M.I.	34,8	37,0	34,7

KUMKUM GABBRONORITE

	K28	K22	K30A	K37A	K65	GBW225	GBW439
QZ							
CO							
OR	1,77	2,60	3,55	1,36	2,36	1,06	5,32
PL	33,30	55,10	37,99	59,94	57,29	62,00	40,22
(AB)	11,51	17,43	6,94	15,91	19,63	15,91	7,87
(AN)	21,80	37,67	31,06	44,03	37,66	46,09	32,35
LC							
NE							
DI	10,21	9,67	12,93	8,10	9,02	3,06	15,77
(WO)	5,33	4,96	6,72	4,19	4,68	1,59	8,16
(EN)	3,71	2,95	4,50	2,72	3,11	1,06	5,31
(FS)	1,18	1,77	1,72	1,20	1,23	0,41	2,29
HY	13,25	27,51	32,56	12,45	3,62	25,95	32,17
(EN)	10,06	17,20	23,56	8,64	2,59	18,74	22,47
(FS)	3,19	10,31	9,00	3,80	1,02	7,21	9,69
OL	36,84	1,02	8,52	15,06	24,34	5,69	2,58
(FO)	27,30	0,61	5,99	10,14	16,96	4,00	1,75
(FA)	9,54	0,40	2,52	4,92	7,38	1,70	0,83
MT	3,06	2,35	2,61	2,06	2,13	1,74	2,41
CM							
IL	1,42	1,44	1,56	0,91	0,87	0,44	1,29
HM							
SP							
AP	0,26	0,31	0,36	0,14	0,14	0,09	0,28
CC							
Wt% ALK	4,68	12,09	5,28	10,04	11,54	10,56	7,64
FE	35,65	47,07	40,10	40,63	37,48	36,92	41,61
MG	59,67	40,83	54,63	49,33	50,98	52,51	50,75
D.I. Wt%	13,28	20,03	10,48	17,27	21,99	16,97	13,19
M.I.	37,2	53,6	42,2	45,1	43,0	41,2	45,0

CONTAMINATED GABBRONORITE

	K44	K80	K34A	K63A	K39
QZ	1,73	3,31	10,41	8,83	6,45
CO					
OR	5,50	3,60	1,65	5,14	1,54
PL	46,63	48,19	49,22	49,94	50,48
(AB)	14,55	14,47	12,44	17,52	13,20
(AN)	32,07	33,72	36,78	32,42	37,28
LC					
NE					
DI	18,09	11,46	5,43	5,87	6,91
(WO)	9,25	5,84	2,75	2,98	3,52
(EN)	5,32	3,22	1,45	1,58	1,92
(FS)	3,52	2,40	1,22	1,31	1,47
HY	23,62	28,30	28,09	25,01	29,51
(EN)	14,21	16,21	15,28	13,64	16,73
(FS)	9,41	12,09	12,81	11,37	12,78
OL					
(FO)					
(FA)					
MT	2,45	2,74	2,70	2,48	2,71
CM					
IL	1,73	1,88	2,13	2,17	2,03
HM					
SP					
AP	0,28	0,40	0,43	0,57	0,43
CC					
Wt% ALK	12,85	10,81	8,91	15,23	8,86
FE	49,15	52,84	56,85	53,11	54,70
MG	38,00	36,35	34,23	31,66	36,45
D.I. Wt%	21,78	21,38	24,51	31,49	21,18
M.I.	56,4	59,5	62,3	62,6	59,9

Inequigranular granite gniess (K49, TV306, GBW744), tonalite and granodiorite from Tantalite Valley (TV299, TV305) and Warmbad granite(GBW 608, GBW458)

	K49	TV306	GBW744	TV299	TV305	GBW458	GBW608
QZ	34,76	20,54	32,14	32,56	16,78	32,80	30,82
CO	2,48	1,36	2,79	2,79	0,68	0,86	1,10
OR	29,55	11,76	26,71	26,00	10,64	38,71	36,76
PL	25,98	50,34	26,32	27,18	67,06	24,79	26,96
(AB)	20,56	29,62	15,91	16,25	54,83	19,97	22,68
(AN)	5,42	20,72	10,41	10,93	12,23	4,82	4,29
LC							
NE							
DI							
(WO)							
(EN)							
(FS)							
HY	5,63	12,31	8,74	9,51	3,89	2,03	3,17
(EN)	2,27	4,71	3,36	4,48	1,79	0,47	0,40
(FS)	3,36	7,60	5,38	5,03	2,10	1,56	2,77
OL							
(FO)							
(FA)							
MT	0,67	1,54	1,20	0,96	0,41	0,32	0,54
CM							
IL	0,66	1,60	1,88	0,84	0,36	0,36	0,47
HM							
SP							
AP	0,28	0,47	0,24	0,12	0,19	0,14	0,12
CC							
Wt% ALK	67,06	40,01	50,35	52,27	77,46	85,51	78,76
FE	24,73	46,21	39,02	32,84	15,81	12,67	19,82
MG	8,21	13,78	10,62	14,89	6,74	1,82	1,42
D.I. Wt%	84,87	61,91	74,76	74,80	82,25	91,48	90,25
M.I.	75,1	77,3	78,6	69,1	70,0	87,2	93,4

Table 48: NIGGLI VALUES OF AMPHIBOLITES

	AM76	AM77	AM113	AM157	K94	K40
fm	31,64	54,85	61,21	67,75	56,27	47,88
alk	1,44	2,09	4,07	7,67	3,70	3,97
ca	38,71	29,75	25,68	9,58	32,35	26,77
al	28,21	13,31	9,04	15,00	7,67	21,39
k	0,15	0,25	0,24	0,83	0,18	0,33
mg	0,44	0,68	0,56	0,79	0,57	0,53
si	84,02	124,28	112,36	79,22	130,25	87,17
qz	-21,74	15,92	- 3,92	-51,46	15,43	-36,69
ti	3,13	1,07	1,86	0,37	2,27	1,58
p	0,37	0,10	0,09	0,06	0,13	0,06
100 (O.R.)	52,49	27,84	26,96	16,42	23,28	37,67
g	1,144	0,907	0,756	0,372	0,415	1,426

O.R. (Oxidation Ration) $= \frac{2\ Fe_2O_3}{2\ Fe_2O_3 + FeO}$ using molec. prop.

$g = \frac{mg \times O.R.}{MnO\ (wt\%)}$ where g is the garnet formation parameter of Leake (1972)

Table 49: Tungsten analyses of samples from some scheelite prospects of Tantalite Valley (Map 3) quoted as WO_3 in parts per million unless otherwise indicated.

BDL = less than 40 ppm

Sample	WO_3	
Deposit S		
22	57	coarse-grained hornblendite
25	497	mica-rich hornblendite
26	BDL	mica-rich hornblendite
40	182	ol-tremolite rock
41A	BDL	micaceous inclusion within pegmatite
50	BDL	mylonite pegmatite (older pegmatite)
56	68	hornblendite with quartz veins
56A	BDL	hornblendite
62	130	hornblendite
77	418	partly metasomatised hornblendite (average)
88	0,20%	mica-hornblendite with quartz veins
90	107	ol-tremolite rock
95	2,18%	metasomatised hornblendite with quartz veins
117	0,13%	micaceous hornblendite
121	70	phlogopite-rich zone near pegmatite
121A	110	tremolite-olivine rock
125	68	ol-tremolite rock near contact
125 Peg	95	younger pegmatite near contact
157 a/b	0,48% / 2,9%	mica-hornblendite (2 samples)
157 peg	57	younger pegmatite
Deposit T		
T2	0,20%	mica-hornblendite pods in gneiss, near shear
T5	0,65%	mica-hornblendite within shear zone
T6	723	quartz-rich vein (along strike with shear)
Deposit U		
U2	136	pegmatite-tremolite rock contact
U4	86	veins of hornblende with mica margins
U8	220	altered mafic rocks with quartz veins
U8A	109	pegmatite
Deposit W-X-Y		
W1A	44	pegmatite
W1B	176	ol-tremolite rock
W1C	77	hornblende-mica rock
W1D	BDL	amphibole-rich rock with mica disseminations
W3A	BDL	pegmatite
X1	BDL	mica shist
X2	0,63%	mica-hornblendite
X3	107	amphibole-rich rock; mica dissemination
X4	BDL	"pegmatite" schist

Analyses by Mineral Services (Pty) Ltd

Table 50: Some ages for rocks which are correlated with those from the Kumkum - Tantalite Valley area

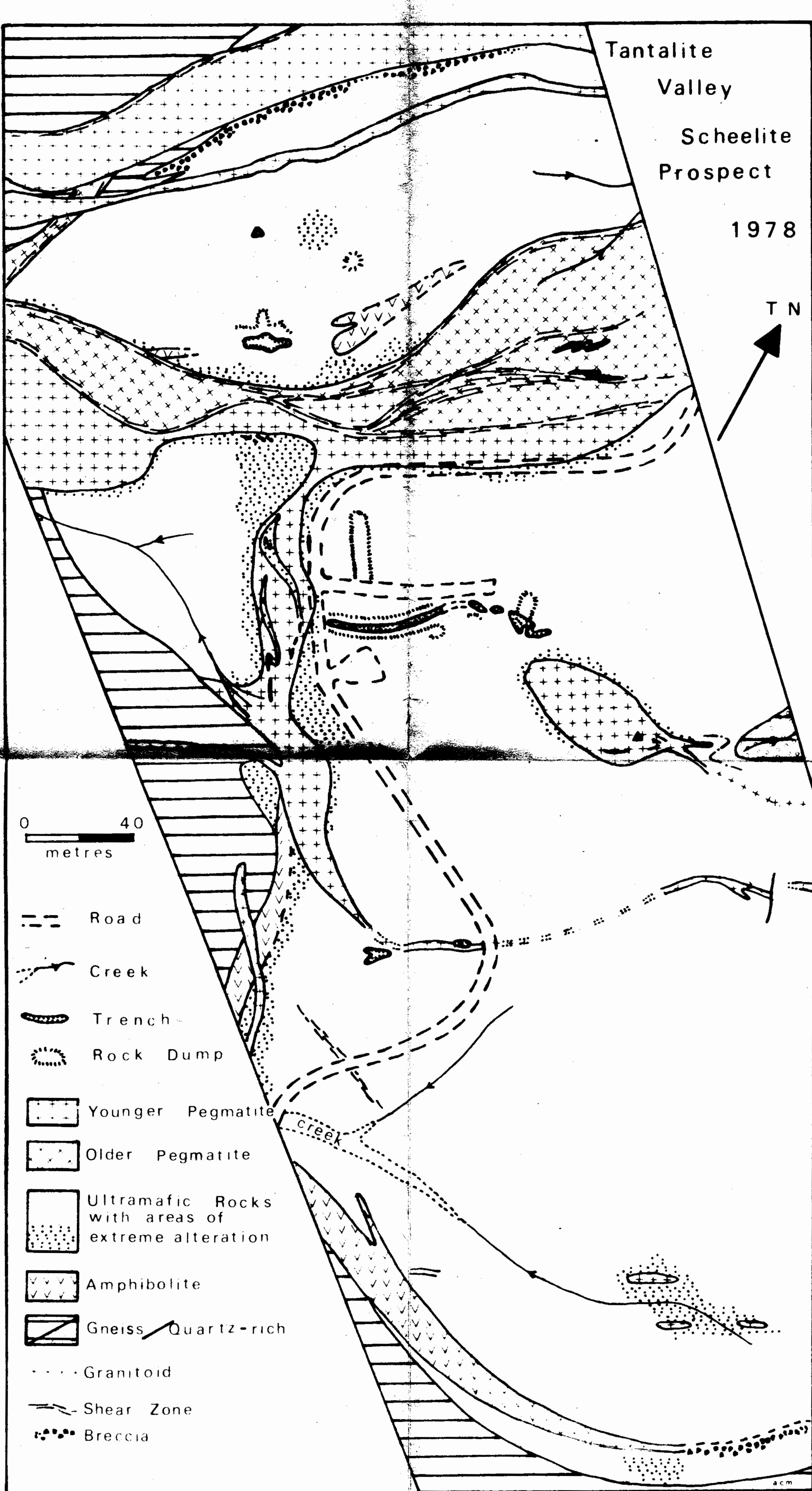
Rock type	Correlate	Reference	Calculated ages (Ma) *			Age (in Ma) for
			Pb^{207}/Pb^{206}	Pb^{207}/U^{235}	Pb^{206}/U^{238}	Rb^{87}/Sr^{87} method
Tsirub gneiss	Inequigranular granite gneiss	Jackson (1976)	1052	960	920	-
Beenbreek granite	"	Toogood (1976)	1218	1016	928	
Nababeep Gneiss	"	Clifford *et al* (1975a)	-	-	-	1213 ± 22ǂ
Orangefall biotite gneiss	Grey Gneiss s.s.	Toogood (1976)	1142	866	764	
Orangefall biotite gneiss	"	"	1720	1384	1042	
Stolzenfels norite	Contaminated gàbbronorite	"	1110	524	404	
Tantalite Valley Lithium Pegmatite	Young pegmatite	Nicolaysen (1962)	-	-	-	988 ϕ

* minimum U - Pb ages from single zircons

ǂ whole rock age

ϕ muscorite age

Ma = 10^6 years


Tantalite Valley Scheelite Prospect
1978
TN
0 40
metres
Road
Creek
Trench
Rock Dump
Younger Pegmatite
Older Pegmatite
Ultramafic Rocks with areas of extreme alteration
Amphibolite
Gneiss Quartz-rich
Granitoid
Shear Zone
Breccia
creek
acm