The mineralogy of amphiboles in amphibolites

Layton, W.

THE MINERALOGY OF AMPHIBOLES IN AMPHIBOLITES

Being a Thesis for the Degree of Doctor of Philosophy

submitted in

October 1959

by

William Layton B.Sc F.G.S.

of St Cuthbert's Society in the University of Durham.

VOLUME II

Figures, Maps and Plates.

CONTENTS.

PART 1.

Number.		Page.
Fig. 1.	General Classification of the Amphiboles. After Winchell and Rabbitt.	1.
Fig. 1a.	Suggested Classification of the Amphibole Group.	2.
Fig. 2.	The Structure of Tremolite (Warren 1929).	3.
TABLE 1.	Observed (h01) Reflexions from Tremolite and Diopside. (Warren 1929).	4.
Fig. 3.	Projections of the Tremolite and Diopside Structures on 010 (Warren 1929).	5.
Fig. 4.	Projection of the Tremolite and Diopside Structures on (001). (Warren 1929).	6.
Fig. 5.	Graph Showing the Relationship Between Al Replacing Si and the Amount of Alkali in the Vacant Spaces.	7.
Fig. 6.	The Relation Between the Silicon-Oxygen Chains and the Cleavage in Pyroxenes and Amphiboles.	8.
TABLE 2.	Selected Modern Analyses of Anthophyllite 1890-1946. (Rabbitt 1948).	9.
TABLE 3.	Analyses of some Anthophyllite Asbestos. (Merrill 1895).	10.
Fig. 7.	Graph to show the Relationship Between SiO_2 and Al_2O_3 in Anthophyllites.	11.
Fig. 8.	Graph to show the Relationship Between Al_2O_3 and TiO_2 in Anthophyllites.	11.

Number.		Page.
TABLE 4.	Spectrographic Analysis of Ten Anthophyllites and one Cummingtonite (Rabbitt 1948).	12.
TABLE 5.	Optical Properties of Some Anthophyllites from Table 2.	13.
TABLE 6.	Physical Properties of 7 Montana Anthophyllites (Rabbitt 1948).	14-16.
Fig. 9.	General Classification of the Monoclinic Amphiboles.	17.
TABLE 7.	Dana/Schaller Prefixes.	18.
Fig. 10.	Plot of Edenites from the Literature on the Hallimond Diagram (Francis 1958).	19.
TABLE 8.	Writer's List of Tremolite Series from the Literature.	20.
	Tremolite Series Analyses recalculated.	24.
	Physical Properties of Tremolite Series.	28.
	a) Writer's List of Common Hornblendes from the Literature.	33.
	Common Hornblende Analyses Recalculated.	41.
	Physical Properties of Common Hornblendes.	47.
Fig. 11.	Classification of the Pargasite Series.	49.
Fig. 12.	Distribution of Amphibole Analyses in Respect (a) Si atoms (b) Atoms in the Vacant Space (Hallimond 1943).	50.
Fig. 13.	Composition of Calciferous Hornblendes. (Winchell 1945).	51.
Fig. 14.	Incidence of Amphibole Analyses with more than 1.5 Ca Atoms (Hallimond 1943).	52.
TABLE 9.	Hallimond (1943) List of Amphiboles.	53.
TABLE 10.	Winchell (1945) List of Amphiboles.	57.

Number.		Page.
Fig. 15.	Relationship Between the Amounts of Si and Al in the Formula Unit of Hornblende.	59.
Fig. 15a.	Frequency Diagram for Silicon Atom Content in Calciferous Amphiboles.	60.
Fig. 16.	Relationship of Fe''' to Fe'' in Calciferous Amphiboles.	61.
Fig. 17.	Plot Showing the Relationship Between the Ng and Nm Indices in Aluminous Hornblendes.	62.
Fig. 18.	Plot Showing the Relationship Between Ng and Nm Indices in the Tremolite Series.	63.
Fig. 19.	Relationship Between Birefringence Ng-Np and the Ng Index in Hornblendes.	64.
Fig. 20.	Plot Showing the Relationship Between Ng and Np Indices in Common Hornblendes.	65.
Fig. 21.	Plot Showing the Relationship Between Ng and Np Indices in the Tremolite Series.	66.
Fig. 22.	Plot Showing the Relationship Between Ng and Np Indices in Hornblendes.	67.
Fig. 23.	Plot Showing the Relationship Between Ng and Nm in the Pyroxene Series.	68.
Fig. 23a.	Nomogram for the Determination of 2V from Refractive Indices (Hartshorne and Stuart 1950).	69.
Fig. 24.	Plot Showing the Relationship Between Density and the Heavy Elements in the Hornblende Series.	70.
Fig. 25.	Plot Showing the Relationship Between the Ng Refractive Index and Density in the Hornblende Series.	71.

Number.		Page.
TABLE 11.	Table of Selected Analyses of the Cummingtonite Series.	72-75
Fig. 26.	Revised Classification of the Cummingtonite Series.	76.
Fig. 27.	Diagram Showing the Development of the Cummingtonites and the Types of Anthophyllite.	77.
Fig. 27 a	Tremolite Structure. (Warren 1929)	78
b	Anthophyllite Structure. Warren & Modell (1930).	
c	Enstatite Structure. " " "	
TABLE 12.	Physical Properties of the Cummingtonite Series from Table 11.	79.
TABLE 13.	Miyashiro (1957) List of Alkali Amphiboles.	80-81.
TABLE 14.	Optical Data for Table 13.	82.
Fig. 28.	The Ca and R''' Relationship in Alkali Amphiboles (Miyashiro 1957).	83.
TABLE 15.	Crystallographic Data for Amphiboles. (Sundius 1946)	83.
Fig. 29.	Diagrams Illustrating Solid Solution in the Anthophyllite and Cummingtonite Series A = Anthophyllite Field, B = Cummingtonite Field (Sundius 1933), C = Extension of B to Include Collins (1942) Data. Paired Minerals are Connected by Lines. (Rabbitt 1948)	84.
Fig. 30.	Triangular Diagram to Show Solid Solution Relations in the Hornblende Series.	85.
TABLE 16.	Analyses of Amphiboles from the Literature covering the Immiscibility gap of Fig. 12.	86-87
Fig. 31.	Diagram to show Suggested Compositional Limits of the Hornblende Series with Respect to Si and Na+K.	88.

Number.		Page.
Fig. 32.	Diagram to show Immiscibility with Respect to the Iron Component in the Hornblende Series.	89.
Fig. 33.	The Relationship Between Si and R"' in Alkali Amphiboles (Miyashiro 1957).	90.
Fig. 34.	The Relationship Between Fe"/R" and Fe"'/R"' in the Riebeckite-Glaucophane Series. (Miyashiro 1957)	91.
Fig. 35.	Fe"'/R"' and Fe"/R" Ratios in Amphiboles of the Arfvedsonite, Katophorite and Soda Tremolite Groups (Miyashiro 1957) Showing Occurrence of Types.	92.
Fig. 36.	Sundius (1946) Triangular Diagram for Solid Solution Relations Between the Hornblende Series and the Alkali Amphiboles.	93.
Fig. 37.	Suggested Classification of the Amphibole Group.	94.
Fig. 38.	Relation Between Na+K and Ca in Hornblendes and Alkali Amphiboles.	95.
Fig. 39.	The Relationships Between Ng and Nm Refractive Indices in the Monoclinic Amphiboles.	96.
Fig. 40.	The Relation Between Ng Index and the Birefringence Ng-Np for Tremolites and Alkali Amphiboles.	97.
Fig. 41. Fig. 42.	Plot of Various Chemical Parameters in Weight per cent. Against Mean Refractive Index (Ford 1914)	98. 99.
Fig. 43.	The Effects of Increasing Content of Fe_2O_3 and TiO_2 on the Ng Refractive Index in Hornblendes.	100.
Fig. 44.	Plot Showing the Relationship Between Weight % FeO + Fe_2O_3 and the Ng Refractive Index for Calciferous Amphiboles.	101.

Number.		Page.
Fig. 45.	Plot Showing the Relationship Between the Ng Refractive Index and Fe" + Fe"' + Mn + Ti in Calciferous Amphiboles.	102.
Fig. 46.	Plot Showing the Relationship Between the Nm Refractive Index and Fe" + Fe"' + Mn + Ti in Common Hornblendes.	103.
Fig. 47.	The Relationship Between SiO_2 and the Ng Refractive Index in Hornblendes.	104.
Fig. 48.	The Relationship Between Extinction Angle and FeO + Fe_2O_3 and also with Mean Refractive Index (Ford 1914).	105.
Fig. 49.	The Relationship Between Ng Refractive Index and Weight % FeO + Fe_2O_3 + TiO_2 + MnO in the Anthophyllite Series (Rabbitt 1948).	106.
Fig. 50.	The Relationship Between Density and Weight % FeO + Fe_2O_3 + TiO_2 + MnO in the Anthophyllite Series (Rabbitt 1948).	108.
Fig. 51.	Relationship Between Mg + $Al^{(6)}$/Y and Various Physical Properties in the Hornblende Series. (Rosenzweig & Watson 1954).	107.
Fig. 52.	Winchell (1951) Diagrams for the Determination of the Composition of Anthophyllite.	108.
Fig. 53.	Winchell (1951) Diagrams for the Determination of the Composition of Anthophyllite.	108.
Fig. 54, 55.	Properties of Fluor-Cummingtonite Compared With Hydroxy-Cummingtonite (Bowen, Schairer 1935).	109.
Fig. 56.	Properties of the Grunerite-Kupfferite-Mn_7 Si_8 O_{22} $(OH)_2$ System (Winchell 1951).	109.
Fig. 57.	Variation in Composition and Properties in the Tremolite-Actinolite Series (Winchell 1931).	110.

Number.		Page.
Fig. 58.	Variation in Composition and Properties in the Tremolite-Pargasite Series. Note Formula is Edenite not Pargasite (Winchell 1934).	110.
Fig. 59.	The Properties of the Tremolite-Ferrotremolite Series (Winchell 1951).	111.
Fig. 60.	The Physical Properties of the Calciferous Amphiboles (Winchell 1945) The Partial Prism.	112.
Fig. 61.	The Physical Properties on the Faces of the Partial Prism.	113.
Fig. 62.	The Relationship Between Ng Refractive Index and $Al^{(4)}$.	114.
Fig. 63.	The Relationship Between the Ng Refractive Index and $Al^{(6)}$.	115.
Fig. 64.	Two Axial Diagrams for Study of Sesqui-Oxides in the Hornblende Series (Sundius 1946).	116.
Fig. 65.	Refractive Index Values of Various Sesqui-Oxide Levels (Sundius 1946).	117.
Fig. 66.	Showing the Relationship of Ti + Fe''' to Various Contents of Al(ii) and Fe'' (Sundius 1946).	118.
Fig. 67.	The Calcium Trend with Increasing Ng Index in Common Hornblendes.	119.
Fig. 68.	The Relationship Between Axial Angle, Al(ii) and Heavy Ion Content (Sundius 1946).	120.
Fig. 69.	Illustrating the Break in Optical Properties Between the Tremolite Series and the Common Hornblendes (Sundius 1946).	121.
Fig. 70.	The Approximate Relation Between the Compositions and Optical Properties of Amphiboles of the Riebeckite-Arfvedsonite-Katophorite Series excluding Glaucophane. (Miyashiro 1957).	121.

Number.		Page.
Fig. 71.	See Fig. 34.	122.
Fig. 72.	Writer's Suggested Method for Identification of Alkali Amphiboles.	123.
Fig. 73.	Graph Showing the Relationship Between d-space and % Al_2O_3 Content in the Hornblende Series.	124.
Fig. 74.	Graphs Showing the Relationship Between d-space and % SiO_2 and MgO Content.	125.
Fig. 75.	Graphs Showing the Relationship Between d-space and % FeO and % (Na_2O + K_2O) Content.	126.
Fig. 76.	Graph Showing the Relationship Between d-space and Si (in atomic proportions).	127.
APPENDIX 1.	Additional Statistical Data.	
APPENDIX 2.	Example of Methods of Calculation of Regression Equations and other Statistical Data.	
APPENDIX 3.	X-Ray Powder Data.	
TABLE 17.	Analyses and Optical Properties of Ghana Amphiboles and Analyses of Amphiboles from Dr. B. Leake.	

PART 2.

Fig. 77.	Map Showing the Location of the Winneba District in Ghana.	128.
Fig. 78.	Map Showing the Distribution of the Facies of the Upper Birrimian Series.	129.
Fig. 79.	Approximate Limits of Composition of Amphiboles Derived from Various Rocks. (Hallimond 1943)	130.

Number.		Page.
TABLE 18a.	Analyses of Birrimian Rocks, Parents for Analysed Amphiboles.	131.
TABLE 18b.	Analyses of Birrimian Rock, Parents for Analysed Amphiboles.	132.
TABLE 18c.	Analyses of Selected Winneba Rocks.	133.
TABLE 19.	Analyses of Basalts for Comparison with Birrimian Greenstones and Actinolite Schists.	134.
Fig. 79a.	Semi-Diagrammatic Sections Across the Birrimian Series.	135.
Fig. 80.	Sketch Map Showing General Geology and Important Mineral Occurrences in the Mankwadzi Coastal Section.	136.
Fig. 81.	Plan of Trenches in Sandy Bay Between Mankwadzi and Abrekum.	137.

PART 3.

TABLE 20.	The Accuracy of the Rapid Methods Determined by Single Analyses of W1 and G1. (Mercy 1955).	138.
TABLE 21.	Comparison of Precision of Rapid Methods and Conventional Methods (Mercy 1955).	138.
Fig. 82.	The Univariant Equilibrium Curve for the Reaction Tremolite 3 Enstatite + 2 Diopside + Quartz + Vapour. (Ann. Rep. Geophys. Lab. 1954-55)	139.
Fig. 84.	The Stability Field of the Magnesian Hornblende Pargasite. (Ann. Rep. Geophys. Lab. 1955-56).	140.
Fig. 85.	Preliminary Prepour T diagram for the Composition Na_2O. 3MgO. Al_2O_3. $8SiO_2$ with excess water. (Ann. Rep. Geophys. Lab. 1957-58).	141.

Number.		Page.
Fig. 86.	The Relation Between the Compositions and Modes of Occurrence of Amphiboles of the Riebeckite-Arfvedsonite-Katophorite Series. (Miyashiro 1957).	141.
TABLE 22.	Chemical Analyses of Hornblendes from the Nakoso and Gosaisyo-Takanuki Districts (Shido 1958).	142.
TABLE 23.	Recalculation of Analyses in Table 22 into Atomic Proportions.	142.
Fig. 87.	Suggested (Layton) Relationship of Composition to Colour in the Shido (1958) Amphiboles.	143.
Fig. 88.	Relationship Between Iron Content, Refractive Index and Occurrence of the Common Hornblende Series.	144.
Fig. 89.	Relationship Between Amphibole Composition and Occurrence in the Hornblende Series.	145.
Fig. 90.	Diagram to show Increasing Alkali Content with Increasing Metamorphic Grade (Shido 1958).	146.
TABLE 24.	Table of 'End Members' Resulting from Various Types of Substitution Derived by Shido (1958).	147.
TABLE 25.	Typical Recalculation of a Shido Amphibole on the Basis of Table 24 (Shido 1958).	147.
TABLE 26.	Complete Recalculation of Analyses from Table 22.	147.
Fig. 91.	Occurrence and 'Z' Axial Colours of the Winneba (Ghana) Amphiboles.	148.

LIST OF PLATES.

			Page.
Plate 1	A.	Recumbent Folding in the Togo Series, West of Senya Beraku near a wedge of Dahomeyan Gneiss.	149.
	B.	Strong Folding in Togo Series, West of Senya Beraku.	
Plate 2	A.	Large Pegmatite Exposure in the Coarse Amphibolite Zone near Winneba.	150.
	B.	Quartz Crystal in Quartz Reef near Onyadzi Winneba.	
Plate 3	A.	Composite Quartz-Aplite Dyke in the Sandy Cove Between Mankwadzi and Abrekum.	151.
	B.	Typical Shattering in the Aplites West of Mankwadzi Village.	
Plate 4	A.	Cassiterite Bearing Pegmatite in Hornblende Biotite Schists West of Mankwadzi Village.	152.
	B.	Typical Banding in the Ilmenite-Monazite Bearing Beach Sands West of Mankwadzi Village.	
Plate 5	A.	Typical Exposure of Graphic Pegmatites in Eastern Migmatite Gneiss along the Winneba-Accra Road.	153.
	B.	Texture of the Graphic Pegmatites.	
Plate 6	A.	Typical Banding in the Eastern Migmatites.	154.
	B.	Typical Ptygmatic Folding in the Eastern Migmatite Gneiss near Mile 9 Accra Road.	
Plate 7	A.	Pillow Structure on the Beach West of Mankwadzi Village.	155.
	B.	Typical Contact Between Feldspar Amphibolites and Garnet Schists Winneba Saltpond Road.	
Plate 8	A.	Typical Winneba Granite Topography.	156.
	B.	Porphyroblastic Texture of the Winneba Granite.	

Number.		Page.
Plate 9 A.	Typical Flow Banding in the Winneba Granite near Ateiti Village.	157.
B.	Ghosts in the Winneba Granite near Ateiti Village.	
Plate 10 A.	Thrust faulting in Togo Quartzites, West of Senya Beraku.	158.
B.	Multiple faulting resulting in the Exposure of the Probable Base of the Togo Quartzite.	

PHOTOMICROGRAPHS.

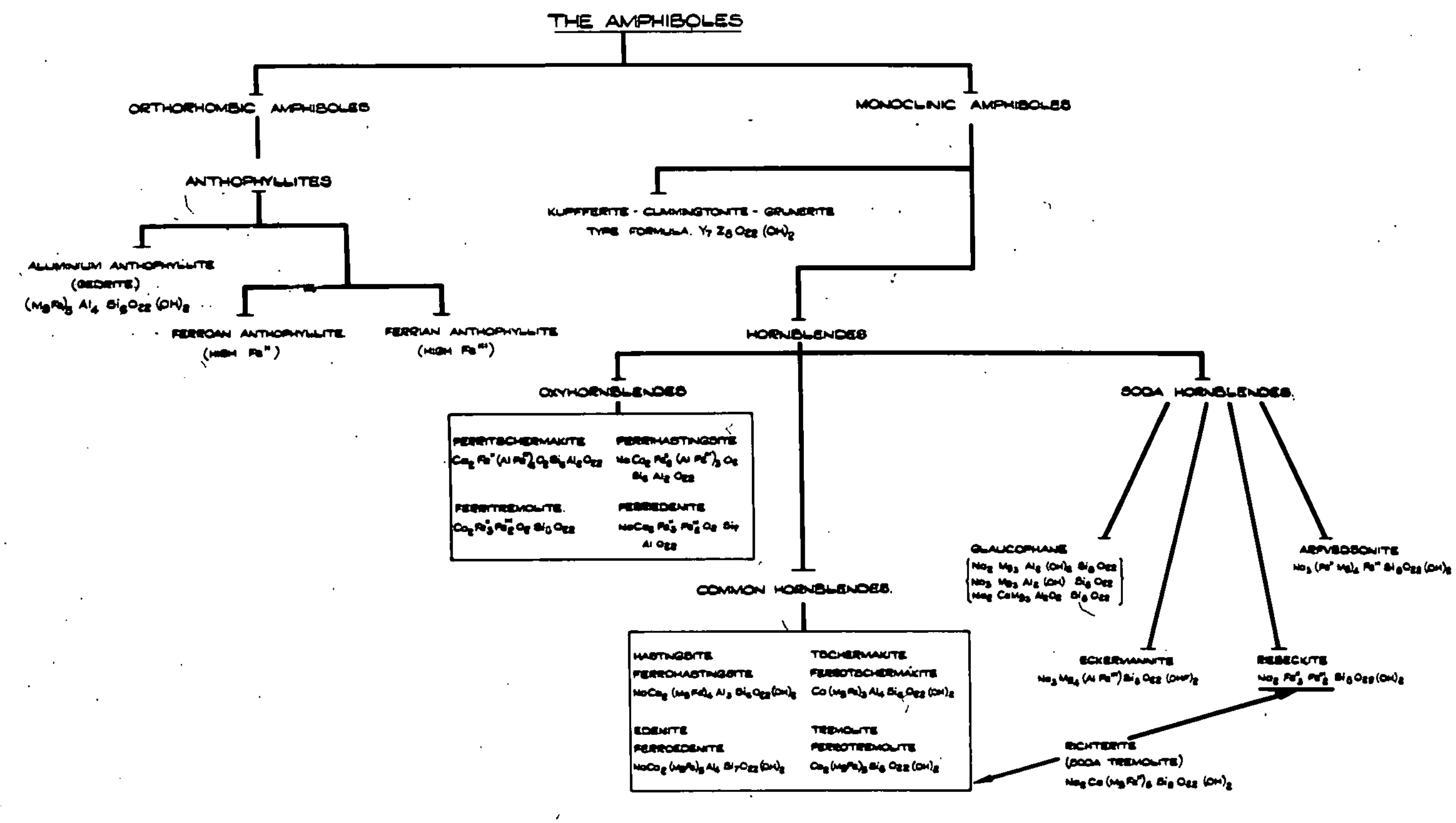
Plate 11 A.	Typical Porphyritic Metamorphosed Lava x70 Crossed Nicols.	159.
B.	Typical Actinolite Schist. x70 Crossed Nicols.	
Plate 12 A.	Hornblendite from zone of coarse Amphibolites Note large Hornblende Plates x70 Crossed Nicols.	160.
B.	Actinolite Amphibolite. Note Mass of Actinolite Hornblende x70 Crossed Nicols.	
Plate 13. A.	Typical Rimmed Amphibole in zone of coarse Amphibolite. Note Granitic Contamination. x70 Crossed Nicols.	161.
B.	Rimmed Amphibole in the coarse Amphibolite Zone x70 Ordinary Light.	

MAPS IN POCKET.

MAP 1. Geological Map of the Winneba District.

MAP 2. Distribution of the Minor Acid Intrusives.

MAP 3. Structural Map of the Winneba District.



GENERAL CLASSIFICATION OF THE AMPHIBOLES (AFTER WINCHELL & RABBITT)

FIG. 1.

— SUGGESTED CLASSIFICATION OF THE AMPHIBOLE GROUP —

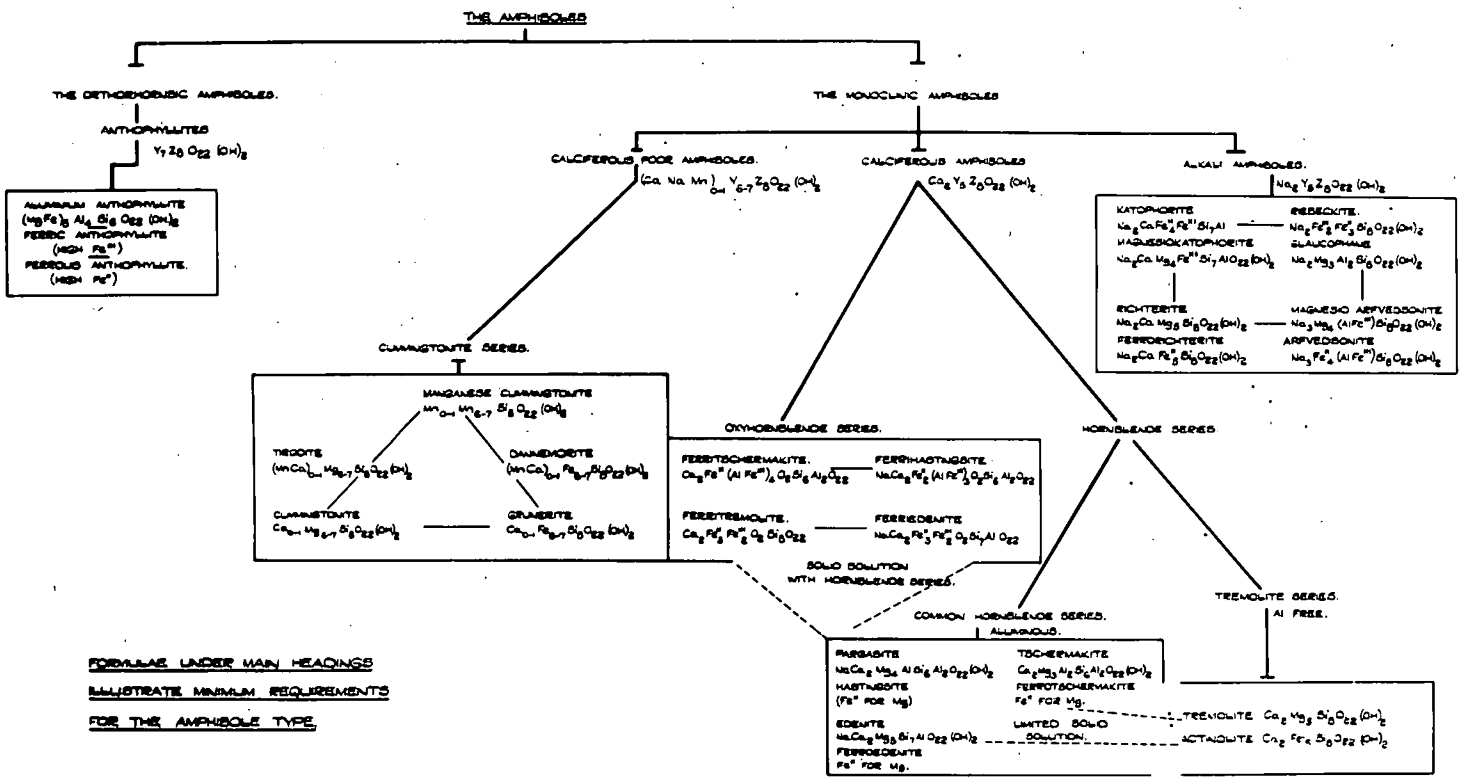


FIG. 1a.

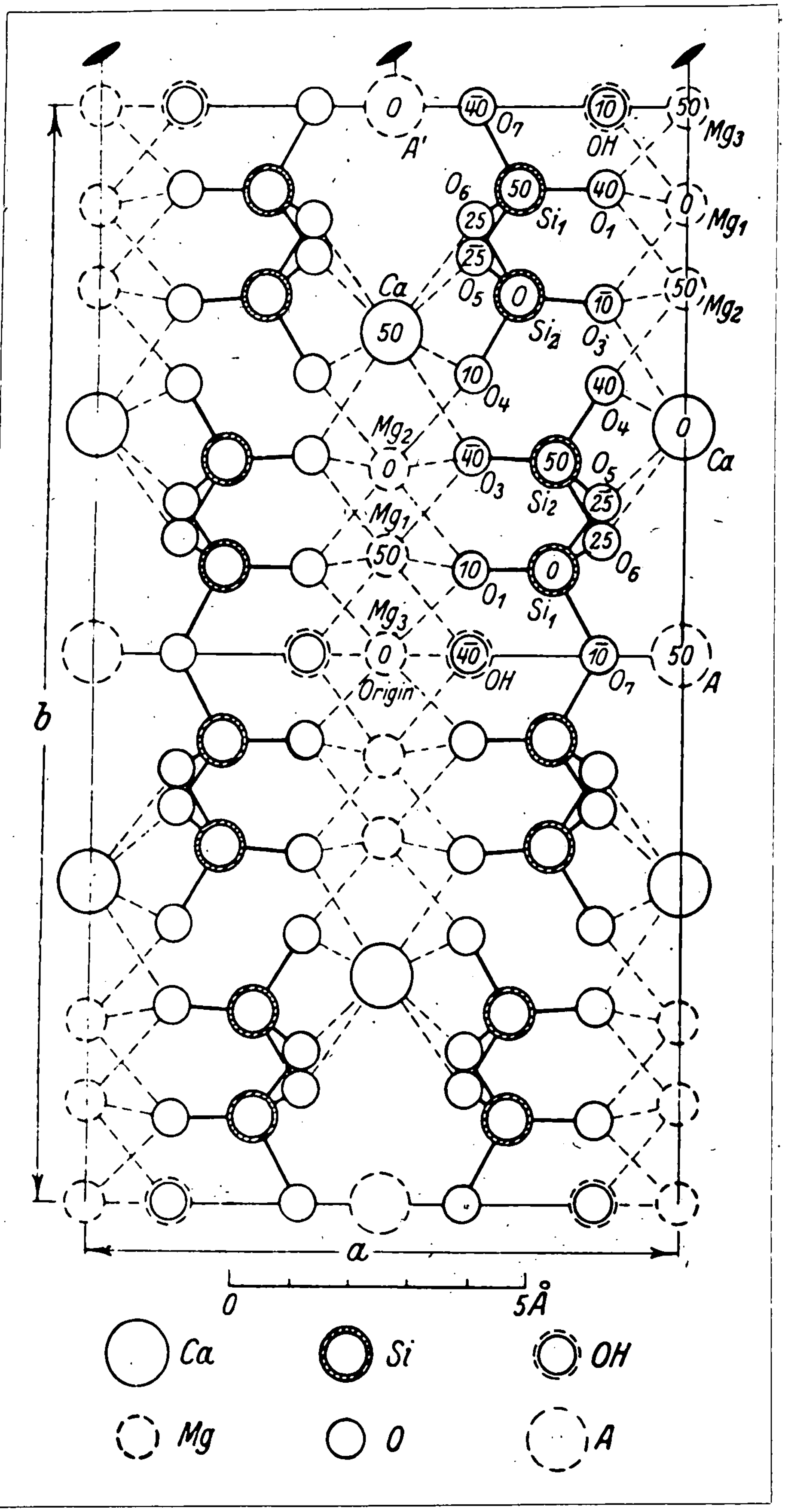

0
A'
$\bar{40}$
O_7
$\bar{10}$
OH
50
Mg_3
O_6
50
40
0
Mg_1
25
Si_1
O_1
$\bar{25}$
Ca
O_5
0
$\bar{10}$
50
Mg_2
50
Si_2
O_3
10
O_4
40
O_4
0
Ca
Mg_2
0
$\bar{40}$
O_3
50
O_5
Si_2
$\bar{25}$
Mg_1
50
25
10
0
O_6
O_1
Si_1
Mg_3
0
40
OH
Origin
$\bar{10}$
O_7
50
A
b
a
0
5Å
Ca
Si
OH
Mg
O
A

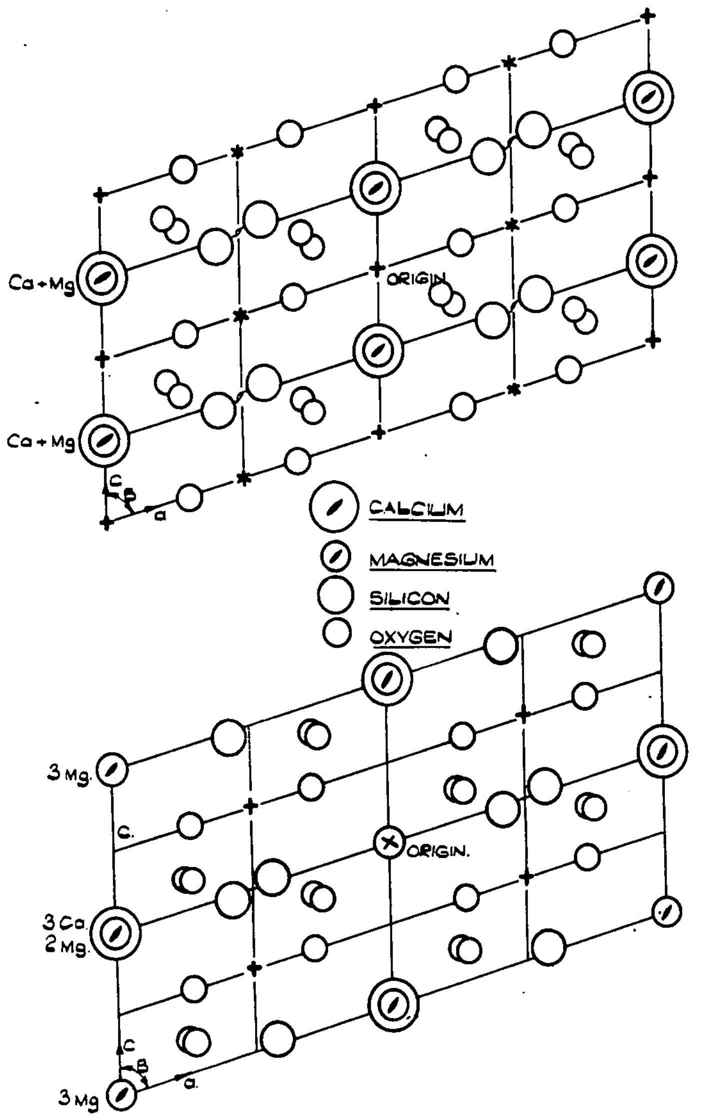
FIG. 2.

TABLE 1.

Observed (h01) reflexions from Tremolite and Diopside.

(h01)	Int. in Tremolite	Int. in Diopside
200	W. -M.	W.
400	V. -W.	3,0
600	S.	31,0
800	S.	21,0
002	V. -S.	60,0
004	S.	34,0
202	S.	19,1
402	V. -S.	28,6
602	S.	26,0
802	W. -M.	5,7
$\bar{2}02$	S.	31,0
$\bar{4}02$	S.	35,5
$\bar{6}02$	W.	W.
204	W.	W.
404	S.	21,9
604	S.	14,7
$\bar{2}04$	W.	2,1
$\bar{4}04$	S.	22,3
101	M.	All (h01) with h and l
301	W.	both odd are absent.
501	W.	
701	W.	
$\bar{1}01$	M.	
$\bar{3}04$	W.	
$\bar{5}01$	W.	
$\bar{7}01$	W.	
103	W.	
303	W.	
503	W.	
703	W.	
$\bar{1}03$	W.	
$\bar{3}03$	W.	
$\bar{5}03$	W.	

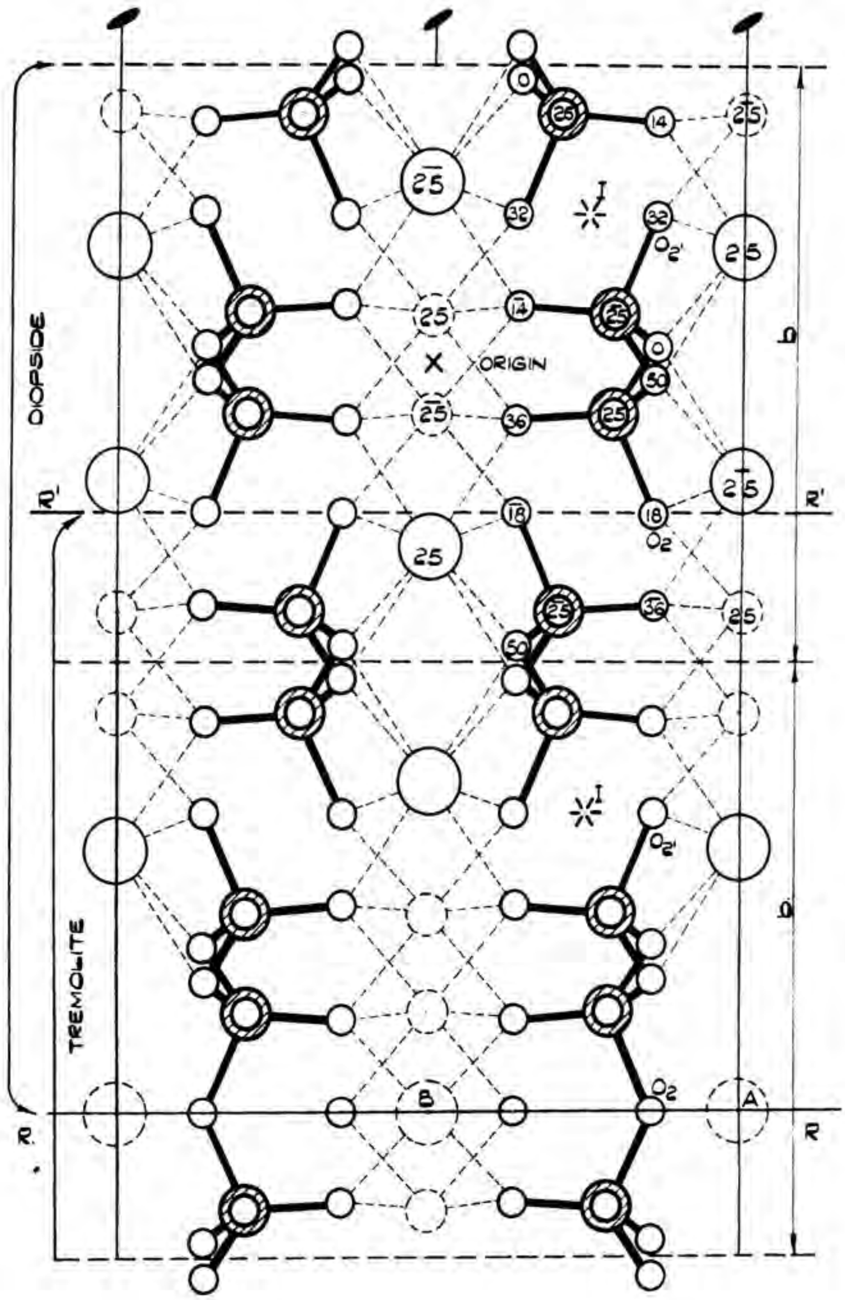
From Warren 1929.



UPPER.— PROJECTION OF DIOPSIDE STRUCTURE ON (010)

LOWER.— PROJECTION OF TREMOLITE STRUCTURE ON (010)

FIG. 3.



- PROJECTION OF TREMOLITE STRUCTURE ON (001.) —

FIG. 4

GRAPH SHOWING THE RELATIONSHIP BETWEEN Al REPLACING Si AND THE AMOUNT OF ALKALI IN THE VACANT SPACES

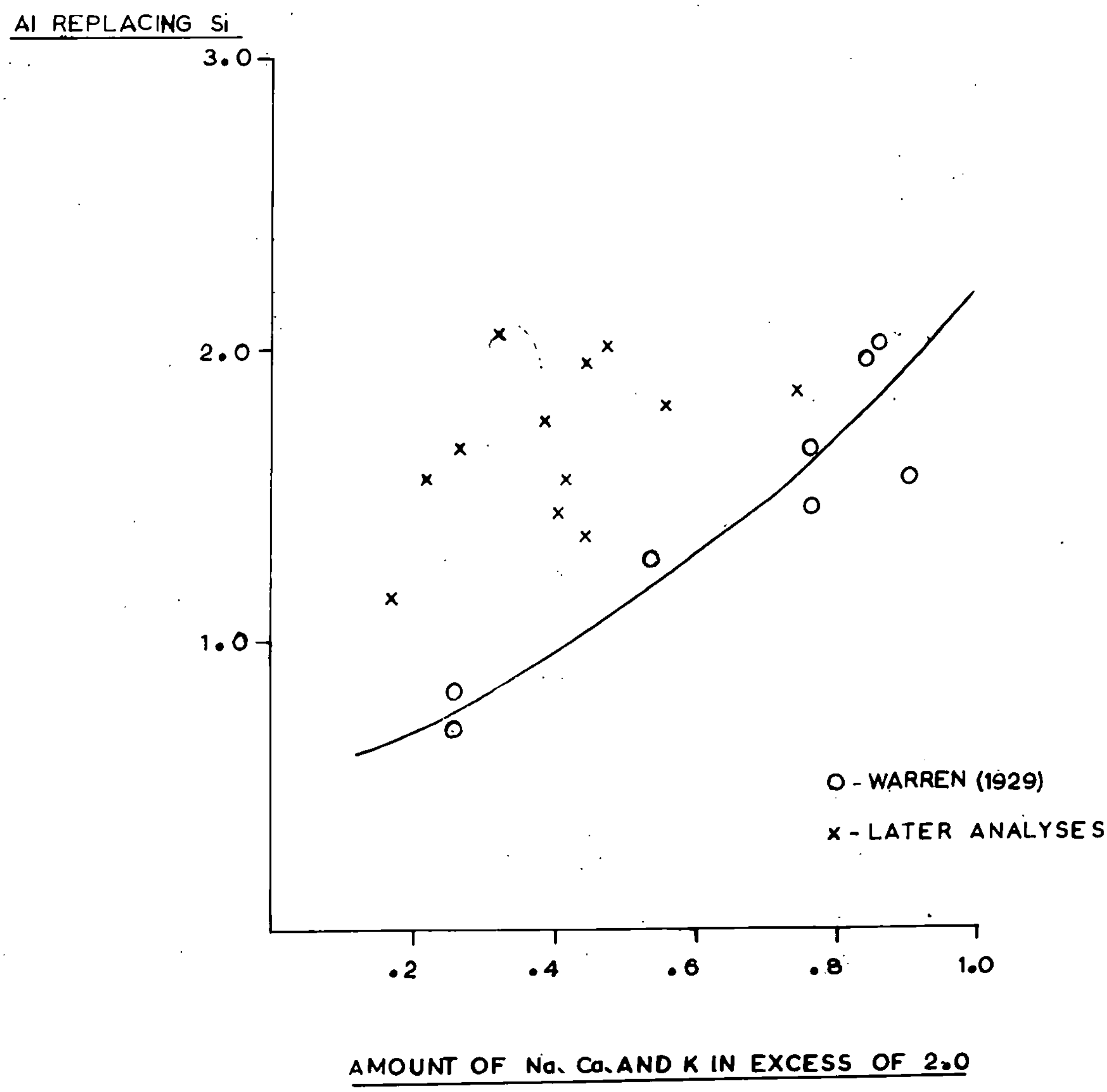
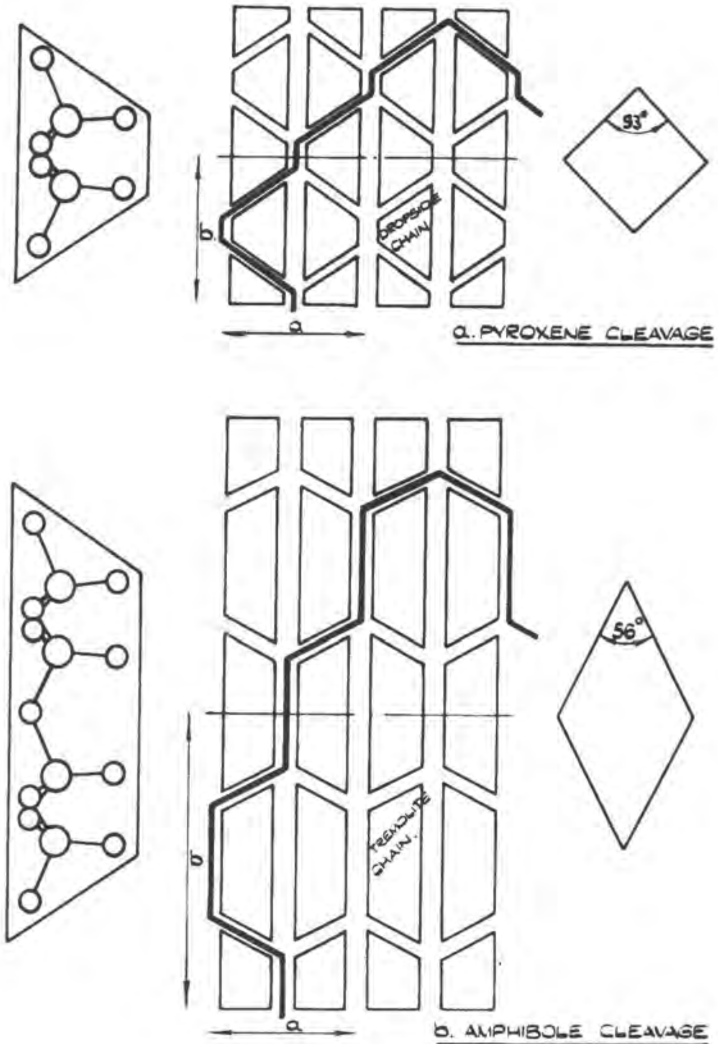


FIG. 5



RELATION BETWEEN THE SILICON-OXYGEN CHAINS & THE CLEAVAGE IN PYROXENES & AMPHIBOLES.

FIG. 6

TABLE SELECTED MODERN ANALYSES OF ANTHOPHYLLITE, 1890–1946

A.—Chemical weight per cent; A is weight per cent MgO+CaO+Na$_2$O+K$_2$O, B is weight per cent FeO+Fe$_2$O$_3$+MnO+TiO$_2$, and C is weight per cent of Al$_2$O$_3$ where A+B+C equal 100 per cent

No.	SiO$_2$	TiO$_2$	Al$_2$O$_3$	Fe$_2$O$_3$	FeO	MnO	MgO	CaO	Na$_2$O	K$_2$O	F	H$_2$O−	H$_2$O+	Total	FeO+Fe$_2$O$_3$+MnO+TiO$_2$	A	B	C
1	42.80	.49	17.78	1.03	18.32	.14	15.54	None	1.52	.03	.31	—	1.94	99.90	19.98	31.2	36.4	32.4
2	43.70	.55	10.88	3.52	26.53	.24	11.48	.54	1.24	.15	—	—	1.21	100.04	30.84	24.4	55.9	19.7
3	44.09	.31	17.22	1.87	15.02	.14	17.12	.51	1.24	tr	—	.29	2.03	99.55	17.34	35.3	32.2	32.5
4	44.22	—	23.79	.20	9.21	.11	20.69	—	—	—	—	—	1.42	100.31	9.37	58.3	17.7	44.0
5	44.32	—	16.04	2.80	16.88	.09	15.95	.77	1.86		—	—	1.31	100.02	19.77	34.1	36.3	29.5
6	44.70	.57	14.22	1.62	18.96	.21	14.89	.69	1.34	None	—	.29	2.27	100.26	21.36	32.0	40.3	27.7
7	45.38	—	14.70	.94	18.14	.31	15.26	.62	1.20	.19	—	.23	2.77	99.74	19.39	33.6	37.7	28.7
8	45.41	.44	15.84	2.94	15.32	.07	17.60	.14	.28	None	None	—	1.84	99.88	18.77	34.2	35.7	30.1
9	45.98	.53	14.92	.62	17.42	.04	18.27	.07	.47	None	None	—	1.51	99.83	18.66	36.0	35.5	28.5
10	46.50	.89	15.48	.89	16.01	None	17.62	.81	.77	.12	—	—	1.19	100.28	17.79	36.7	33.9	29.4
11	47.24	—	9.63	—	21.29	2.70	15.62	1.16	.35	—	—	—	2.31	100.30	23.99	33.8	46.3	19.9
12	47.86	.63	14.09	.33	14.41	.14	19.89	.57	.93	.06	—	None	2.46	100.42	13.88	43.4	28.1	28.5
13	48.00	1.00	7.63	1.11	26.11	.18	12.66	.64	1.21	.24	—	—	1.09	99.87	28.40	29.1	55.9	15.0
14	48.49	.41	13.26	1.28	14.60	None	20.56	.04	.11	None	None	—	1.48	100.23	16.29	41.2	32.4	26.4
15	49.66	—	6.74	1.23	18.09	.05	18.62	3.38	—	—	—	—	1.56	99.33	19.37	45.7	40.3	14.0
16	50.10	.73	7.35	None	22.18	.25	16.64	.60	.54	None	—	—	1.13	99.63	23.16	36.8	48.0	15.2
17	50.36	.43	8.06	2.18	18.36	None	17.57	.74	.70	None	None	—	1.69	99.99	20.87	39.7	43.5	16.8
18	51.06	—	1.90	1.22	24.81	2.03	16.41	.52	—	—	—	—	2.14	100.09	28.06	36.1	59.9	4.0
19	51.62	—	10.32	1.94	3.72	.87	26.82	1.29	.32	.68	—	—	2.23	99.81	6.53	63.3	14.2	22.5
20	52.26	1.11	10.35	4.31	17.13	—	12.52	—	—	—	—	—	2.00	99.68	22.55	27.6	49.6	22.8
21	52.48	.05	4.35	7.03	9.02	—	25.06	.14	—	—	.26	—	2.00	100.39	16.10	55.6	35.1	9.3
22	53.93	.02	1.79	1.84	20.50	.25	18.92	.12	.15	.07	.52	—	2.08	100.19	22.61	44.1	51.8	4.1
23	55.20	.06	2.83	3.43	8.11	—	28.46	.76	—	—	—	.14	1.27	100.26	11.60	67.0	26.5	6.5
24	55.34	—	2.56	—	15.29	.51	22.80	.63	.19	.12	—	—	2.34	99.78	15.80	56.4	37.5	6.1
25	55.90	None	1.13	8.28	.68	.49	29.26	.94	None	None	—	—	3.20	99.88	9.45	74.1	23.2	2.7
26	55.97	—	.59	1.46	15.38	.48	23.04	.37	.11	.03	.45	—	2.33	100.21	17.32	56.8	41.8	1.4
27	56.27	—	2.07	.40	13.81	.59	23.99	1.15	—	—	—	—	1.83	100.11	14.80	59.9	35.2	4.9
28	56.40	—	1.15	—	11.40	—	28.68	.50	—	—	—	—	1.63	99.76	11.40	69.9	27.3	2.8
29	57.02	None	1.40	None	8.71	.09	28.81	1.48	.66	None	None	—	1.59	99.76	8.80	75.2	21.4	3.4
30	57.14	tr	1.94	None	11.12	.11	26.82	.64	.27	.06	None	—	2.06	100.16	11.23	68.8	26.6	4.6
31	57.19	—	.92	—	7.98	.28	28.03	.76	—	—	—	.48	3.83	99.59	8.26	75.8	21.8	2.4
32	57.46	tr	.79	.81	13.21	.50	24.44	.32	.14		—	.06	2.58	100.62	14.52	62.0	36.0	2.0
33	57.60	—	1.94	1.58	6.62	—	30.32	tr	—	—	—	.20	2.66	100.92	8.20	75.0	20.3	4.7
34	57.86	—	2.46	.63	5.96	.33	29.38	.86	.41	—	—	—	2.45	100.34	6.92	76.6	17.3	6.1
35	57.98	—	.63	—	10.39	.31	28.69	.20	—	—	—	.12	1.67	99.99	10.70	71.8	26.6	1.6
36	58.03	—	—	4.87	5.95	—	28.57	—	1.12	.19	—	.17	1.20	100.10	10.82	73.4	26.6	—
37	58.38	—	.10	—	8.37	—	28.82	.61	—	—	—	.68	2.75	99.71	8.27	77.6	22.1	.3
38	58.43	tr	.10	.72	6.84	.12	29.66	tr	tr	tr	—	.16	3.76	99.79	7.68	79.2	20.5	.3
39	58.74	.02	.12	.66	5.61	.06	29.95	tr	tr	tr	—	.24	4.59	99.99	6.35	82.2	17.4	.4
40	58.75	—	1.27	—	5.60	—	31.33	—	.51	—	—	.25	1.70	99.61	5.60	82.3	14.4	3.3
41	58.83	—	.66	.52	—	2.53	30.81	3.45	—	—	.28	—	2.64	99.93	3.05	90.2	8.1	1.7
42	59.12	—	.91	1.01	6.89	.23	29.67	.06	.30	—	—	—	1.97	100.16	8.13	76.9	20.8	2.3
43	59.29	.03	.59	.29	.06	2.77	30.98	1.26	.37	.19	.20	—	3.80	99.83	3.15	89.8	8.6	1.6
44	59.56	—	.66	.76	7.49	.17	28.97	—	—	—	—	.31	2.38	100.30	8.32	76.1	22.1	1.8
45	59.60	—	5.72	.84	3.24	.01	27.94	.22	.12	.04	—	—	2.27	100.00	4.09	74.3	10.7	15.0
46	60.16	tr	.39	.50	5.88	.05	29.04	None	.33		—	.21	2.72	100.14	6.43	81.1	17.8	1.1

1. Deduct .13 for O=F$_2$
12. All TiO$_2$ is rutile; P$_2$O$_5$ = .05
16. V$_2$O$_3$ = .09
20. Average of two analyses
21. Deduct .12 for O=F$_2$
22. Deduct .22 for O=F$_2$
26. Deduct .19 for O=F$_2$
31. Cr$_2$O$_3$ = .12
32. Vol. = .21; CO$_2$ = .10; Cr$_2$O$_3$ = tr.
37. Average of 3 analyses
38. P$_2$O$_5$ = .00
39. P$_2$O$_5$ = .00
41. Deduct .12 for O=F$_2$
43. Deduct .08 for O=F$_2$
45. Average of 2 analyses recalculated to 2(OH)

B.—Number of atoms of each element based on the general anthophyllite formula (Mg, Fe'', Fe''', Mn, Ti, Al)$_7$ (Si, Al)$_8$ O$_{22}$ (OH, F)$_2$ with minor amounts of (Ca, Na, K) which is one-fourth the content of the unit cell. Col. A is the ratio of aluminum replacing silicon to the aluminum plus ferric iron replacing magnesium, etc. Col. B is the atomic per cent of Fe''+Fe'''+Mn+Ti where Mg+Fe''+Fe'''+Mn+Ti+Al(I) equal 100 per cent

No.	Ca	Na	K	Mg	Fe''	Fe'''	Mn	Ti	Al(I)	Total	Si	Al	Total	OH	F	O	A	B
1	—	.41	—	3.37	2.21	.10	.02	.05	1.24	7.40	6.20	1.80	8.00	1.86	.14	22.00	1.34	35.0
2	.09	.37	.02	2.63	3.37	.40	.03	.06	.63	7.60	6.68	1.32	8.00	1.22	—	22.78	1.25	51.0
3	.08	.32	—	3.67	1.78	.20	—	.03	1.20	7.28	6.30	1.70	8.00	1.92	—	22.08	1.21	27.6
4	.09	—	—	4.24	1.05	.01	.01	—	1.91	7.31	6.07	1.93	8.00	1.30	—	22.70	1.00	16.6
5	.12	.43	—	3.47	2.04	.31	.01	—	1.18	7.58	6.44	1.56	8.00	1.25	—	22.75	1.04	31.2
6	.11	.36	—	3.23	2.28	.17	.03	.06	.97	7.21	6.47	1.53	8.00	2.19	—	21.81	1.34	35.1
7	.09	.32	.03	3.28	2.16	.10	.03	—	.99	7.00	6.51	1.49	8.00	2.63	—	21.37	1.36	32.6
8	.01	.07	—	3.78	1.83	.31	—	.04	1.16	7.20	6.50	1.50	8.00	1.75	—	22.25	1.02	30.2
9	—	.12	—	3.93	2.08	.07	—	.05	1.11	7.24	6.60	1.40	8.00	1.43	—	22.57	1.18	30.5
10	.12	.10	—	3.77	1.88	.10	—	.09	1.24	7.30	6.64	1.36	8.00	1.13	—	22.87	1.01	27.6
11	.17	.09	—	3.42	2.59	—	.33	—	.56	7.16	6.91	1.09	8.00	2.25	—	21.75	1.94	40.7
12	.09	.25	—	4.17	1.56	.02	.02	—	.99	7.09	6.68	1.32	8.00	2.28	—	21.72	[illegible]	22.0
13	.10	.34	.04	2.87	3.28	.12	.02	.11	.62	6.88	7.26	.74	8.00	1.09	—	22.91	1.00	47.2
14	—	.02	—	4.34	1.71	.13	—	.04	1.01	7.25	6.82	1.18	8.00	1.39	—	22.61	1.03	25.9
15	.50	—	—	4.07	2.20	.14	—	—	.48	7.39	7.25	.75	8.00	1.51	—	22.49	1.20	31.8
16	.10	.14	—	3.68	2.72	—	.02	.08	.65	7.39	7.38	.62	8.00	1.11	—	22.89	.95	38.1
17	.11	.18	—	3.67	2.11	.24	—	.04	.31	6.67	7.01	.99	8.00	1.55	—	22.45	1.80	35.8
18	.08	—	—	3.65	3.06	.14	.25	—	—	7.18	7.58	.34	7.92	2.12	—	21.88	2.42	48.1
19	.19	.08	.12	5.45	.41	.20	.10	—	.63	7.18	6.99	1.01	8.00	2.00	—	22.00	1.21	9.9
20	—	—	—	2.67	2.02	.46	—	.23	1.14	6.52	7.42	.58	8.00	1.89	—	22.11	.36	41.0
21	.02	—	—	5.22	1.04	.73	—	—	—	7.01	7.29	.69	7.98	1.85	.15	22.00	.94	25.2
22	.01	.03	—	4.09	2.46	.19	.02	—	.08	6.88	7.77	.23	8.00	1.99	.24	21.77	.85	38.8
23	.10	—	—	5.90	.94	.34	—	—	.08	7.36	7.64	.36	8.00	1.16	—	22.84	.85	17.3
24	.09	.05	.02	4.79	1.79	—	.06	—	.17	6.97	7.75	.25	8.00	2.18	—	21.82	1.47	26.3
25	.13	—	—	5.86	.07	.83	.06	—	—	6.95	7.47	.18	7.65	2.83	—	21.17	.21	14.4
26	.05	.03	—	4.83	1.79	.15	.06	—	—	6.91	7.83	.10	7.93	2.16	.20	21.64	.06	28.9
27	.16	—	—	5.02	1.61	.05	.07	—	.19	7.10	7.86	.14	8.00	1.68	—	22.32	.58	24.3
28	.07	—	—	5.96	1.31	—	—	—	—	7.34	7.81	.18	7.99	1.49	—	22.51	—	17.9
29	.21	.16	—	5.95	.99	—	.01	—	.08	7.40	7.85	.15	8.00	1.42	—	22.58	1.87	13.5
30	.09	.06	.01	5.51	1.26	—	.01	—	.15	7.09	7.84	.16	8.00	1.88	—	22.12	1.06	17.9
31	.10	—	—	5.65	.89	—	.03	—	—	6.67	7.69	.15	7.84	3.42	—	20.58	—	13.7
32	.04	.03	—	5.06	1.50	.08	.04	—	.06	6.81	7.93	.07	8.00	2.35	—	21.65	.50	23.3
33	—	—	—	6.06	.73	.16	—	—	—	6.95	7.36	.30	7.66	2.35	—	21.65	1.87	12.5
34	.12	.10	—	5.89	.66	.06	.03	—	.14	7.00	7.74	.26	8.00	2.18	—	21.82	1.30	10.7
35	.03	—	—	5.91	1.18	—	.04	—	.06	7.22	7.96	.04	8.00	1.53	—	22.47	.00	16.9
36	—	.30	.03	5.89	.68	.49	—	—	—	7.39	7.98	—	7.98	1.09	—	22.91	—	15.8
37	.09	—	—	5.86	.95	—	—	—	—	6.90	7.92	.02	7.94	2.44	—	21.56	—	13.7
38	—	—	—	5.92	.75	.06	.01	—	—	6.74	7.77	.02	7.79	3.32	—	20.68	.33	12.2
39	—	—	—	5.88	.62	.06	—	—	—	6.56	7.71	.02	7.73	4.01	—	19.99	.33	10.4
40	—	.06	—	6.38	.63	—	—	—	.13	7.20	7.92	.08	8.00	1.52	—	22.38	.63	8.7
41	.49	.05	—	6.13	—	.05	.28	—	—	7.00	7.80	.11	7.91	2.32	.12	21.56	2.20	4.7
42	.01	.06	—	5.99	.77	.10	.02	—	.11	7.06	7.96	.04	8.00	1.76	—	22.24	.19	12.7
43	.18	.10	.03	6.04	.01	.03	.31	—	—	6.70	7.76	.09	7.85	3.32	.08	20.60	3.00	8.2
44	—	—	—	5.83	.83	.06	.02	—	.10	6.84	8.00	—	8.00	2.13	—	21.87	—	13.5
45	.03	.03	—	5.50	.35	.08	—	—	.71	6.70	7.83	.17	8.00	2.00	—	22.00	2.12	0.4
46	—	.06	—	5.83	.67	.05	—	—	.06	6.67	8.05	—	8.05	2.42	—	21.58	—	10.7

No.	Date	Author	Locality	Analyst
1	1948	Rabbitt	Cherry Creek Area, Madison Co., Montana	Forest Gonyer
2	1936	Eskola	Isopää, Kalvola, Finland	Tauno Kervinen
3	1939	Tilley	Karelia, U.S.S.R.	H. C. G. Vincent
4	1931	Henderson	Masons Creek, Franklin Co., North Carolina	E. P. Henderson
5	1908	Evans and Bancroft	Haliburton Co., Ontario, Canada	N. N. Evans
6	1942	Collins	Sutherland, England	Geochemical Laboratories
7	1931	Simpson	Bullsbrook, Western Australia	D. G. Murray
8	1948	Rabbitt	Cherry Creek Area, Madison Co., Montana	Forest Gonyer
9	1948	Rabbitt	Dillon Complex, Beaverhead Co., Montana	Forest Gonyer
10	1934	Ignatiev	Karelia, U.S.S.R.	Author (?)
11	1930	Kunitz	Haddam, Connecticut	W. Kunitz
12	1895	Emerson	Warwick, Massachusetts	E. A. Schneider
13	1914	Eskola	Träskböle, Finland	Pentti Eskola
14	1948	Rabbitt	Ruby River, Madison Co., Montana	Forest Gonyer
15	1920	Shannon	Chesterfield, Massachusetts	E. V. Shannon
16	1914	Eskola	Träskböle, Finland	Pentti Eskola
17	1948	Rabbitt	Cherry Creek Area, Madison Co., Montana	Forest Gonyer
18	1930	Kunitz	Bamble, Norway	W. Kunitz
19	1930	Kunitz	Ötztal, Tyrol	W. Kunitz
20	1937	Rama Rao	Bidaloti, Mysore, India	E. R. Tirumalachar
21	1922	La Croix	Mt. Tsilaizina, Madagascar	Raoult
22	1933	Sundius	Trondhjem, Norway	A. Bygdén
23	1922	La Croix	Mt. Tsilaizina, Madagascar	Raoult
24	1930	Kunitz	Kjernerud, Norway	W. Kunitz
25	1936	Serdiuchenko	Malaya Laba River, North Caucasus, U.S.S.R.	G. Maksimovich
26	1930	Johansson	Falun, Sweden	K. Johansson
27	1917	Ishyul	Kongsberg, Norway	Author (?)
28	1898	Pratt	Bakersville, Mitchell Co., North Carolina	Charles Baskerville
29	1948	Rabbitt	Cherry Creek Area, Madison Co., Montana	Forest Gonyer
30	1948	Rabbitt	Dillon Complex, Beaverhead Co., Montana	Forest Gonyer
31	1902	Rosický	Böhmisch-Schützendorf, Near Deutsch-Brod, Bohemia	Hynek Němeček
32	1939	Uralsky and Buchneva	Kochnevsky, Southern Urals, U.S.S.R.	Authors (?)
33	1926	Shannon	Kamiah, Idaho Co., Idaho	E. V. Shannon
34	1930	Kunitz	Miask, U.S.S.R.	W. Kunitz
35	1890	Penfield	Franklin, Macon Co., North Carolina	S. L. Penfield
36	1932	Stappenbeck	Morogoro, Tanganyika Territory, Africa	Author (?)
37	1902	Friedel	St. Germain-l'Hermite, France	G. Friedel
38	1936	Rimann	Paakila, Finland	G. Grosser
39	1936	Rimann	Paakila, Finland	G. Grosser
40	1913	D'Achiardi	St. Piero in Campo, Island of Elba	Author (?)
41	1930	Kunitz	Edwards, St. Lawrence Co., New York	W. Kunitz
42	1936	Haapala	Paakkilanniemi, Finland	R. Kalajoki
43	1908	Allen and Clement	Edwards, St. Lawrence Co., New York	E. T. Allen and J. K. Clement
44	1936	Haapala	Tiillikainen, Finland	E. Savolainen
45	1943	Bugge	Vormlitjern, Sondeled, Norway	M. Khuever
46	1939	Uralsky and Buchneva	Mramorsky, Middle Urals, U.S.S.R.	Authors (?)

TABLE 2.

TABLE 3

ANALYSES OF SOME ANTHOPHYLLITE ASBESTOS FROM G.P. MERRILL (1895)

	53	54	55	56	57	58	59	60	61	62
SiO_2	54.56	54.79	55.92	56.21	56.52	56.72	57.00	57.31	57.73	59.00
TiO_2	-	-	-	-	-	-	-	-	-	-
Al_2O_3	1.47	-	3.69	2.78	3.57	1.54	-	1.57	.72	.91
Fe_2O_3	-	13.65	-	-	-	-	10.32	-	-	-
FeO	12.39	-	11.00	8.58	10.08	10.76	-	7.06	8.61	6.09
MnO	-	-	-		-		-	-	-	-
MgO	25.28	28.52	26.32	28.95	27.13	27.46	29.98	30.24	28.77	29.90
CaO	1.86	-	.60	.82		.10		-	.08	.45
Na_2O	-	-	-	-	-	-	-	-	.57	.68
K_2O	-	-	-	-	-	-	-	-	.14	.43
F	-	-	-	-	-	-	-	-	-	-
H_2O-	-	-	-	-	-	-	-	-	-	-
$+H_2O$	2.95	2.55	2.40	2.23	2.96	2.88	2.29	2.73	2.52	2.35
Total	98.51	99.51	99.94	99.57	100.26	99.49	99.59	98.91	99.14	99.81

Locality	Analyst
53. Carbon County, Wyoming.	G.P. Merrill.
54. Franklin County, N. Carolina.	- -
55. Tallapoosa County (?) Alabama.	- -
56. Lenoir, Caldwell County, N. Carolina.	- -
57. Rabun County, Georgia.	- -
58. Alberton, Mafyland.	- -
59. Warre nton, Warrenton County, N. Carolina.	- -
60. San Diego, California.	- -
61. Nacoochee, Georgia.	R.L. Packard.
62. Mitchell County, N. Carolina.	- -

Fig. 7

Graph to show the Relationship between SiO_2 and Al_2O_3 in Anthophyllites.

Fig. 8

Graph to show the Relationship between Al_2O_3 and TiO_2 in Anthophyllites.

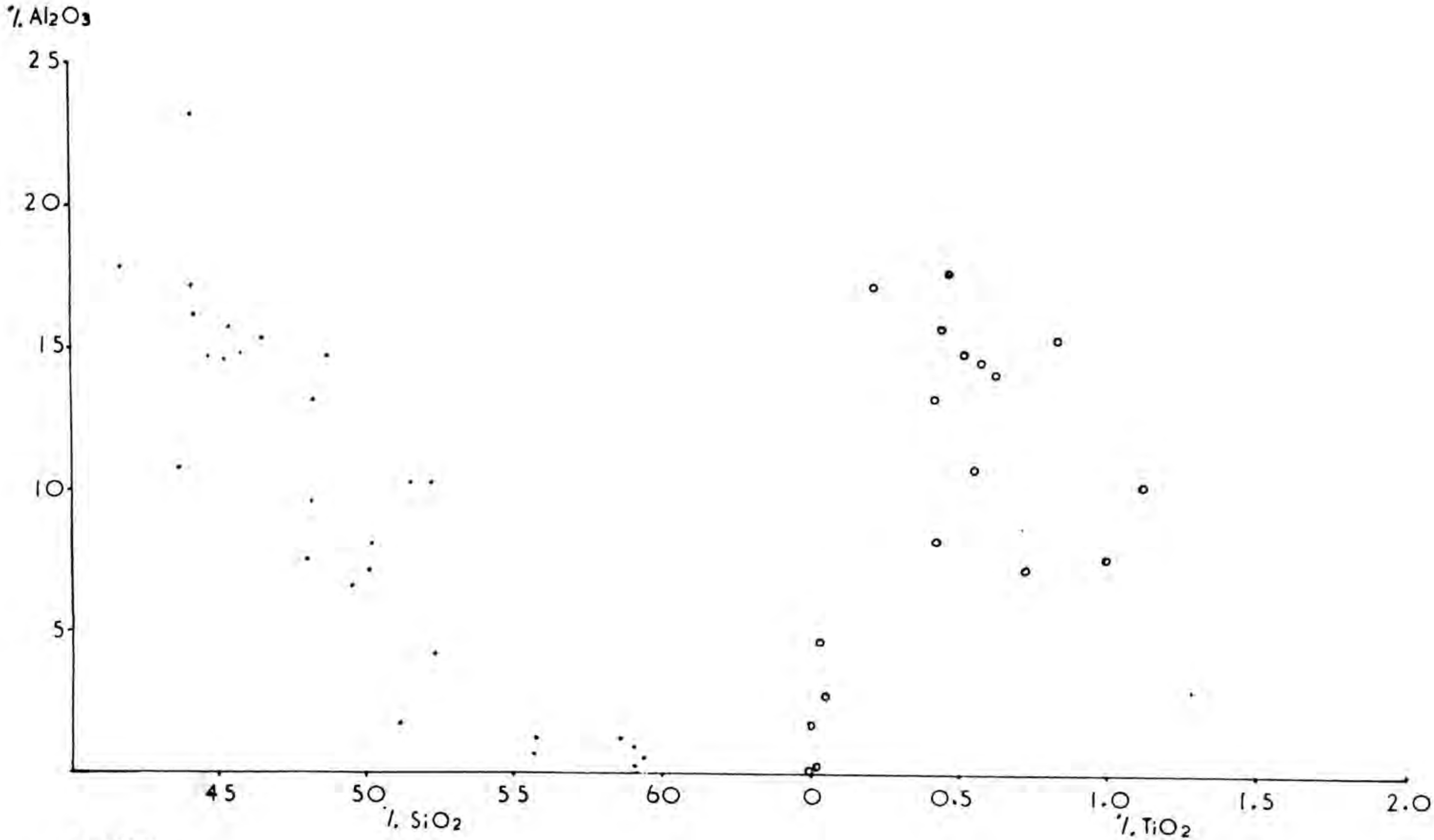


FIG. 7 & 8.

TABLE 4.

SPECTROGRAPHIC ANALYSIS OF TEN ANTHOPHYLLITES AND ONE CUMMINGTONITE

After John C. Rabbitt. Weight per cent. (Dashes = $<$ 0.001%)

ANTHOPHYLLITE	Ag	Ba	Co	Cr	Cu	Li	Mo	Ni	Pb	Sn	Sr	V	Zr
1	.004	-	.003	-	.004	.03		.002	-	-		.001	-
8	.002	-	.007	.03	.005	.03		.01	-	-		.04	.001
9	.002	-	.006	.02	.005	.03		.008	-	-		.03	.002
10	.003	-	.004	.01	.006	.04		.01	-	-		.01	.003
14	.002	-	.005	.003	.005	.03		.004	-	-		.03	.001
17	.003	-	.008	.002	.02	.04		.006	-	-		.05	.001
29	.002	-	.007	.2	.008	.005		.1	-	.002		.01	.002
30	.002	.006	.006	.03	.003	.02		.06	-	-		.001	.002
53	.002	-	.007	.006	.03	.001		.07	-	-		-	.003
59	.008	-	.008	.008	.02	.002		.06	-	-	.008	-	.001
CUMMINGTONITE									-	-			
Cc. 352 A.	.003	-	.003	.005	.01	.002	.001	.01	.001	.002	.001	.002	.005

TABLE 5

OPTICAL PROPERTIES OF SOME ANTHOPHYLLITES.

From Table 2

sg.		nX	nY	nZ	nZ-nX	Sign and 2V	Remarks
3.37	2.	1.674	-	1.697	.023	(+) -	
3.259	3.	1.651	-	1.672	.021	(+) -	
3.178	4.	1.642	1.655	1.661	.019	(-) large	Indices ± 0.003
3.24	6.	1.652	1.656	1.666	.014	(+) 85°	Positive elongation
3.16	7.	1.643	1.653	1.659	.016	-	Positive elongation
	10.	1.642	1.648	1.658	.016	(+) 78°	
	12.	-	-	-	-	(-) -	
3.23	13.	-	1.662	1.676	-	70°-80°	
	15.	1.644	-	1.660	.016	-	
	16.	-	1.653	1.667	-	70°-80°	
3.22	20.	1.656	1.667	1.672	.015	(-) 57°	2V±; red violet
	21.	-	-	-	-	(-) -	
	22.	1.6454	1.649	1.6605	.015	(+) 59-3°	Birefringence measured
	24.	1.629	-	1.652	.021	(-) -	
	25.	1.626	1.638	1.651	.025	(+) 87°	Red violet
	26.	1.6329	1.6384	1.6517	.0188	(+) 66°02'	2V measured with optic angle apparatus
	33.	1.605	-	1.625	.020	-	
	34.	1.608	-	1.631	.023	-	
	35.	1.6195	1.6301	1.6404	.0209	(-) 88°46'	As corrected by Bowen; 2V measured with optic angle apparatus
	38.	1.605	-	1.626	-	-	nX is nX'; F-C=0.014
	39.	1.60	-	1.623	-	-	nX is nX'; F-C=0.014
	40.	-	1.64	-	-	(-) 67°	nZ minus nY=0.0065
	41.	1.598	-	1.623	.025	-	
	43.	-	-	1.62	-	-	
	44.	-	-	1.634	-	-	
	45.	1.610	1.627	1.630	.020	(-) 69°	2V measured on the Fedorov stage

Pleochroism and orientation

	X	Y	Z
3.	greenish yellow	greenish yellow	grayish green
5.	pale yellow	brownish yellow	dove gray
6.	yellow	brownish	smoke gray
13.	pale clove brown	clove brown	dark brown
15.	colorless	colorless	colorless
16.	colorless	colorless	colorless
20.	pale yellow to colorless	same to pale brownish	lilac
25.	colorless	colorless	gray brown

In all of these Z=c, Y=b, the optic plane is parallel to (010), and absorption is X=Y Z.

TABLE 6a

PHYSICAL PROPERTIES OF SEVEN MONTANA ANTHOPHYLLITES

(RABBITT 1948)

		1			8			9		
		Z	Y	X	Z	Y	X	Z	Y	X
F=4861.3A°	F	1.6910	1.6839	1.6751	1.6821	1.6768	1.6710	1.6850	1.6792	1.6728
D=5892.9A°	D	1.6781	1.6670	1.6506	1.6718	1.6630	1.6553	1.6695	1.6603	1.6520
C=6562.8A°	C	1.6726	1.6600	1.6477	1.6673	1.6570	1.6485	1.6630	1.6520	1.6431
Dispersion	F-C	.0184	.0239	.0274	.0148	.0198	.0225	.0220	.0272	.0297
	F	.0159			.0111			.0122		
Birefringence	D	.0215			.0165			.0175		
	C	.0249			.0188			.1099		
Optic	F	(-)86z			(-)88°			(-)84°		
Sign	D	(+)87°			(+)86°			(+)87°		
and										
2V	C	(±)90°			(+)85°			(+)84°		
	X	Pale tan			Pale tan			Pale tan		
Pleochroism	Y	"			"			"		
	Z	Tan			Tan			Smoke grey		

TABLE 6b

PHYSICAL PROPERTIES OF SEVEN MONTANA ANTHOPHYLLITES

(RABBITT 1948)

		14			17		
		Z	Y	X	Z	Y	X
F=4861.3A°	F	1.6725	1.6681	1.6631	1.6777	1.6736	1.6680
D=5892.9A°	D	1.6619	1.6545	1.6476	1.6671	1.6595	1.6540
C=6562.8A°	C	1.6574	1.6488	1.6410	1.6630	1.6540	1.6480
Dispersion	F-C	.0151	.0207	.0221	.0147	.0196	.0200
	F	.0094			.0097		
Birefringence	D	.0143			.0131		
	C	.0164			.0150		
Optic	F	(-)88°			(-)84°		
Sign	D	(+)87°			(+)81°		
and							
2V	C	(+)86°			(+)78°		
	X	Pale tan			Pale tan		
Pleochroism	Y	"			"		
	Z	Tan			Tan		

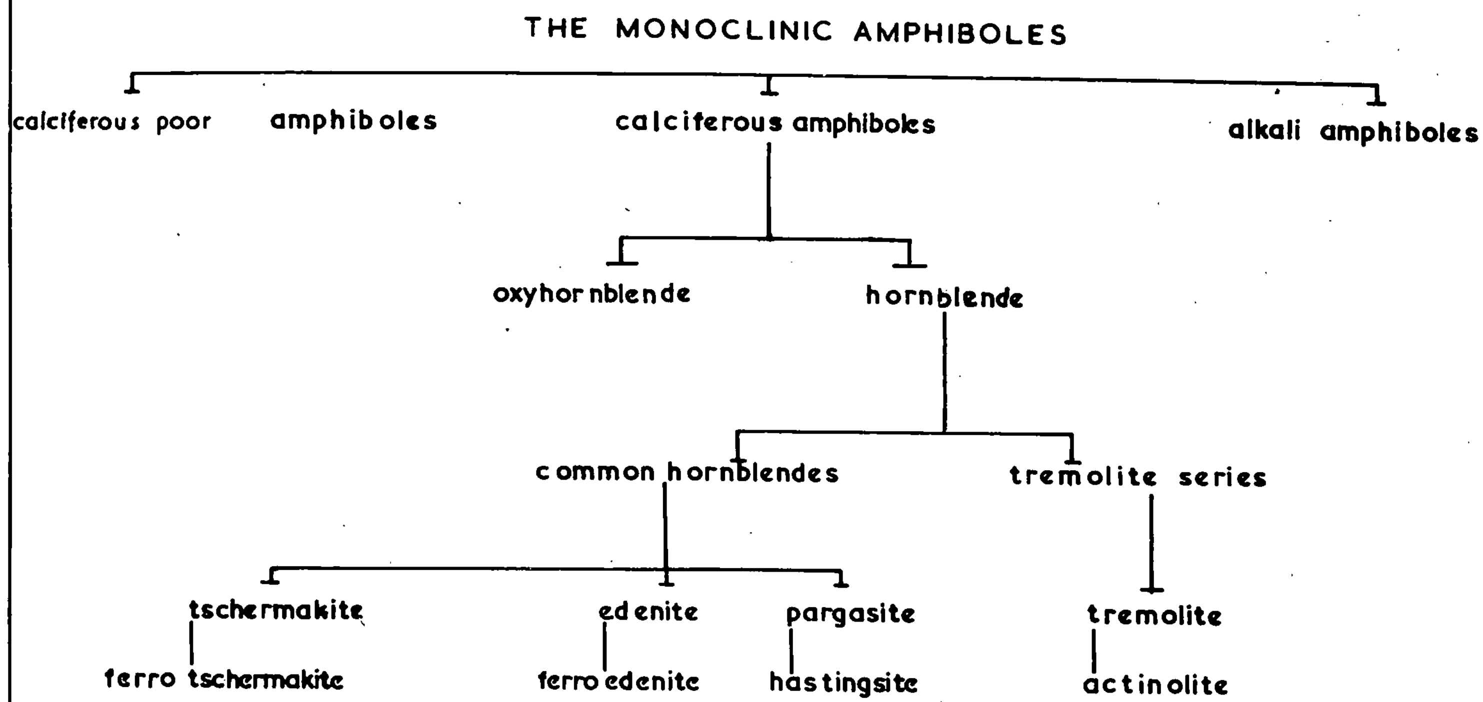
TABLE 6c

PHYSICAL PROPERTIES OF SEVEN MONTANA ANTHOPHYLLITES

(RABBITT 1948)

		29 Z	29 Y	29 X	30 Z	30 Y	30 X
F=4861.3A°	F	1.6451	1.6365	1.6305	1.6505	1.6430	1.6340
D=5892.9A°	D	1.6354	1.6370	1.6180	1.6410	1.6280	1.6162
C=6562.8A°	C	1.6315	1.6230	1.6127	1.6372	1.6205	1.6092
Dispersion	F≅C	.0136	.0135	.0178	.0133	.0725	.0248
	F	.0146			.0165		
Birefringence	D	.0174			.0248		
	C	.0188			.0280		
Optic	F	+80°			(-)85°		
Sign	D	( )88°			+ 88°		
and							
2V	C	(-)84°			(+)79°		
	X	Colourless			Colourless		
Pleochroism	Y	"			"		
	Z	Colourless			Colourless		

Pleochroism in 1, 8, 14 and 17 is weak, 9 it is moderate
Absorption X = Y< Z   Orientation all varieties Z = c Y = b



GENERAL CLASSIFICATION OF THE MONOCLINIC AMPHIBOLES.

FIG. 9.

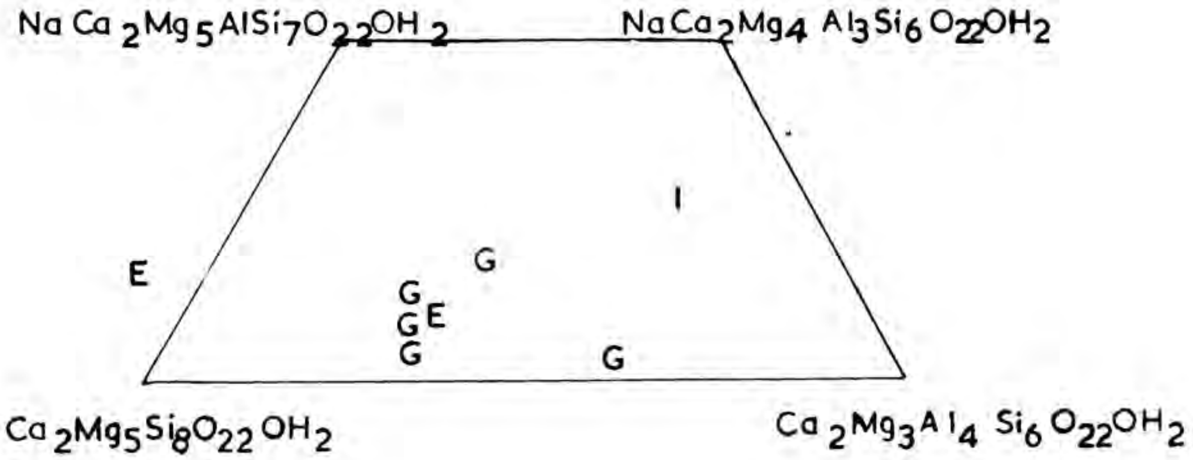
TABLE 7.

Aluminium - aluminian
Antimony - antimonian
Argon - argonian
Arsenic - arsenoan, arsenian
Barium - barian
Beryllium - beryllian
Bismuth - bismuthian
Boron - borian
Bromine - bromian
Cadmium - cadmian
Calcium - calcian
Carbon - carbonian
Cerium - cerian
Cesium - cesian
Chlorine - chlorian
Hydrogen - hydrogenian
Indium - indian
Iodine - iodian
Iridium - iridian
Iron - ferroan, ferrian
Krypton - kryptonian
Lanthanum - lanthanian
Lead - plumbian
Lithium - lithian
Lutecium - lutecian
Magnesium - magnesian
Manganese - manganoan,
manganian
Mercury - mercuroan, mercurian
Molybdenum - molybdenian
Neodymium - neodymian
Neon - neonian
Nickel - nickelian
Nitrogen - nitrogenian
Osmium - osmian
Oxygen - oxygenian
Palladium - palladian
Phosphorus - phosphorian
Platinum - platinian
Potassium - potassian
Praseodymium - praseodymian
Radium - radian
Radon - radonian

Chromium - chromian
Cobalt - cobaltian
Columbium - columbian
Copper - cuproan, cuprian
Dysprosium - dysprosian
Erbium - erbian
Europium - europian
Fluorine - fluorian
Gadolinium - gadolinian
Gallium - gallian
Germanium - germanian
Gold - aurian
Hafnium - hafnian
Helium - helian
Holmium - holmian
Rhedium - rhenian
Rhodium - rhodian
Rubidium - rubidian
Ruthenium - ruthenian
Samarium - samarian
Scandium - scandian
Selenium - selenian
Silicon - silician
Silver - argentian
Sodium - sodian
Strontium - strontian
Sulfur - sulfurian
Tantalum - tantalian
Tellurium - tellurian
Terbium - terbian
Thallium - thallian
Thorium - thorian
Thulium - thulian
Tin - stannian
Titanium - titanian
Tungsten - tungstenian
Uranium - uranoan, uranian
Vanadium - vanadian
Xenon - xenonian
Ytterbium - ytterbian
Yttrium - yttrian
Zinc - Zincian
Zirconium - zirconian

Fig. 10

Plot of Edenites from the Literature
on the Hallimond Diagram (Francis 1958).



E EDENITES FROM EDENVILLE, NEW YORK

G EDENITE TYPES FROM GLEN URQUHART

I EDENITE FROM MADRAS, INDIA

FIG 10

TABLE 8

WRITER'S LIST OF TREMOLITE SERIES FROM THE LITERATURE.

No.	A	B	C	D	E	F	G
SiO_2	53.96	54.73	54.80	51.86	52.78	54.78	54.33
Al_2O_3	3.79	1.46	2.58	3.81	5.77	3.67	2.68
Fe_2O_3	1.15	-	2.50	2.19	2.45	0.15	1.09
FeO	3.48	9.60	4.75	5.97	6.61	7.38	11.68
MnO	0.20	0.16	tr	0.04	0.17	0.18	0.00
MgO	25.01	17.94	20.30	19.40	17.43	19.10	15.31
CaO	9.53	12.76	12.08	10.73	11.90	12.65	12.46
Na_2O	0.54	1.44	0.82	2.16	0.68	nil	0.54
K_2O	0.13	tr	0.24	0.28	0.07	nil	0.12
H_2O^+	1.07	2.27	1.60	0.98	2.10	2.39	2.04
H_2O^-	-	-	0.11	-		0.09	0.20
F	-	-	0.77	0.46	0.01	-	-
Cl	-	-		-	0.02		-
Total	-	-	100.65	99.58	100.58	100.91	100.74
O for F+Cl	-		.32	-	.01		-
TiO_2	0.12		0.10	1.92	0.43	0.22	0.29
Total	99.81		100.33	99.58	100.51	100.91	100.74

TABLE 8

WRITER'S LIST OF TREMOLITE SERIES FROM THE LITERATURE.

(cont.)

No.	H	I	J	K	L	M	O
SiO_2	54.73	54.33	56.15	51.85	56.60	56.04	56.10
Al_2O_3	1.46	2.68	1.24	4.36	1.41	1.23	1.30
Fe_2O_3	-	1.09	0.78	2.58	1.04	1.40	0.48
FeO	9.60	11.68	5.50	5.46	4.28	4.10	1.01
MnO	0.16	0.00	0.48	0.35	0.20	0.18	0.14
MgO	17.94	15.31	21.19	19.48	22.26	22.20	24.94
CaO	12.76	12.46	12.08	10.60	12.50	11.56	13.06
Na_2O	1.44	0.54	0.19	2.15	0.58	0.79	0.84
K_2O	tr	0.12	0.28	0.35	0.27	0.48	0.90
H_2O^+	2.27	2.04	1.81	1.21	0.82	0.67	n.d.
H_2O^-	-	-		0.13	-	-	
F	-	-	0.04	0.46	-	0.16	0.83
Cl	-	-	-		-	-	
Total	100.57	100.74	99.84	100.24	100.00	99.97	100.35
O for F+Cl				.22	-	0.08	0.42
TiO_2	0.21	0.29	-	1.26	0.07	0.15	0.10
Total	100.57	100.74	99.84	100.02	100.00	99.89	99.93

TABLE 8

WRITER'S LIST OF TREMOLITE SERIES FROM THE LITERATURE.

(cont.)

No.	P	Q	R	S	T	U
SiO_2	57.30	56.00	54.84	57.69	58.38	57.45
Al_2O_3	1.42	2.01	3.02	1.80	0.44	1.30
Fe_2O_3	0.96	1.34	2.22	0.00	0.37	0.18
FeO	0.28	4.27	11.22	0.55	-	0.22
MnO	0.05	0.15	0.30	tr	1.54	0.07
MgO	25.20	22.12	15.28	24.12	25.01	24.85
CaO	12.84	11.84	11.52	13.19	10.95	12.89
Na_2O	0.18	1.44	0.32	0.48	0.76	0.67
K_2O	0.66	0.36	0.19	0.22	0.07	0.54
H_2O^+	0.68	0.63	1.02	1.56	2.17	1.16
H_2O^-	-	-	-	0.10		0.09
F	0.28	-	-	0.37	0.27	0.77
Cl	-	-	-	-	-	-
Total	100.56	100.16	99.93	100.22	100.01	100.19
O for F+Cl	0.14	-	-	0.15	0.11	0.32
TiO_2	0.09	tr	tr	0.14	0.05	-
Total	100.42	100.16	99.93	100.07	99.90	99.87

TABLE 8

WRITER'S LIST OF TREMOLITE SERIES FROM THE LITERATURE.

(cont.)

A.	Actinolite.	Pirani.	(Min. Abs. 12 p. 30).
B.	Actinolite.	Tilley.	(1938).
C.	Actinolite.	Ford.	(1914).
D.	Actinolite.	Merwin & Washington.	(1923).
E.	Actinolite.	Mathias.	(1952).
F.	Actinolite.	Tilley.	(1938).
G.	Actinolite.	Tilley.	(1938).
H.	Actinolite.	Tilley.	(1938).
I.	Actinolite.	Tilley.	(1938).
J.	Actinolite.	Ford.	(1914).
K.	Actinolite.	Ford.	(1914).
L.	Tremolite.	Parsons.	(1930).
M.	Tremolite.	Parsons.	(1930).
O.	Tremolite.	Parsons.	(1930).
P.	Tremolite.	Parsons.	(1930).
Q.	Tremolite.	Parsons.	(1930).
R.	Tremolite.	Parsons.	(1930).
S.	Tremolite.	Ford.	(1914).
T.	Tremolite.	Bygden.	(1933).
U.	Tremolite.	Ford.	(1914).

TABLE 8

TREMOLITE SERIES ANALYSES RECALCULATED ON THE BASIS 24 (O,OH,F).

(cont.)

	A	B	C	D	E	F
Si	7.21	7.73	7.65	7.79	7.39	7.59
Al (4)	0.6	0.24	0.35	0.21	0.609	0.409
Al (6)	-	-	0.07	0.58	0.348	0.189
Fe"	0.112	-	0.26	0.22	0.252	0.046
Fe"	0.35	1.14	0.55	0.65	0.774	0.855
Mn	0.22	0.02	tr	-	0.017	0.021
Mg	4.97	3.78	4.22	3.80	3.66	3.94
Ca	1.36	1.93	1.81	1.5	1.78	1.878
Na	0.14	0.39	0.22	0.54	0.185	-
K	0.26	tr	0.04	0.04	0.017	-
OH	1.3	2.14	1.49	.84	1.948	2.21
F	-	-	0.34	0.18	0.008	-
Ti	0.26	-	0.01	0.19	0.04	0.024
Cl	-	-	-	-	.02	-
Al	0.6	0.24	0.42	0.58	0.957	0.598
(Fe)+Al	1.59	1.40	1.24	1.67	2.01	1.55
Ca+Na+K+Mg	6.73	6.10	6.29	5.88	5.54	5.82
Na+K	0.40	0.39	0.26	0.58	0.20	0.00
Fe"+Fe"' +MnO+Ti	0.97	1.16	0.82	1.09	1.05	.95

TABLE 8

TREMOLITE SERIES ANALYSES RECALCULATED ON THE BASIS 24 (O,OH,F).

(cont.)

	G	H	I	J	K	L
Si	7.43	7.73	7.74	7.83	7.38	7.95
$Al^{(4)}$	0.257	0.244	0.26	0.17	0.62	0.05
$Al^{(6)}$	0.193	-	0.19	0.04	0.11	0.18
Fe"	0.116	-	0.12	0.02	0.22	0.11
Fe"	1.393	1.135	1.39	0.61	0.65	0.50
Mn	-	0.019	-	0.03	0.04	0.02
Mg	3.25	3.78	3.25	4.49	4.13	4.66
Ca	1.901	1.932	1.90	1.85	1.62	1.88
Na	0.145	0.394	0.15	0.13	0.59	0.16
K	0.022	-	0.02	0.03	0.06	0.05
OH	1.94	2.14	1.94	1.82	1.15	.77
F	-	-	-	0.05	0.21	-
Ti	0.032	0.022	0.03	nil	0.14	0.01
Cl	-	-	-	-	-	-
Al	0.450	0.244	0.45	0.21	0.73	0.23
(Fe)+Al	1.99	1.42	1.80	.87	1.84	0.89
Ca+Na+K+Mg	5.30	6.10	5.32	6.50	6.40	6.75
Na+K	0.17	0.39	0.17	0.16	0.65	0.21
Fe"+Fe"' +MnO+Ti	1.54	1.18	1.54	0.66	1.11	0.64

TABLE 8

TREMOLITE SERIES ANALYSES RECALCULATED ON THE BASIS 24 (O,OH,F).

(cont.)

	M	O	P	Q	R	S
Si	7.92	7.91	7.91	7.90	7.92	7.88
$Al^{(4)}$	0.08	0.09	0.09	0.16	0.08	0.12
$Al^{(6)}$	0.13	0.13	0.14	0.23	0.43	0.17
Fe"	0.15	0.05	0.10	0.14	0.24	-
Fe"	0.48	0.12	0.03	0.50	1.35	0.06
Mn	0.02	0.02	0.01	0.02	0.04	tr
Mg	4.67	5.24	5.18	4.65	3.29	4.90
Ca	1.90	1.97	1.90	1.79	1.78	1.93
Na	0.22	0.23	0.21	0.39	0.09	0.13
K	0.09	0.16	0.12	0.06	0.04	0.04
OH	.63	n.d.	0.63	0.59	0.98	0.42
F	0.07	0.87	0.12	-	-	0.16
Ti	0.02	0.01	0.01	-	tr	0.02
Cl	-	-	-	-	-	-
Al	0.21	0.22	0.23	0.33	0.51	0.29
(Fe)+Al	0.88	0.42	.38	.99	2.14	.37
Ca+Na+K+Mg	6.88	7.60	7.41	6.89	5.26	7.00
Na+K	0.31	0.39	0.33	0.45	0.51	0.70
Fe"+Fe"' +MnO+Ti	0.67	0.20	0.15	0.66	1.63	0.08

TABLE 8

TREMOLITE SERIES ANALYSES RECALCULATED ON THE BASIS 24 (O,OH,F).

(cont.)

	T	U		
Si	7.97	7.87	E154.70	E^{2}1197.5562
$Al^{(4)}$	0.07	0.13		
$Al^{(6)}$	-	0.08		
Fe"	0.03	0.02		
Fe"	-	0.02		
Mn	0.18	0.02		
Mg	5.08	5.10	E58.04	E^{2}378.8748
Ca	1.59	1.90		
Na	0.19	0.17		
K	0.02	0.08		
OH	1.97	1.09		
F	0.11	0.37		
Ti	0.01	-		
Cl	-	-		
Al	0.07	0.21		
(Fe)+Al	.29	0.27	E23.99	E^{2}36.32 19
Ca+Na+K+Mg	7.05	7.25	E128.01	E^{2}829.3599
Na+K	0.38	0.25	E7.35	E^{2} 3.519
Fe"+Fe"' +MnO+Ti	0.22	0.06	E16.38	E^{2} 18.0272

TABLE 8

PHYSICAL PROPERTIES OF TREMOLITE SERIES.

No.	A	B	C	D	E
Ng	1.634	1.641	1.641	1.660	1.638
Nm	1.628	1.630	1.6304	1.650	1.642
Np	1.619	1.617	1.616	1.636	1.627
$Z_{\wedge}c$	19	18	$14^{o}47^{o}$	$15^{o}-22^{o}$	17^{o}
2V	$79\frac{1}{2}$	calc. $105^{o}6'$ Np incorrect	2Vm $81^{o}30$ calc. $83^{o}16$	75^{o}	83^{o}
S.G	3.190	3.090	3.029	3.079	3.105
$\sin Z_{\wedge}c$	3256	3090	2551	3090	2924
Sin2V	9833	9999	9890	9659	9925
Y-x	.015	.024	.025	.024	.026

TABLE 8

PHYSICAL PROPERTIES OF TREMOLITE SERIES.

(cont.)

No.	F	G	H	I	J
Ng	1.638	1.650	1.641	1.650	1.641
Nm	1.623	1.641	1.630	1.641	1.6330
Np	1.618	1.627	1.617	1.627	1.617
$Z_{\wedge}c$	17	20	18^{o}	20	14^{o} 57^{o}
2V	84 28	77 26	85-12	77 26	$81^{o}38'$
S.G	3.060	3.110	3.090	3.110	3.047
Sin$Z_{\wedge}c$	2924	2420	3090	3420	2585
Sin2V	9953	9761	9965	9760	9895
Y-x	.020	.023	.024	.023	.024

TABLE 8

PHYSICAL PROPERTIES OF TREMOLITE SERIES.

(cont.)

No.	K	L	M	θ	P
Ng	1.655	1.634	1.639	1.636	1.636
Nm	1.6442	1.626	1.626	1.622	1.623
Np	1.628	1.616	1.611	1.609	1.609
$Z_{\wedge}c$	13° 35'	18	17°	17°-18°	16
2V	76° 58'	83° 34'	85° 54'	Calc. 92°6' Np incorrect	87-54
S.G	3.137	3.044	3.051	3.024	2.998
$SinZ_{\wedge}c$	2348	3090	2924	3007	2756
Sin2V	9743	9937	9974	9999	9993
Y-x	.027	.018	.028	.027	.027

TABLE 8

PHYSICAL PROPERTIES OF TREMOLITE SERIES.

(cont.)

No.	Q	R	S
Ng	1.636	1.653	1.635
Nm	1.626	1.642	1.6192
Np	1.613	1.628	1.602
$Z_{\wedge}c$	16°	15°	16° 38'
2V	82° 6'	83°-16'	86°-29'
S.G	3.042	3.131	2.980
$\sin Z_{\wedge}c$	2756	2588	2863
Sin2V	9905	9931	9981
Y-x	.023	.025	.033

TABLE 8

PHYSICAL PROPERTIES OF TREMOLITE SERIES.

(cont.)

No.	T	U		
Ng	1.629	1.625	E32.827	E^{2} 53.8822
Nm	-	1.6132		
Np	1.604	1.599	E32.340	E^{2} 52.295588
$Z_{\wedge}c$	15^{o}	20^{o} 1'		
2V	79^{o} 20'	83^{o} 23'		
S.G	2.980	2.997	E61.294	E^{2} 187.908036
$SinZ_{\wedge}c$	2588	3423	E5.8693	E^{2} 1.74081301
Sin2V	9827	9934	E19.7864	E^{2} 19.57690252
Y-x	.025	.026		

TABLE 8a

WRITER'S LIST OF COMMON HORNBLENDES FROM THE LITERATURE.

No.	1	2	3	4	5	6	7
SiO_2	39.78	41.25	41.15	37.40	34.185	38.44	38.74
Al_2O_3	11.39	10.46	16.14	12.34	11.527	11.03	11.42
Fe_2O_3	5.93	3.85	2.38	4.16	12.621	5.80	4.34
FeO	14.21	16.28	12.38	25.84	21.979	24.67	23.28
MnO	0.68	0.76	0.09	1.24	0.629	0.48	0.44
MgO	9.62	8.02	11.45	2.20	1.353	1.97	3.25
CaO	9.68	10.26	11.15	9.72	9.867	9.56	10.16
Na_2O	1.57	1.58	1.68	1.80	3.290	1.81	1.98
K_2O	1.60	1.46	1.93	1.36	2.286	1.72	1.97
H_2O^+	2.59	1.69	1.36	-	0.348	1.09	0.83
H_2O^-	0.25	0.10	0.05	0.60	-	0.19	1.09
F	1.29	1.17	0.8	-	-	.96	-
TiO_2	1.47	2.90	0.50	3.20	-	2.37	2.83
Cl	0.58	0.60	-	-	-	.60	0.77
Total	100.64	100.32	101.06	99.86	98.084	100.69	101.05
O for F+Cl	0.67	0.62	0.34	-	-	0.54	0.57
Total	99.97	99.70	100.72	-	-	100.15	100.48

TABLE 8a

WRITER'S LIST OF COMMON HORNBLENDES FROM THE LITERATURE.

(cont.)

No.	8	9	10	11	12	13	14
SiO_2	38.24	41.67	36.66	43.30	52.19	42.32	48.38
Al_2O_3	10.17	11.52	14.81	10.69	6.24	15.62	10.83
Fe_2O_3	5.00	4.71	8.10	3.94	0.64	4.22	0.76
FeO	26.64	14.91	21.67	7.00	4.61	6.78	1.56
MnO	0.28	0.13	0.61	0.35	0.19	0.15	0.04
MgO	1.07	9.46	2.20	16.02	20.00	13.68	20.78
CaO	10.64	11.04	9.38	9.73	13.15	11.78	12.24
Na_2O	1.50	1.54	2.87	4.58	0.45	2.41	2.69
K_2O	1.57	2.13	2.61	0.66	0.24	0.34	1.38
H_2O^+	1.88	1.01	0.33	1.80	0.44	2.13	0.91
H_2O^-	-	0.03	-	-	-	-	-
F	1.06	1.40	-	-	-	0.02	1.82
TiO_2	2.00	1.72	1.04	1.55	0.48	0.27	0.05
Cl	0.51	-	-	-	-	-	-
Total	100.07	101.28	100.28	99.62	99.84	99.90	101.44
O for F+Cl		0.59	-	-	-	-	0.76
Total		100.69	-	-	-	-	100.68

TABLE 8a

WRITER'S LIST OF COMMON HORNBLENDES FROM THE LITERATURE.

(cont.)

No.	15	16	17	18	19	20	21	22
SiO_2	42.05	48.10	43.90	44.96	43.33	41.90	44.56	53.56
Al_2O_3	12.60	11.05	12.52	14.90	15.28	14.90	9.57	6.45
Fe_2O_3	1.60	0.67	0.38	1.51	1.11	1.90	0.54	0.49
FeO	11.51	1.65	5.95	4.05	8.89	3.50	7.99	4.53
MnO	-	-	-	0.09	0.13	0.06	0.22	0.19
MgO	13.48	20.60	18.91	16.05	13.77	18.54	22.37	19.49
CaO	11.85	12.50	12.69	11.92	12.15	13.11	7.94	13.49
Na_2O	1.97	2.54	1.34	1.51	2.41	2.33	0.27	0.46
K_2O	1.90	1.24	1.30	0.12	0.87	1.46	0.07	0.24
H_2O^+	0.41	0.71	0.51	2.26	0.85	0.35	5.51	0.45
H_2O^-	0.07	0.11	0.10	-	-	-	-	-
F	1.82	1.90	2.29	0.02	0.73	3.06	0.00	-
TiO_2	0.91	0.10	.009	0.23	1.23	0.46	0.56	0.49
Cl	-	-	-	0.05	0.06	-	-	-
Total	100.17	101.17	100.59	99.72	100.81	100.30	100.14	100.00
O for F+Cl	0.17	.80	-	Chromium 1.92	0.32	-		-
Total	99.41	100.37	99.63		100.45	-		-

TABLE 8a

WRITER'S LIST OF COMMON HORNBLENDES FROM THE LITERATURE.

(cont.)

No.	23	24	25	26	27	28
SiO_2	51.88	44.15	42.11	47.14	43.01	45.50
Al_2O_3	7.36	10.59	10.05	9.44	12.01	9.66
Fe_2O_3	2.13	5.02	2.82	3.66	3.35	6.06
FeO	5.68	8.89	15.14	8.38	9.07	6.90
MnO	0.25	0.17	0.24	0.11	0.19	0.18
MgO	16.36	12.30	11.48	14.44	14.00	14.61
CaO	13.70	11.80	11.34	10.53	11.79	11.24
Na_2O	0.44	1.26	1.01	1.15	1.08	1.20
K_2O	0.60	1.10	1.43	1.30	1.01	0.92
H_2O^+	0.96	0.95	2.02	2.00	1.40	1.73
H_2O^-	-	0.11	0.06	0.53	0.06	0.19
F	-	0.84	-	-	0.84	trace
TiO_2	0.41	3.73	2.76	1.74	2.87	1.73
Cl	co2 0.10	-	-	-	-	-
Total	99.87	100.91	100.46	100.42	100.68	99.92
O for F+Cl		0.36	-	-	0.36	-
Total		100.55	-	-	100.32	-

TABLE 8a

WRITER'S LIST OF COMMON HORNBLENDES FROM THE LITERATURE.

(cont.)

No.	29	30	31	32	33	34
SiO_2	48.32	48.96	48.92	44.23	48.71	45.09
Al_2O_3	6.43	7.85	5.88	14.62	9.48	10.43
Fe_2O_3	5.45	3.62	6.50	5.11	2.33	3.90
FeO	7.90	8.25	7.79	8.94	9.12	10.14
MnO	0.13	0.12	0.17	0.21	0.23	0.24
MgO	14.82	15.69	14.32	10.78	14.43	12.52
CaO	11.99	11.90	11.37	10.81	11.93	12.29
Na_2O	0.99	1.04	1.20	1.51	1.16	1.60
K_2O	0.67	0.53	0.71	0.61	0.16	0.78
H_2O^+	1.61	0.63	1.37	1.42	1.83	1.76
H_2O^-	0.06	0.08	0.18	0.08		-
F	trace	1.41	0.27	0.22	0.23	0.28
TiO_2	1.43	1.07	1.21	1.81	0.32	0.84
Cl	-	-	-	-	-	-
Total	99.80	101.15	99.89	100.35	99.92	99.87
O for F+Cl	-	0.61	0.11	0.09	0.10	0.12
Total	-	100.54	99.78	100.26	99.82	99.75

TABLE 8a

WRITER'S LIST OF COMMON HORNBLENDES FROM THE LITERATURE.

(cont.)

No.	35	36	37	38	39	40
SiO_2	45.28	44.94	42.90	42.65	44.73	41.72
Al_2O_3	11.00	11.24	11.92	15.89	11.54	15.80
Fe_2O_3	4.42	2.87	5.04	5.33	2.87	3.36
FeO	10.50	12.61	12.58	14.65	11.07	6.03
MnO	0.28	0.22	0.30	0.43	0.40	0.12
MgO	12.02	11.98	10.30	6.64	11.89	14.14
CaO	12.48	11.61	11.49	10.13	11.83	12.92
Na_2O	1.59	1.86	2.40	2.08	1.45	1.42
K_2O	0.97	0.47	1.19	0.28	0.60	2.60
H_2O^+	1.02	1.26	1.32	1.64	1.79	0.85
H_2O^-	-	-	-	-	-	0.04
F	0.31	0.24	0.20	0.27	0.16	0.16
TiO_2	1.01	1.79	1.44	0.65	1.32	0.81
Cl	-	-	-	-	-	-
Total	100.68	101.09	101.08	100.68	99.65	-
O for F+Cl	0.11	0.10	0.08	0.11	0.07	-
Total	100.57	100.99	101.00	100.57	99.58	100.33

TABLE 8a

WRITER'S LIST OF COMMON HORNBLENDES FROM THE LITERATURE.

(cont.)

REFERENCE.

1.	Femaghastingsite.	Buddington & Leonard.	(1953).
2.	Femaghastingsite.	Buddington & Leonard.	(1953).
3.	Pargasite.	Howie, R. A.	(1955).
4.	Ferrohastingsite.	Billings.	(1928).
5.	Ferrohastingsite.	Billings.	(1928).
6.	Ferrohastingsite.	Billings.	(1928).
7.	Ferrohastingsite.	Buddington & Leonard.	(1953).
8.	Ferrohastingsite.	Sahama.	(1947).
9.	Hornblende.	Howie.	(1955).
10.	Hastingsite.	Walker.	(1924).
11.	Magnesio-hastingsite.	Billings.	(1928).
12.	Called Edenite.	Mikkola & Sahama.	(1936).
13.	Edenite.	Subramanian.	(1956).
14.	Pargasite.	Laitakari.	(1918-23).
15.	Pargasite.	Laitakari.	(1918-23).
16.	Pargasite.	Laitakari.	(1918-23).
17.	Pargasite.	Laitakari.	(1918-23).
18.	Pargasite.	Subramanian.	(1956).
19.	Pargasite.	Rosenzweig & Watson.	(1954).
20.	Pargasite.	Parsons.	(1930).
21.	Hornblende.	Kennedy & Dixon.	(1936).
22.	Hornblende.	Mikkola & Sahama.	(1936).

TABLE 8a

WRITER'S LIST OF COMMON HORNBLENDES FROM THE LITERATURE.

(cont.)

REFERENCE.

23.	Hornblende.	Jones.	(1930).
24.	Hornblende.	Deer.	(1938).
25.	Hornblende.	Deer.	(1938).
26.	Hornblende.	Deer.	(1938).
27.	Hornblende.	Deer.	(1938).
28.	Hornblende.	Deer.	(1938).
29.	Hornblende.	Deer.	(1938).
30.	Hornblende.	Deer.	(1938).
31.	Hornblende.	Deer.	(1938).
32.	Hornblende.	Deer.	(1938).
33.	Hornblende.	Rosenzweig & Watson.	(1954).
34.	Hornblende.	Rosenzweig & Watson.	(1954).
35.	Hornblende.	Rosenzweig & Watson.	(1954).
36.	Hornblende.	Rosenzweig & Watson.	(1954).
37.	Hornblende.	Rosenzweig & Watson.	(1954).
38.	Tschermakite.	Rosenzweig & Watson.	(1954).
39.	Hornblende.	Rosenzweig & Watson.	(1954).
40.	Hornblende.	Hallimond.	(1947).

TABLE 8a

COMMON HORNBLENDE ANALYSES RECALCULATED ON THE BASIS 24 (O,OH,F).

No.	1	2	3	4	5	6	7	8
Si	5.98	6.30	6.039	6.10	5.75	6.20	6.18	6.16
$Al^{(4)}$	2.02	1.70	1.961	1.47	2.25	1.80	1.82	1.84
$Al^{(6)}$	0.01	0.17	0.821	0.90	0.04	0.29	0.33	0.09
Fe'''	0.67	0.44	0.264	0.51	1.60	0.070	0.52	0.60
Fe''	1.77	2.07	1.515	3.53	3.09	3.31	3.12	3.60
Mn	0.09	0.09	0.011	0.17	0.09	0.07	0.06	0.04
Mg	2.17	1.84	2.519	0.53	0.34	0.47	0.78	0.26
Ca	1.56	1.68	1.752	1.70	1.78	1.65	1.74	1.84
Na	0.46	0.48	0.475	0.57	1.07	0.56	0.61	0.47
K	0.31	0.28	0.352	0.28	0.49	0.35	0.40	0.32
OH	2.60	1.72	1.340	0.65	0.39	1.17	0.88	2.04
F	0.61	0.56	0.370	0.00	-	0.48	0.48	0.54
Ti	0.17	0.33	0.053	0.39	-	0.29	0.34	0.30
Cl	0.16	0.15	-		-	0.15	0.21	0.14
Al	2.03	1.87	2.78	2.37	2.29	2.09	2.15	1.93
Fe''+Mn +Fe'''+Ti	2.70	2.93	1.84	4.60	4.78	4.37	4.04	4.38
(Fe)+Al	4.73	4.80	4.62	6.97	7.07	6.46	6.19	6.31
Ca+K+Na+Mg	4.5	4.28	5.10	3.08	3.68	3.03	3.53	2.89
Na+K	0.77	0.76	0.83	0.85	1.56	0.91	1.01	0.79

TABLE 8a

COMMON HORNBLENDE ANALYSES RECALCULATED ON THE BASIS 24 (O,OH,F).

(cont.)

No.	9	10	11	12	13	14	15	16
Si	6.229	5.97	6.44	7.151	6.33	6.33	6.46	6.76
$Al^{(4)}$	1.771	2.03	1.56	1.00	1.67	1.58	1.54	1.24
$Al^{(6)}$	0.257	0.81	0.30	0.11	0.99	-	0.56	0.58
Fe'''	0.520	0.99	0.42	0.07	0.452	0.06	0.09	0.07
Fe''	1.857	2.95	0.87	0.56	0.818	0.17	1.48	0.18
Mn	0.016	0.08	0.04	0.02	0.017	-	-	-
Mg	2.120	0.53	3.56	4.29	2.95	4.11	3.05	4.35
Ca	1.766	1.64	1.54	2.03	1.83	1.70	1.85	1.88
Na	0.448	0.91	1.24	0.13	0.678	0.68	0.60	0.69
K	0.394	0.54	0.14	0.04	0.052	0.24	0.40	0.24
OH	1.004	0.36	1.60	0.42	2.053	0.82	0.40	0.67
F	0.665	-	-	-	0.008	0.38	0.44	0.84
Ti	0.188	0.14	0.17	0.05	0.035	-	-	0.001
Cl	-	-	-	-	0.008	-	-	-
Al	2.03	2.84	2.28	1.06	2.66	1.58	2.10	1.82
Fe''+Mn +Fe'''+Ti	2.58	4.16	1.50	0.70	1.32	0.23	1.57	0.26
(Fe)+Al	4.61	7.00	3.78	1.76	3.98	1.81	3.67	2.08
Ca+K+Na+Mg	4.73	3.62	6.48	6.49	5.51	6.73	5.90	7.16
Na+K	0.84	1.45	1.38	0.17	0.73	0.92	1.00	0.93

TABLE 8a

COMMON HORNBLENDE ANALYSES RECALCULATED ON THE BASIS 24 (O,OH,F).

(cont.)

No.	17	18	19	20	21	22	23	24
Si	6.35	6.38	6.32	6.04	6.25	7.58	7.42	6.451
$Al^{(4)}$	1.65	1.62	1.68	1.96	1.59	0.48	0.58	1.509
$Al^{(6)}$	0.49	0.87	0.95	0.58	-	0.60	0.68	0.320
Fe'''	0.04	0.16	0.12	0.21	0.05	0.07	0.23	0.555
Fe''	0.72	0.48	1.09	0.42	0.93	0.54	0.68	1.091
Mn	-	0.01	0.02	0.01	0.03	0.02	0.03	1.021
Mg	4.10	3.39	3.00	3.99	4.68	4.11	3.49	2.694
Ca	1.97	1.80	1.90	2.03	1.20	2.04	2.10	1.858
Na	0.38	0.41	0.68	0.65	0.06	0.13	0.12	0.359
K	0.24	0.02	0.16	0.27	0.02	0.04	0.11	0.207
OH	0.50	2.15	0.83	0.16	3.98	0.42	0.92	0.930
F	1.04	0.01	0.33	1.40	-	-	-	0.406
Ti	0.08	0.03	0.13	0.50	0.06	0.05	0.04	0.411
Cl	-	0.02	0.02	-	-	-	-	-
Al	2.14	2.49	2.63	2.54	1.64	1.02	1.26	1.83
Fe''+Mn +Fe'''+Ti	0.84	0.70	1.36	0.69	1.07	0.68	0.98	2.08
(Fe)+Al	2.98	3.19	3.99	3.23	2.71	1.70	2.24	3.91
Ca+K+Na+Mg	6.69	5.62	5.74	6.94	5.96	6.49	5.82	5.12
Na+K	0.62	0.43	0.84	0.92	0.08	0.17	0.23	0.57

TABLE 8a

COMMON HORNBLENDE ANALYSES RECALCULATED ON THE BASIS 24 (O,OH,F).

(cont.)

No.	25	26	27	28	29	30	31	32
Si	6.314	6.813	6.288	6.630	7.044	7.068	7.155	6.436
$Al^{(4)}$	1.680	1.187	1.712	1.370	0.956	0.932	0.845	1.564
$Al^{(6)}$	0.090	0.410	0.350	0.280	0.145	0.400	0.165	0.934
Fe'''	0.319	0.397	0.368	0.663	0.597	0.394	0.715	0.559
Fe''	1.896	1.013	1.109	0.840	0.964	0.995	0.952	1.087
Mn	0.031	0.013	0.023	0.022	0.016	0.015	0.021	0.026
Mg	2.565	3.109	3.049	3.171	3.218	3.373	3.120	2.337
Ca	1.822	1.629	1.845	1.754	1.871	1.840	1.780	1.685
Na	0.294	0.321	0.306	0.338	0.280	0.291	0.339	0.424
K	0.274	0.240	0.188	0.172	0.124	0.097	0.132	0.114
OH	2.018	1.927	1.364	1.681	1.565	0.607	1.335	1.377
F	-	-	0.386	-	-	0.642	0.123	0.105
Ti	0.311	0.188	0.314	0.189	0.156	0.117	0.135	0.198
Cl	-	-	-	-				
Al	1.78	1.60	2.06	1.65	1.10	1.33	1.01	2.50
Fe''+Mn +Fe'''+Ti	2.56	1.61	1.72	1.71	1.73	1.52	1.81	1.87
(Fe)+Al	4.34	3.21	4.78	3.36	2.83	2.85	2.92	4.37
Ca+K+Na+Mg	4.95	5.28	5.40	5.43	5.45	5.60	5.37	4.50
Na+K	0.56	0.56	0.50	0.51	0.40	0.39	0.47	0.53

TABLE 8a

COMMON HORNBLENDE ANALYSES RECALCULATED ON THE BASIS 24 (O,OH,F).

(cont.)

No.	33	34	35	36	37	38
Si	6.99	6.65	6.67	6.62	6.38	6.34
Al (4)	1.01	1.35	1.33	1.38	1.62	1.66
Al (6)	0.59	0.46	0.58	0.57	0.47	1.13
Fe'''	0.25	0.43	0.49	0.32	0.56	0.60
Fe''	1.09	1.25	1.29	1.55	1.56	1.82
Mn	0.03	0.03	0.04	0.03	0.04	0.05
Mg	3.09	2.74	2.62	2.63	2.28	1.46
Ca	1.84	1.94	1.97	1.83	1.83	1.62
Na	0.32	0.46	0.46	0.53	0.69	0.60
K	0.03	0.15	0.18	0.09	0.22	0.05
OH	1.76	1.73	1.01	1.24	1.30	1.63
F	0.10	0.13	0.14	0.12	0.10	0.13
Ti	0.03	0.09	0.11	0.19	0.16	0.07
Cl						
Al	1.70	1.81	1.91	1.95	2.09	2.79
Fe''+Mn +Fe'''+Ti	1.40	1.80	1.93	2.09	2.32	2.54
(Fe)+Al	3.10	3.61	3.84	4.04	4.41	5.33
Ca+K+Na+Mg	5.28	5.29	5.23	5.08	5.02	4.73
Na+K	0.35	0.61	0.64	0.62	0.91	0.65

TABLE 8a

COMMON HORNBLENDE ANALYSES RECALCULATED ON THE BASIS 24 (O,OH,F).

(cont.)

No.	39	40		
Si	6.59	6.14	E259.34	E^{2} 1687.9682
$Al^{(4)}$	1.41	1.86		
$Al^{(6)}$	0.60	0.89		
Fe'''	0.32	0.37		
Fe''	1.36	0.74		
Mn	0.05	0.01		
Mg	2.61	3.10	E107.80	E^{2}343.9966
Ca	1.87	2.04		
Na	0.42	0.40		
K	0.12	0.49		
OH	1.76	0.83		
F	0.07	0.19		
Ti	0.15	0.09		
Cl				
Al	2.01	2.75	E79.47	E^{2}167.8553
Fe''+Mn +Fe'''+Ti	1.88	1.21	E80.06	E^{2}216.5470
(Fe)+Al	3.89	3.96	E160.63	E725.0985
Ca+K+Na+Mg	5.02	6.03	E208.85	E^{2}1134.4105
Na+K	0.54	0.89	E27.89	E^{2} 23.049

TABLE 8a

PHYSICAL PROPERTIES OF COMMON HORNBLENDES.

No.	Ng	Nm	Np	$Z_{\wedge}c$	2V	S.G	Sin$Z_{\wedge}$c	Sin2V	Ng-Np
1.	1.693	1.689	1.666	$41^{\circ}\pm5^{\circ}$	$51^{\circ}\pm1^{\circ}$	3.211	.35837	.77715	.027
2.	1.696	1.692	1.680	$15^{\circ}\pm5^{\circ}$	$58\pm4^{\circ}$	3.258	.25882	.84805	.016
3.	1.680	1.671	1.663	20	82	3.20	.34202	.98481	.017
4.	1.722	1.719	1.698	20	47	3.375	.34202	.73135	.024
5.	1.732	1.731	1.705	13	25	3.433	.22495	.42262	.027
6.	1.724	1.717	1.694	12-13	52 ± 2	3.445	.21644	.78801	.030
7.	1.716	1.712	1.692	$9\frac{1}{2}\pm3$	52 ± 3	3.432	.16505	.78801	.024
8.	1.730	-	1.702	12	0	3.447	.20791	.0000	.028
9.	1.685	1.680	1.665	20	68	3.260	.34202	.86603	.020
10.	1.711	1.711	1.697	17	0	3.426	.29237	.0000	.014
11.	1.670	1.663	1.653	40	64	3.160	.64279	.89879	.017
12.	1.642	1.634	1.625	12	86°	3.054	.20791	.99820	.017
13.	1.669	1.6611	1.651	16 ± 1	$83\pm2^{\circ}$	3.167	.27564	.99357	.018
14.	1.635	1.6205	1.616	26°	$58^{\circ}51'$	3.095	.45321	.85582	.019
15.	1.659	1.6456	1.640	$25^{\circ}-30'$	$65^{\circ}09'$	3.189	.43051	.90740	.019
16.	1.635	1.6180	1.613	26°	$60^{\circ}29'$	3.069	.43837	.87021	.022
17.	1.651	1.6380	1.633	$26^{\circ}15'$	63	3.186	.44229	.89114	.018
18.	1.656	1.6473	1.640	$19^{\circ}\pm1^{\circ}$	$85\frac{1}{2}\pm2$	3.117	.32557	.99692	.016
19.	1.664	1.651	1.441	22	98	3.175	.37461	.99027	.023
20.	1.441	1.632	1.122	18-19	88	3.163	.31730	.99940	.019
21.	1.637	-	1.615	17	77	2.950	.29237	.97437	.022
22.	1.642	1.634	1.625	12	$86^{\circ}-6'$	3.05	.20791	.99820	.017

TABLE 8a

PHYSICAL PROPERTIES OF COMMON HORNBLENDES.

No.	Ng	Nm	Np	Z c	2V	S. G	SinZ c	Sin2V	Ng-Np
23.	1.642	1.631	1.618	16	90	3.147	.27564	.99990	.024
24.	1.673	1.665	1.654	17	71	3.176	.29237	.94552	.019
25.	1.680	1.673	1.662	15	66	3.205	.25882	.91355	.018
26.	1.669	1.661	1.651	18	74	3.162	.30902	.96126	.018
27.	1.672	1.664	1.650	15	70	3.170	.25882	.93969	.022
28.	1.669	1.660	1.651	18	77	3.164	.30902	.97457	.018
29.	1.671	1.663	1.653	20	76	3.159	.34202	.97030	.018
30.	1.670	1.662	1.651	19	75	3.160	.32557	.96593	.019
31.	1.664	1.655	1.643	19	78	3.159	.32557	.97815	.02 1
32.	1.677	1.670	1.659	18	70	3.174	.30902	.93969	.018
33.	1.661	1.652	1.638	18	78	3.115	.30902	.97815	.023
34.	1.669	1.662	1.650	17	72	3.153	.29237	.96126	.019
35.	1.673	1.664	1.650	17	75	3.181	.29237	.97437	.023
36.	1.677	1.668	1.653	16	72	3.204	.27564	.96126	.024
37.	1.683	1.677	1.644	15	65	3.203	.25882	.92718	.037
38.	1.684	1.678	1.665	19	67	3.234	.32557	.92718	.019
39.	1.674	1.666	1.654	19	78	3.192	.32557	.97815	.020
40.	1.677	1.668	1.659	22	86	3.175	.37461	.99756	.0.18
	E66.975		E66.141			E127.995	E12.61829	E34.87373	
	2		2			2			
	E 112.167109		E 109.388993			E 410.056677		E32.440604229	
							E4.2589972295		

Fig. 11

Classification of the Pargasite Series.

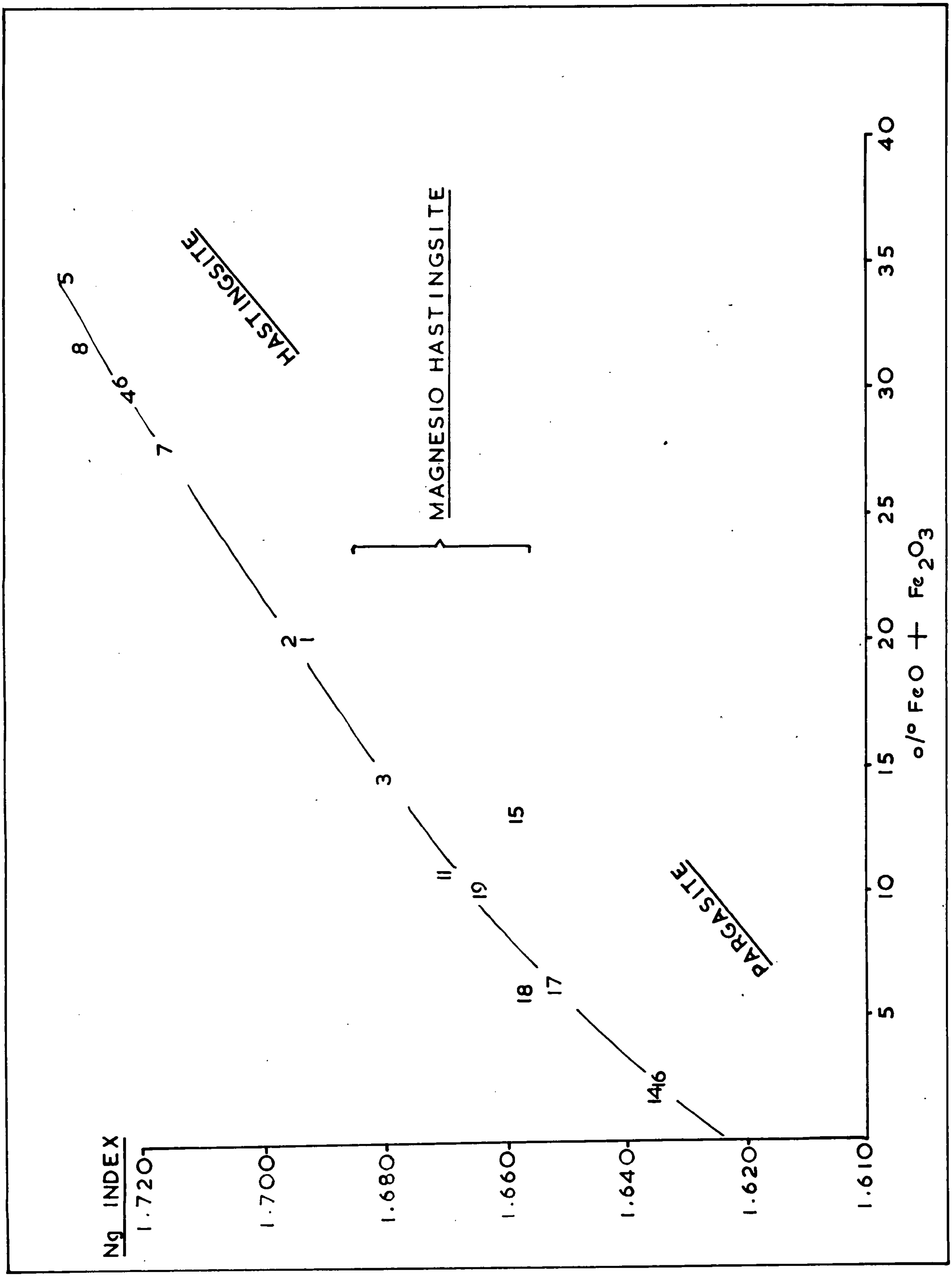
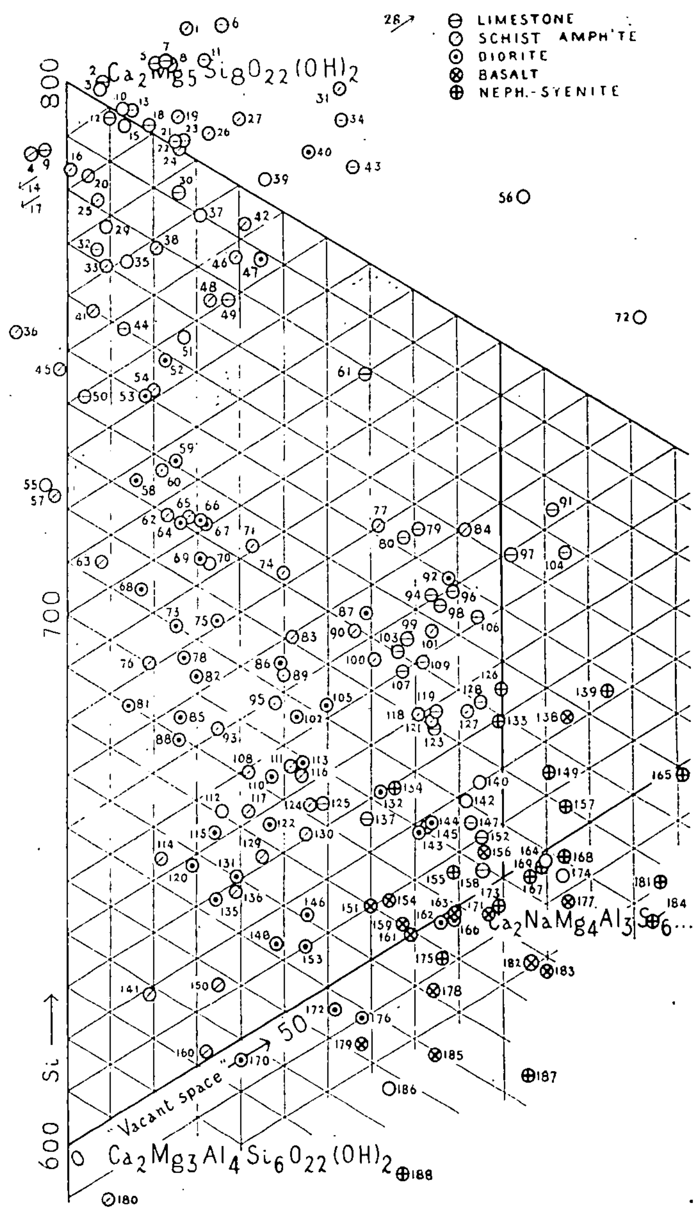
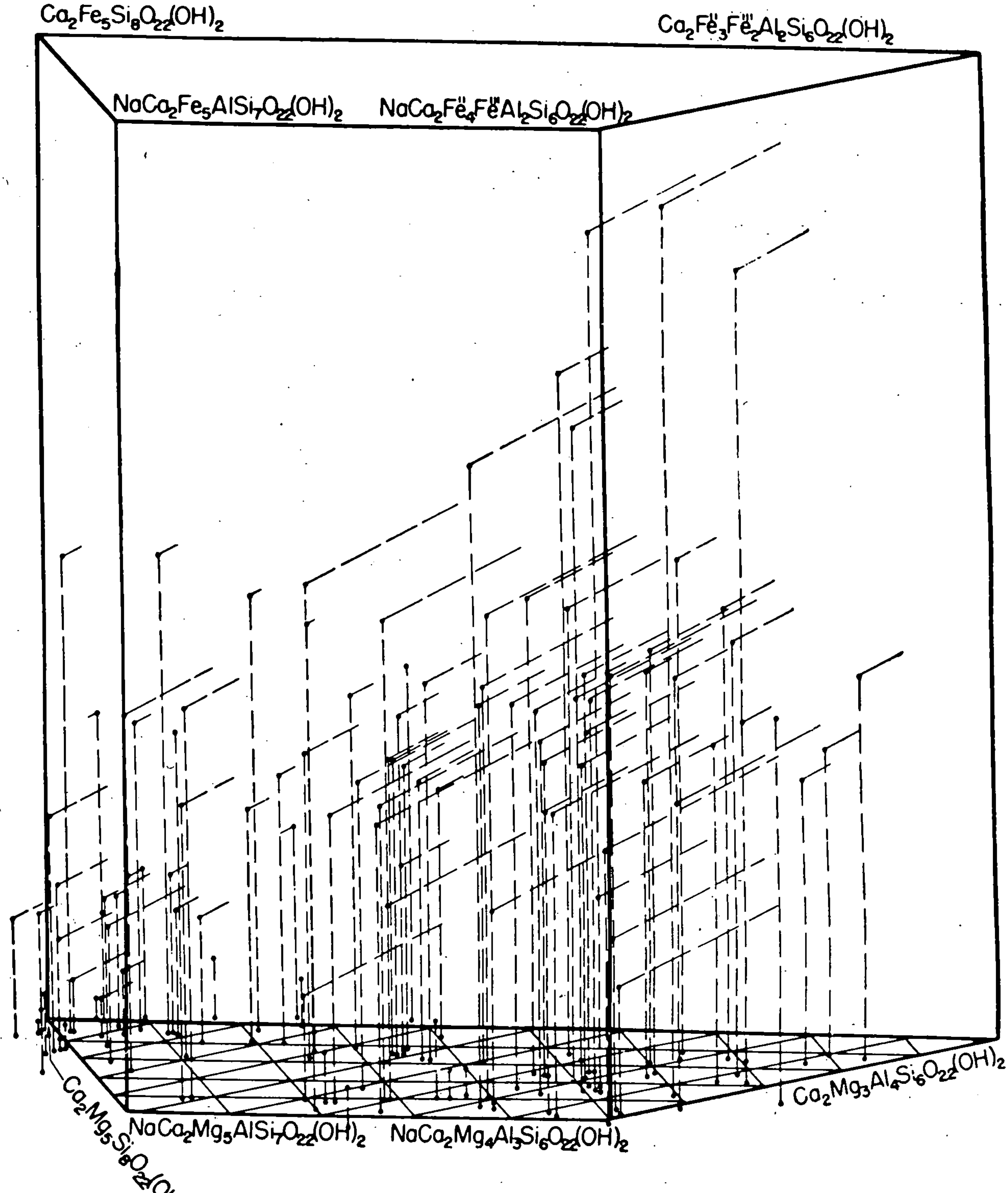

Ng INDEX
1.720
1.700
1.680
1.660
1.640
1.620
1.610
5
10
15
20
25
30
35
40
o/o FeO + Fe2O3
HASTINGSITE
MAGNESIO HASTINGSITE
PARGASITE
5
8
4
6
7
2
1
3
15
11
19
18
17
14
16

FIG. 11.



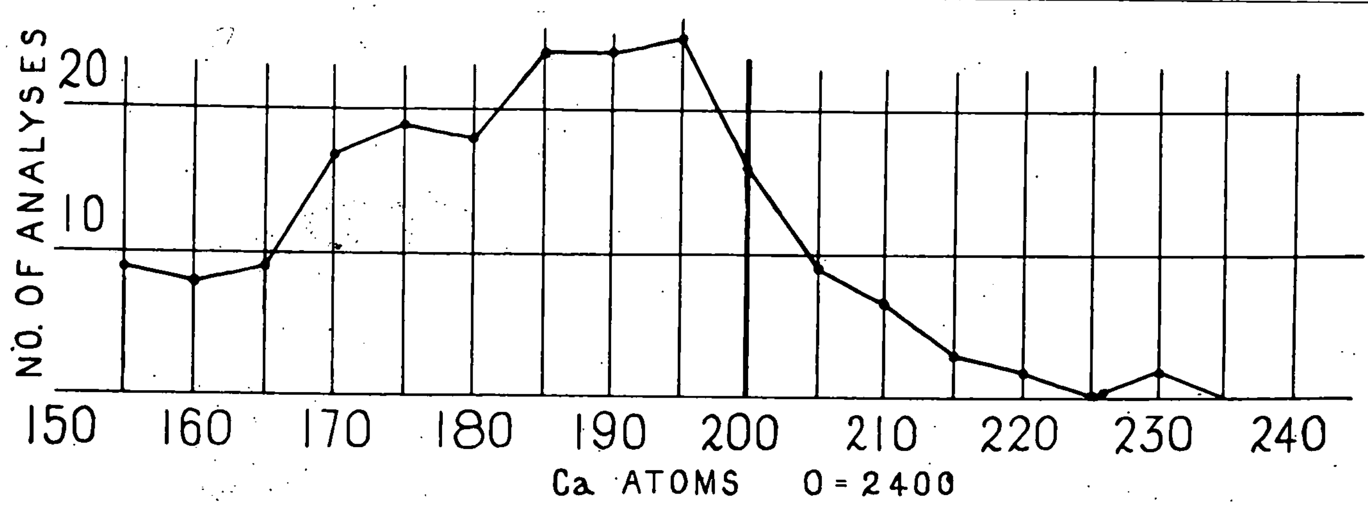
Distribution of amphibole analyses in respect to (*a*) Si atoms and (*b*) atoms in the vacant space. The signs represent an approximate classification of the parent-rocks.

FIG. 12.



Composition of calciferous hornblendes.

FIG. 13.



Incidence of amphibole analyses with more than 1.5 (×100) Ca atoms.

FIG. 14.

Analyses of Calciferous Amphiboles Calculated to Atomic Ratios for (O, OH, F) = 2400.

For abbreviations, etc. see key on preceding page.

No.	Locality	Name	Occurrence	Authors
1	Cumberland, Rh. I.	Ac.	Chlorite-ac.-hortonolite vein	Johnson & Warren
2	Packenham, Ont.	Am.	Limestone contact?	Parsons
3	Ham I., Alaska	Tr.	With diopside	Allen & Clement
4	Sulzer, Alaska	Ur.	*	Parsons
5	Pierrepont, N. Y.	Am.	Limestone contact?	Parsons
6	Sarahsburg, N. Y.	Tr.	Limestone contact?	Parsons
7	Gouverneur, N. Y.	Tr.	Limestone contact?	Parsons
8	Zillerthal, Tyrol	Am.	*	Parsons
9	Switzerland	Tr.	Crystalline limestone	Kreutz, p. 915
10	Kupferberg, Silesia	Ac.	Crystals	Kunitz
11	Edenville, N. Y.	Ed.	Limestone contact?	Winchell
12	Lee, Mass.	Tr.	Dolomite marble	Penfield & Stanley, p. 31
13	Richville, N. Y.	Tr.	Crystals	Penfield & Stanley, p. 31
14	Edwards, N. Y.	Tr.	With kupfferite	Allen & Clement
15	Kishengarh, India	Ho.	With nepheline-syenite	Heron
16	Greiner, Tyrol†	Ac.	Crystals in talc	Penfield & Stanley, p. 32
17	Edwards, N. Y.	He.	Limestone contact? See 14	Kunitz
18	Ossining, N. Y.	Tr.	Limestone contact?	Allen & Clement
19	Berkeley, Cal.	Ac.	Schist	Blasdale
20	Kaveltorp, Sweden	Gr.	With blende and chalcopyrite	Johansson
21	Gouverneur, N. Y.	Tr.	Limestone contact?	Allen & Clement
22	Russell, N. Y.	Am.	Limestone contact?	Parsons
23	Russell, N. Y.	Tr.	Limestone contact?	Allen & Clement
24	Kragerö, Norway	Ac.	Pseudomorphous after diopside	Hillebrand
25	Start, Devon	Ho.	Ho.-epidote-albite-schist	Tilley, 1938, p. 504
26	Start, Devon	Ho.	Ho.-clinozoisite-albite-schist	Tilley, 1938, p. 505
27	San Pablo, Cal.	Ac.	Schist	Blasdale
28	Haut du Falte, Vosges	Am.	Amphibole-biotite granite	Weyberg
29	Rhode Island	Ac.	Crystals	Kunitz
30	St. Lawrence Co., N. Y.	Am.	Limestone contact?	Parsons
31	Coll I., Hebrides	Ho.	Amphibolite	Duparc & Pearce, 1908
32	Russell, N. Y.	Ac.	Crystals	Penfield & Stanley, p. 33
33	Loch Gair, Argyll	Ho.	Chlorite-epidote-ab.-amp'te.	Wiseman, p. 368
34	Russell, N. Y.	Ho.	Crystalline limestone	Kreutz, p. 929
35	Arendal, Norway	Ac.	Crystal	Kunitz
36	Start, Devon	Ho.	Ho.-talc-chlorite-schist	Tilley, 1938, p. 506
37	'Piz Valesa'	Ac.	*	Kunitz
38	Kussuolinkivaara, Finl.	Am.	Ho.-or.-pyr.-spinel-carb.-rock	Mikkola & Sahama
39	Snarum, Norway	Ho.	Crystal	Kreutz, p. 926
40	Washington, D. C.	Ho.	Gabbro	Clarke, 1910, p. 266
41	Billy Goat Creek, N. Z.	Ac.	Ab.-stilpnomelane-ac.-schist	Hutton, 1940, p. 14
42	Saualpe, Carinthia†	Ca.	Eclogite	Kunitz
43	Djagdalik, Afghanistan	Pa.	Cipolin limestone	Barthoux
44	Pierrepont, N. Y.†	Ac.	With calcite	Penfield & Stanley, p. 34
45	Coronet Peak, N. Z.	Ac.	Ab.-epidote-ac.-calcite-schist	Hutton, 1940, p. 13
46	Ravenberget, Norway	Ho.	Altered from pyroxene?	Kolderup
47	Biella, Piedmont	Am.	Druse in syenite	Zambonini
48	Sudbury, Ont.	Ho.	Margin of xenolith in gabbro	Jones
49	Monteagle, Ont.	Ho.	Limestone contact?	Parsons
50	New Hampshire	Ac.	Limestone	Kunitz
51	Kragerö, Norway†	Ac.	Crystal	Penfield & Stanley, p. 34
52	Carsphairn, Scotld.	Ho.	From pegmatite in ho. hybrids	Deer, 1937
53	Esasi, Japan	Ho.	Diorite	Harada, p. 281
54	Signal Peak, Colo.	Ho.	Xenolithic crystal in granodiorite	Pabst
55	Nordmarken, Sweden	Ac.	Crystals	Kunitz
56	Cheremshanka R., Ural	Ho.?	Augite-pegmatite	Belyankin, 1910, a

No.	(a) Si	Al	Ti	Fe'''	Fe''	Mn	Mg	Ca	Na	K	H	F	R''' in Y	Y− res.	(b) v. sp.	F, OH	V
1	796	17	tr.	1	85	1	435	214	14	tr.	76	?	14	35	28	76	279
2	795	23	1	11	50	2	466	188	16	5	77	•	31	48	9	77	278
3	794	2	—	—	—	—	500	203	3	2	209	nil	−4	−4	8	209	
4	792	51	tr.	24	135	4	329	178	9	4	98	•	67	35	−9	98	277
5	792	21	2	15	48	2	467	190	22	9	63	7	32	47	21	70	279
6	791	22	1	5	12	2	524	197	23	16	•	37	20	57	36	37	280
7	791	23	1	10	3	1	518	190	21	12	63	12	26	47	23	75	277
8	790	33	tr.	14	50	2	465	179	39	6	59	•	37	54	24	59	279
9	790	22	—	1	7	1	485	188	6	1	196	7	13	6	−5	203	274
10	788	12	11	•	22	•	458	190	18	5	209	•	11	−9	13	209	
11	788	21	1	1	26	1	464	209	20	3	141	9	12	2	32	150	
12	788	29	2	nil	6	tr.	490	193	13	4	142	16	21	15	10	158	275
13	787	21	•	2	2	2	510	190	17	8	109	37	10	24	15	146	275
14	786	10	tr.	4	nil	15	506	157	21	3	225	10	0	21	−19	235	
15	786	49	tr.	31	216	7	251	175	31	7	61	16	66	40	13	77	290
16	783	21	nil	2	61	3	449	185	13	3	182	5	6	19	1	187	278
17	783	5	•	11	•	24	525	154	14	3	197	•	0	49	−29	197	
18	782	20	1	3	3	tr.	485	205	11	3	201	5	7	−6	19	206	
19	780	58	•	—	87	•	390	160	66	—	165	•	38	15	26	165	271
20	780	21	•	7	20	6	477	186	15	4	159	41	8	11	5	200	273
21	776	27	1	4	nil	—	483	183	32	10	183	44	9	−9	25	227	
22	775	37	1	14	43	2	462	186	26	14	55	59	28	34	26	114	277
23	775	30	1	6	12	1	470	189	25	13	158	53	13	−5	27	211	
24	774	25	—	21	97	—	378	194	21	11	193	—	20	−5	26	193	279
25	774	45	3	12	139	nil	325	190	15	2	194	•	37	−2	7	194	278
26	773	24	2	nil	114	2	378	193	39	tr.	214	•	−1	−5	33	214	275
27	772	34	•	—	70	•	405	182	53	5	240	•	6	−19	40	240	
28	771	71	2	8	146	5	321	180	103	11	49	•	54	24	94	49	
29	768	34	•	31	212	•	257	193	16	•	195	•	33	2	9	195	278
30	766	34	2	23	50	2	444	183	32	11	36	111	27	21	26	147	277
31	766	51	3	70	67	1	376	211	46	6	•	•	93	34	63	•	289
32	765	42	1	26	55	tr.	422	181	22	4	149	34	35	11	7	183	271
33	761	41	5	28	187	3	285	173	27	9	202	•	40	10	9	202	
34	760	36	—	9	17	2	461	172	68	23	190	37	5	−15	63	227	275
35	759	49	•	16	49	•	427	200	14	•	202	•	24	0	14	202	
36	759	60	2	5	86	2	394	188	nil	nil	221	•	28	8	−12	196	272
37	759	76	•	30	214	7	198	156	69	6	212	•	66	−15	31	212	279
38	758	108	5	7	54	2	411	204	13	4	42	•	83	45	21	42	
39	758	52	2	27	87	•	385	156	87	3	105	68	41	11	46	173	276
40	758	54	—	39	101	1	333	222	32	2	121	•	51	−14	56	121	
41	754	67	8	42	182	4	247	160	44	2	192	•	79	4	6	192	
42	752	61	•	13	50	3	404	197	31	13	211	•	26	−17	41	211	
43	750	84	8	—	3	1	502	202	52	12	23	•	53	51	66	23	280
44	747	45	3	33	80	8	404	182	22	9	136	47	31	20	13	183	276
45	747	65	4	52	128	tr.	312	157	41	tr.	206	•	73	9	−2	206	
46	747	53	2	49	98	2	345	194	43	2	176	•	53	−4	39	176	
47	744	104	11	36	90	tr.	349	212	26	7	29	•	106	34	45	29	
48	742	124	4	23	68	3	349	210	12	11	92	•	97	13	33	92	273
49	740	83	4	33	147	2	325	192	33	12	98	•	64	34	37	98	280
50	739	73	•	31	175	•	284	195	9	•	218	•	43	2	4	218	275
51	738	73	14	28	65	4	413	162	59	6	115	21	67	35	27	136	272
52	736	74	18	31	175	4	258	187	27	9	190	•	77	−4	23	190	
53	732	83	18	66	170	4	243	172	33	13	131	•	117	16	18	131	
54	732	125	10	87	131	—	254	172	35	13	33	•	164	39	20	33	
55	727	37	16	61	307	9	142	195	•	•	229	•	57	−1	−5	229	281
56	724	82	6	49	69	5	325	198	83	25	129	52	67	−40	106	181	

No	Locality	Name	Occurrence	Authors
57	Sädbolm, Sweden	Ur.	Uralite-porphyrite	Sederholm
58	Butte-Plumas Cos., Cal.	Am.	Quartz-am.-diorite	Clarke, 1910, p. 266
59	Glen Tilt, Scotland	Ho.	Coarse appinite	Deer, 1938, no. 3
60	Loch-na-Craige, Scot.	Ho.	Garnet-bi.-epidote-ab.-amp'te.	Wiseman, p. 382
61	Eganville, Ont.	Ho.	Limestone contact?	Winchell
62	Glen Tilt, Scotland	Ho.	Hornblendite xenolith	Deer, 1938, no. 6
63	Loch-na-Craige, Scot.	Ho.	Biotite-epidote-ab.-amp'te.	Wiseman, p. 383
64	Radauthal, Harz	Ho.	Gabbro, uralitic	Kunitz
65	Glen Tilt, Scotland	Ho.	Quartz-or.-pla.-ho.-rock	Deer, 1938, no. 5
66	Garabal Hill, Scotland	Ho.	Hornblende-gabbro (modified)	Nockolds, 1940
67	S. Felix, Cortegana	Ho.	Diorite	Kunitz
68	Tioga Road, Cal.	Am.	Quartz-monzonite	Turner
69	Bornthal, Saxony	Ho.	Diorite	Kunitz
70	Filipstad, Sweden	Ho.	Zoned crystal	Daly
71	Hohen Waid, Baden	Ho.	Garnet-rock	Erdmannsdörffer
72	Wausau, Wis.	Bk.	Umptekite	Weidman, 1907
73	Walkerville, Mont.	Ho.	Quartz-monzonite	Clarke, 1900
74	Umhausen, Tyrol	Ho.	Altered eclogite	Hezner, 1903
75	Sheep Cr., Colo.	Ho.	Quartz-latite	Larsen & others
76	Glen Tilt, Scotland	Ho.	Hornblende-schist xenolith	Deer, 1938, no. 9.
77	Gabbi, Lapland	Ho.	Effusive amphibolite	Kulling
78	Purcell sills, B.C.	Am.	Diorite	Rice
79	Pargas, Finland	Pa.	Limestone contact	Laitakari
80	Pargas, Finland	Pa.	Limestone contact	Kreutz, p. 933
81	Cabo de Gata, Spain	Ho.	Dacite	Osann
82	Dry Gulch, Colo.	Ba.	Quartz-latite	Larsen & others
83	Sommervik, Norway	Ho.	Altered from pyroxene?	Kolderup
84	Chester, Mass.	Ho.	Amphibolite	Duparc & Pearce, 1908
85	Purcell sills, B.C.	Am.	Diorite with chalcopyrite and pyrrhotine	Rice
86	Beaver Creek, Cal.	Am.	Hornblende-gabbro	Turner
87	Ernsthofen, Hesse	Ho.	Luciite-porphyrite	Klemm
88	Glen Tilt, Scotland	Ho.	Pyroxene-appinite	Deer, 1938, no. 4
89	Ipponmatu, Japan	Ho.	Amphibolite	Tsuboi, 1936
90	Nieripeivi, Sweden	Ho.	Zoisite-amphibolite	Du Rietz
91	Ulisna Muduna, Ceylon	Am.	Inclusion in metam. limestone	Coomaraswamy
92	Ilmen Mts., Ural	Ho.	Granodiorite	Belyankin, 1910, b
93	Carlingford, Ireland	Ho.	Junction hybrids	Nockolds, 1935
94	Renfrew, Ont.	Ho.	Crystal	Penfield & Stanley, p. 39
95	Kantalahti, Finland	Ho.	Altered eclogite	Eskola
96	Edenville, N. Y.	Ho.	Limestone contact? with pyroxene	Hawes
97	Franklin, N. J.	Am.	Limestone contact?	Parsons
98	Warwick, N. Y.	Pa.	Limestone contact?	Winchell
99	Amity, N. Y.	Ed.	Limestone contact?	Parsons
100	Kleinhöhe, Alsace-Lor.	Ho.	Hornblende-gneiss	Rhein
101	Schlossberg, Austria	Ho.	Amphibolite	Marchet
102	S. Cristobal, Colo.	Ho.	Andesite dike	Larsen & Irving
103	Edenville, N. Y.	Pa.	Limestone contact?	Winchell
104	Grenville, Quebec†	Ho.	Limestone contact?	Penfield & Stanley, p. 49
105	Mt. Wati, Uganda	Ho.	Quartz-hypersthene-diorite	Groves
106	Lanark Co. Ont.	Ho.	Limestone contact?	Barnes
107	Amity, N. Y.†	Pa.	Limestone contact?	Winchell
108	Glen Tilt, Scotland	Ho.	Injected hornblende-schist	Deer, 1938, no. 8
109	Edenville, N. Y.†	Ho.	Crystals	Penfield & Stanley, p. 40
110	Brocken, Harz	Ho.	Diorite ('granite' Kunitz p. 207)	Kunitz
111	Palmer Center, Mass.†	Ho.	Amphibolite dike	Clarke, 1910, p. 21
112	Skudeskunksjär, Nor.	Bk.	Crystal	Gossner & Spielberger, p. 118
113	Plauen, Saxony	Ho.	Syenite	Kunitz
114	Glen Tilt, Scotland	Ho.	Hornblende-schist	Deer, 1938, no. 7
115	Eulengebirge, Silesia	Ho.	Diorite	Kunitz

No.	(a) Si	Al	Ti	Fe'''	Fe''	Mn	Mg	Ca	Na	K	H	F	R''' in Y	Y – res.	(b) v. sp.	F, OH	V
57	724	117	3	37	151	•	304	183	9	5	141	n.d.	84	36	–3	141	281
58	717	137	10	29	80	6	348	172	34	10	134	•	103	27	16	134	
59	716	101	13	72	95	2	312	178	34	13	134	12	115	11	25	146	278
60	716	140	14	33	222	3	158	168	39	15	206	•	118	–14	22	206	
61	710	110	4	64	146	5	286	153	89	27	116	9	92	25	69	125	
62	707	133	12	39	100	2	337	181	29	10	61	64	103	29	23	125	
63	706	149	8	32	214	3	198	163	19	26	202	•	103	9	8	202	
64	704	98	8	31	61	•	429	200	23	3	161	•	49	31	26	161	276
65	704	110	16	60	96	2	322	187	28	12	157	tr.	105	10	28	157	277
66	702	124	12	27	116	1	343	175	53	3	165	•	77	25	31	165	—
67	701	118	5	40	105	•	338	204	28	•	180	•	69	7	32	180	272
68	696	122	13	54	131	6	285	187	21	9	182	3	98	7	17	185	275
69	695	125	•	22	125	•	353	197	28	6	203	•	42	20	31	203	272
70	693	132	10	87	202	20	192	202	24	7	72	—	132	36	33	72	281
71	691	220	5	55	247	21	72	185	31	27	57	27	166	1	43	84	287
72	688	189	tr.	62	305	tr.	58	197	60	75	39	•	139	2	132	39	
73	685	119	16	56	130	7	275	180	22	23	229	13	92	–12	25	242	
74	682	248	4	44	101	—	255	162	68	20	53	•	182	34	50	53	
75	681	167	19	55	113	4	292	176	39	20	64	37	141	31	35	101	
76	681	160	19	40	101	1	311	163	32	24	193	—	118	13	19	193	275
77	680	177	11	22	122	tr.	290	183	79	10	159	•	101	2	72	159	—
78	678	230	•	173	113	n.d.	110	174	53	w.Na	•	•	281	4	27	—	—
79	676	182	1	7	18	•	435	188	69	24	67	84	67	19	81	151	275
80	676	178	tr.	8	18	tr.	436	182	72	23	84	80	62	16	77	164	271
81	676	153	20	59	139	7	310	168	40	6	84	•	128	64	14	84	276
82	673	135	24	160	35	5	298	178	39	21	19	16	216	30	30	35	
83	669	218	1	39	197	2	166	209	42	1	155	•	128	–8	52	155	
84	669	101	13	140	150	1	270	213	68	11	•	•	136	44	92	•	273
85	667	207	•	176	185	n.d.	89	168	58	w.Na	•	•	250	24	26	—	
86	666	180	10	31	100	2	310	196	45	8	190	nil	97	–1	49	190	
87	665	255	15	83	153	•	121	175	84	10	75	•	233	–8	69	75	
88	663	165	19	66	84	2	317	175	34	17	168	tr.	133	17	26	168	277
89	663	234	3	24	78	2	317	157	86	7	171	•	127	21	50	171	
90	663	240	7	20	130	2	279	184	76	6	69	•	137	41	66	69	
91	663	229	•	tr.	•	•	446	202	110	•	56	•	92	38	112	56	290
92	662	188	9	54	166	4	246	196	68	24	71	•	122	29	88	71	
93	661	155	23	18	287	•	167	172	46	17	228	•	80	11	35	228	
94	661	148	9	78	132	6	284	159	100	25	65	87	105	18	84	152	276
95	659	227	15	21	221	2	194	193	31	24	87	•	137	39	48	87	
96	659	215	•	36	177	6	262	191	81	17	39	•	110	55	89	39	
97	659	146	14	67	123	4	301	165	95	42	52	87	100	14	102	139	277
98	658	203	5	13	27	1	429	197	74	15	95	11	84	36	86	106	
99	656	162	10	10	20	1	462	193	67	18	42	138	48	21	78	180	275
100	656	252	—	56	152	—	215	231	28	12	10	•	164	31	71	10	
101	655	203	21	47	187	2	200	230	33	21	52	•	147	15	84	52	283
102	654	200	20	53	112	2	304	177	60	16	78	n.d.	147	45	53	78	
103	654	227	tr.	4	12	1	429	189	77	10	127	12	[illegible]	27	76	139	
104	653	204	7	3	9	1	442	206	77	32	38	72	74	19	115	110	273
105	652	159	45	94	177	•	173	199	50	11	96	•	195	0	60	96	
106	651	197	10	52	93	4	325	186	72	37	74	14	120	32	95	88	283
107	650	234	tr.	39	10	1	425	192	75	10	127	15	123	59	77	142	
108	649	183	41	56	109	2	269	186	36	21	93	41	170	9	42	134	278
109	649	209	17	31	164	2	262	191	72	19	70	19	123	34	82	89	279
110	646	183	15	25	153	•	295	192	55	•	204	•	84	17	47	204	
111	646	196	19	56	163	5	209	189	34	29	192	•	136	–6	52	192	279
112	645	213	•	34	285	10	194	164	61	11	97	•	92	81	36	97	278
113	645	198	11	53	144	•	277	173	57	24	163	•	118	28	54	163	273
114	644	250	20	56	109	3	234	169	42	11	138	11	189	14	22	148	275
115	642	189	18	36	160	•	272	181	41	12	200	•	102	16	34	200	274

TABLE 9a.

No.	Locality	Name	Occurrence	Authors
116	Senftenberg, Austria	Ho.	Anorthosite-amphibolite	Morozewicz
117	Clemgia, Switzerland	Ho.	Biotite-hornblendite	Hezner, 1909
118	Kammegg, Austria	Ho.	Amphibolite	Marchet
119	Renfrew Co., Ont.	Ho.	Limestone contact?	Barnes
120	Lindenfels, Odenwald	Ho.	Gabbro	Kunitz
121	Gertrusk, Carinthia†	Ca.	Eclogite	Koritnig
122	Arendal, Norway	Ho.	Crystal from syenite	Kunitz
123	Pärgas, Finland	Pa.	Limestone contact	Laitakari
124	Cullakenee, N. Car.†	Sm.	Corundum-serpentine contact	Genth
125	Pargas, Finland	Pa.	Limestone contact	Laitakari
126	Stavarnsjö, Norway	Bk.	Elaeolite-syenite	Kunitz
127	Ristjåkko, Lapland	Ho.	Hornblende-schist	Kulling
128	Iron Hill, Colo.	Ma.	Metam. limestone with nepheline rocks	Billings
129	Salaja, Ural	Pa.	Amphibole-trap-granulite	Loewinson-Lessing
130	'Barnaschka-Kudnik'	Ho.	Amphibolite	Kunitz
131	Glen Tilt, Scotland	Ho.	Glen Tilt diorite	Deer, 1938, no. 1
132	Beerberg, Thuringia	Ho.	Diorite	Kunitz
133	Skuttersundskjär, Nor.	Bk.	Elaeolite-syenite	Kunitz
134	'S. Vincent'	Ba.	Essexite	Kunitz
135	Glen Tilt, Scotland	Ho.	Coarse appinite	Deer, 1938, no. 2
136	Yokodake, Japan	Ho.	Amphibolite	Tsuboi, 1935
137	Custer Co., Idaho	Am.	Contact (?)-metam. limestone	Shannon
138	Kilimanjaro, E. Africa	Ho.	Sodic lavas	Washington & Merwin
139	Heum, Norway	Ho.	Ho.-feldspar vein with nepheline	Brögger
140	Shoal Creek, N. Car.	Ha.	Crystals	Kunitz
141	Glenelg, Scotland	Ho.	Garnet-amphibolite (altered eclogite)	Alderman
142	White Mts., N. H.	Ha.	Crystals	Kunitz
143	Österskär, Sweden	Ho.	Pegmatite	Geijer
144	Koswinsky, N. Ural	So.	Anorthite-diorite veins	Duparc & Pearce, 1903
145	Montville, N. J.	Ac.	Serpentine	Eakins
146	Garabal Hill, Scotland	Ho.	Davainite 'early'	Nockolds, 1940
147	Tiree, Hebrides†	Pa.	Inclusion in metam. limestone	Unpublished
148	Garabal Hill	Ho.	Appinitic diorite	Nockolds 1940
149	Square Butte, Mont.	Bk.	Sodalite-syenite	Lindgren & Melville
150	Glenelg, Scotland	Ho.	Kyanite-garnet-amphibolite	Tilley, 1937
151	Linosa, Mediterranean	Ka.	Volcanic lapilli	Washington, 1908, p. 192
152	Mansjö, Sweden	Pa.	Centre of pyroxene dike	Eckermann
153	Jackson, N. H.	Fe	Nordmarkite	Billings
154	Almunge, Sweden	Ha.	Umptekite	Quensel
155	'Tejedatal'	Ba.	Essexitic phonolite	Kunitz
156	Mte. Somma, Italy	Ho.	Crystals	Penfield & Stanley, p. 41
157	Hukusinzan, Japan	Ha.	Sodalite-nepheline-syenite	Harada, p. 283
158	Pargas, Finland	Pa.	Limestone contact	Parsons
159	Todtenköpfchen, Rhön	Ho.	Hornblende-basalt	Galkin
160	Titianul, Hungary	Ho.	Pla.-garnet-quartz-biotite-amp'te.	Vendl, 1932
161	Dôgo, Oki Is., Japan	Ka.	Basaltic dike	Tomita
162	Shabô-zan, Formosa	Ho.	Hornblende-andesite	Ichimura
163	'Isleta-Krater'	Ba.	Volcanic bomb	Kunitz
164	Cornwall, N. Y.	Hu.	Quartz-felspar aggregate	Weidman, 1903
165	Cuttingsville, Vt.	Ho.	Ho. syenite with nepheline rocks	Eggleston
166	Stenzelberg, Siebeng.	Ho.	Andesite	Rammelsberg
167	S. Vincente, C. Verde	Bk.	Foyaite	Kunitz
168	Copinshay, Orkney	Ba.	Hornblende-monchiquite	Flett
169	Dungannon, Ont.	Ha.	Nepheline-syenite	Walker
170	Stockholm, Sweden	Ho.	Pegmatite	Geijer
171	Madeira	Ba.	Trachydolerite	Kunitz
172	Shabô-zan, Formosa	Ba.	Hornblende-andesite	Ichimura
173	Montreal, Canada	Am.	Coarse-grained essexite	Harrington
174	Kaersut, Greenland†	Ka.	Crystal	Gossner & Spielberger, p. 121

TABLE 9b.

No.	(a) Si	Al	Ti	Fe'''	Fe''	Mn	Mg	Ca	Na	K	H	F	R''' in Y	Y – res.	(b) v. sp.	F, OH	V
116	642	259	3	25	132	4	256	180	61	12	145	*	132	21	53	145	278
117	642	189	20	55	46	*	404	174	49	19	106	*	126	56	42	106	280
118	640	217	33	34	185	2	210	210	47	24	71	*	157	21	81	71	280
119	638	178	12	108	215	tr.	167	177	82	26	95	20	148	18	85	115	287
120	638	193	12	39	188	*	255	181	39	9	206	*	94	25	29	206	276
121	637	238	14	19	59	*	328	175	88	21	191	*	122	–5	84	191	274
122	637	209	4	51	162	*	251	176	48	23	210	*	105	14	47	210	271
123	636	223	10	18	139	*	305	190	58	36	41	82	97	31	84	123	285
124	636	292	—	8	41	*	350	189	61	6	128	*	136	83	56	128	—
125	635	214	8	4	72	*	410	197	38	24	50	104	69	43	59	154	273
126	635	201	5	77	234	13	143	173	110	19	149	*	123	8	100	149	273
127	635	231	15	76	169	1	167	170	110	12	141	*	172	–6	92	141	—
128	635	185	17	43	86	4	350	153	130	12	176	*	97	20	95	176	279
129	632	306	—	35	120	tr.	252	157	88	tr.	102	—	173	45	45	102	—
130	631	227	3	33	134	*	310	187	54	14	155	*	97	38	55	155	275
131	631	178	31	32	190	3	257	182	29	27	202	—	103	21	39	202	281
132	630	209	15	57	137	*	276	197	51	24	130	*	126	24	72	130	276
133	629	218	3	88	225	17	137	173	111	15	120	*	141	17	99	120	274
134	629	223	20	97	80	*	278	198	60	17	60	*	189	27	75	60	277
135	629	206	31	37	111	2	305	185	31	19	136	39	135	21	34	175	277
136	628	219	35	23	153	4	252	173	64	2	192	*	140	14	39	192	—
137	627	209	tr.	82	371	tr.	34	197	38	34	138	*	118	23	69	138	—
138	622	220	47	52	73	n.d.	315	192	92	31	20	n.d.	188	29	115	20	—
139	622	199	51	91	125	2	225	196	96	32	nil	15	214	14	124	15	—
140	620	210	8	56	269	*	136	168	98	29	212	*	102	– 1	95	212	275
141	619	233	11	65	96	2	316	185	19	15	150	*	139	42	19	150	282
142	618	191	17	114	286	6	53	155	117	20	196	*	157	–15	92	196	279
143	618	222	3	83	322	15	70	170	72	39	130	5	129	33	81	135	—
144	618	198	20	111	125	tr.	269	201	70	13	51	—	167	41	84	51	284
145	618	292	*	8	7	2	411	196	62	25	111	*	118	38	83	111	—
146	616	200	26	44	107	1	323	185	58	12	198	*	112	17	55	198	—
147	614	275	9	37	74	1	310	204	40	49	83	19	144	20	93	103	279
148	614	211	29	45	149	tr.	251	184	53	11	229	*	128	–1	48	229	—
149	614	309	15	45	291	2	60	180	91	40	26	*	198	36	111	26	279
150	613	294	8	29	112	1	259	172	47	16	198	*	152	16	35	198	272
151	610	174	96	98	46	1	280	196	63	11	20	14	274	5	70	34	270
152	610	260	5	16	38	*	382	212	56	27	156	5	97	10	95	160	273
153	610	237	39	51	353	17	53	170	57	28	65	*	176	60	55	65	291
154	609	206	10	92	342	13	33	169	65	40	217	*	127	5	74	217	—
155	607	218	30	137	103	*	222	201	68	20	46	*	222	17	89	46	282
156	607	235	4	84	138	13	262	198	51	47	78	2	134	43	96	80	281
157	606	245	16	105	294	18	36	165	110	39	88	*	188	20	114	88	—
158	604	254	5	21	42	1	399	203	65	27	16	140	89	26	95	156	274
159	603	248	56	82	61	*	264	194	61	22	48	*	245	14	77	48	275
160	602	325	12	80	130	4	183	161	52	19	99	*	231	36	32	99	278
161	600	251	79	52	92	2	247	174	75	30	37	*	261	23	79	37	278
162	599	210	33	131	3	9	315	187	70	29	122	*	206	0	86	122	—
163	599	226	46	84	80	*	291	194	66	29	72	*	201	26	89	72	280
164	598	231	13	90	317	11	46	184	101	25	141	14	145	6	110	155	—
165	598	250	13	73	208	16	170	209	98	34	50	*	147	28	141	50	268
166	598	265	3	117	97	3	254	205	33	51	48	*	186	37	89	48	278
167	597	224	14	137	217	10	95	187	105	14	128	*	186	–6	106	128	278
168	597	296	62	47	68	4	218	202	49	63	35	*	264	–8	114	35	280
169	597	284	14	99	295	8	53	164	91	54	36	*	194	50	109	36	286
170	596	269	12	51	295	5	98	161	40	39	205	4	140	67	40	209	—
171	595	230	48	76	74	*	303	199	81	17	67	*	197	26	97	67	280
172	595	195	35	127	103	7	231	220	29	13	150	*	187	–7	62	150	—
173	595	257	52	33	108	8	294	190	90	19	36	n.d.	189	47	99	36	288
174	593	196	116	6	118	1	281	176	111	27	59	*	227	11	114	59	282

No.	Locality	Name	Occurrence	Authors
175	Grosspriessen, Bohemia	Ba.	Tephrite	Kunitz
176	Mt. Wati, Uganda	Ho.	Biotite-hornblende-tonalite-gneiss	Groves
177	Bilin, Bohemia	Ba.	Crystals	Penfield & Stanley, p. 47
178	Uturyôtô, Korea	Ka.	Volcanic ejectamenta	Harada, p. 282
179	L. Balaton, Hungary	Ba.	Tuff-breccia	Vendl, 1924
180	Seigertshausen, Hesse	Ho.	Large phenocrysts in basalt	Trenzen
181	Ditro, Transylvania	Am.	Elaeolite-syenite pegmatite	Mauritz
182	Lukow, Bohemia	Ba.	Crystal	Kreutz, p. 958
183	Lukow, Bohemia†	Ba.	Crystal	Kawano
184	Dungannon, Ont.†	Ha.	Nepheline-syenite	Adams & Harrington
185	Yôdôlô, Korea	Ba.	Crystal	Kawano
186	Kaersut, Greenland	Ka.	Plagioclase and alk.-felsp.	Washington, 1908, p. 198
187	Fuerte Ventura, Canary	Bk.	Essexite	Kunitz
188	Mt. Royal, Canada	Ba.	Dioritic phase in essexite	Bancroft & Howard
	Hydrous amphiboles			
189	Kashinskaya, Ural	Ac.*	*	Belyankin & Donskaya
190	Gabbi, Lapland	Ho.	Uralite-porphyrite	Kulling
191	Bracken Creek, N. Z.	Ac.	Actinolite-schist	Hutton, 1940, p. 15
192	Goryczkowi Pokredni	Am.	Diorite	Weyberg
193	Lieserschlucht, Carin.	Ho.	In clefts in eclogite	Heritsch
194	Mortojäkko, Lapland	Ho.	Amphibolite	Kulling
195	Start, Devon	Hy.	Amphibole-talc-chlorite-schist	Kennedy & Dixon
196	Pavone, Piedmont	Ho.	Hornblende-gabbro	Van Horn
	Effect of error in water and fluorine			
	Analysis no. 173 above			
	Do recalculated with addition of 1% H_2O			
	Difference			
	Do. recalculated with addition of 1% F			
	Difference			

No.	(a) Si	Al	Ti	Fe'''	Fe''	Mn	Mg	Ca	Na	K	H	F	R''' in Y	Y− res.	(b) v. sp.	F, OH	V
175	592	261	29	86	47	*	321	196	66	24	59	*	197	36	86	59	280
176	590	219	40	80	208	*	196	163	43	62	142	*	169	33	68	142	
177	587	305	19	80	27	tr.	310	188	90	37	40	1	210	28	115	41	274
178	587	245	73	45	92	1	267	198	58	28	87	—	223	10	84	87	276
179	585	258	41	60	73	1	272	175	64	29	205	*	185	−10	68	205	276
180	585	389	13	27	111	*	270	164	33	12	23	*	227	−5	9	23	
181	581	244	82	73	134	6	198	181	109	46	—	*	262	18	136	—	
182	581	320	28	61	28	9	308	198	73	35	25	5	218	35	106	30	275
183	577	254	49	99	13	1	302	190	79	41	95	3	228	−5	110	98	
184	575	229	19	160	309	9	34	178	107	49	39	*	202	35	134	39	295
185	575	227	68	90	88	1	264	169	90	25	110	3	228	13	84	113	
186	573	244	112	13	107	8	287	170	83	20	57	*	254	44	73	57	277
187	560	228	56	112	135	4	210	199	78	28	106	*	212	5	105	106	280
188	556	220	91	69	157	1	256	187	70	20	37	*	233	53	77	37	
	Hydrous amphiboles																
189	726	60	2	12	75	1	412	163	22	w.Na	342	2	0	−12	−15	344	
190	708	118	7	17	94	tr.	301	189	36	3	324	*	57	−55	28	324	
191	697	73	13	30	104	3	372	144	10	3	375	7	15	−7	−43	382	
192	679	104	7	37	77	8	321	179	38	16	402	—	34	−67	33	402	
193	648	174	6	45	178	2	213	178	18	26	336	nil	79	−31	22	336	
194	644	258	9	44	115	8	185	167	68	9	269	*	164	−77	44	269	
195	625	159	6	5	93	3	468	120	6	2	398	nil	0	61	−72	398	286
196	581	258	tr.	44	131	tr.	285	185	81	12	273	—	83	−1	78	273	274
	Effect of error in water and fluorine																
	595	257	52	33	108	8	294	190	90	19	36	n.d.	189	47	99	36	288
	582	251	51	33	106	8	288	186	88	19	135	—	168	19	93	135	282
	13	6	1	—	2	—	6	4	2	—	99	—	21	28	6	99	6
	589	254	51	33	107	8	291	188	89	19	36	47	178	33	96	83	286
	6	3	1	—	1	—	3	2	1	—	—	47	11	14	3	47	2

TABLE 9C.

No.	Si −600	Al	Fe'''	Fe''	Mn	Ti	Mg	Ca	Na	K	H	F	Ca+Na+K −200	200(Mg+Al')/Mg+Al'+Fe	Hallimond's No.	Reference
1	195	23	11	50	3	1	406	189	15	5	77		9	176	2	1
2	192	51	24	135	4		329	178	9	4	96		−9	139	4	1
3	192	20	15	48	2	2	468	190	21	9	63	7	20	176	5	1
4	190	22		7	1		485	188	6	1	197	7	−5	197	9	1
5	190	21	2	2	1		509	190	18	9	106	33	17	198	13	1
6	187	29		6		2	490	193	13	4	142	16	10	197	12	1
7	186	17		22		8	458	190	18	5	209		13	188	10	1
8	186	49	31	217	7		248	176	31	7	61	14	14	105	15	1
9	186	20	8	64	3		442	181	5	5	168	2	−9	171	16	1
10	184	20	2	61	3		450	185	13	3	182		1	175		2
11	182	20	2	2		1	485	205	11	3	202	5	19	198	18	1
12	179	21	6	20	6		477	186	15	4	161	41	5	188	20	1
13	178	2		17			483	200	10	3	136		13	193		3
14	177	57		88			398	158	68		164		26	166	19	1
15	176	37	14	43			463	186	25	14	56	58	25	179	22	1
16	174	45	12	139		3	325	190	15	2	194		7	138	25	1
17	173	21	8	27			474	181	33	12	183	27	26	186		4
18	173	24	0	114	2	2	378	193	39		214		32	152	26	1
19	169	75	5	22		3	450	194	35	12	80	11	41	188		5
20	168	34	32	211			257	192	16		194		8	103	29	1
21	167	34	23	50	2	2	446	184	32	11	36	111	27	171	30	1
22	167	22		27	2	1	484	192	2		123		−6	188		6
23	165	42	27	52		1	422	180	22	5	148	34	7	169	32	1
24	161	49	16	48			426	199	15		200		14	174	35	1
25	159	36	9	17	2		466	169	65	19	200	37	53	189	34	1
26	159	60	5	86	2	2	394	188			221		−12	162	36	1
27	154	62	13	51	Ni 3		401	196	31	14	212		41	172	42	1
28	151	106	7	56	2	5	429	203	13	4	42		20	175	38	1
29	151	40	28	185			280	171	26	10	254		7	114	33	1
30	147	45	33	80	9	3	410	182	21	9	136	41	12	153	44	1
31	146	38	2	21		1	486	187	8	2	148		2	190		7
32	142	124	23	68	3	4	349	210	12	10	91		32	162	48	1
33	141	68	31	176			284	195	10		217		5	117	50	1
34	140	83	33	147	2	4	325	192	33	12	98		37	130	49	1
35	139	160	2	194	4	11	279	203	13	38	17		54	128		8
36	137	21	32	103	2	8	391	187	32		243	19	19	146		9
37	124	118	37	151		3	304	183	9	5	140		−3	129	57	1
38	116	101	72	95	2	13	312	178	34	13	134	12	25	129	59	1
39	114	67	66	103	3	1	380	206	31	1	119		38	137		10
40	109	155	17	107	14	3	358	198	14	5	66		17	150		11
41	107	133	39	100	2	12	337	184	29	10	61	64	23	142	62	1
42	104	98	31	61		8	429	200	22	3	160		25	163	64	1
43	104	110	60	96	2	16	322	187	28	12	157		27	132	65	1
44	102	124	27	116	1	12	343	175	53	3	166		31	141	66	1
45	102	115	16	152		10	289	199	83		198		82	126		12
46	101	118	40	104		5	338	204	28		180		32	142	67	1
47	95	125	22	125			352	197	27	7	203		31	143	69	1
48	89	212	9	156		21	207	208	28		129		36	125		13
49	80	166	54	113	4	19	292	175	39	21	64	37	35	128	75	1
50	79	183	7	20		1	433	189	69	22	67		80	189	79	1
51	78	176	22	121		11	289	183	79	10	176		72	138	77	1
52	77	146	11	40	2	4	457	189	79	15	100	31	83	179		14
53	76	178	8	18			433	183	73	25	93	81	81	190	80	1

TABLE 10.

No.	Sign	2V	N_g	N_m	N_p	N_g-N_p	$Z \wedge c$	G
1	−		1.634	1.626	1.616	0.018	18°	3.044
2	−		1.653	1.642	1.628	0.025	15°	3.131
3	−		1.639	1.626	1.611	0.028	17°	3.051
4	−	79°38′	1.6272	1.6155	1.6000	0.0272	15°25′	2.98
5	−	88°23′	1.6246	1.6132	1.5992	0.0254	20°1′	2.997
6	−	86°29′	1.6347	1.6192	1.6022	0.0325	16°38′	2.980
7	−		1.632		1.609	9.023		
8	−		1.659	1.649	1.631	0.028	24–27°	3.126
9	−	81°38′	1.6450	1.6330	1.6173	0.0277	14°59′	3.047
10	−	79°49′	1.6410	1.6297	1.6139	0.0271	16°31′	3.047
11	−	82°	1.6307	1.6183	1.6024	0.0283	15°30′	
12	−	87°56′	1.6299	1.6171	1.6036	0.0263	18°18′	3.025
13	−	80°	1.631	1.620	1.608	0.023	17°	2.989
14			1.6529		1.6267	0.0262	14°34′	3.116
15	+		1.634	1.621	1.613	0.021	17°	3.056
16	−		1.650	1.641	1.627	0.023	20°	3.11
17	−	84°5′	1.6319	1.6210	1.6065	0.0254	16°54′	3.031
18	−		1.641	1.630	1.617	0.024	18°	3.09
19		83°				0.0241	16°	2.996
20			1.663		1.642	0.021	15°	3.211
21	−		1.637	1.628	1.618	0.019	19°	3.064
22	−	78°30′	1.632	1.620	1.607	0.025	17°30′	
23	−	81°30′	1.6412	1.6304	1.6162	0.0250	14°27′	3.092
24			1.638		1.615	0.023	18°	
25	−	86°14′	1.6244	1.6134	1.6017	0.0227	19°31′	3.03–3.04
26	−	Lg.	1.638	1.629	1.618	0.020	17°	3.06
27	−		1.650		1.628	0.022		
28	−		1.642	1.634	1.625	0.017	12°	3.054
29	−		1.664	1.652	1.637	0.027	20°	
30	−	84°8′	1.6503	1.6382	1.6237	0.0266		3.111
31	−	81°30′	1.634	1.624	1.612	0.022	18°	
32	−	Lg.	1.642	1.631	1.618	0.024	16°	3.147
33	−		1.659		1.638	0.021	17°	3.188
34	−		1.647	1.645	1.631	0.016	18°	3.171
35	+		1.672	1.660	1.649	0.023		3.18
36	−	76°	1.652	1.642	1.626	0.026	16°	3.11
37	−	83°57′	1.6678	1.6551	1.6416	0.0262	15°30′	
38	−	78°	1.664	1.655	1.643	0.021	19°	3.159
39	−	70°	1.654	1.646	1.627	0.027	17°	3.12
40	−	88°30′	1.661		1.636	0.025	16°	3.12
41	−	75°	1.670	1.662	1.651	0.019	19°	3.160
42	−		1.654		1.633	0.021		3.110
43	−	76°	1.671	1.663	1.653	0.018	20°	3.159
44	−	81°	1.652	1.642	1.629	0.023	25°	
45	−	77°	1.666	1.657	1.643	0.023	15°	3.15
46	−		1.661		1.641	0.020		3.18
47	−		1.658		1.640	0.018	17°	3.182
48	−	79°	1.675	1.665	1.650	0.025	19°	3.18
49	−		1.680	1.675	1.652	0.028	14°30′	3.188
50	+	60°29′	1.6351	1.6180	1.6131	0.0220	26°	3.069
51		78–82°	1.658		1.638	0.020	14°30′	
52	+	60°	1.645	1.630	1.622	0.023	27°	

No.	Si −600	Al	Fe‴	Fe″	Mn	Ti	Mg	Ca	Na	K	H	F	Ca+Na+K −200	200(Mg+Al′) / Mg+Al′+Fe	Hallimond's No.	Reference
54	73	138	50	101	1	1	379	211	35	35	25	57	81	143		15
55	68	100	141	150	1	13	271	213	68	11			92	94	84	1
56	68	163	28	294	17	22	128	184	30	13	176		27	61		16
57	63	165	66	84	2	19	317	175	34	17	168		26	134	88	1
58	60	154	17	228	1	23	166	172	47	16	229		35	80	93	1
59	59	141	46	94	3	16	378	206	39	40	32	66	85	140		17
60	59	227	21	221	2	15	195	193	31	23	88		47	104	95	1
61	58	203	13	27	1	5	430	197	74	15	94	11	86	182	98	1
62	57	203	43	187	2	21	202	230	33	21	52		84	102	101	1
63	56	162	10	20	1	9	463	193	67	18	43	138	78	185	99	1
64	53	227	4	12	1		430	190	78	10	127	12	78	194	103	1
65	53	198	53	112	2	20	304	177	60	16	79		53	131	102	1
66	51	196	52	93	4	10	324	185	72	37	73	23	94	140	106	1
67	51	194	34	98	1	17	348	189	44	16	116		49	145		18
68	50	233	3	9	1		426	192	75	9	128	14	76	195	107	1
69	49	183	56	109	2	41	269	186	36	21	93	41	42	118	108	1
70	48	174	45	177	2	6	213	177	18	26	336		21	101		19
71	46	181	27	153		15	295	191	55		203		46	125	110	1
72	45	204	3	9	1	7	437	202	76	32	68	125	110	192		20
73	44	201	54	143		10	277	186	57	23	163		66	122	113	1
74	44	189	36	160		18	272	181	41	13	200		35	117	115	1
75	42	207	78	158	5	9	221	190	49	20	122		59	104		21
76	42	258	25	132	4	4	259	181	60	12	145		53	137	116	1
77	41	209	31	182	3	17	254	189	73	19	62	39	81	113	109	1
78	40	217	33	185	2	33	209	210	47	23	70		80	102	118	1
79	40	219	116	98			279	207	27				34	122		22
80	38	178	108	215		12	167	178	83	26	96	19	87	71	119	1
81	37	238	19	59		14	328	175	88	21	192		84	163	121	1
82	36	186	70	103		28	289	188	79		136		67	121		23
83	36	214	3	72		8	409	197	38	24	49	105	59	169	125	1
84	36	208	51	162		5	251	176	47	23	210		46	115	122	1
85	36	194	41	187		13	254	181	40	10	204		31	109	120	1
86	31	228	33	133		2	309	186	53	14	156		53	137	130	1
87	30	209	57	137		15	276	197	50	23	132		70	120	132	1
88	29	206	37	111	2	31	305	185	31	19	136	39	35	131	135	1
89	28	267	18	74	1	2	295	189	58	22	224		69	161		24
90	27	209	82	372			34	197	39	34	138		70	27	137	1
91	19	252	29	128	2	31	259	201	67	27	77	17	95	127		25
92	19	233	65	96	2	11	317	185	19	15	150		19	138	141	1
93	17	263	16	38		5	385	213	57	27	106	10	97	177	152	1
94	17	200	44	107	1	26	323	186	58	12	197		56	131	146	1
95	14	211	44	149		28	252	184	53	11	230		48	111	148	1
96	13	294	29	112	1	8	259	172	47	16	198		35	142	150	1
97	10	237	51	353	17	39	53	170	57	27	65		54	36	153	1
98	8	207	92	341	13	11	33	169	64	39	217		72	19	154	1
99	7	235	84	138	13	4	263	198	50	46	78	3	94	112	156	1
100	7	191	187	3	1	2	296	192	29	2	224		23	121		26
101	4	253	21	42	1	5	399	203	65	27	33	137	95	174	158	1
102	−2	251	53	72	3	20	330	203	64	35	60	35	102	142		27
103	−7	241	78	29	1	57	334	187	54	46	43		87	139		28
104	−10	239	56	86	2	24	304	196	67	6	203		69	133		29

TABLE 10a.

No.	Sign	2V	N_g	N_m	N_p	N_g-N_p	$Z\wedge c$	G
53	+	58°51′	1.6353	1.6205	1.6158	0.0195	26°57′	3.095
54	+	74°	1.654	1.644	1.638	0.016	21°	3.20
55	−	75°44′	1.6798	1.6729	1.6598	0.020	14°40′	3.21
56	−	59°	1.701	1.692	1.673	0.928	15°+	
57	−	77°	1.669	1.660	1.651	0.018	18°	3.164
58	−	77°	1.700	1.687	1.666	0.034	22°	
59	+	76°	1.654	1.643	1.636	0.018	22°	3.20
60	−	75°		1.675		0.016	18°	3.27
61	+	66°	1.6429	1.6284	1.6218	0.0211	24°	
62	−	70°	1.684	1.676	1.660	0.024	17°	3.254
63	−	83°	1.638	1.631	1.622	1.016	20–22°	3.000
64	+	70°	1.6430	1.6291	1.6221	1.0209	21°	
65	−	Lg.	1.683	1.673	1.658	0.025	13°30′	
66	−	88°	1.6665	1.6589	1.6511	0.0154	23°	
67	−	81°	1.666	1.652	1.633	0.033	15°	3.15
68	+	64°	1.6416	1.6265	1.6206	0.0210	22°	
69	−	71°	1.673	1.665	1.654	0.019	17°	3.176
70	−	77°6′	1.673	1.659	1.651	0.022	25°	3.15
71	−		1.574		1.653	0.021		
72	+	52°9′	1.6332	1.6180	1.6142	0.0190	27°30′	3.11
73	−		1.678		1.658	0.020	24°	3.268
74	−		1.676		1.657	0.019	18°	3.26
75	−		1.681		1.661	0.020		3.292
76	−	86°	1.674	1.663	1.651	0.023	16°15′	3.171
77	−	81°42′	1.6789	1.6701	1.6583	0.0206	23°48′	3.285
78	−	66°30′	1.679	1.674	1.661	0.018	13°30′	3.278
79	−	80°4′	1.6843	1.6753	1.6648	0.0195	16°	
80	−	38°	1.7000	1.6980	1.6804	0.0198	20°	
81	−	85°	1.659	1.647	1.636	0.023	21°22′	3.13
82	−	86°	1.673	1.662	1.647	0.026	20°	3.18
83	+	63°1′	1.6519	1.6380	1.6329	0.0190	26°15′	3.186
84	−		1.677		1.658	0.019		3.284
85	−	65°38′	1.681	1.673	1.659	0.022	16°30′	3.234
86	−		1.671		1.652	0.019		3.214
87	−		1.678		1.658	0.020	16°	3.258
88	−	70°	1.672	1.664	1.650	0.022	15°	3.170
89		72–74°	1.668		1.635	0.033	15–17°	3.258
90	−	Sm.	1.713	1.710	1.693	0.020	17°	
91	−	73°	1.697	1.691	1.680	0.017	19°	3.267
92				1.65			26°	3.13
93	+	64°5′	1.6530	1.6384	1.6327	0.0203	26°20′	3.18
94	−	75°	1.677	1.669	1.652	0.025	26°	
95	−	78°	1.683	1.674	1.658	0.025	23°	
96	−	84°	1.672	1.661	1.648	0.024	19°	3.20
97	−	47°	1.722	1.719	1.698	0.024	20°	3.375
98	−	16°	1.714	1.713	1.697	0.017	(Y) 15°	
99				1.68				3.283
100	−	79°38′	1.6823	1.6743	1.6576	0.0207	20°	3.224
101	−	88°	1.641	1.632	1.622	0.019	18–19°	3.163
102	−	80°	1.685	1.674	1.665	0.020	26°30′	3.189
103	−	83°	1.718	1.700	1.676	0.042	13°	3.221
104	−	80°	1.685	1.671	1.658	0.027	22°6′	3.187

Fig. 15

Relationship between the Amounts of Si and Al in the Formula Unit of Hornblende.

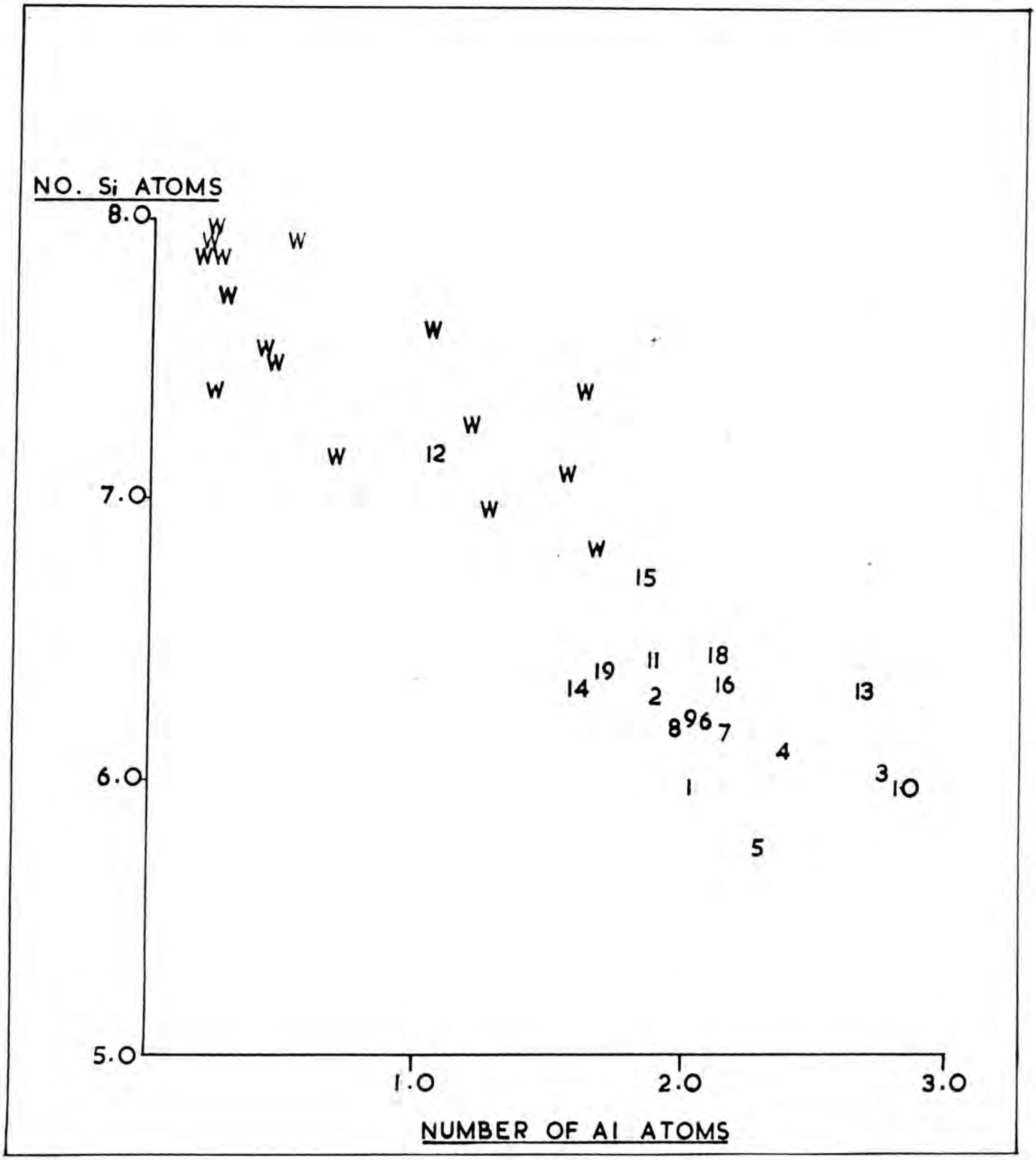

NO. Si ATOMS
8.0
7.0
6.0
5.0
1.0
2.0
3.0
NUMBER OF Al ATOMS
W
12
15
19
14
11
18
16
2
13
8
9
6
7
4
3
10
1
5

FIG. 15.

FREQUENCY DIAGRAM FOR SILICON ATOM CONTENT IN CALCIFEROUS AMPHIBOLES SHOWING LOWER LIMIT PEAK AT 6.0 ATOMS PER UNIT CELL

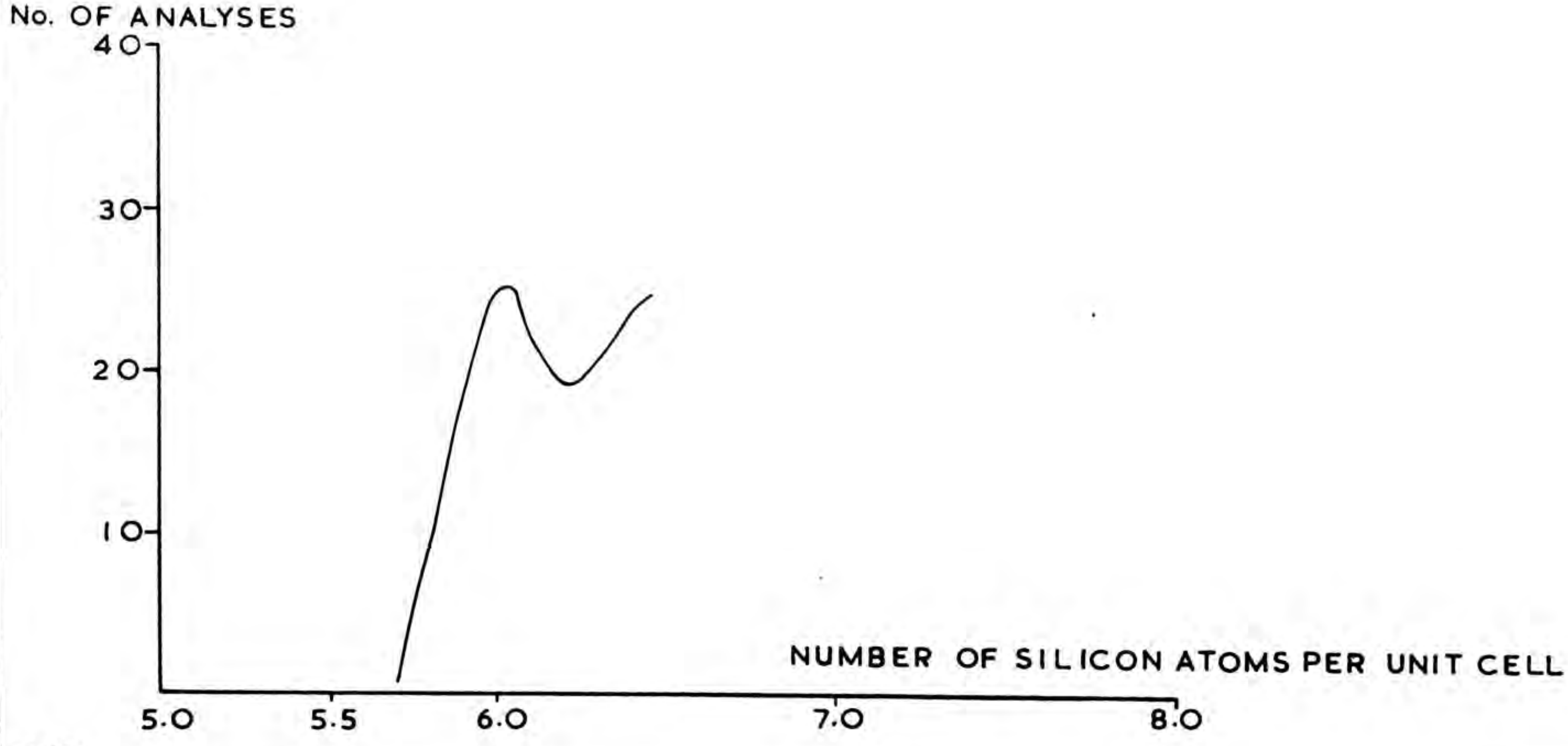


FIG. 15a.

THE RELATIONSHIP OF Fe''' TO Fe'' IN THE CALCIFEROUS AMPHIBOLES

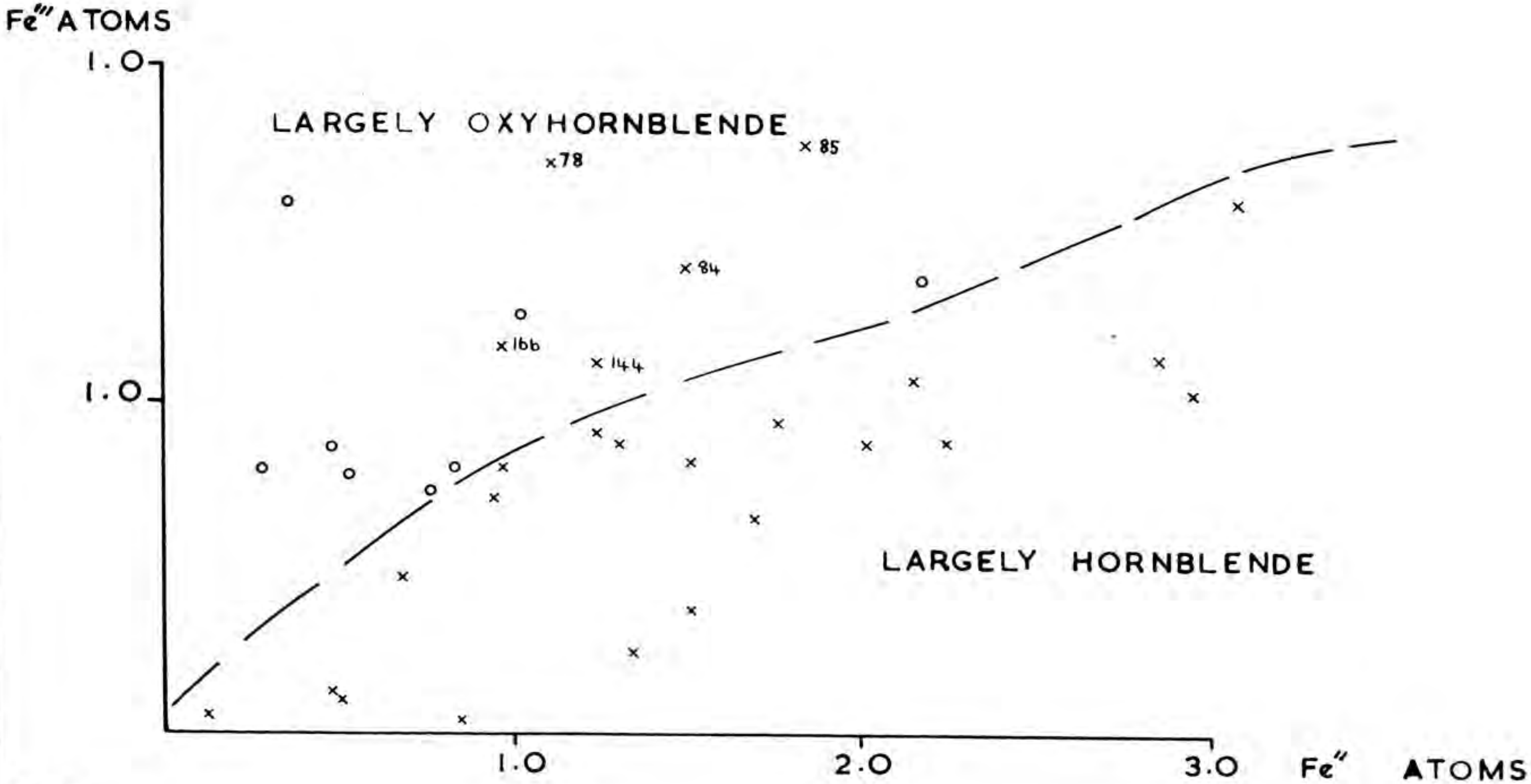
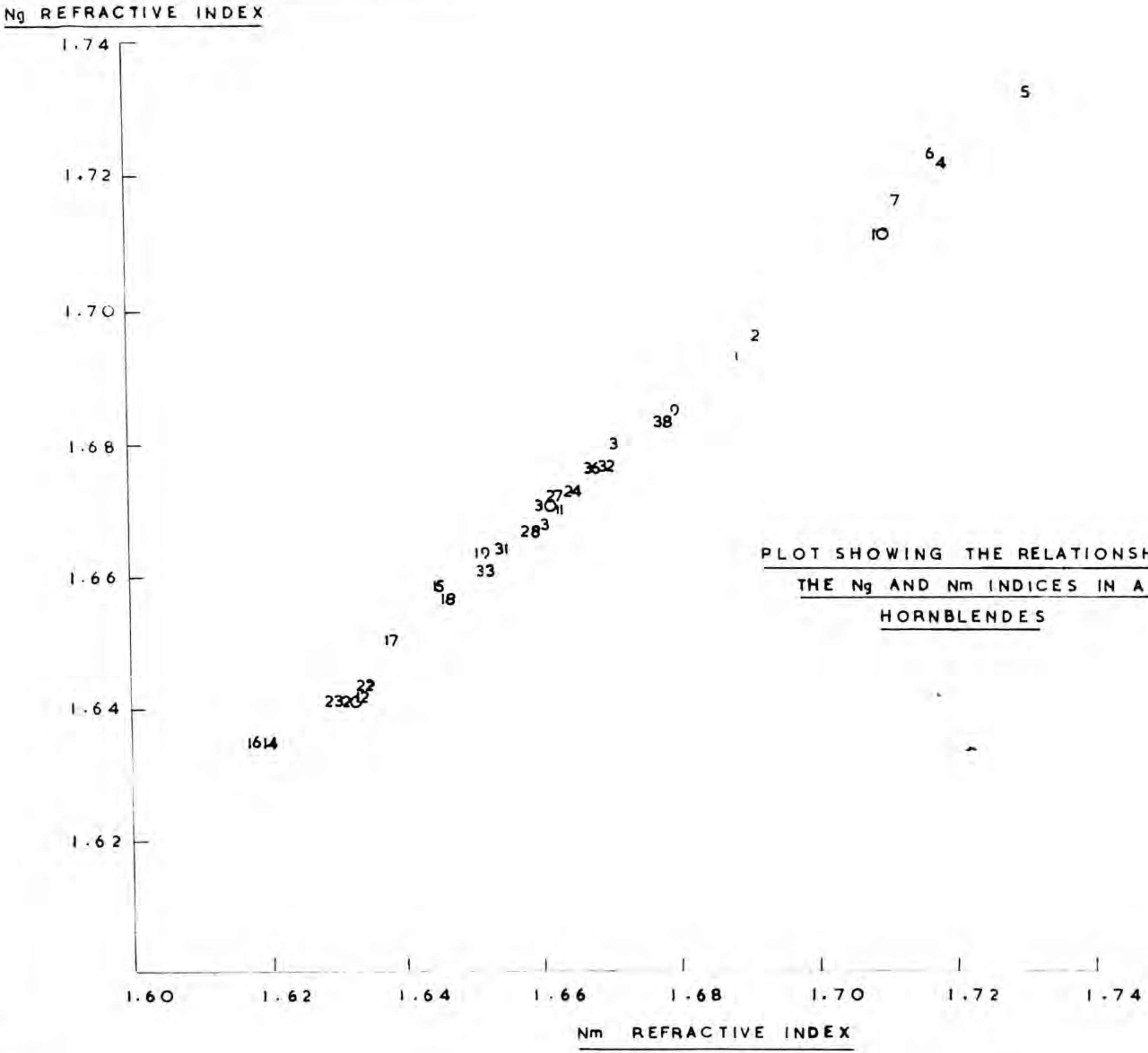
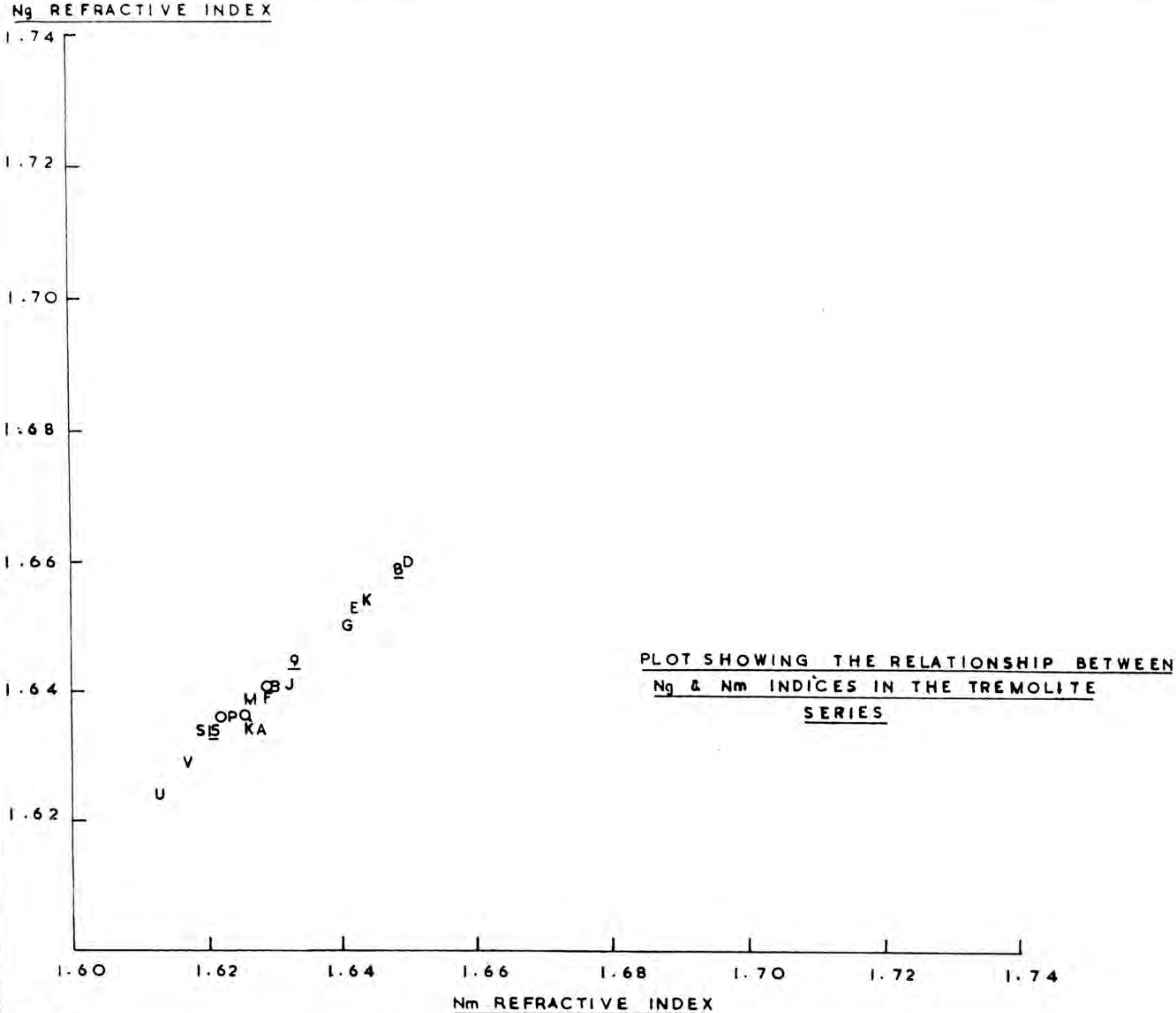


FIG. 16.



PLOT SHOWING THE RELATIONSHIP BETWEEN THE Ng AND Nm INDICES IN Al HORNBLENDES

FIG. 17



PLOT SHOWING THE RELATIONSHIP BETWEEN Ng & Nm INDICES IN THE TREMOLITE SERIES

FIG. 18.

Fig. 19

Relationship between Birefringence Ng-Np
and the Ng Index in Hornblendes.

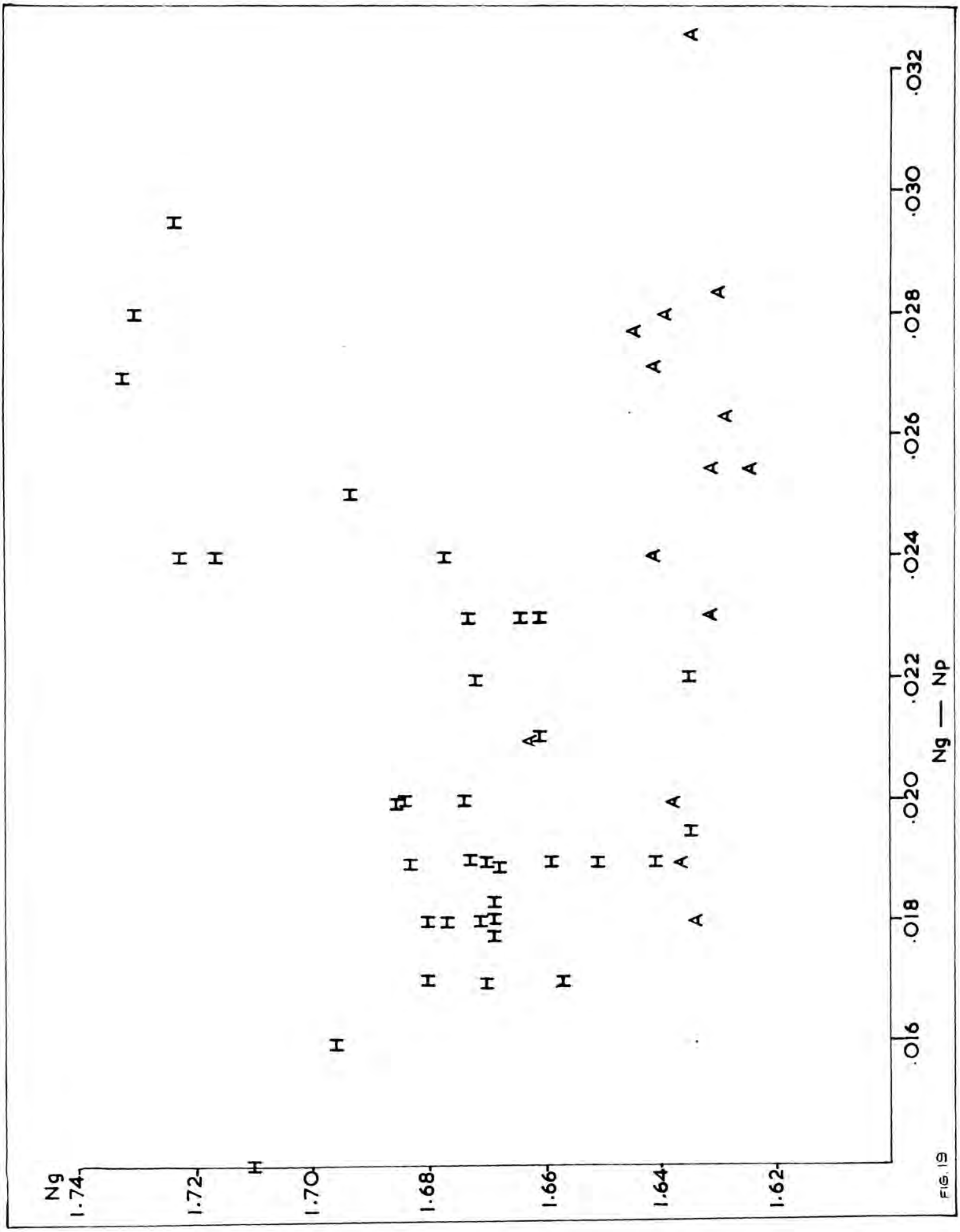
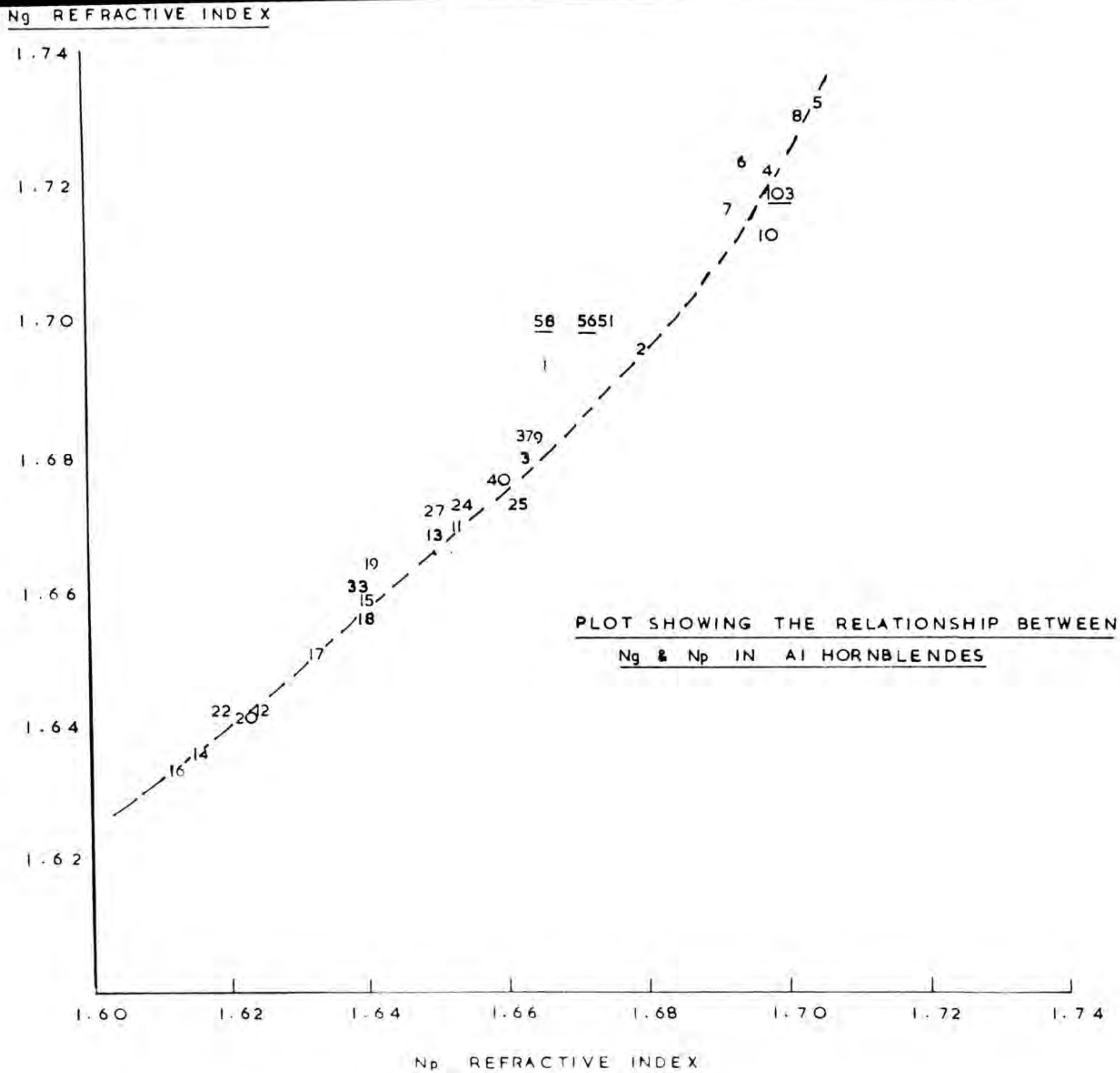
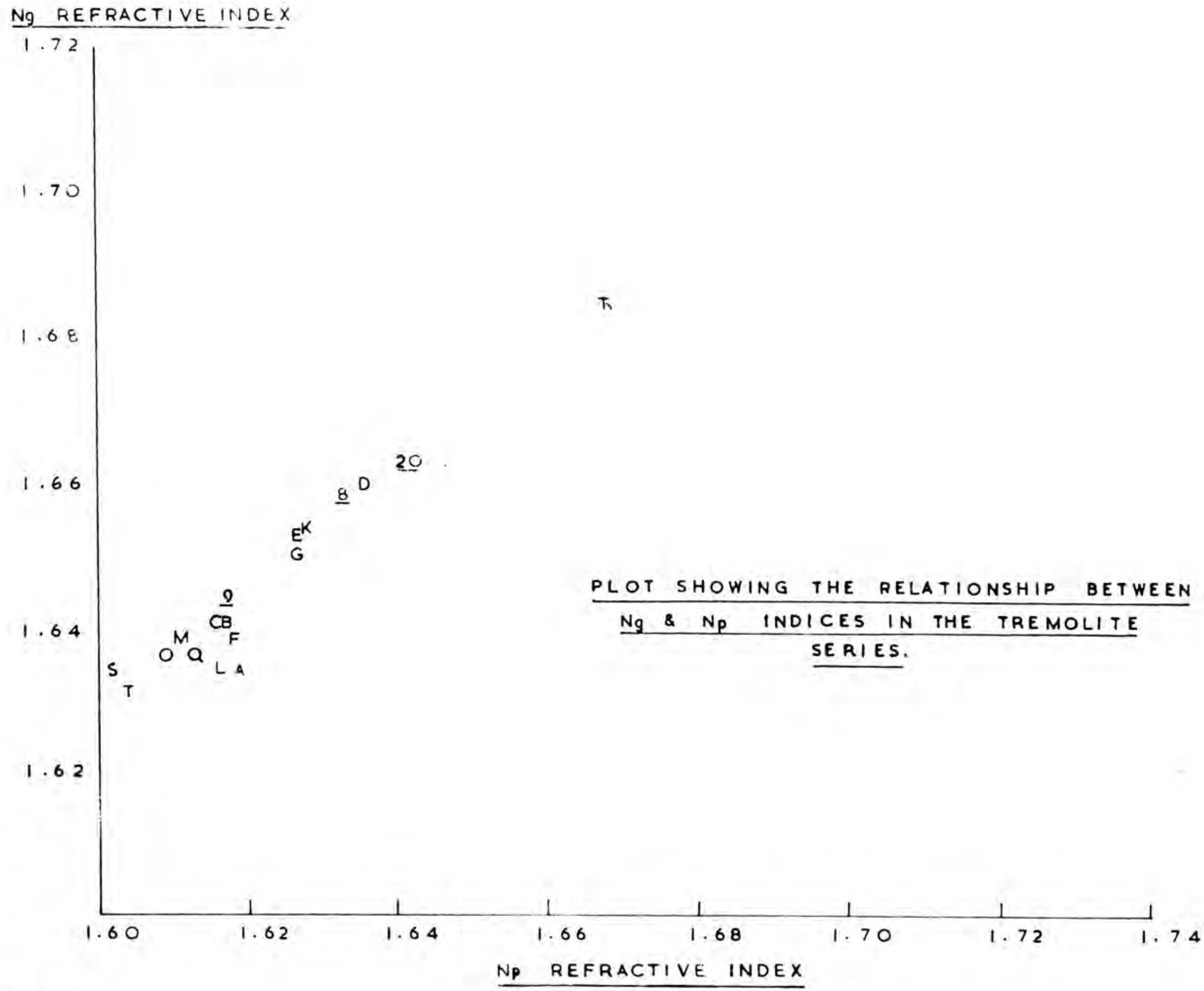

Ng
1.74
1.72
1.70
1.68
1.66
1.64
1.62
.016
.018
.020
.022
.024
.026
.028
.030
.032
Ng — Np

FIG. 19



PLOT SHOWING THE RELATIONSHIP BETWEEN Ng & Np IN Al HORNBLENDES

FIG. 20



PLOT SHOWING THE RELATIONSHIP BETWEEN Ng & Np INDICES IN THE TREMOLITE SERIES.

FIG. 21.

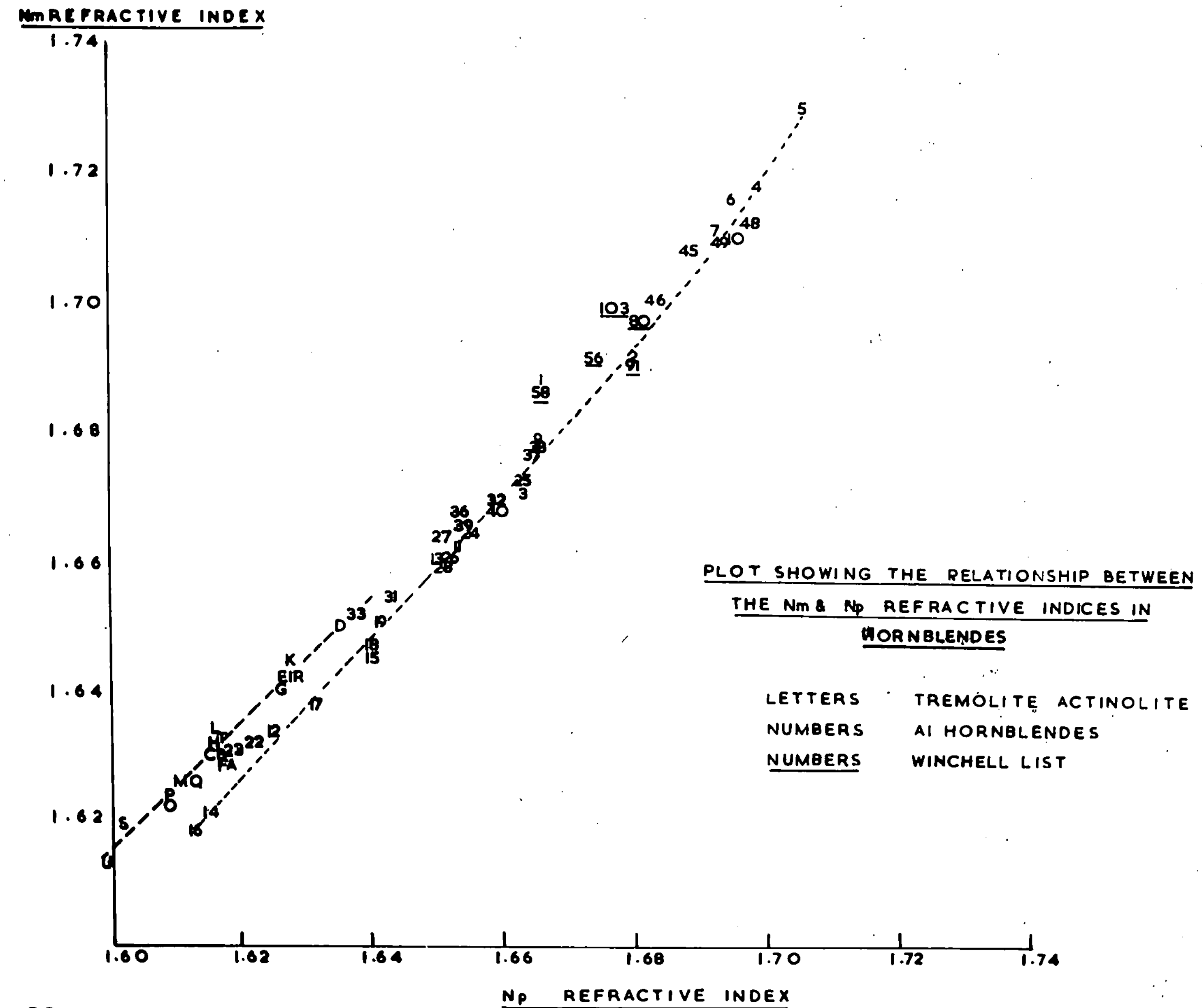

Nm REFRACTIVE INDEX
1.74
1.72
1.70
1.68
1.66
1.64
1.62
1.60
1.62
1.64
1.66
1.68
1.70
1.72
1.74
Np REFRACTIVE INDEX
PLOT SHOWING THE RELATIONSHIP BETWEEN
THE Nm & Np REFRACTIVE INDICES IN
HORNBLENDES
LETTERS TREMOLITE ACTINOLITE
NUMBERS AI HORNBLENDES
NUMBERS WINCHELL LIST

FIG. 22

Fig. 23

Plot showing the Relationship between Ng and Nm in the Pyroxene Series.

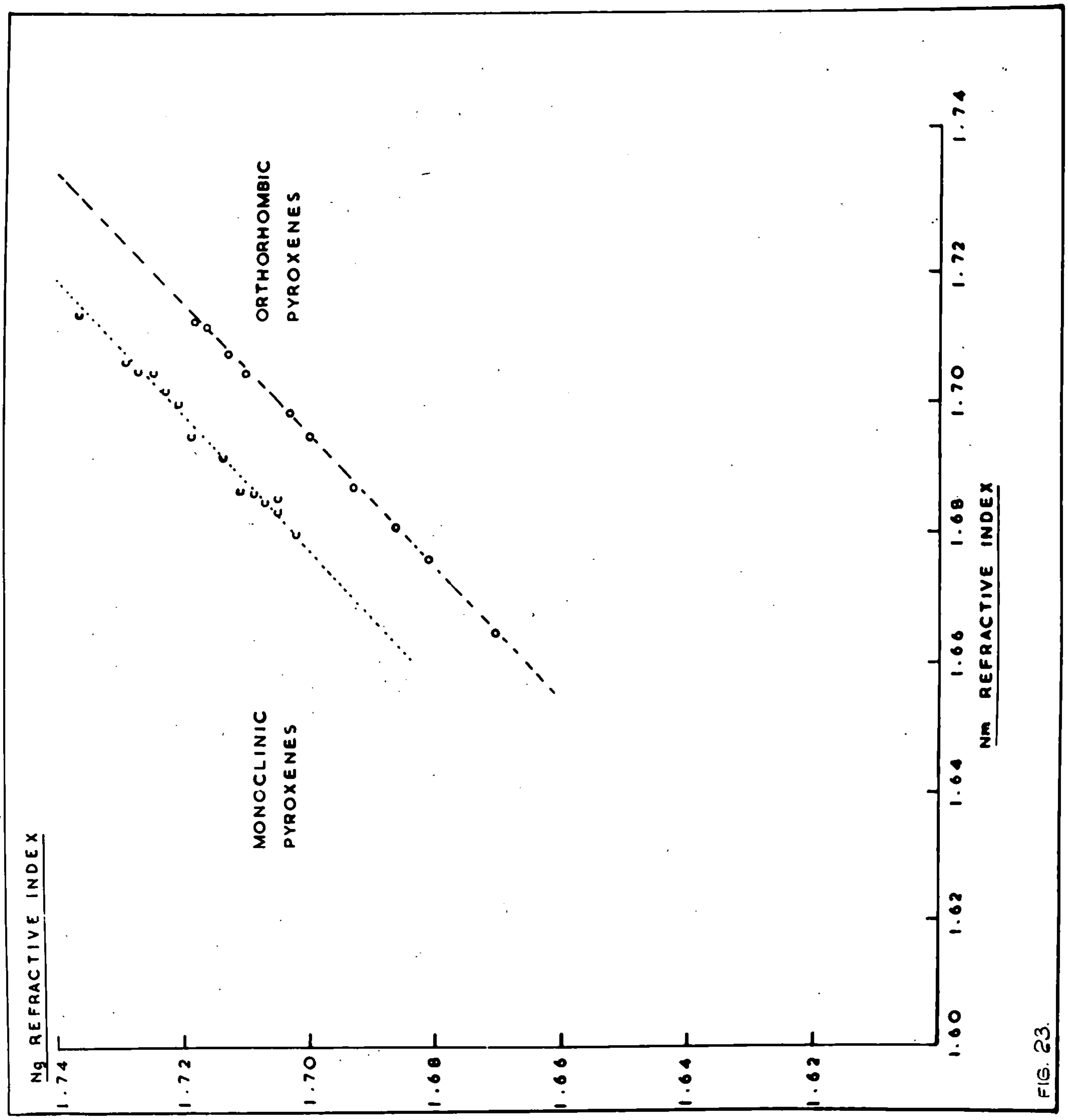
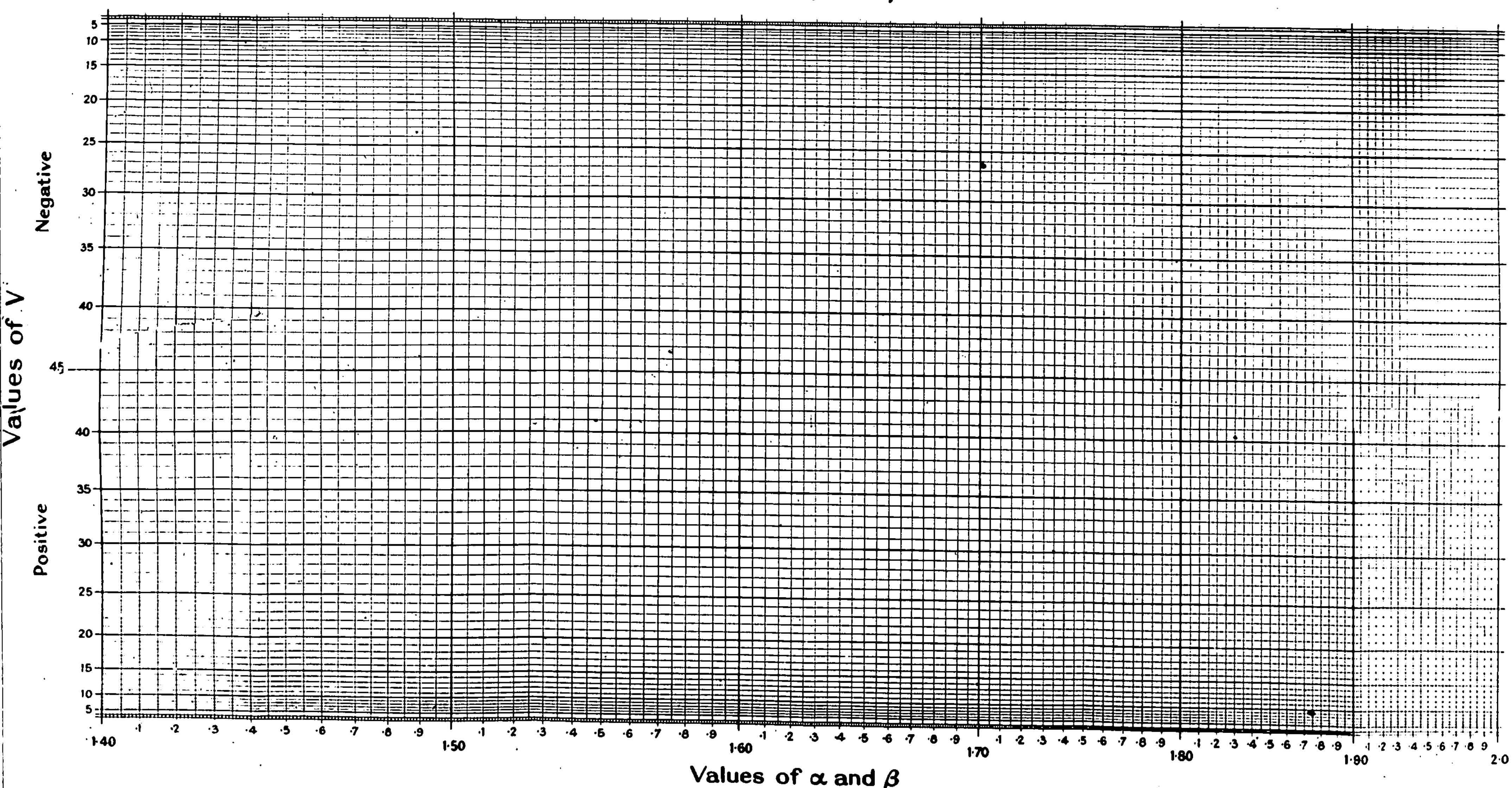

Ng REFRACTIVE INDEX
Nm REFRACTIVE INDEX
ORTHORHOMBIC PYROXENES
MONOCLINIC PYROXENES
1.74
1.72
1.70
1.68
1.66
1.64
1.62
1.60

FIG. 23.



Nomogram for Determination of Refractive Indices

FIG. 23a.

PLOT SHOWING THE RELATIONSHIP BETWEEN DENSITY AND THE HEAVY ELEMENTS IN THE HORNBLENDE SERIES

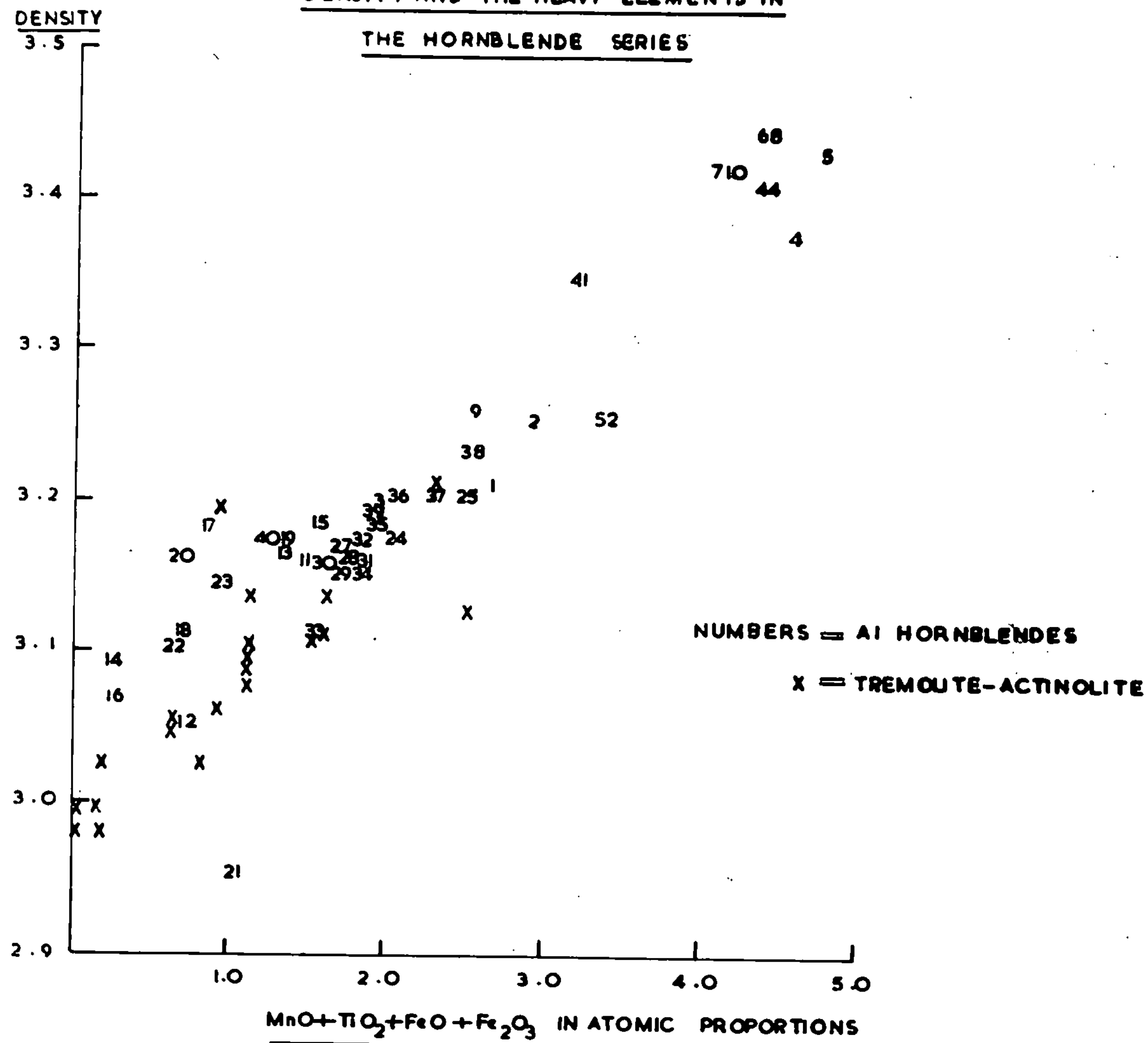


FIG. 24

PLOT SHOWING THE RELATIONSHIP BETWEEN THE Ng REFRACTIVE INDEX AND DENSITY IN THE HORNBLENDE SERIES

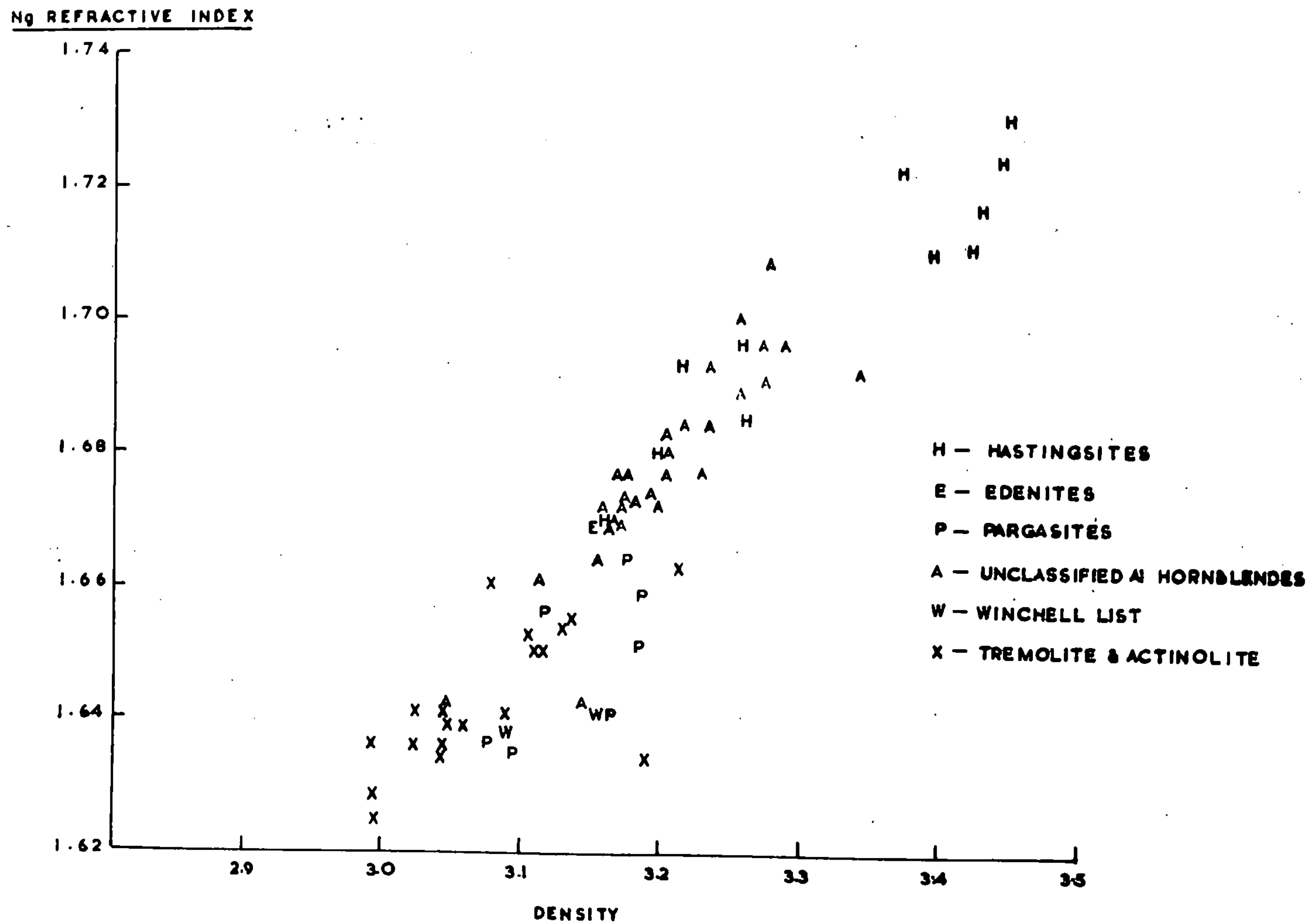


FIG. 25

TABLE 11a

TABLE OF SELECTED ANALYSES OF THE CUMMINGTONITE SERIES.

	1	2	3	4	5	6	7	8
SiO_2	43.9	46.42	49.11	48.53	47.17	50.10	50.32	54.28
Al_2O_3	1.9	0.25	1.81	1.02	1.00	1.72	0.86	1.26
TiO_2	-	0.15	0.12	-	-	0.31	-	0.02
Fe_2O_3	-	0.09	2.03	1.14	1.12	3.11	1.75	0.80
FeO	52.2	42.60	38.98	39.20	43.40	26.63	35.36	21.79
MnO	-	2.23	0.79	0.66	0.08	.19	.02	0.26
MgO	1.1	3.12	2.97	4.06	2.61	14.36	8.61	18.64
CaO	-	1.51	0.75	1.31	1.90	.87	.88	0.15
Na_2O	-	0.70	0.94	1.06	0.47	.60	.13	0.14
K_2O	-	0.43	0.64	0.19	0.07	.15	-	tr
H_2O	0.5	$^{+}$1.78 $^{-}$0.4	$^{+}$1.39 $^{-}$0.10	$^{+}$1.71	2.22	$^{+}$1.46	1.82	2.16
Cl	-	0.65	0.31	-	-	-	-	-
F	-	-	-	-	0.07	-	-	0.57
TOTAL	99.6	100.07	99.94	99.88	100.11	100.10	99.93	100.07

TABLE 11b

TABLE OF SELECTED ANALYSES OF THE CUMMINGTONITE SERIES.

	9	10	11	12	13	14	15
SiO_2	50.99	53.12	51.53	49.60	50.78	52.9	54.97
Al_2O_3	3.78	2.78	5.02	8.65	1.77	2.37	2.38
TiO_2	0.02	0.21	0.31	0.26	0.40	0.06	0.14
Fe_2O_3	0.85	0.25	0.82	0.48	1.88	nil	0.06
FeO	21.70	22.46	16.91	18.54	29.64	28.00	17.25
MnO	0.18	0.27	0.22	1.08	0.14	0.97	0.02
MgO	18.61	15.46	20.84	16.78	11.83	13.71	22.11
CaO	-	2.26	1.34	0.97	1.33	0.55	1.84
Na_2O	0.24	-	0.65	0.79	nil	0.1	0.30
K_2O	0.31	-	nil	nil	nil	-	0.10
H_2O	2.77	3.33	2.15 (+) .64 (−)	2.52 (+) .29 (−)	2.01 (+)	1.04 (+)	0.80 (+)
Cl	-	-	-	-	-		-
F	-	-	-	-	-		-
TOTAL	99.45	100.14	100.43	100.30	99.78	99.60	100.00

TABLE 11c

TABLE OF SELECTED ANALYSES OF THE CUMMINGTONITE SERIES.

	16	17	18	19	20	21	22
SiO_2	56.74	50.37	50.74	53.26	53.26	52.29	53.25
Al_2O_3	0.91	0.54	0.88	2.26	1.25	0.59	2.31
TiO_2	-	-	0.06	0.78	-	-	0.97
Fe_2O_3	3.41	0.56	1.80	0.60	2.63	0.29	1.81
FeO	24.41	40.08	24.03	1.12	1.06	0.06	1.62
MnO	1.58	1.07	7.39	6.24	8.25	2.77	4.66
MgO	9.72	4.47	10.57	29.16	31.26	30.98	28.42
CaO	0.42	0.83	2.00	1.10	1.11	1.26	3.42
Na_2O	-	-	0.22	1.39	1.56	0.37	1.25
K_2O	-	-	0.08	0.09	0.07	0.19	0.06
H_2O	3.81	+ 2.24 − 6.20	+ 1.94	+ 1.87	0.05	3.80	2.04
Cl	-	-		-	-	+ ~~2.04~~	-
F	-	-	0.07	-	-	0.20	-
TOTAL	100.73	100.38	99.87	99.87	100.50	99.83	99.63

TABLE 11d

TABLE OF SELECTED ANALYSES OF THE CUMMINGTONITE SERIES.

Locality and Reference.

1. Collobrieres, Original Grunerite, Gruner (1848).
2. Pierrefitte, Warren (1931).
3. Pierrefitte, Warren (1927).
4. Mt. Humbolt, Michigan, U.S.A., S. Richarz (1927).
5. La Malliere near Collobrieres, Kreutz 1908.
6. Kalvola, Finland, Eskola (1936). (see Rabbitt 1948 (No. 2)).
7. Cherry Creek, Montana, Rabbitt (1948).
8. Trondheim, Norway, Sundius (1933).
9. Odal faltet, Persberg, Sweden, Johannson (1914).
10. Kenidjack, Cornwall, Tilley and Flett (1930).
11. Strathy, Sutherland, Collins (1942).
12. Toll Egain, Strathy, Collins (1942).
13. Lake Paarlahti, Teisko, Finland, Seitsaari (1952).
14. Mikonni River, New Zealand, Mason (1953).
15. Muuruvesi, Finland, Eskola (1950).
16. Warr eda, S.W. Div. Simpson (E.S.) (1928).
17. Mt. Palmer, W. Australia, Miles (1943).
18. Sodermanland, Johannson (1930).
19. Chikla, India, Bilgrami (1955).
20. Tirodi, India, Bilgrami (1955).
21. Edwards, N.Y. Allen and Clement (1908).
22. Tirodi, India, Bilgrami (1955).

THE REVISED CLASSIFICATION OF THE CUMMINGTONITE SERIES.

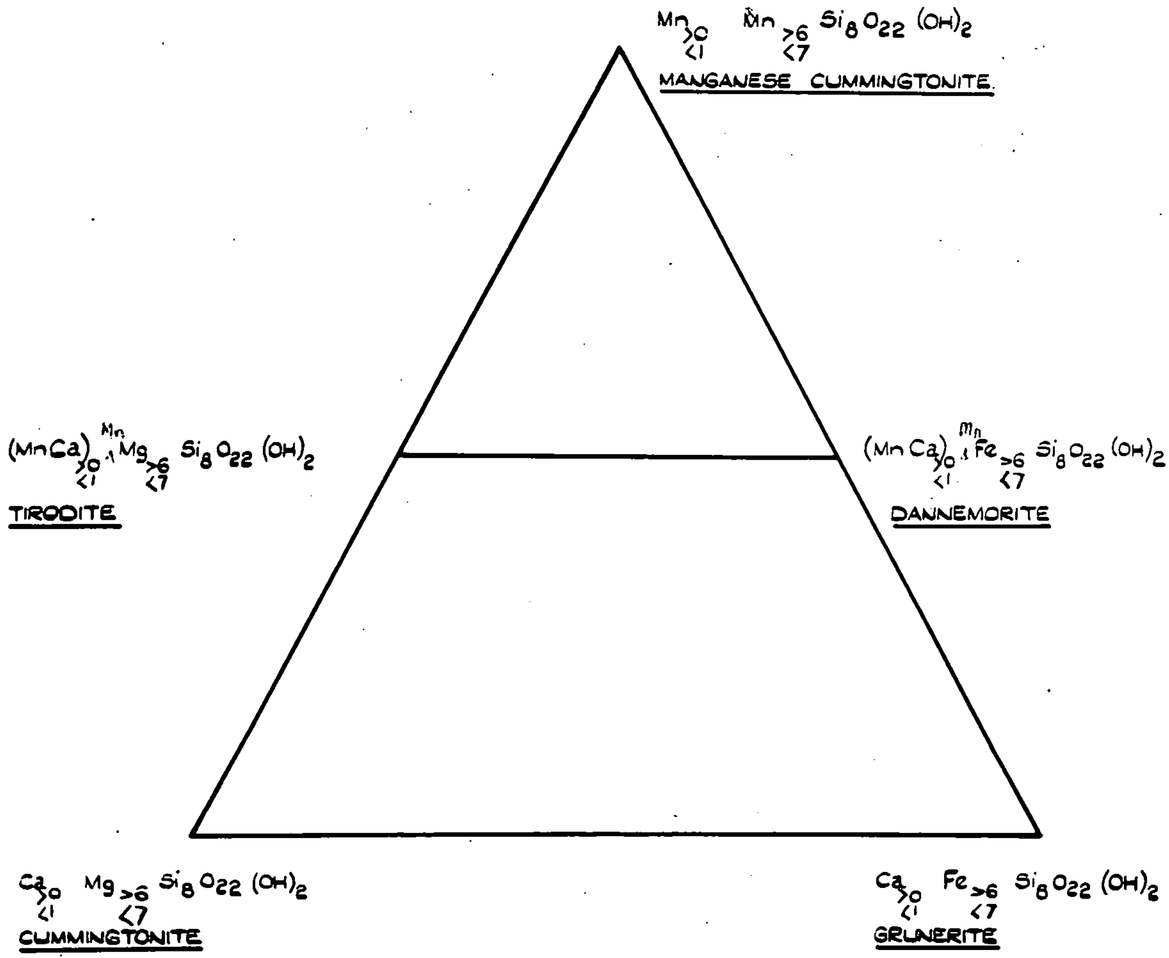


FIG. 26

DIAGRAM SHOWING THE DEVELOPMENT OF THE CUMMINGTONITES & TWO TYPES OF ANTHOPHYLLITES FROM THE HORNBLENDE SERIES.

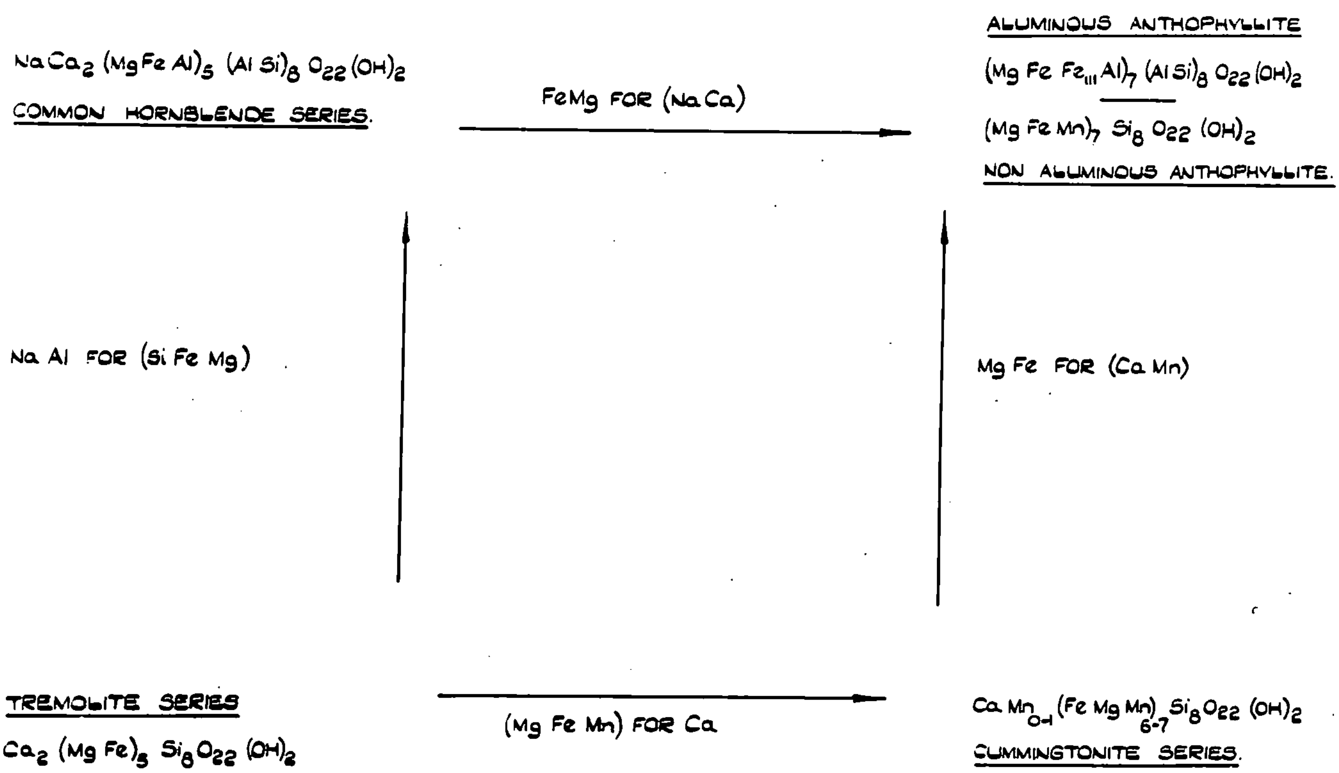
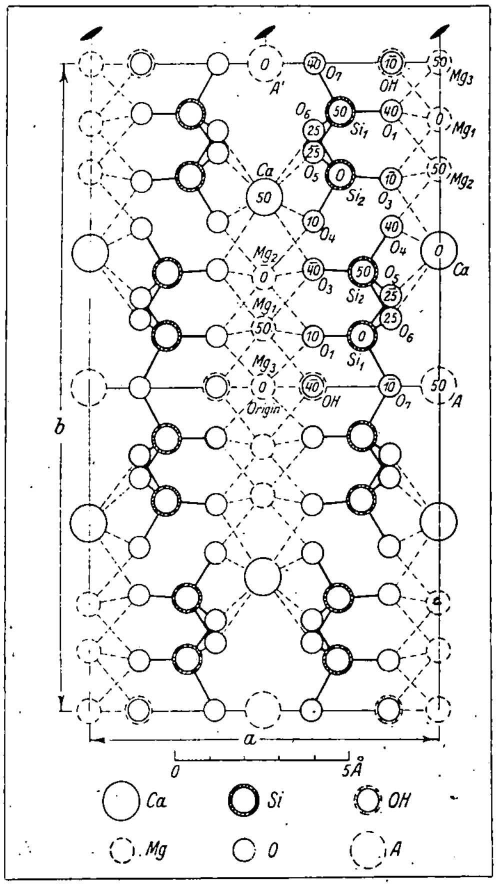
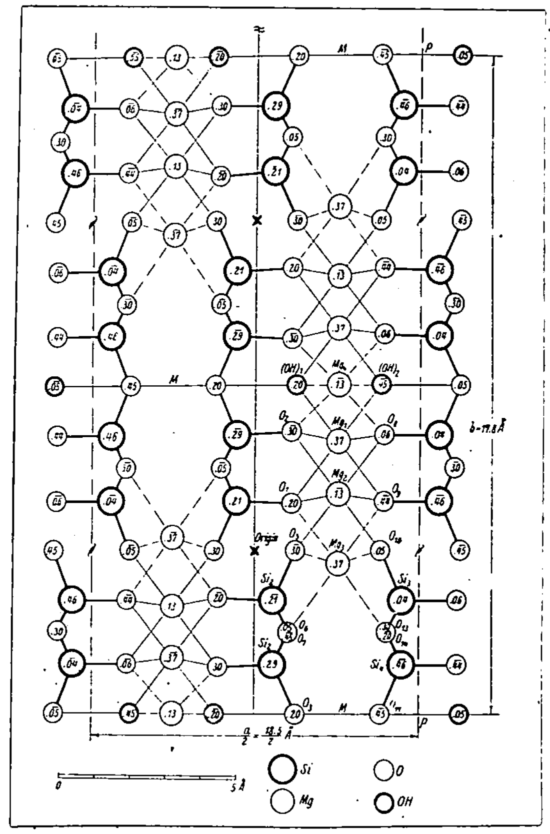


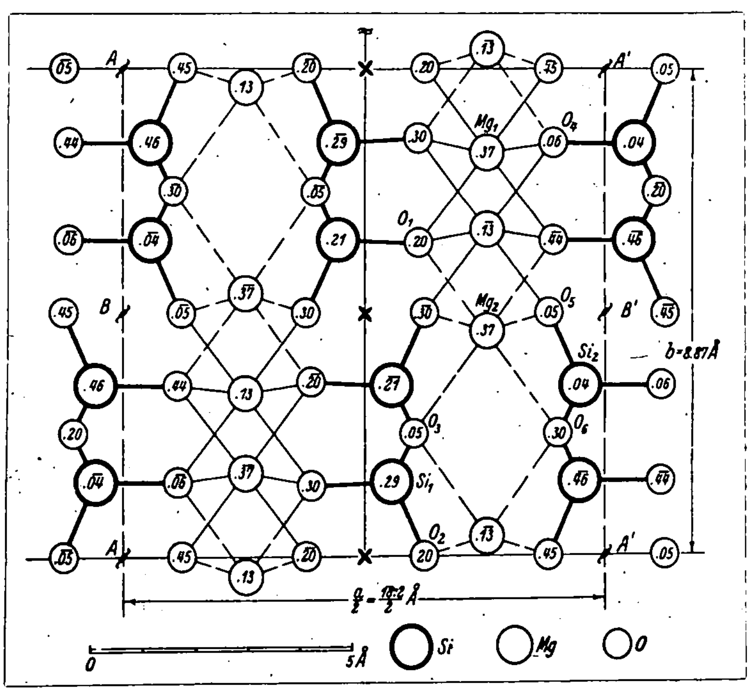
FIG. 27



a.



b.



c.

FIG. 27. a, b, c.

TABLE 12

PHYSICAL PROPERTIES OF THE CUMMINGTONITE SERIES.

	Density	Np	Nm	Ng	2V	Z∧c	Ng-Np	Sign	
1	3.713	-	1.73	-	50°	11°-15°	0.056	-ve	
2) 3)		1.676	1.693	1.707	84°-15'	13°-22'	0.031	-ve	
4	3.44	1.666	1.684	1.700	85°	14°-15°	0.034	-ve	
5									
6	3.307	1.661	-	1.681	-	-	0.020	-	
7									
8	3.241	1.639	1.647	1.664	68°	20°	0.025	+ve	
9	-	1.640	1.647	1.665	65°	20	0.025	+ve	
10	-	1.643	-	1.670	-	19	0.027	-	
11	3.10	1.643	1.650	1.663	75°	20	0.020	+ve	
12	3.18	1.645	1.652	1.664	75°	19	0.019	+ve	
13	3.359	1.658	-	1.687	68-66	16-21	.029	+ve	
14	3.27	1.651	1.664	1.678	86°	16°		+ve	
15	3.175	-	-	-	90*	20°-22°	-		
		1.626	1.635	1.65	78°	18			Winchell figs.
16	3.04	1.630		1.660	-	17°	-	-+ve	given above
17	-	1.673	1.694	1.711	85°	13½-14	-	-ve	
18	3.337	1.655	1.674	1.685	85° 15'	15°		-ve	
19	3.312	1.629	1.639	1.650	88	21	.021		Straw yellow colour.
20	3.248	1.629	-	1.650	41	18	.021		

TABLE 13

Miyashiro (1957) List of Alkali Amphiboles.

No.	Name and occurrence	Locality	Author
1	Riebeckite (crocid.) from ironstone	Hamersley Range, Australia	SIMPSON
2	Riebeckite from schist	Mill Creek, Calif.	SWITZER
3	Riebeckite from schist	Vallone delle Miniere, Piemont	GRILL
4	Riebeckite (crocid.) from ironstone	Kliphuis, S. Africa	PEACOCK
5	Riebeckite (crocid.) from ironstone	Hamersley Range, Australia	SIMPSON
6	Riebeckite (osannite) from metamor. neph. gneiss	Cevadaes, Portugal	HLAWATSCH
7	Riebeckite from quartz-syenite-pegmatite	Fukushin-zan, Korea	MIYASHIRO, 1956
8	Riebeckite from granite-pegmatite	Quincy, Mass.	PALACHE & WARREN
9	Riebeckite from neph.-syenite (?)	Mariupol, Ukraine	AINBERG
10	Riebeckite from quartz-syenite	Fukushin-zan, Korea	MIYASHIRO, 1956
11	Riebeckite from syenite-pegmatite	Alter Pedroso, Portugal	VENDL
12	Magnesioriebeckite (crocid.) from limestone	S. Australia	JACK
13	Magnesioriebeckite (ternovskite) from schist (?)	Krivoi Rog, Ukraine	POLOVINKINA
14	Magnesioriebeckite (crocid.) from metasediment	Cochabamba, Bolivia	AHLFELD
15	Magnesioriebeckite (fluotaram.) from syenite-pegmatite	Mariupol, Ukraine	MOROZEWICZ
16	Magnesioriebeckite (riebeck.-cross.) from metamor. rock	Glen Lui, Scotland	MCLACHLAN
17	Subglaucophane (glaucoph.) from gneiss	Alpe de Sevreu, Switz.	WOYNO
18	Subglaucophane (riebeck.) assoc. with schist	Saint-Véran, Hautes-Alpes	ROUTHIER
19	Subglaucophane (crossite) from schist	Vodno, Jugoslavia	NIKITIN & KLEMEN
20	Subglaucophane (crossite) from schist	Berkeley, Calif.	KUNITZ
21	Subglaucophane (crossite) from schist	Berkeley, Calif.	SWITZER
22	Subglaucophane (glaucoph.) from schist	Lavintzie, Switzerland	GRUBENMANN
23	Subglaucophane (crossite) from schist	Anglesey, Wales	HOLGATE
24	Ferroglaucophane (glaucoph.) from schist	Cykladen, Greece	KUNITZ
25	Glaucophane proper from prasinite	Rocca Bianca, Piemont	ZAMBONINI
26	Glaucophane proper from schist	Horokanai Pass, Hokkaido	SUZUKI
27	Glaucophane proper from schist	Syra, Greece	WASHINGTON
28	Glaucophane proper from schist	Champ de Praz, Piemont	KUNITZ
29	Glaucophane proper from schist	Smyrna, Turkey	KUNINZ
30	Glaucophane proper (gastaldite) assoc. with schist	St. Marcel, Piemont	ZAMBONINI
31	Glaucophane proper from schist	Zermatt, Switzerland	KUNITZ
32	Glaucophane proper from schist	San Pablo, Calif.	BLASDALE
33	Glaucophane proper from schist	San Pablo, Calif.	BLASDALE
34	Glaucophane proper from schist	Mt. Saleve, Switzerland	KUNITZ

to Atomic Ratios for O=2300 (Excluding H_2O)

No.	Si	Al^{IV}	Al^{VI}	Ti	Fe'''	Fe''	Mn	Mg	Ca	Na	K	H_2O	F	R'''	Fe'''/R'''	F''/R''
1	792	1	0	0	233	189	0	74	8	181	6	+100	—	233	1.00	0.72
2	754	46	29	1	192	165	63	79	6	144	6	+44	0	222	0.87	0.54
3	783	17	32	0	186	218	3	23	13	230	22	+60	—	218	0.85	0.89
4	798	2	2	—	215	249	—	31	3	181	1	+132	—	217	0.99	0.89
5	789	4	0	0	217	194	0	89	6	177	5	+135	—	217	1.00	0.69
6	779	18	0	4	196	268	17	4	15	199	17	97	—	197	1.00	0.93
7	773	9	0	11	193	279	7	25	13	197	11	+105	22	193	1.00	0.90
8	793	7	5	15	167	274	15	2	21	181	22	+66	10	187	0.89	0.94
9	755	14	0	46	167	222	7	86	38	130	15	+173	—	182	0.92	0.70
10	796	4	7	5	164	188	19	115	22	145	41	+102	14	176	0.93	0.58
11	775	25	11	8	156	240	29	48	21	197	19	+105	22	175	0.89	0.76
12	771	29	61	—	164	41	0	234	7	176	13	+111	—	225	0.73	0.15
13	764	36	26	3	168	99	—	198	33	166	13	89	—	197	0.85	0.33
14	768	32	33	0	148	87	3	256	19	151	8	34	—	181	0.82	0.25
15	773	27	3	15	143	110	69	130	8	239	57	+67	116	161	0.89	0.36
16	757	34	0	16	146	136	2	191	77	142	14	+120	9	153	0.95	0.41
17	780	20	81	29	125	109	3	118	36	141	13	+78	—	235	0.53	0.47
18	802	0	66	1	150	208	2	70	12	150	8	+84	—	217	0.69	0.74
19	780	20	122	4	74	110	1	183	19	188	2	+57	—	200	0.37	0.37
20	781	19	120	—	75	141	4	154	24	175	7	+93	—	195	0.38	0.47
21	777	23	72	3	119	119	2	193	24	162	2	+96	1	194	0.61	0.38
22	750	50	64	10	111	100	—	199	34	198	20	+21	—	185	0.60	0.33
23	731	69	65	18	95	131	2	160	62	198	11	+57	—	178	0.53	0.45
24	776	24	180	—	17	160	—	153	6	182	15	94	—	197	0.09	0.51
25	780	20	182	—	25	93	0	195	31	157	6	+125	—	207	0.12	0.32
26	809	0	139	3	53	92	1	190	18	162	10	+65	—	195	0.27	0.32
27	784	16	161	—	33	110	1	199	14	179	7	+16	—	194	0.17	0.35
28	787	13	163	—	30	95	—	215	10	182	11	103	—	193	0.16	0.31
29	787	13	171	—	20	126	—	184	18	173	11	89	—	191	0.10	0.41
30	775	25	170	—	21	71	—	254	18	167	0	111	—	191	0.11	0.22
31	780	20	172	—	12	61	—	262	15	183	12	102	—	184	0.07	0.19
32	740	60	128	2	40	108	0	239	46	168	0	+121	—	170	0.24	0.31
33	762	38	114	4	47	115	5	215	30	205	3	+83	—	165	0.28	0.34
34	781	19	127	—	25	123	—	231	49	149	10	85	—	152	0.16	0.35

TABLE 13

No.	Name and occurrence	Locality	Author
35	Arfvedsonite	Hackmannschlucht	KUNITZ
36	Arfvedsonite (heikolite) from granite pegmatite	Fukushin-zan, Korea	MIYASHIRO, 1956
37	Arfvedsonite from neph.-syenite	Kangerdluarsuk, Greenland	SAHAMA
38	Arfvedsonite from neph.-syenite	Kangerdluarsuk, Greenland	KUNITZ
39	Arfvedsonite from pegmatite	Urma-varaka, Kola Penin.	KUPLETSKIJ
40	Arfvedsonite from pegmatite	Kakasnjujakok, Kola Penin.	KUNITZ
41	Arfvedsonite from neph.-syenite	Loparsky Pass, Kola Penin.	KUNITZ
42	Arfvedsonite (riebeck.-arfved.) from neph.-syenite	Kiihtelysvaara, Finland	ESKOLA & SAHLSTEIN
43	Arfvedsonite from neph.-syenite	Los-Archipel, W. Africa	KUNITZ
44	Magnesioarfvedsonite (torendrikite) from syenite	Ambatofinandrahana, Madagascar	LACROIX, 1920
45	Magnesioarfvedsonite (fluotaramite) from syenite pegm.	Mariupol, Ukraine	MOROZEWICZ
46	Magnesioarfvedsonite (fluotaramite) from syenite pegm.	Mariupol, Ukraine	AINBERG
47	Magnesioarfvedsonite from hydrothermal rock	Iron Hill, Colorado	LARSEN
48	Magnesioarfvedsonite (fluotaramite) from syenite pegm.	Mariupol, Ukraine	MOROZEWICZ
49	Katophorite from sanidinite inclusion in trachyte	Sao Miguel, Azores	OSANN, 1888
50	Katophorite from trachyte	Fuente Vaca	KUNITZ
51	Magnesiokatophorite (anophorite) from shonkinite	Katzenbuckel, Odenwald	FREUDENBERG
52	Magnesiokatophorite (Katophorite)	Chibinpachk, Kola Penin.	KUNITZ
53	Magnesiokatophorite from theralite	Crazy Mts., Montana	WOLFF
54	Soda-tremolite from metamorphic rock (?)	Krivoi Rog, Ukraine	POLOVINKINA
55	Soda-tremolite (asbestos) from lead deposit	Camp Albion, Colorado	WAHLSTROM
56	Soda-tremolite from hydrothermal rock	Iron Hill, Colorado	LARSEN
57	Soda-tremolite from hydrothermal rock	Iron Hill, Colorado	LARSEN
58	Soda-tremolite from hydrothermal rock	Iron Hill, Colorado	LARSEN
59	Soda-tremolite (imerinite) from limestone	Ambatoharina, Madagascar	LACROIX, 1921
60	Soda-tremolite from hydrothermal rock	Iron Hill, Colorado	LARSEN
61	Soda-tremolite from hydrothermal rock	Iron Hill, Colorado	LARSEN
62	Soda-tremolite (richterite) from limestone	Långban, Sweden	SUNDIUS, 1945
63	Soda-tremolite (richterite) from limestone	Långban, Sweden	SUNDIUS, 1945

Note. In the original descriptions, amphibole No. 53 was erroneously called "hastingsite", and amphiboles Nos. 47 and 54 were unfortunately called "soda-tremolite-glaucophane" and "tremolite-glaucophane" respectively. The optical properties of amphibole No. 44 were re-examined by WINCHELL (1925).

No.	Si	Al^{IV}	Al^{VI}	Ti	Fe'''	Fe''	Mn	Mg	Ca	Na	K	H_2O	F	R'''	Fe'''/R'''	Fe''/R''
35	737	52	0	25	141	212	16	110	37	207	17	100	—	155	0.91	0.63
36	745	55	9	13	130	246	13	106	43	143	28	+148	—	152	0.86	0.67
37	742	58	17	6	119	343	10	6	35	203	59	+66	—	142	0.84	0.98
38	775	25	1	12	128	339	6	7	17	219	31	110	—	141	0.91	0.96
39	738	62	21	10	104	353	10	10	53	163	34	60	—	135	0.77	0.95
40	734	56	0	26	119	234	18	100	58	191	24	86	—	135	0.88	0.66
41	741	50	0	24	115	241	10	103	52	211	21	98	—	130	0.89	0.68
42	738	62	19	23	87	210	6	126	46	240	35	55	—	129	0.67	0.61
43	751	49	1	24	94	232	11	134	30	232	17	104	—	119	0.79	0.61
44	773	17	0	5	140	97	—	273	58	145	17	6	5	140	1.00	0.26
45	752	48	13	7	117	157	5	185	57	179	41	+82	83	137	0.85	0.45
46	765	25	0	10	131	131	7	242	41	156	35	+104	80	131	1.00	0.34
47	750	50	5	14	105	50	2	317	60	192	9	+59	35	124	0.85	0.14
48	784	16	13	13	86	147	8	207	54	196	39	+72	97	112	0.77	0.41
49	715	76	0	—	110	311	39	57	82	185	18	—	—	110	1.00	0.76
50	724	67	0	19	94	233	19	135	80	187	19	79	—	104	0.90	0.60
51	729	34	0	59	83	112	4	253	50	225	34	74	—	105	0.79	0.30
52	686	114	23	11	61	105	15	288	121	126	33	91	—	95	0.64	0.26
53	703	97	16	14	45	115	2	319	87	169	41	+71	—	75	0.60	0.26
54	748	52	11	12	87	0	—	366	115	144	5	69	—	110	0.79	0.00
55	787	13	7	3	88	31	—	361	40	218	32	40	—	98	0.90	0.08
56	746	54	14	5	72	77	4	331	69	203	14	+76	19	91	0.79	0.19
57	769	31	3	0	79	35	6	374	50	214	38	+29	96	82	0.96	0.08
58	735	65	7	6	46	62	3	380	101	151	39	+7	—	59	0.78	0.14
59	753	45	0	4	50	55	—	430	41	202	32	40	41	52	0.96	0.11
60	783	12	0	3	49	10	1	451	91	138	32	+40	57	49	1.00	0.02
61	791	5	0	3	42	29	7	429	77	148	54	+113	0	42	1.00	0.06
62	775	23	0	1	20	0	106	396	84	157	32	92	16	20	indef.	0.00
63	796	4	2	0	3	0	28	486	133	84	11	110	16	5	indef.	0.00

TABLE 13a.

TABLE 14

Optical Data for TABLE 13.

No.	α	β	γ	$\gamma-\alpha$	2V over X	Disp.	Optic Orient.
2	1.680	1.683	1.685	0.005	50°		b=Z, c∧Y=5°
3		1.692					c∧X=4°
4	1.698	1.699	1.706	0.008			b=Z, c∧X=0°
6		1.693					
7	1.701	1.711					
8		1.695					b=Z, c∧X=4-5°
9	1.688		1.691	0.003	112°	$\rho<\upsilon$	b=Z, c∧Y=1°
10		1.686					
11		1.6934					b=Z, c∧X=2°
13	1.655	1.664	1.668	0.013	42°		b=Y, c∧Z=27-35°
16	1.668		1.680	0.012	50°		b=Z, c∧X=14°
19		1.645		0.011	12-65°		b=Z, c∧Y=8°
20	1.640		1.652	0.012			b=Y, c∧Z=3°
21	1.659	1.663	1.666	0.007	50°	$\rho>\upsilon$	b=Z, c∧Y=2°
23	1.649	1.656	1.657	0.008	17°		b=Y, c∧Z=11°
24	1.622		1.640	0.018			b=Y, c∧Z=5-6°
26		1.660			10-15°	$\rho>\upsilon$	b=Y, c∧Z=8-14°
28	1.615		1.634	0.019	41°		b=Y, c∧Z=6-8°
29	1.618		1.637	0.019			b=Y, c∧Z=4°
31	1.606		1.627	0.021			b=Y, c∧Z=8°
34	1.619		1.640	0.021			c∧Z=6°
35	1.690	1.695					b=Z, c∧X=27°
36	1.680	1.687	1.691	0.011			b=Z
37	1.696	1.700	1.705	0.009			b=Z, c∧X=0°
38	1.695	1.698			large		b=Z, c∧X=8°
39	1.695		1.700	0.005			b=Z, c∧X=7°
40	1.688	1.693					b=Z, c∧X=30°
41	1.687	1.693					b=Z, c∧X=28°
42	1.670	1.680	1.682	0.012	small		b=Z, c∧X=20-25°
43	1.683	1.687					b=Z, c∧X=15°
44		1.665					b=Z, c∧Y=ca. 40°
46	1.655		1.664	0.009	41°	$\rho>\upsilon$	b=Z, c∧X=18-30°
47	1.651	1.661	1.670	0.019	(72°)	($\rho>\upsilon$)	c∧Z=57°
50	1.681	1.688					b=Z, c∧X=36°
51					ca. 25°	$\rho>\upsilon$	b=Z, c∧X=63-70°
52	1.655		1.662	0.007	(small)		b=Y, c∧X=56°
53	1.639	1.658	1.660	0.021	38°	$\rho<\upsilon$	b=Y, c∧X=52°

No.	α	β	γ	$\gamma-\alpha$	2V over X	Disp.	Optic Orient.
54	1.621		1.640	0.019	76-80°		c∧Z=15°
55	1.633	1.639	1.642	0.009			c∧Z=44°
56	1.650	1.657	1.659	0.009	(64°)		c∧Z=35°
57	1.623	1.633	1.641	0.018	(87°)	($\rho>\upsilon$)	c∧Z=40°
58	1.628	1.638	1.644	0.016	(82°)	($\rho>\upsilon$)	c∧Z=24°
59							b=Y, c∧Z=45°
60	1.612	1.623	1.627	0.015			c∧Z=20°
61	1.606	1.616	1.623	0.017			c∧Z=24°
62	1.622	1.635	1.641	0.019	66°		b=Y, c∧Z=19°
63	1.605		1.627	0.022			b=Y, c∧Z=17°

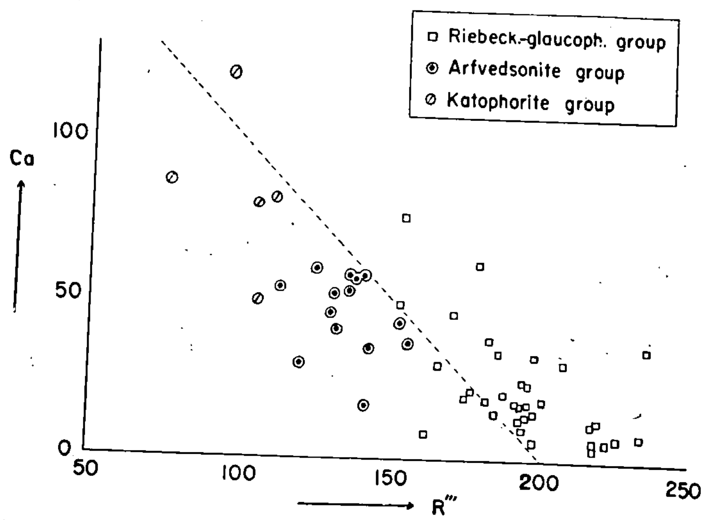
TABLE 14

Fig. 28

The Ca and R''' Relationship in Alkali Amphiboles
(Miyashiro 1957)

TABLE 15

Crystallographic Data for Amphiboles
(Sundius 1946)



The Ca contents of alkali amphiboles (excluding soda-tremolite).

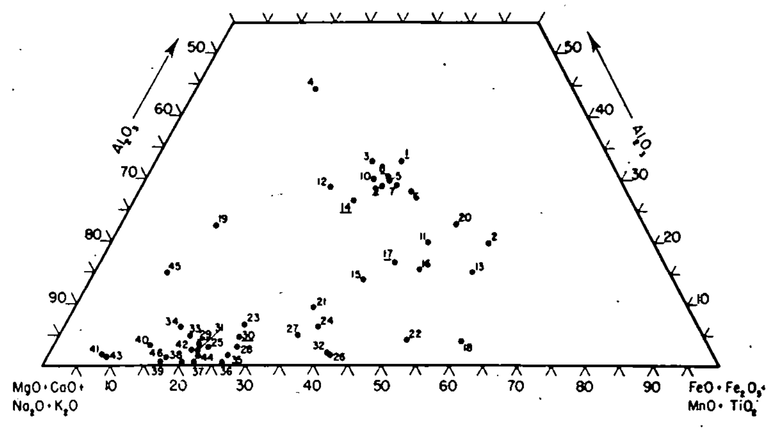
FIG. 28

	β	a₀ : b₀ : c₀	a_0	b_0	c_0	110 : 1̄10
Anthophyllite		1.027 : 1 : 0.292	18.52	18.04	5.27	54°23′
Cummingtonite	109°34′	0.545 : 1 : 0.293	9.93	18.22	5.33	54°20′
Grünerite		0.525 : 1 : 0.294	9.4 ?	17.9	5.27	
Tremolite	106°02′	0.550 : 1 : 0.295	9.78	17.8	5.26	55°36′
Karinthine (Actin.)	106°02′	0.5511 : 1 : 0.2938				
Common hornblende	105°45′	0.541 : 1 : 0.292	9.94(?)	18.38	5.36	
Kaersutite	105°45′	0.542 : 1 : 0.297	9.85(?)	18.17	5.39	55°25′—
Basalt. hornblende	105°45′	0.541 : 1 : 0.292	9.94(?)	18.38	5.36	—55°50′
Barkevikite	105°45′	0.542 : 1 : 0.291	9.92(?)	18.30	5.33	
Richterite	104°14′?	0.5499 : 1 : 0.2854				
Arfvedsonite	104°15,5′	0.539 : 1 : 0.291	9.87(?)	18.31	5.33	56°2′
Glaucophane	104°10′	0.543 : 1 : 0.300	9.72(?)	17.98	5.37	54°55′— —55°30′
Riebeckite	103°30′	0.546 : 1 : 0.293	9.88(?)	18.10	5.31	56°
Osannite (Riebeckite)	107°34′	0.554 : 1 : 0.296	9.98	18.02	5.33	

TABLE 15

Fig. 29

Diagrams Illustrating Solid Solution in the Anthophyllite and Cummingtonite Series. A = Anthophyllite Field, B = Cummingtonite Field (Sundius 1933), C = Extension of B to include Collins (1942) Data. Paired Minerals are connected by Lines. (Rabbitt 1948)



Composition of 46 anthophyllites whose compositions are shown in table 2. The numbers of the Montana varieties are underlined. The plot is based on the chemical weights per cent of the oxides shown, the sum of these oxides being 100%.

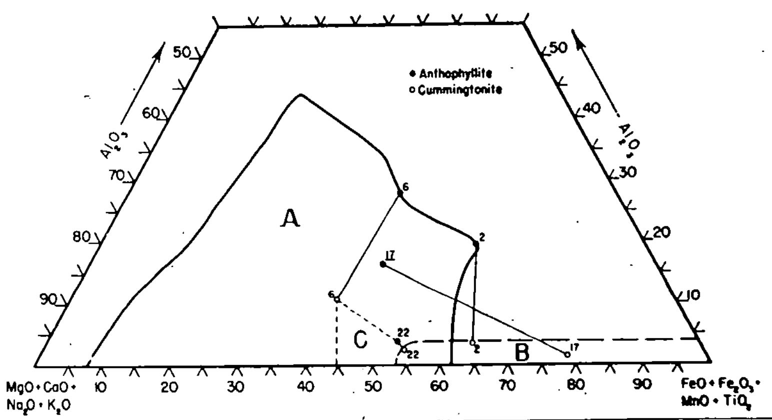


FIG. 29

Fig. 30

Triangular Diagram to show Solid Solution
Relations in the Hornblende Series.

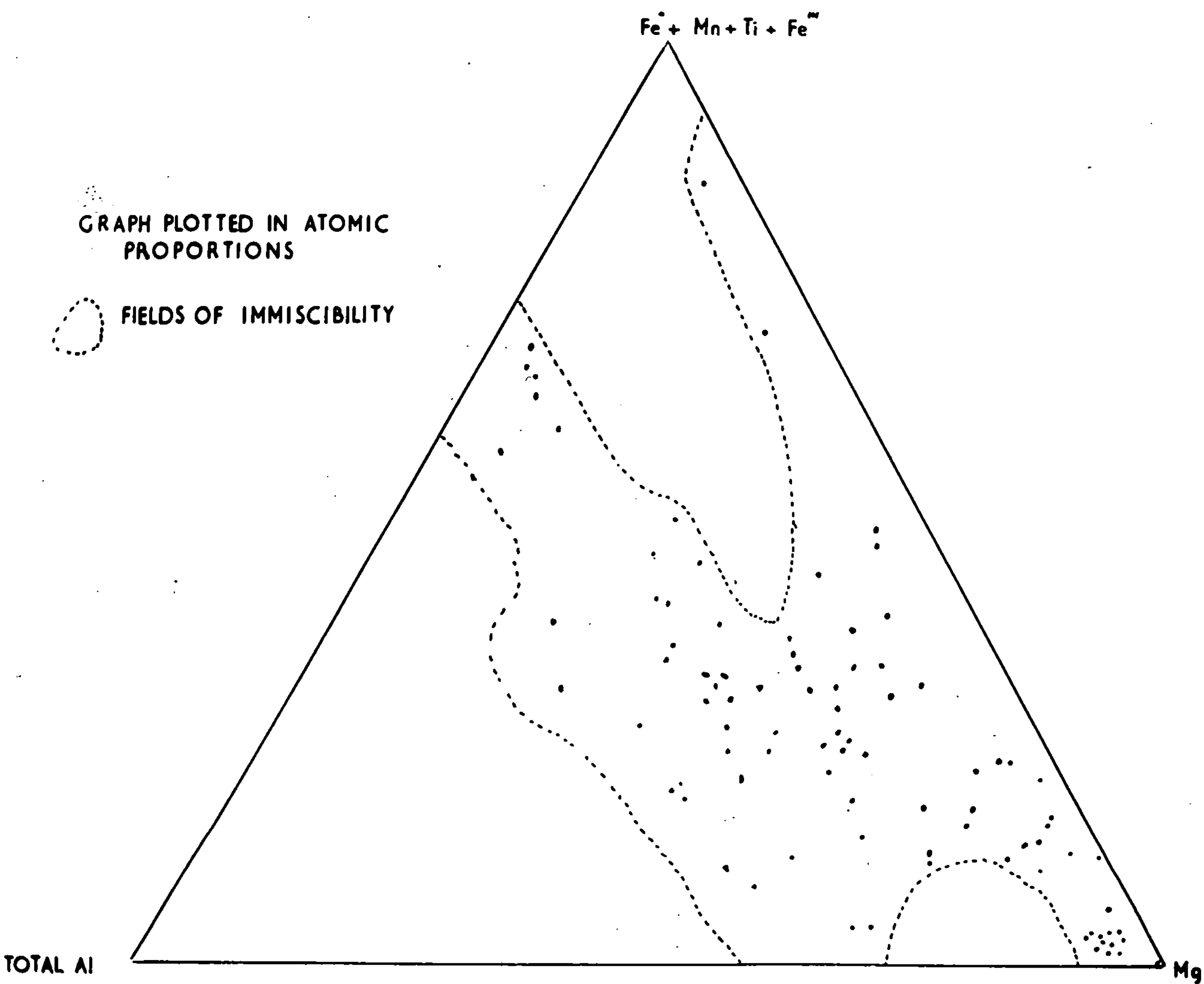

Fe" + Mn + Ti + Fe'''
GRAPH PLOTTED IN ATOMIC PROPORTIONS
FIELDS OF IMMISCIBILITY
TOTAL Al
Mg

FIG. 30.

TABLE 16

Analyses of Amphiboles from the Literature
covering the Immiscibility gap of Fig. 12

TABLE 16.

No. 1.	Hornblende.	Mg rich Edenite, Glen Urquhart.	G.H. Franic (1958)
No. 2.	Actinolite.	Prieska District Cape Prov. S. Africa.	Mathias (1952)
No. 3.	Hornblende.	Outer Granite. Ben Nevis.	Nockolds & Mitchell. Abh. Akad. d. Wiss.
No. 4.	Hornblende.	Tonalite, Komander Ss.	Malkovski Krakau 53. (A) 1913 p117.
No. 5	Hornblende	Plagioclase, Skaru.	Francis (1958)
No. 6.	Hornblende.	Uralitized Gabbro, Aberdeenshire.	N. F. M. Henry. Mem. du Com. Geol.
No. 7	Hornblende.	Hornblende Diorite, Altai.	K. Tisnofeur. N. S. Uvr. 157 1923.

No. 1. Falls within Sundius class but has Al^{iv} .757.

TABLE 16a

No.	1	2	3	4	5	6	7
SiO_2	52.4	51.88	50.42	49.36	52.87	50.75	47.87
Al_2O_3	7.1	8.08	4.75	6.96	6.40	5.12	3.95
TiO_2	0.2	0.18	1.11	0.82	0.28	0.65	2.02
Fe_2O_3	-	1.84	3.05	5.26	1.12	1.31	5.01
FeO	3.4	5.89	8.49	7.25	2.37	13.06	19.48
MgO	19.7	18.48	16.17	15.46	20.52	14.12	7.78
CaO	13.4	11.04	12.38	12.07	13.50	11.33	10.35
Na_2O	0.9	0.78	-	0.36	0.56	1.10	1.87
K_2O	0.4	0.08	-	0.11	0.12	0.83	-
MnO	0.1	0.13	0.39	0.60	0.06	0.29	-
P_2O_5	n.d.	0.03	-	-	-	-	-
H_2O	2.2	1.94	-	1.16	1.60	1.94	1.29
F	0.58	0.01	-		0.30	-	-
TOTAL	100.3	100.36		99.35	99.79	100.56	99.62

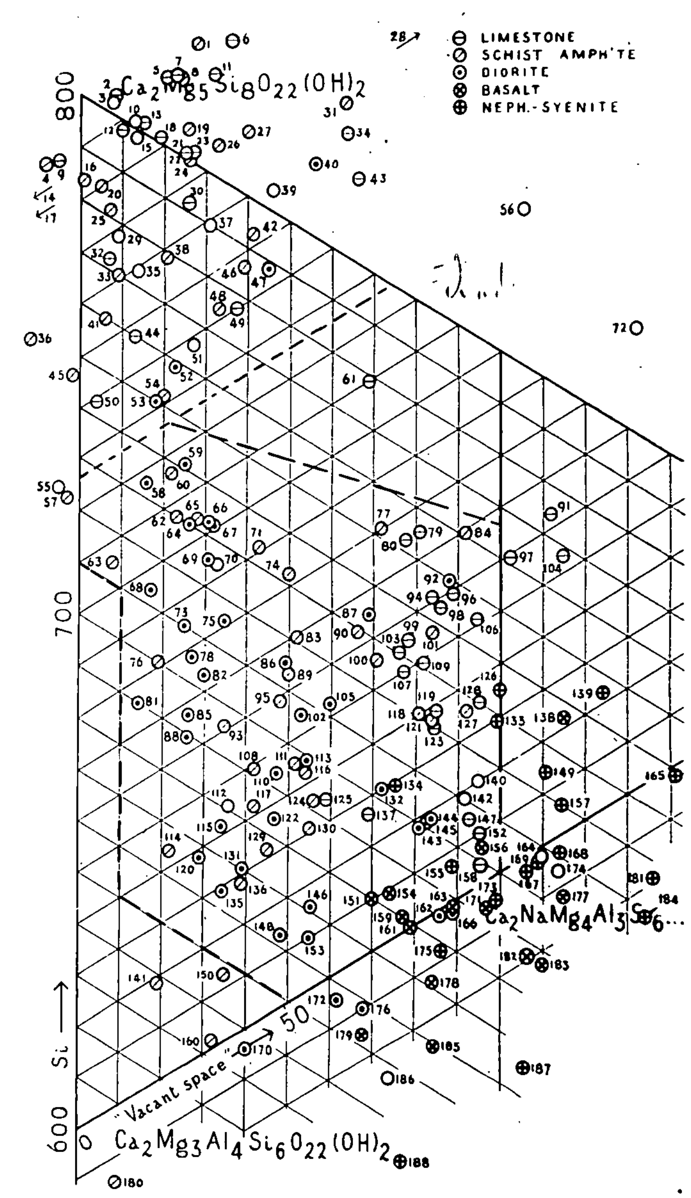
TABLE 16b

ATOMIC PROPORTIONS

	1	2	3	4	5	6	7
SiO_2	7.245	7.240	7.23	7.178	7.367	7.36	7.35
Al_2O_3	.757/.40	.760/545	.77/.02	.822/381	.633/.418	.64/.23	.648/.052
TiO_2	.021	.033	.12	.087	.029	.07	.23
Fe_2O_3	-	.184	.33	.575	.117	.14	.57
FeO	.393	.686	1.01	.881	.276	1.58	2.397
MgO	4.055	3.867	3.48	3.358	4.929	3.07	1.787
CaO	1.983	1.649	1.90	1.875	2.018	1.77	1.704
Na_2O	.241	.217	.041	.105	0.076	0.31	.553
K_2O	.070	0.017	(0.03)	.017	.010	0.16	
MnO	.012	.008	.05	.070	.001	.035	
P_2O_5	2.027	-			1.486		
H_2O	.253	1.825	1.19	1.116	.132	1.88	1.326
F		.005				-	

Fig. 31

Diagram to show suggested Compositional Limits of the Hornblende Series with respect to Si and Na+K.

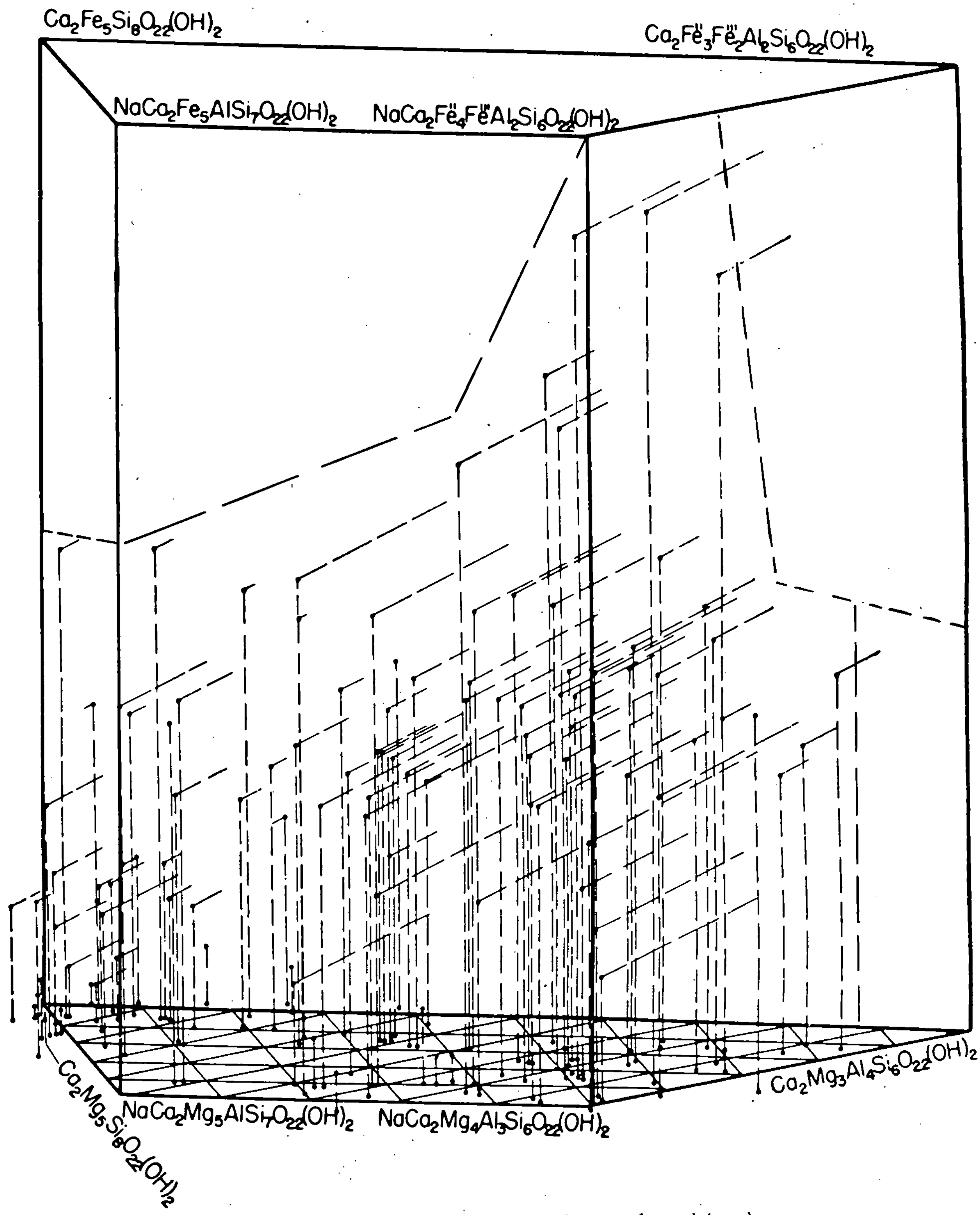


Distribution of amphibole analyses in respect to (*a*) Si atoms and (*b*) atoms in the vacant space. The signs represent an approximate classification of the parent-rocks.

FIG. 31.

Fig. 32

Diagram to show Immiscibility with respect to the Iron Component in the Hornblende Series.

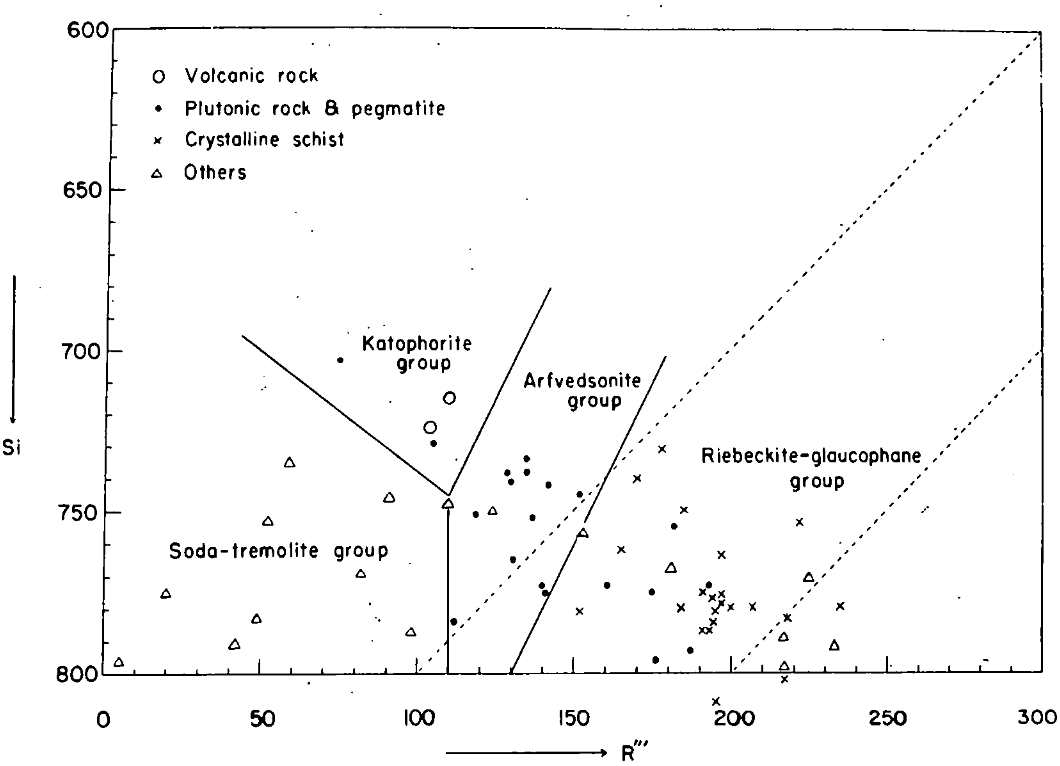


Composition of calciferous hornblendes.

FIG. 32.

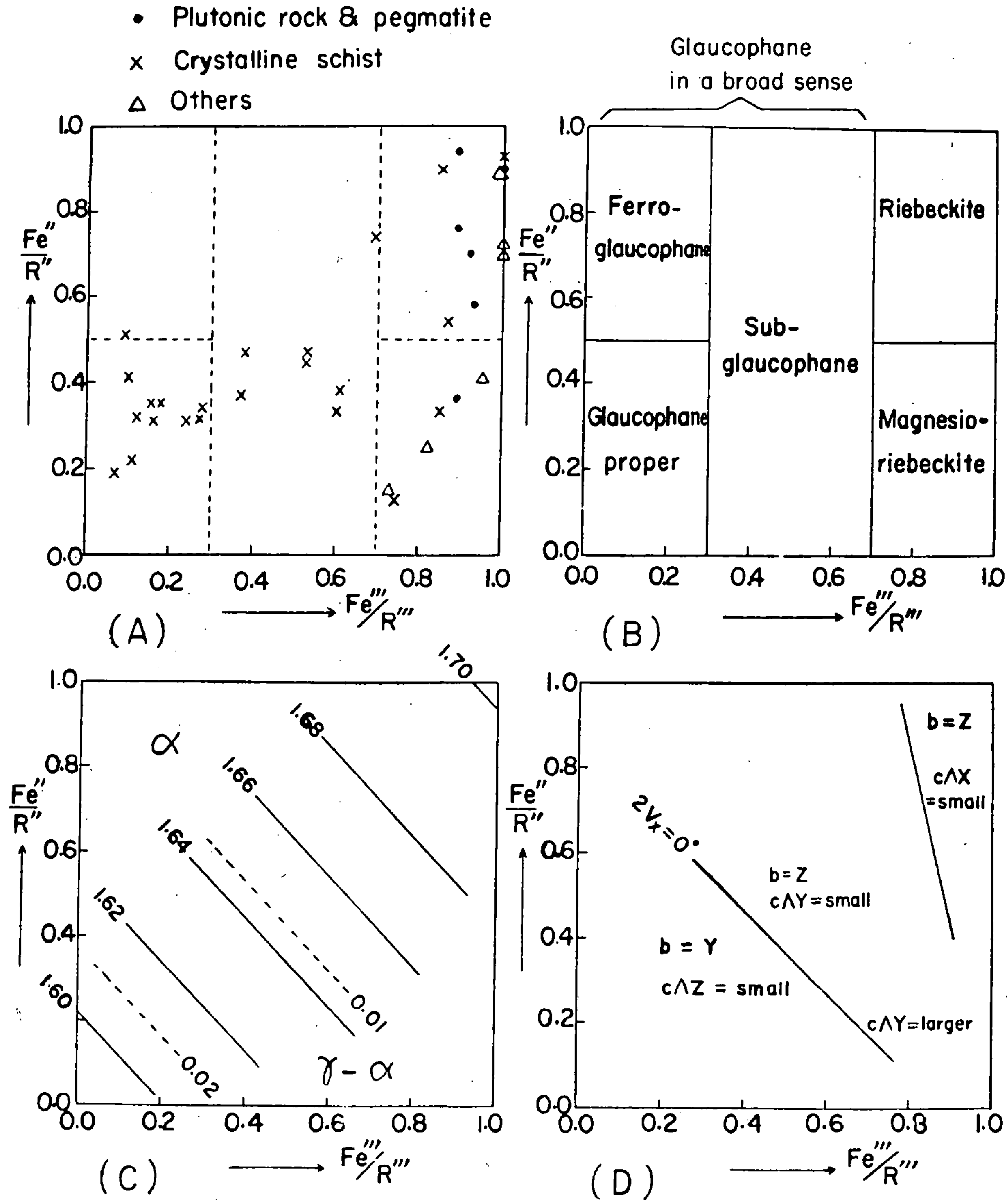
Fig. 33

The Relationship between Si and R''' in Alkali Amphiboles (Miyashiro 1957)



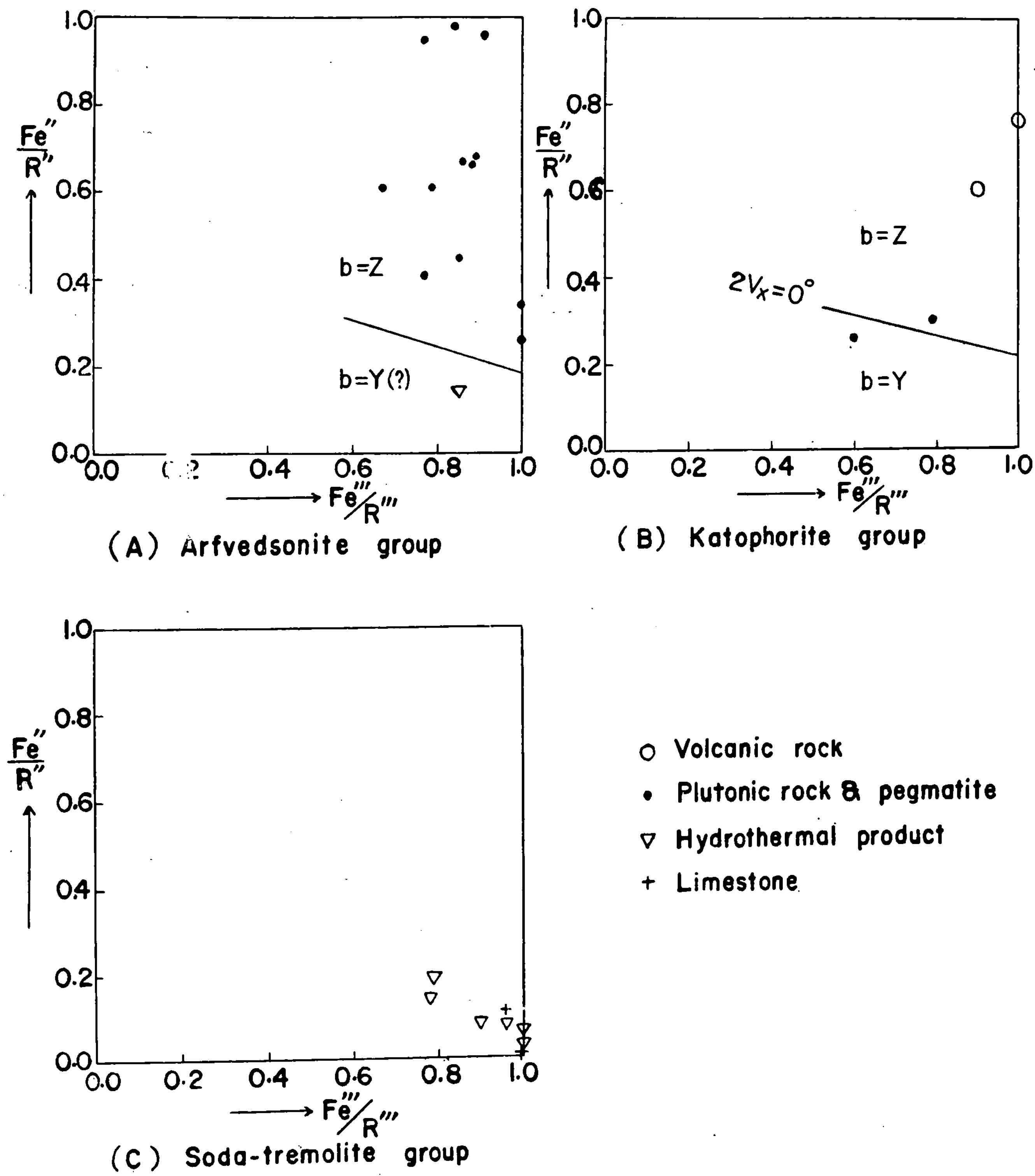
The (Na, K) R''←→R''' and (Na, K) Al←→Si substitutions in the alkali-amphiboles. The symbols represent the host rocks. "Others" represented by triangles include metamorphosed ironstone and limestone and hydrothermal products.

FIG. 33.



The Fe'''/R''' and Fe''/R'' ratios in amphiboles of the riebeckite-glaucophane group. (A) compositions, (B) nomenclature, (C) refractive indices, (D) optic orientation.

FIG. 34.



The Fe'''/R''' and Fe''/R'' ratios in amphiboles of the arfvedsonite, katophorite, and soda-tremolite groups.

FIG. 35

Fig. 36

Sundius (1946) Triangular Diagram for Solid Solution Relations between the Hornblende Series and the Alkali Amphiboles.

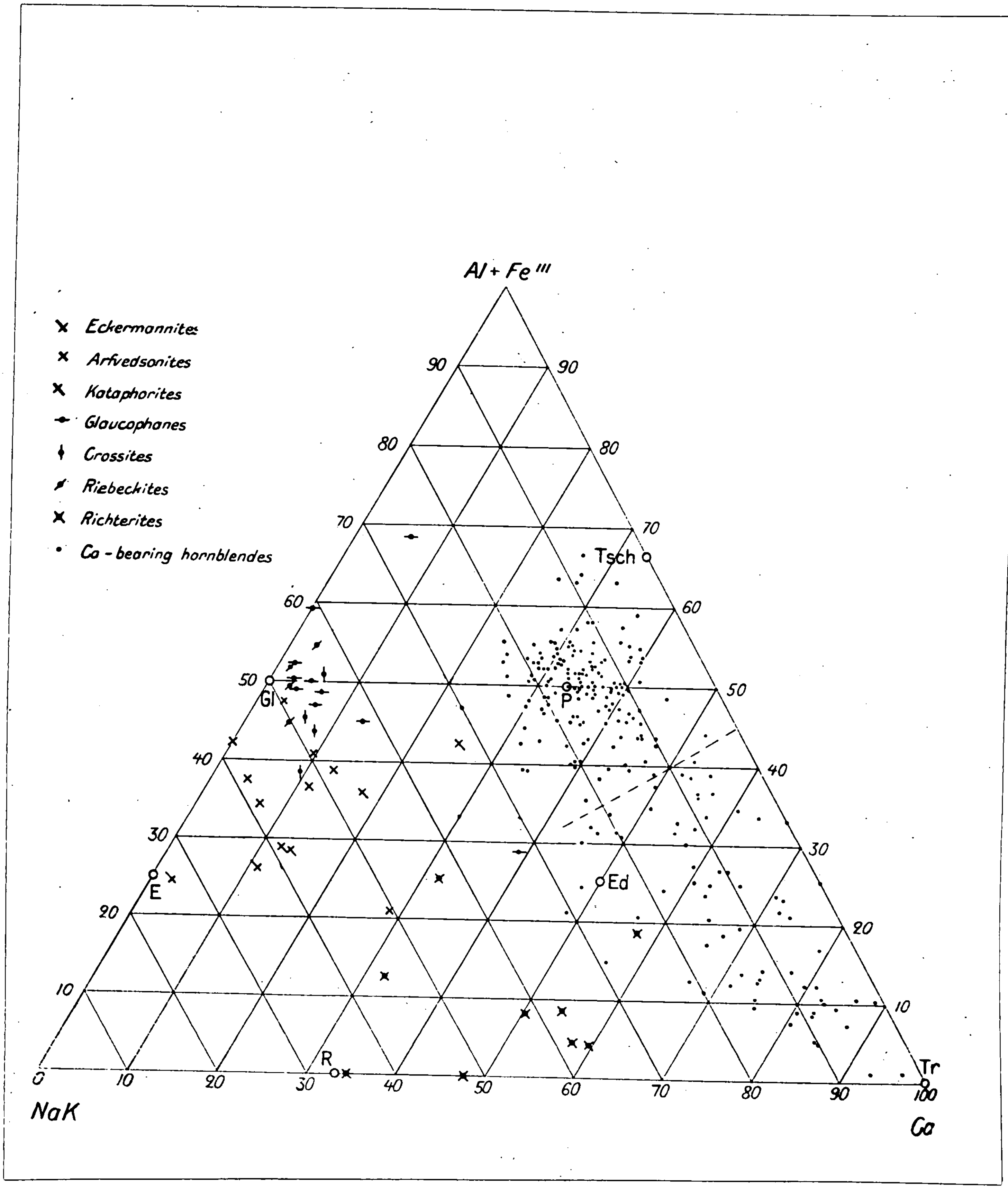

Al + Fe'''
Eckermannites
Arfvedsonites
Kataphorites
Glaucophanes
Crossites
Riebeckites
Richterites
Ca - bearing hornblendes
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
100
Tsch
P
Gl
E
Ed
R
Tr
NaK
Ca

FIG. 36.

SUGGESTED CLASSIFICATION OF THE AMPHIBOLE GROUP

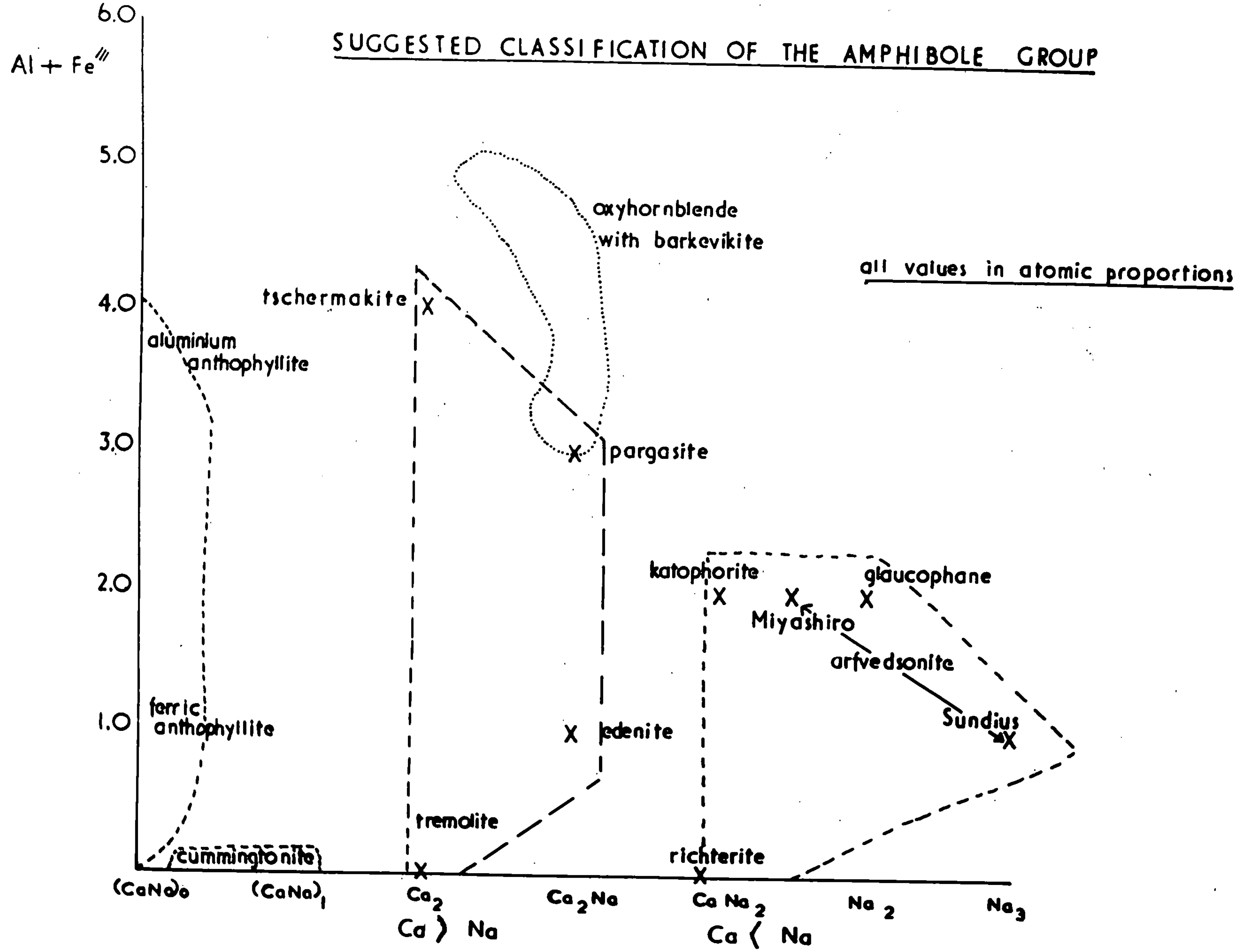


FIG. 37

Fig. 38

Relation between Na+K and Ca in Hornblendes and Alkali Amphiboles.

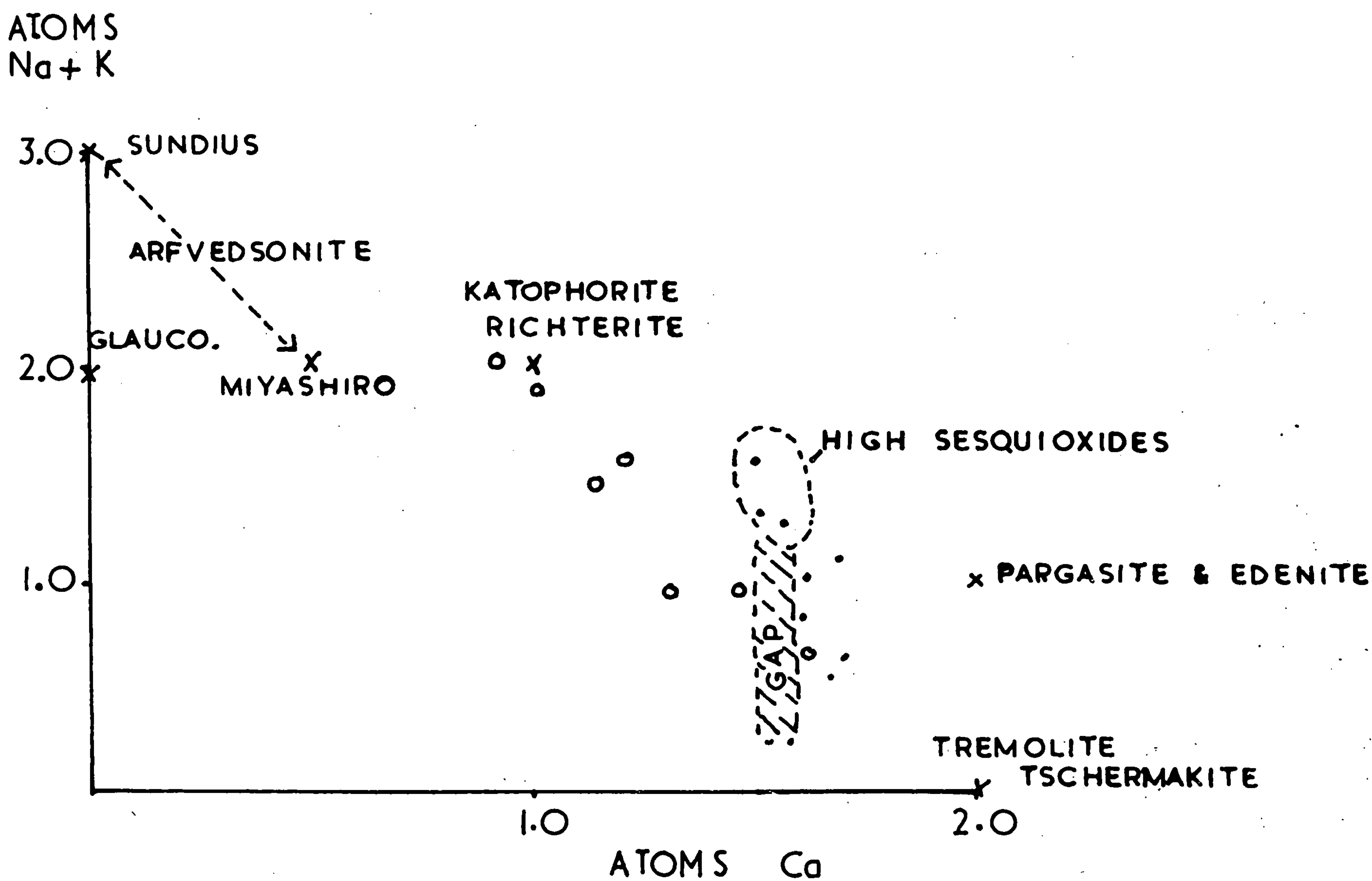
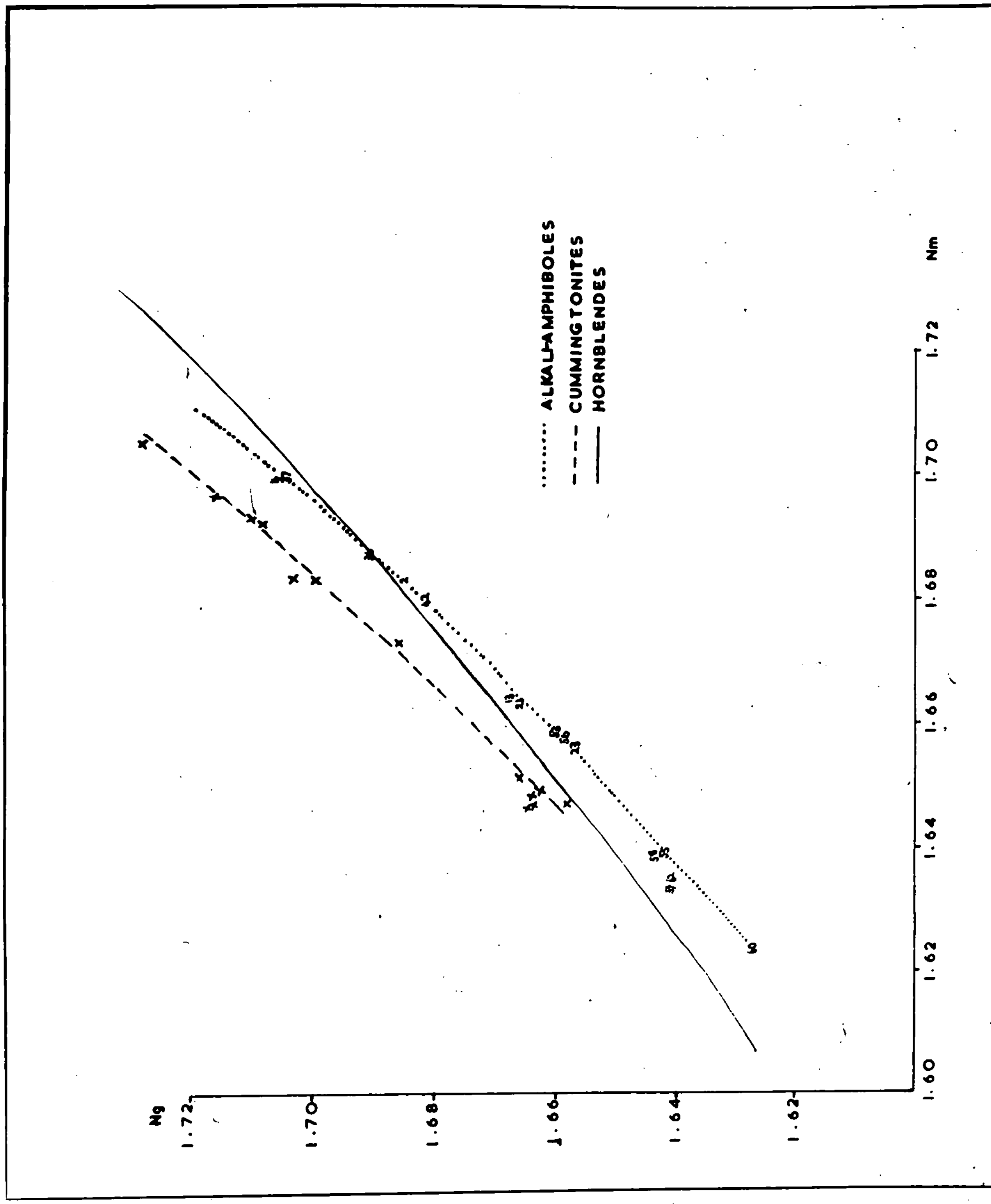

ATOMS
Na + K
3.0
2.0
1.0
SUNDIUS
ARFVEDSONITE
GLAUCO.
MIYASHIRO
KATOPHORITE
RICHTERITE
HIGH SESQUIOXIDES
GAP
PARGASITE & EDENITE
TREMOLITE
TSCHERMAKITE
1.0
2.0
ATOMS Ca

FIG. 38.

Fig. 39

The Relationships between Ng and Nm
Refractive Indices in the Monoclinic Amphiboles.



ALKALI-AMPHIBOLES
CUMMINGTONITES
HORNBLENDES
Ng
1.72
1.70
1.68
1.66
1.64
1.62
1.60
1.62
1.64
1.66
1.68
1.70
1.72
Nm

FIG. 39

Fig. 40

The Relation between Ng index and the Birefringence Ng-Np for Tremolites and Alkali Amphiboles.

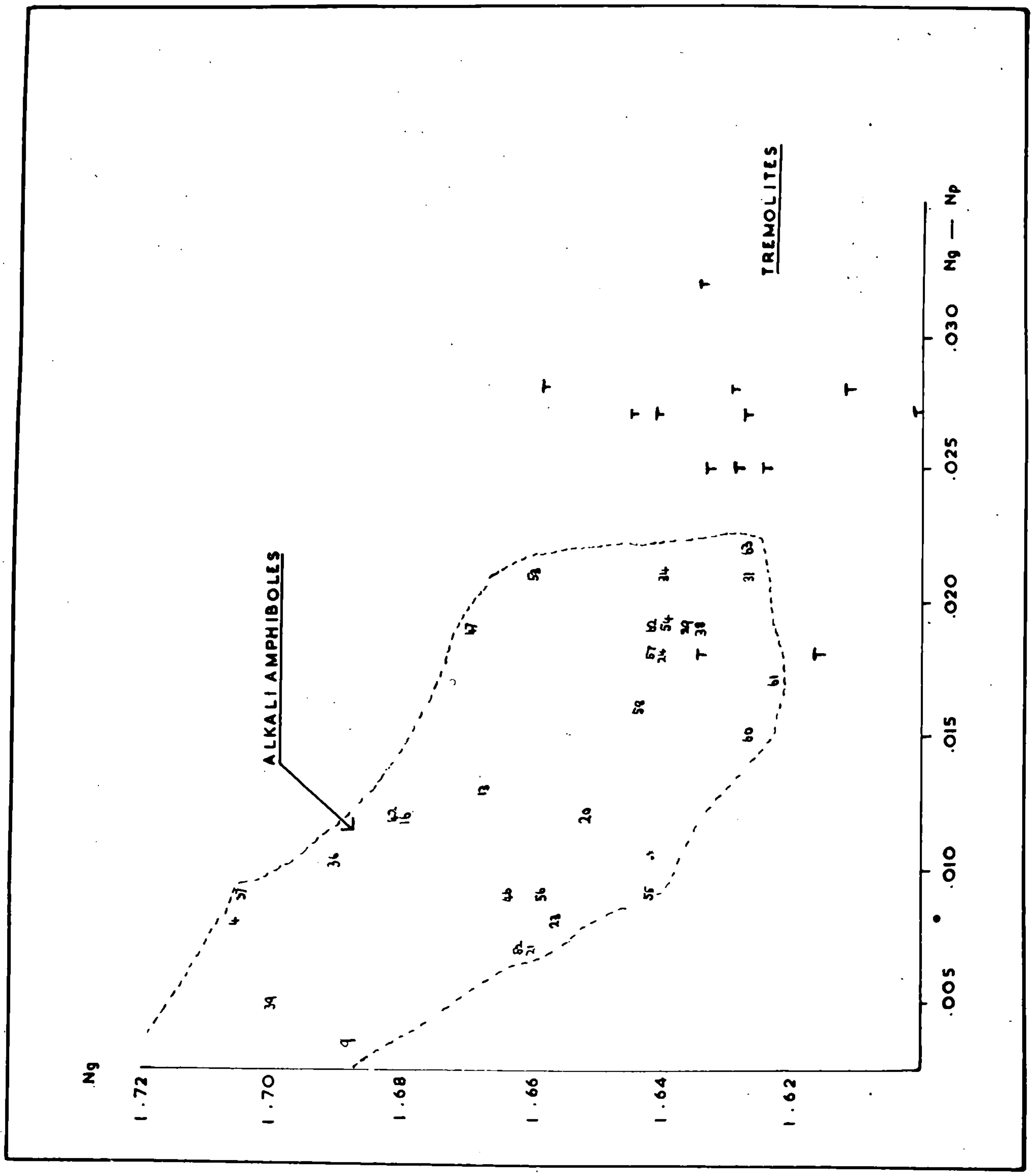
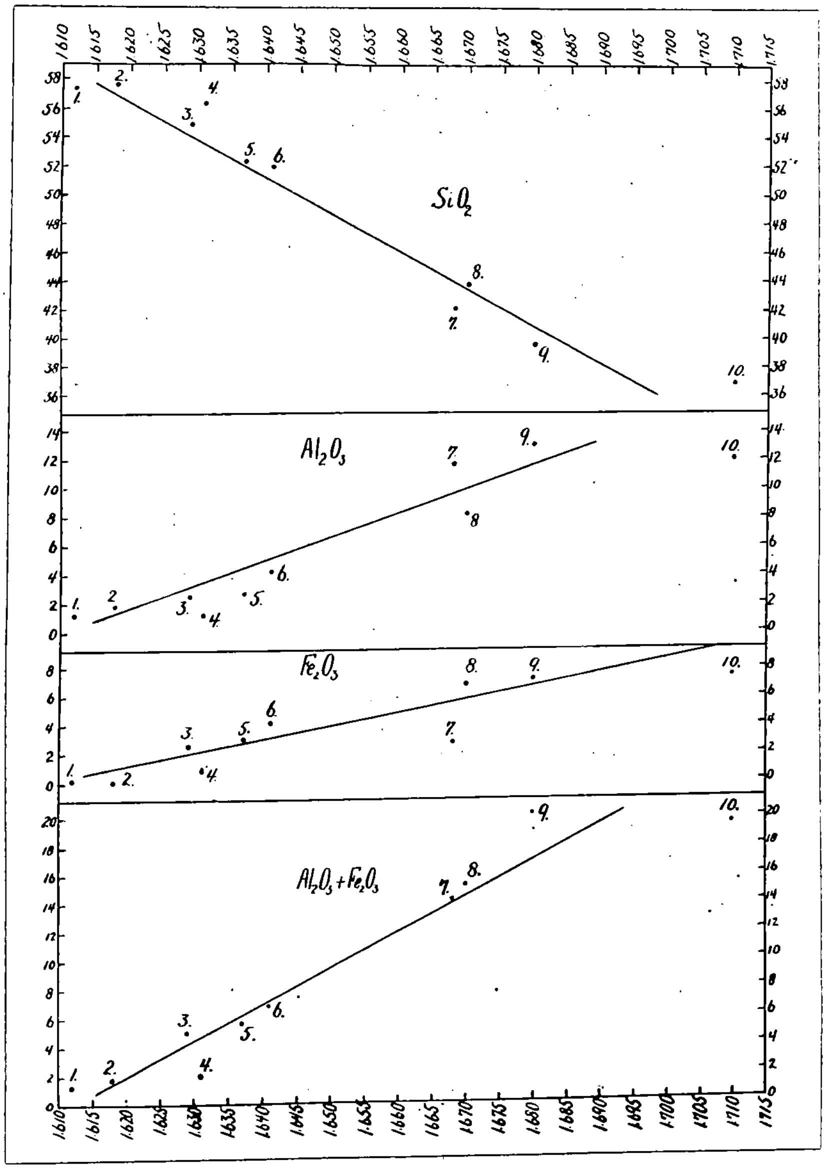

ALKALI AMPHIBOLES
TREMOLITES
Ng
1.72
1.70
1.68
1.66
1.64
1.62
.005
.010
.015
.020
.025
.030
Ng — Np

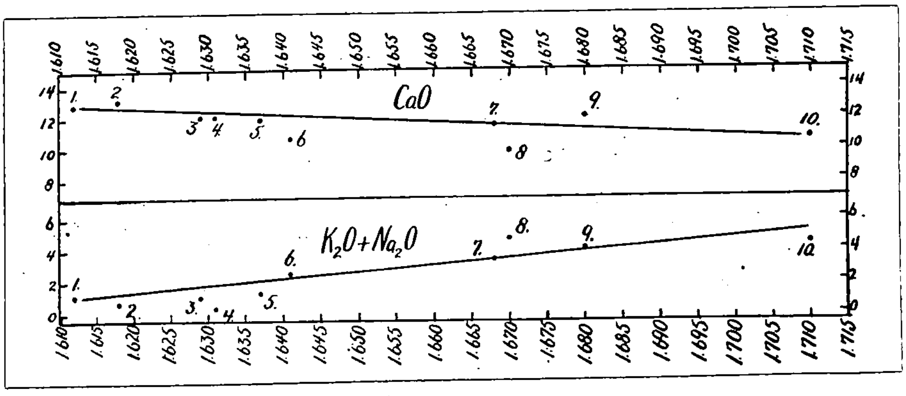
FIG. 40.

Fig. 41

Plot of Various Chemical Parameters in Weight per cent Against Mean Refractive Index (Ford 1914).



a.



b.

FIG. 41

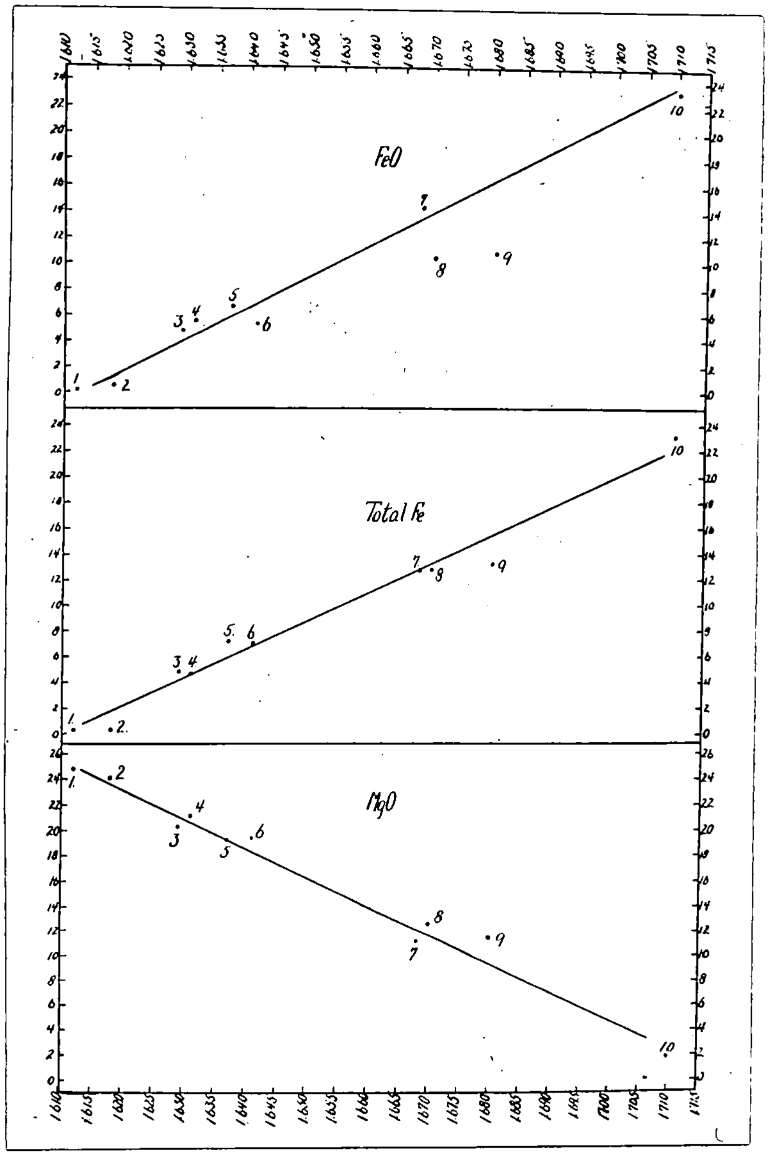


FIG. 42

Fig. 43

The Effects of Increasing Content of Fe_2O_3 and TiO_2 on the Ng Refractive Index in Hornblendes.

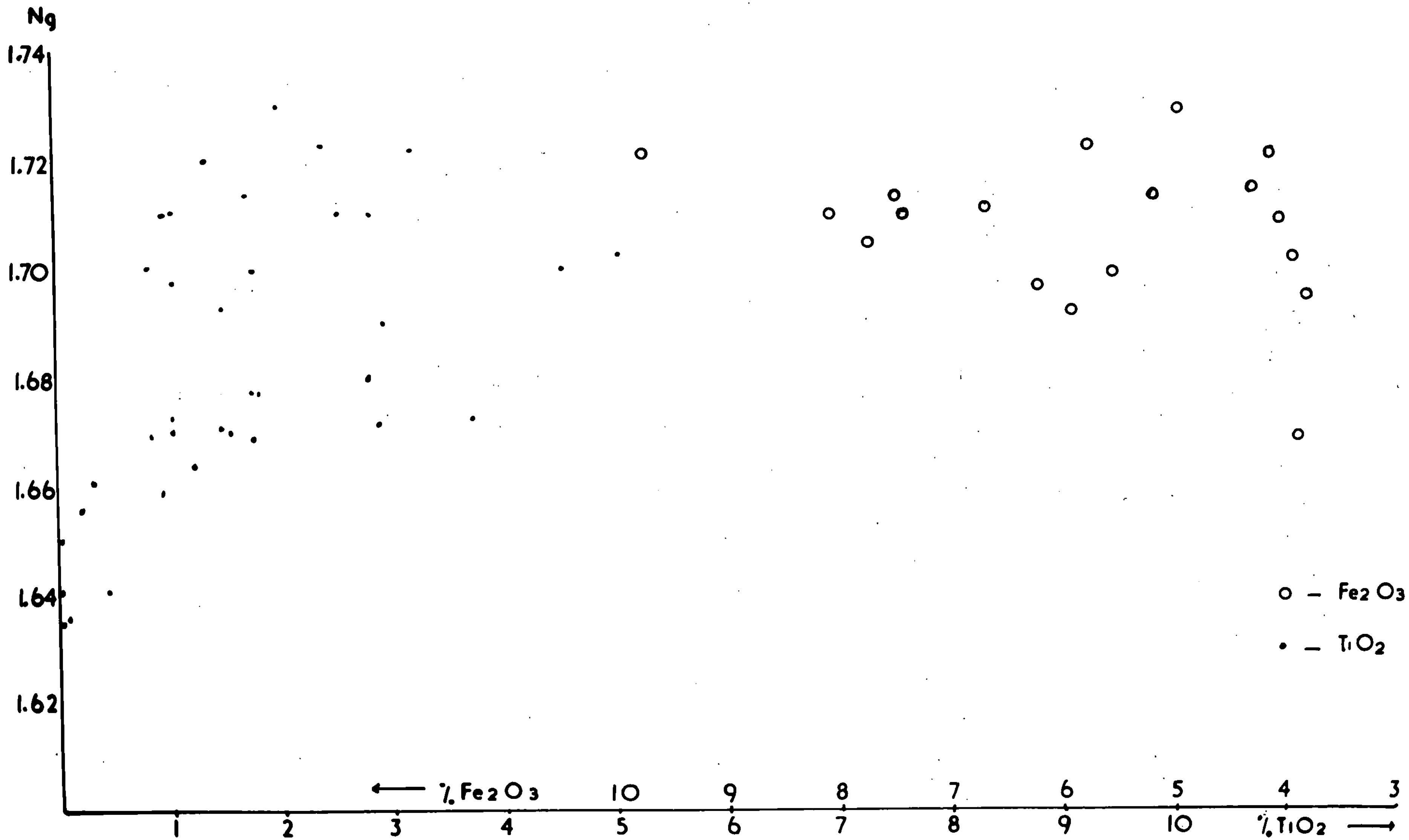

Ng
1.74
1.72
1.70
1.68
1.66
1.64
1.62
% Fe2O3
10 9 8 7 6 5 4 3
1 2 3 4 5 6 7 8 9 10
% TiO2
o – Fe2O3
• – TiO2

FIG. 43.

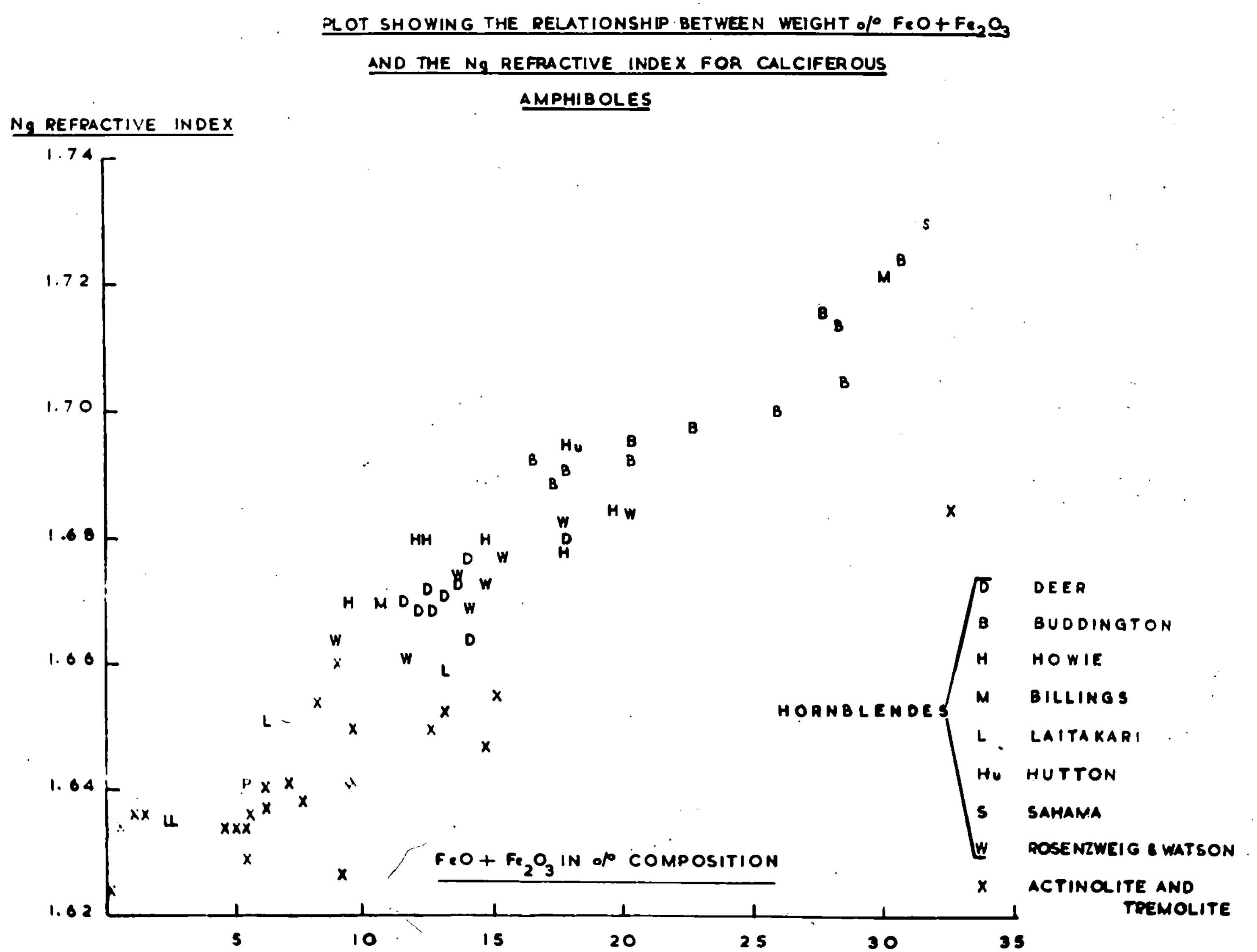
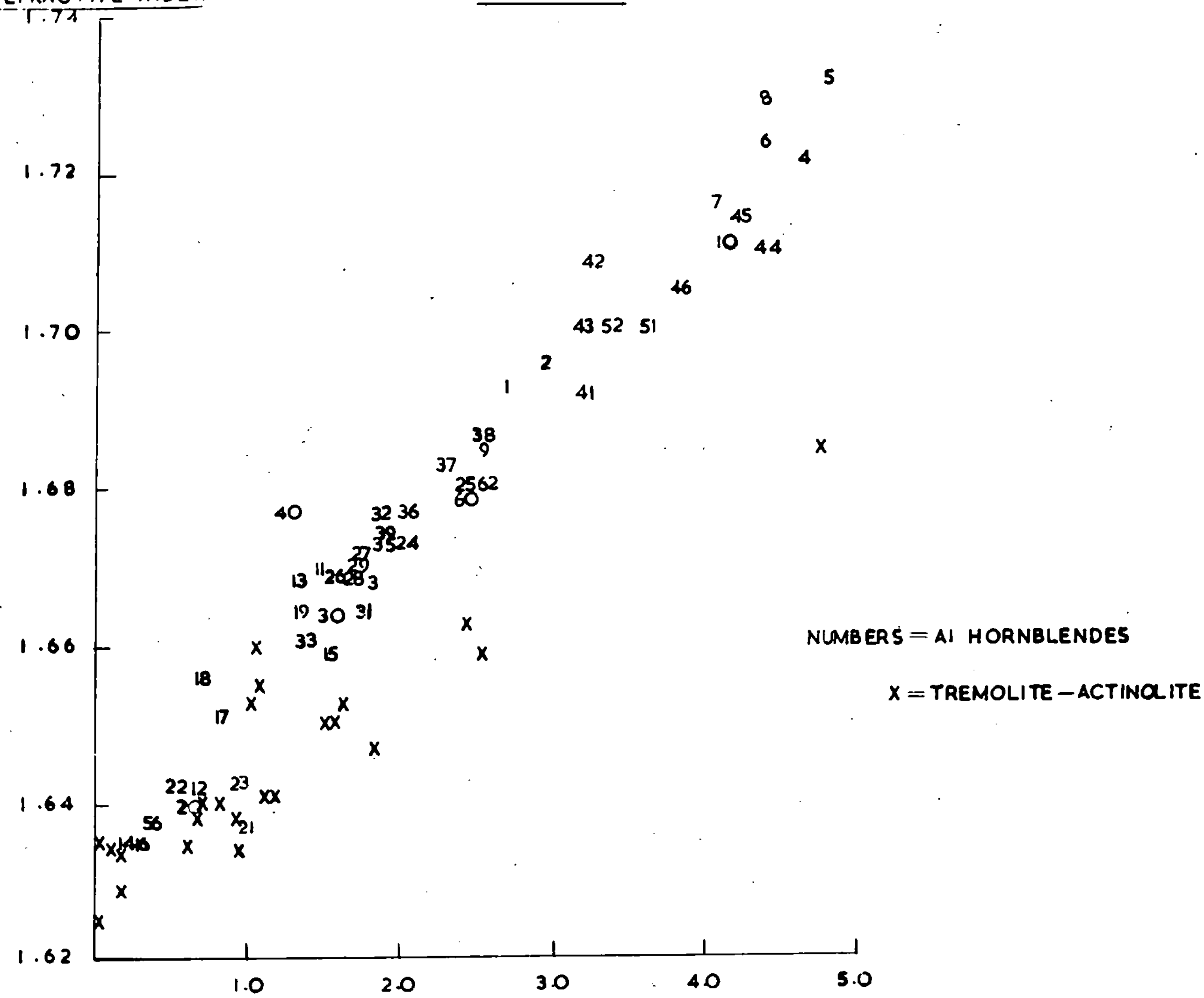

PLOT SHOWING THE RELATIONSHIP BETWEEN WEIGHT % FeO + Fe2O3
AND THE Ng REFRACTIVE INDEX FOR CALCIFEROUS
AMPHIBOLES
Ng REFRACTIVE INDEX
1.74
1.72
1.70
1.68
1.66
1.64
1.62
5
10
15
20
25
30
35
FeO + Fe2O3 IN % COMPOSITION
HORNBLENDES
D DEER
B BUDDINGTON
H HOWIE
M BILLINGS
L LAITAKARI
Hu HUTTON
S SAHAMA
W ROSENZWEIG & WATSON
X ACTINOLITE AND TREMOLITE

FIG. 44

PLOT SHOWING THE RELATIONSHIP BETWEEN THE Ng REFRACTIVE INDEX AND THE HEAVY ELEMENTS IN CALCIFEROUS AMPHIBOLES

Ng REFRACTIVE INDEX



$MnO + TiO_2 + FeO + Fe_2O_3$ IN ATOMIC PROPORTIONS

FIG. 45

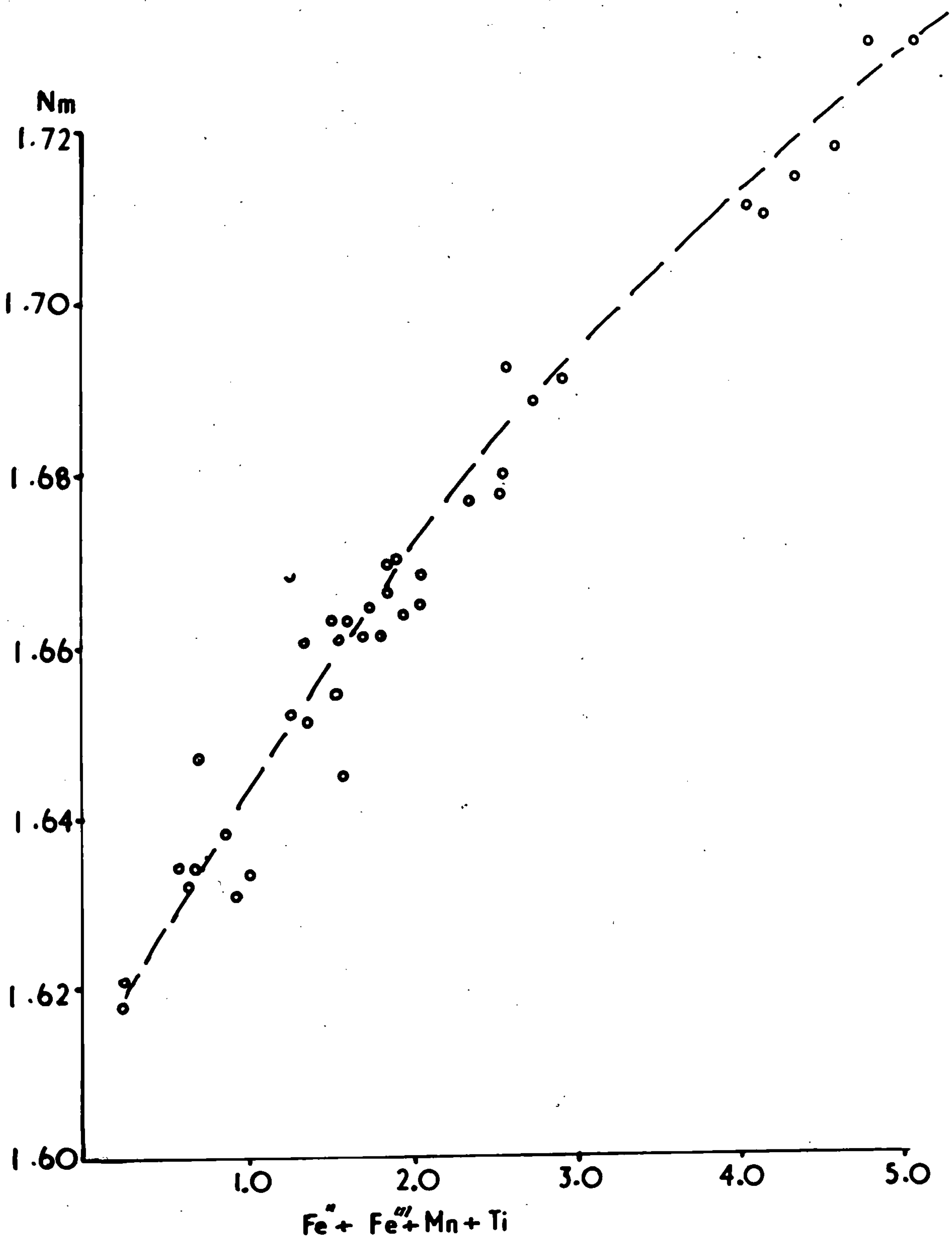


FIG. 46

Fig. 47

The Relationship between SiO_2 and the Ng Refractive Index in Hornblendes.

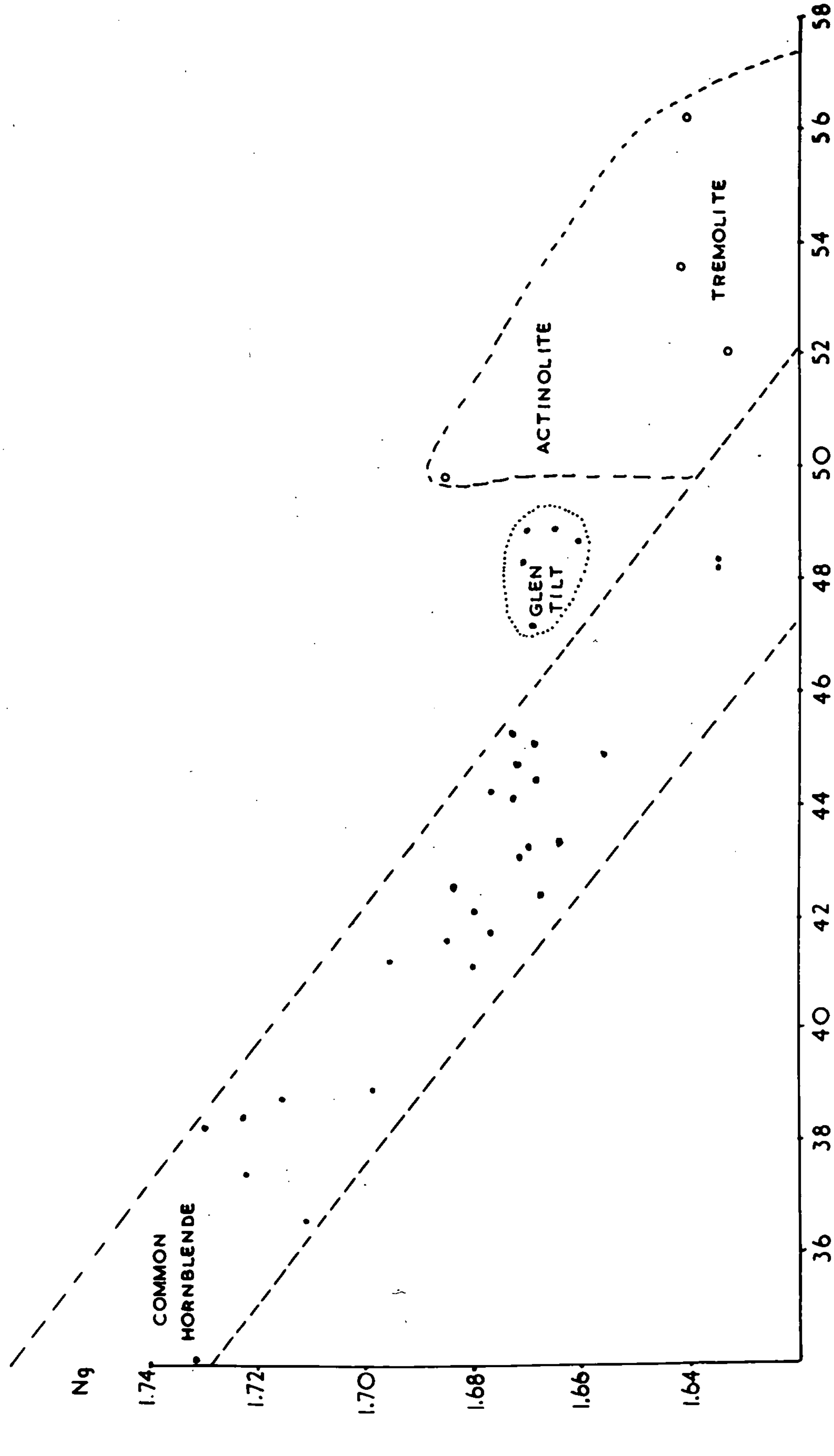

Ng
1.74
1.72
1.70
1.68
1.66
1.64
36
38
40
42
44
46
48
50
52
54
56
58
% SiO2
COMMON HORNBLENDE
GLEN TILT
ACTINOLITE
TREMOLITE

FIG. 47

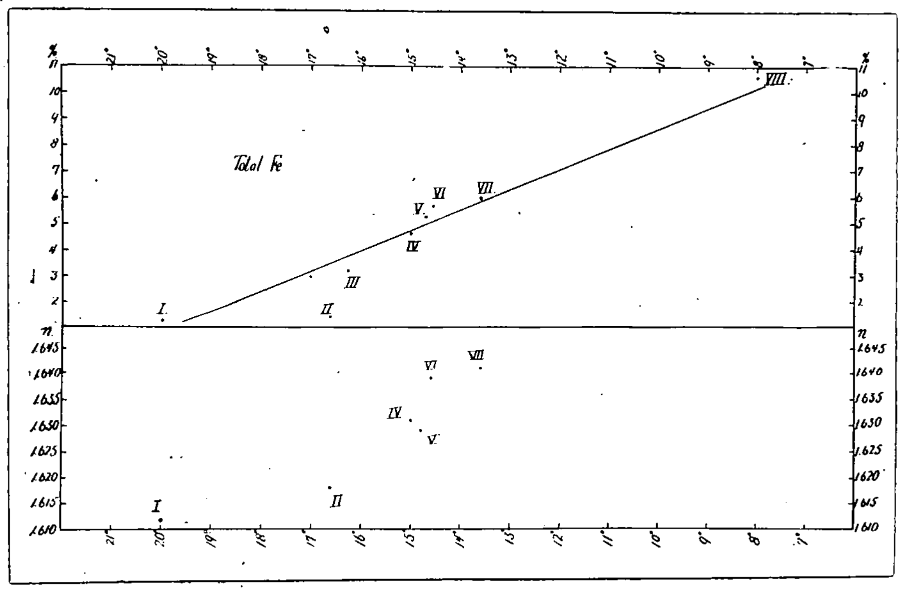
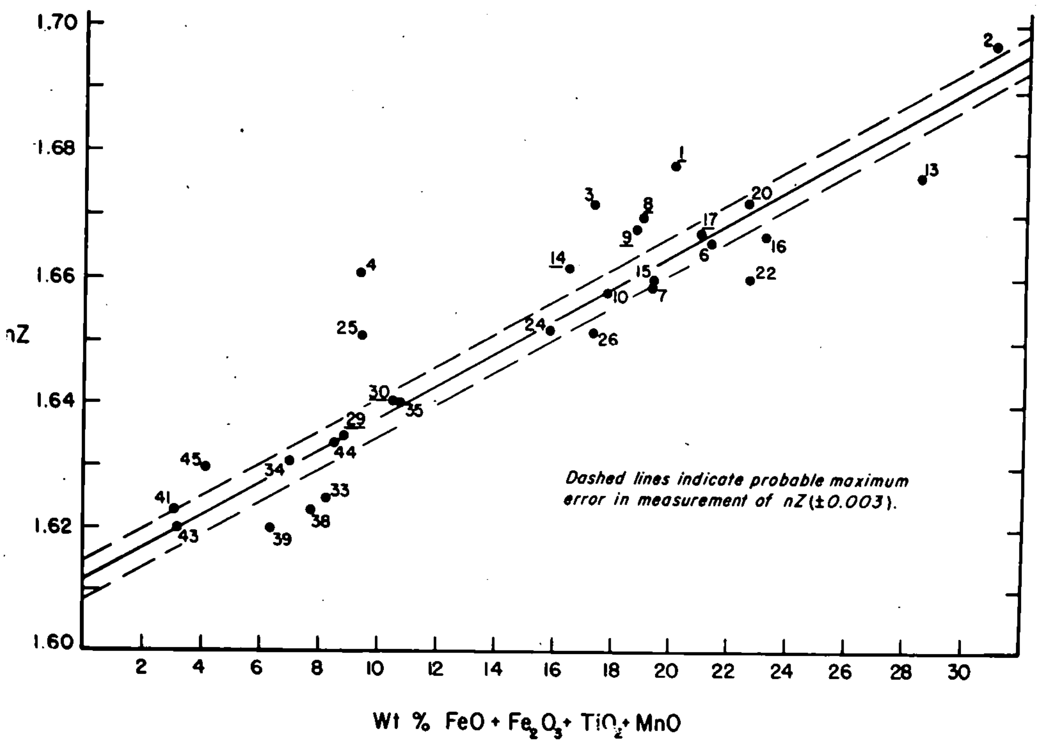
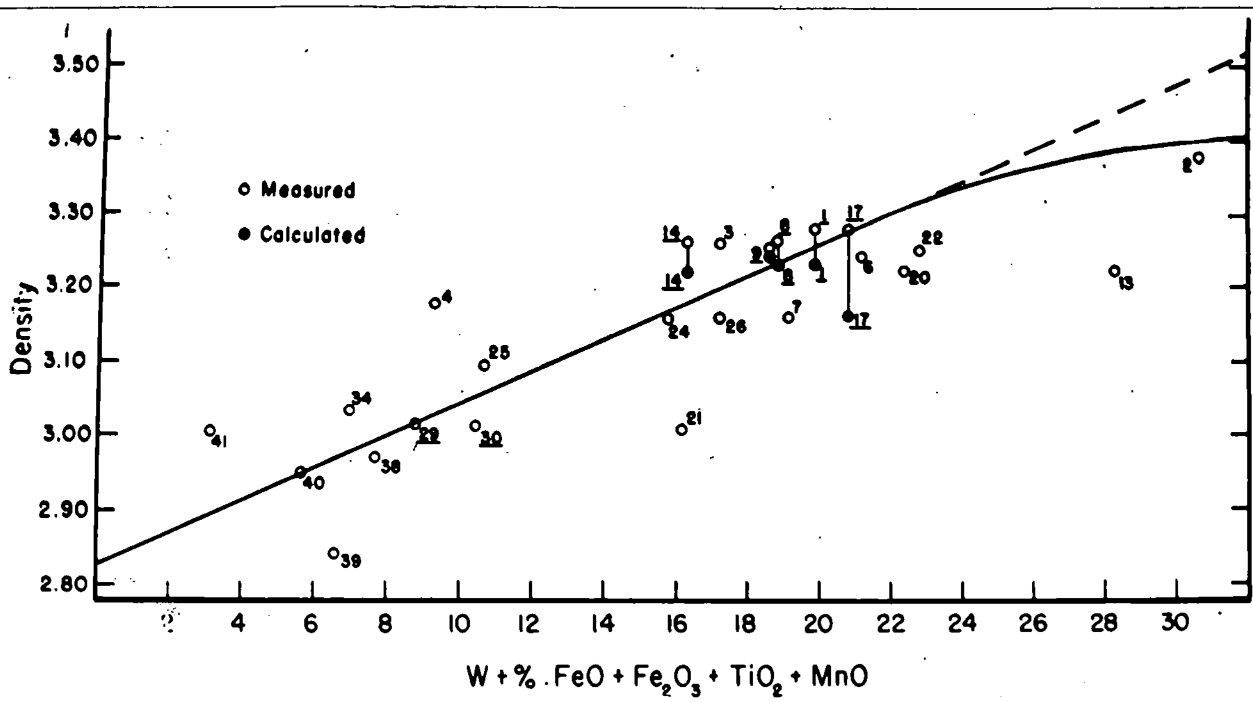


FIG. 48.



The refractive index *n*Z plotted against chemical weights per cent of $FeO+Fe_2O_3+TiO_2+MnO$ for some anthophyllite varieties from the literature and the Montana varieties. The numbers of the Montana varieties are underlined.

FIG. 49

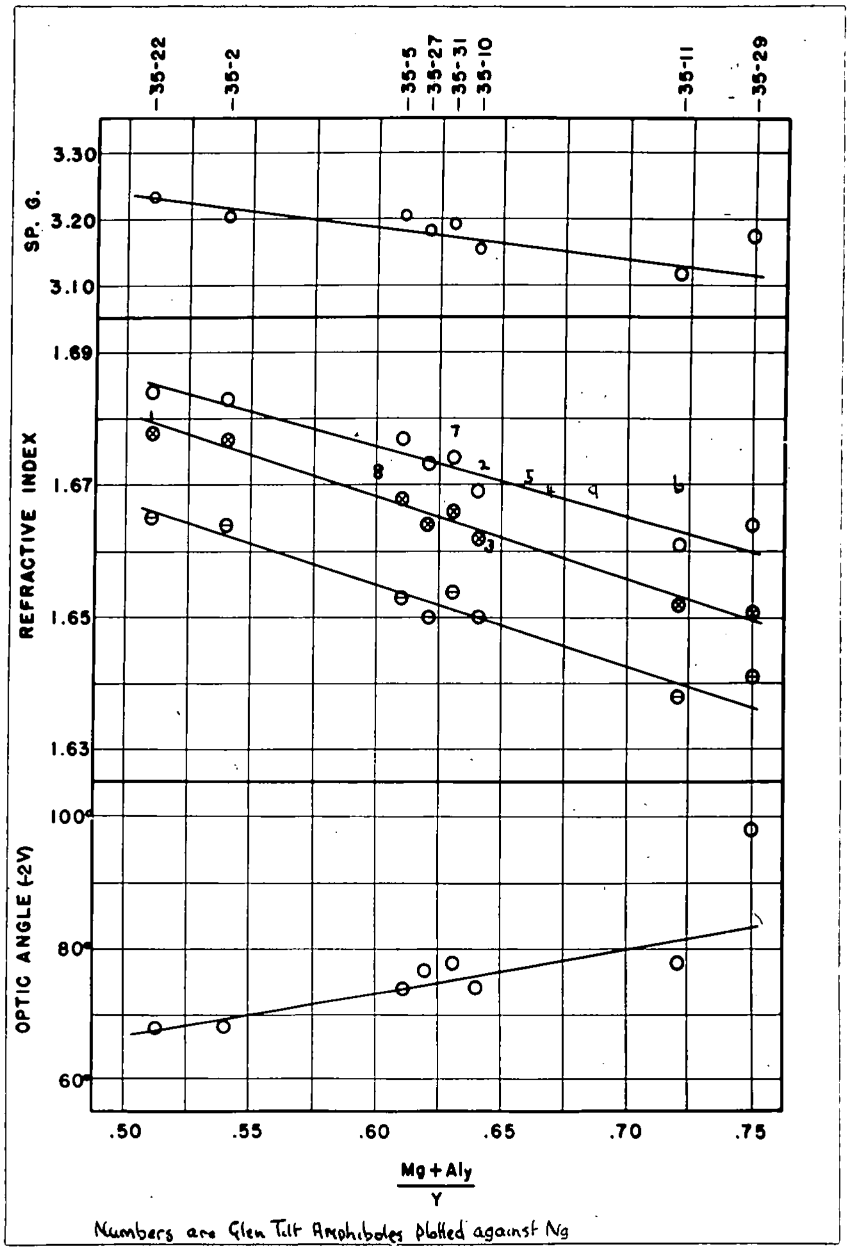


. Density plotted against chemical weights per cent of $FeO+Fe_2O_3+TiO_2+MnO$ for some anthophyllite varieties from the literature and the Montana varieties. The numbers of the Montana varieties are underlined. The measured and calculated figures for the Montana varieties are connected as shown; those for numbers 29 and 30 are nearly identical.

FIG. 50.

Fig. 51

Relationship between Mg+Al$^{(6)}$/Y and Various Physical Properties in the Hornblende Series (Rosenzweig & Watson 1954)



-35-22
-35-2
-35-5
-35-27
-35-31
-35-10
-35-11
-35-29
SP. G.
3.30
3.20
3.10
REFRACTIVE INDEX
1.69
1.67
1.65
1.63
OPTIC ANGLE (-2V)
100°
80°
60°
.50
.55
.60
.65
.70
.75
Mg + Aly / Y
Numbers are Glen Tilt Amphiboles plotted against Ng

FIG. 51

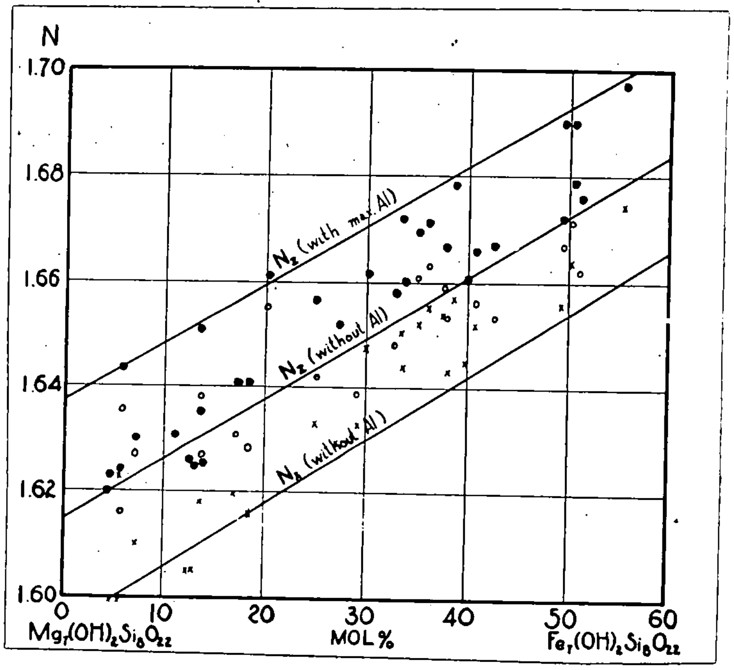

N
1.70
1.68
1.66
1.64
1.62
1.60
0
10
20
30
40
50
60
N_z (with max. Al)
N_z (without Al)
N_x (without Al)
$Mg_7(OH)_2Si_8O_{22}$
MOL %
$Fe_7(OH)_2Si_8O_{22}$

FIG. 52

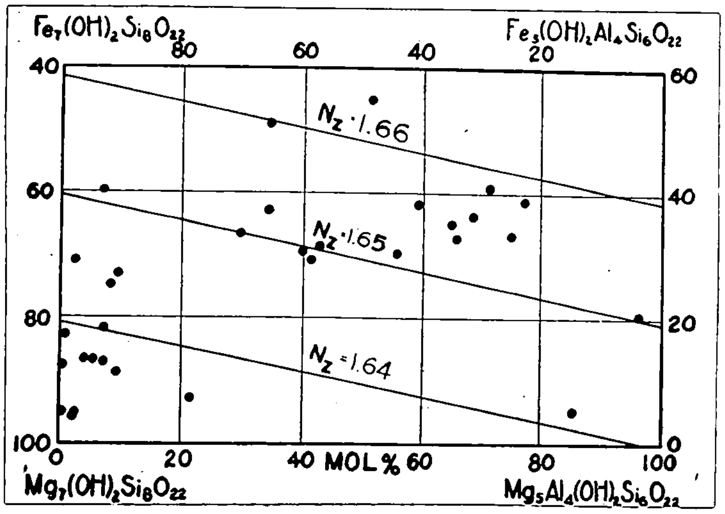
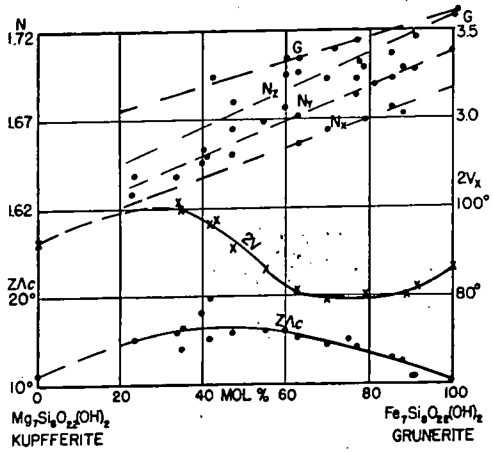
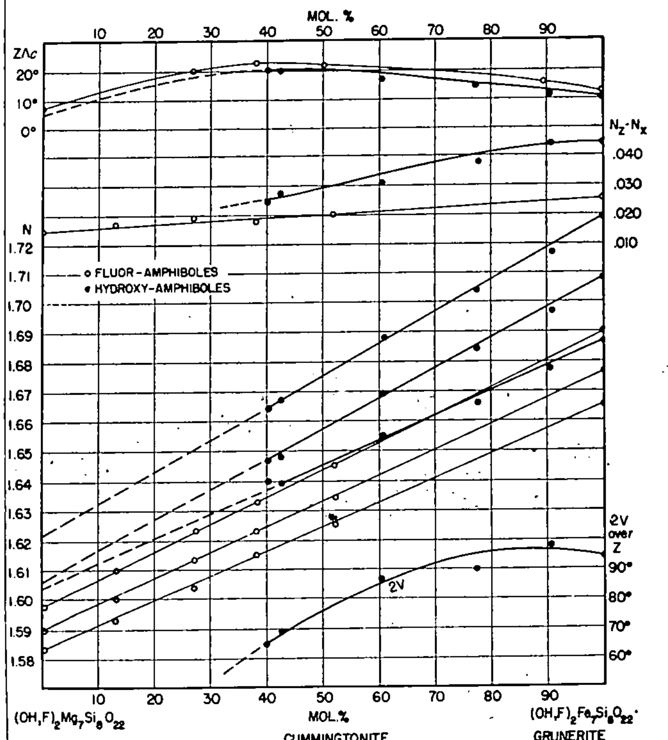

$Fe_7(OH)_2Si_8O_{22}$
$Fe_5(OH)_2Al_4Si_6O_{22}$
80
60
40
20
40
60
80
100
60
40
20
0
N_z 1.66
N_z 1.65
N_z 1.64
0
20
40 MOL % 60
80
100
$Mg_7(OH)_2Si_8O_{22}$
$Mg_5Al_4(OH)_2Si_6O_{22}$

FIG. 53.



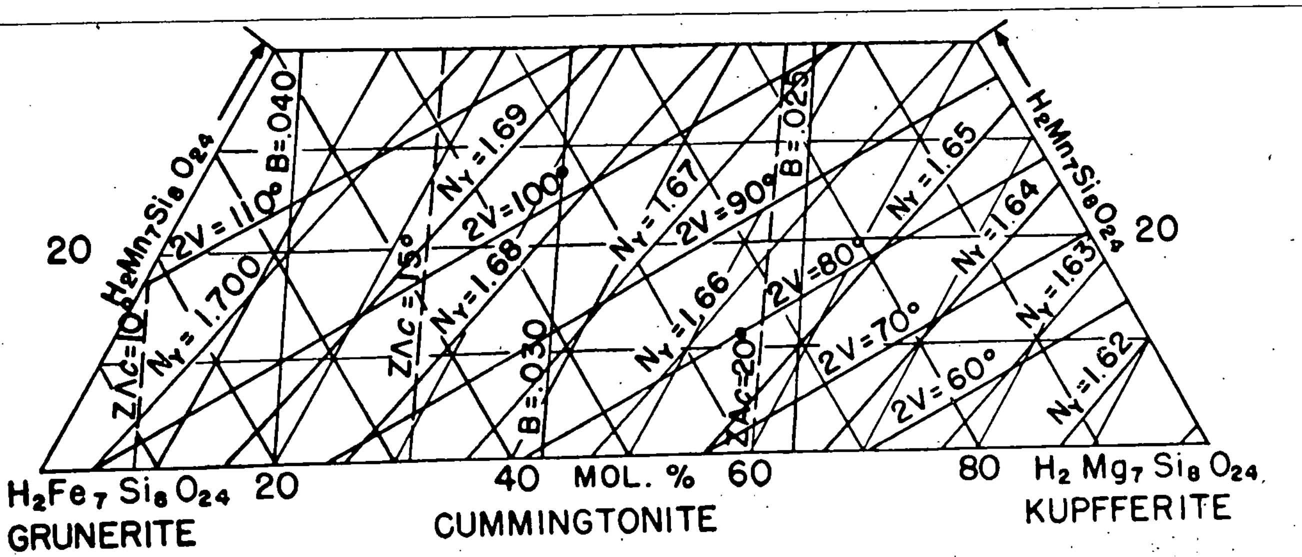
Properties of the cummingtonite series.

FIG. 54



Properties of fluorocummingtonite compared with hydroxycummingtonite.
After N. L. Bowen and J. F. Schairer: *Am. Mineral.*, XX, 543 (1935).

FIG. 55



Properties of the grunerite-kupfferite-$Mn_7(OH)_2Si_8O_{22}$ system.

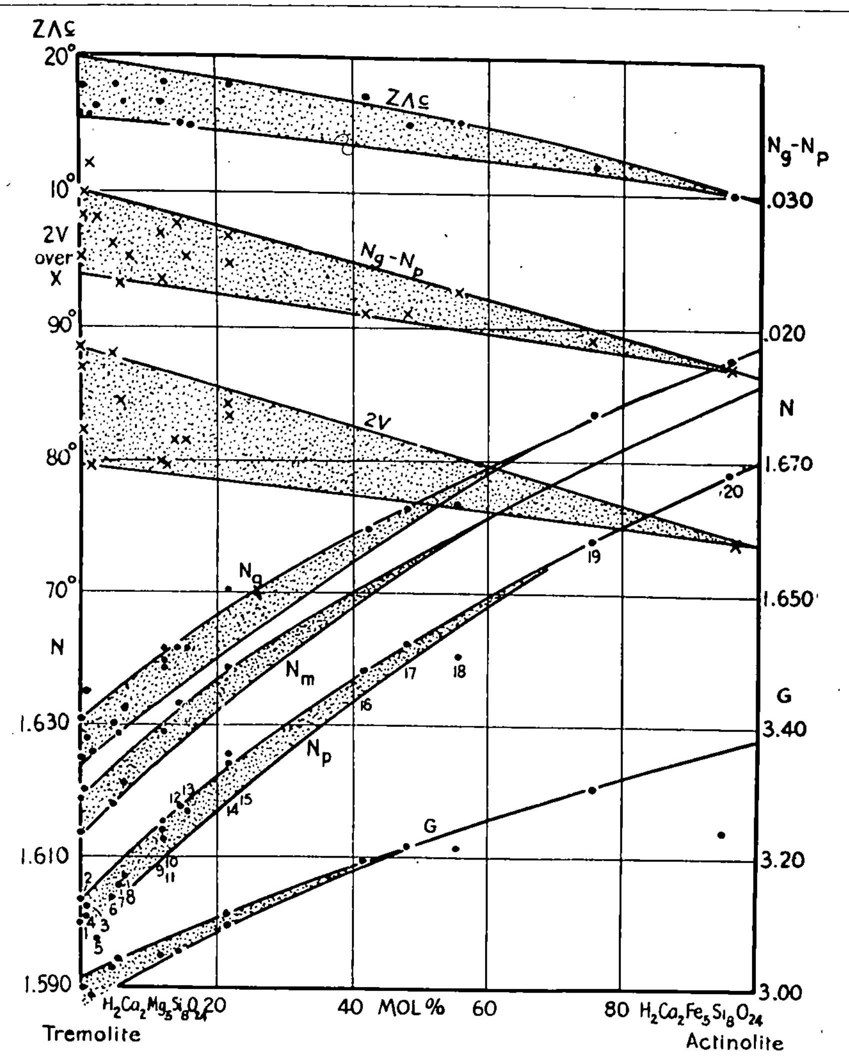
FIG. 56.

Fig. 57

Variation in Composition and Properties in the Tremolite-Actinolite Series (Winchell 1931).

Fig. 58

Variation in Composition and Properties in the Tremolite-Pargasite Series. Note Formula is Edenite not Pargasite (Winchell 1934).



Variations of composition and properties in the tremolite-actinolite series.

FIG. 57

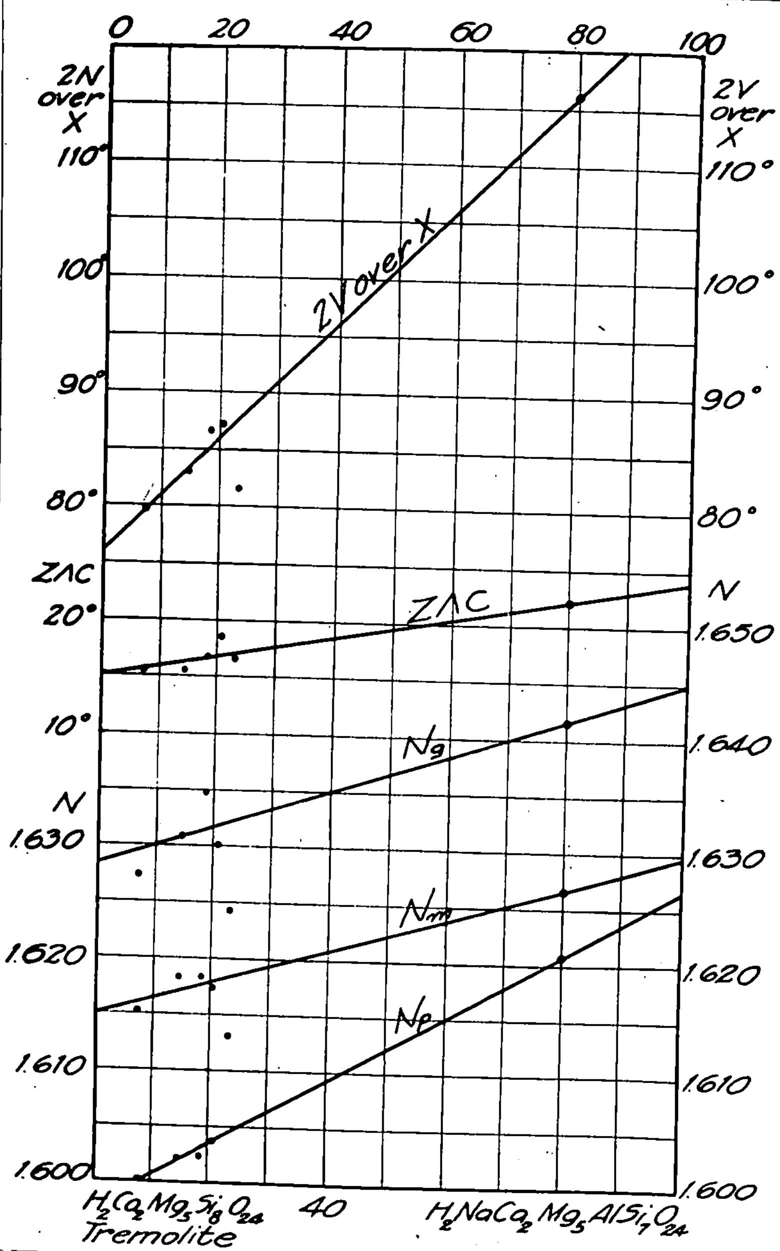
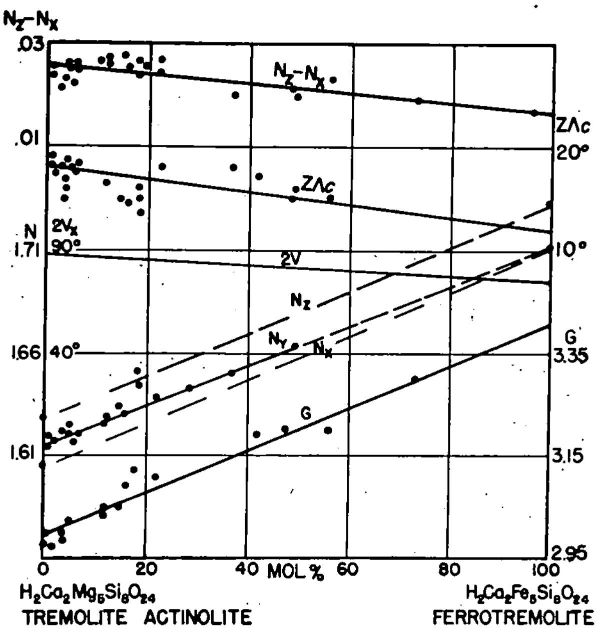


FIG. 58

Fig. 59

The Properties of the Tremolite-Ferrotremolite Series.
(Winchell 1951).

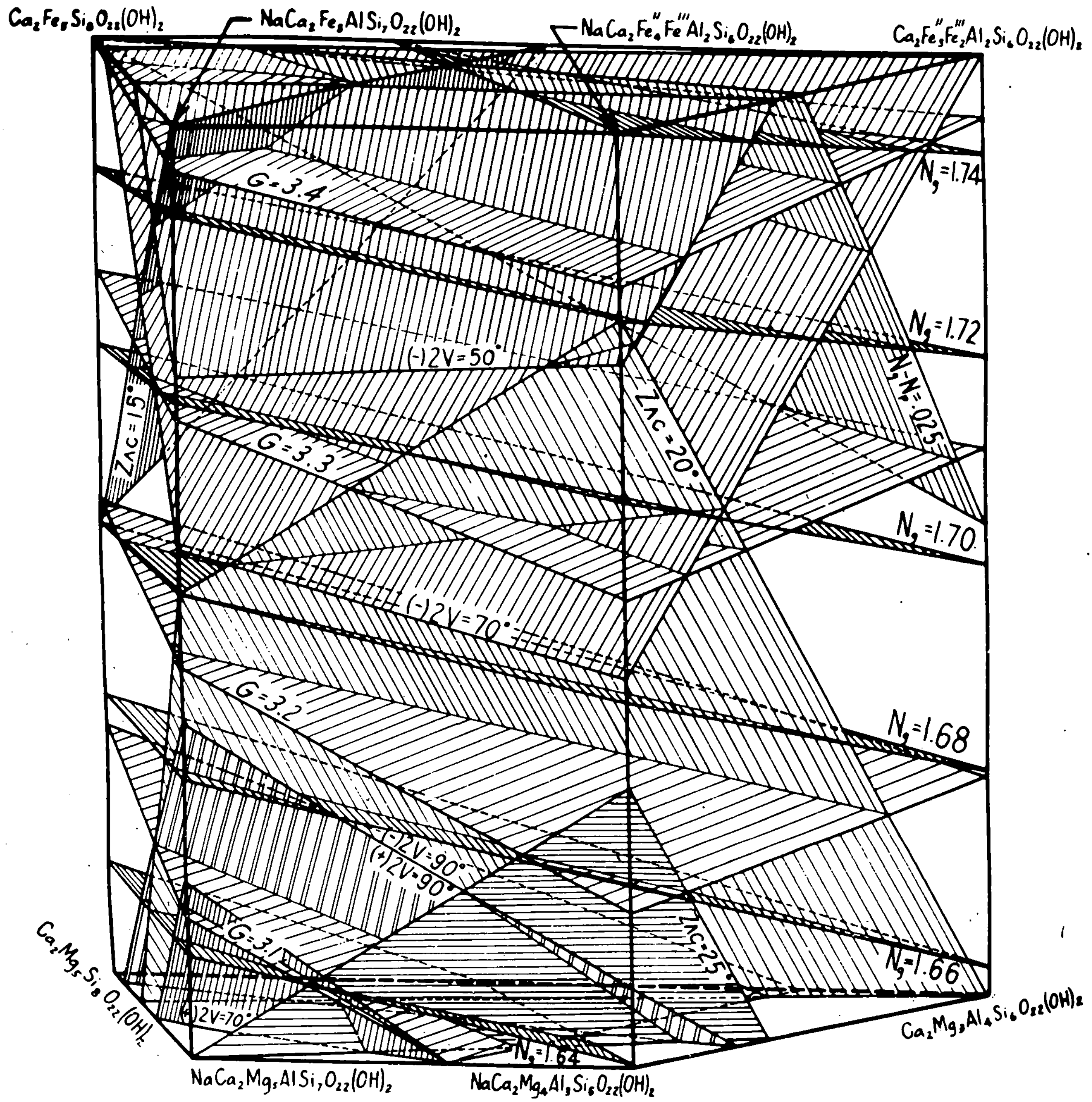


Properties of the tremolite-ferrotremolite series.

FIG. 59

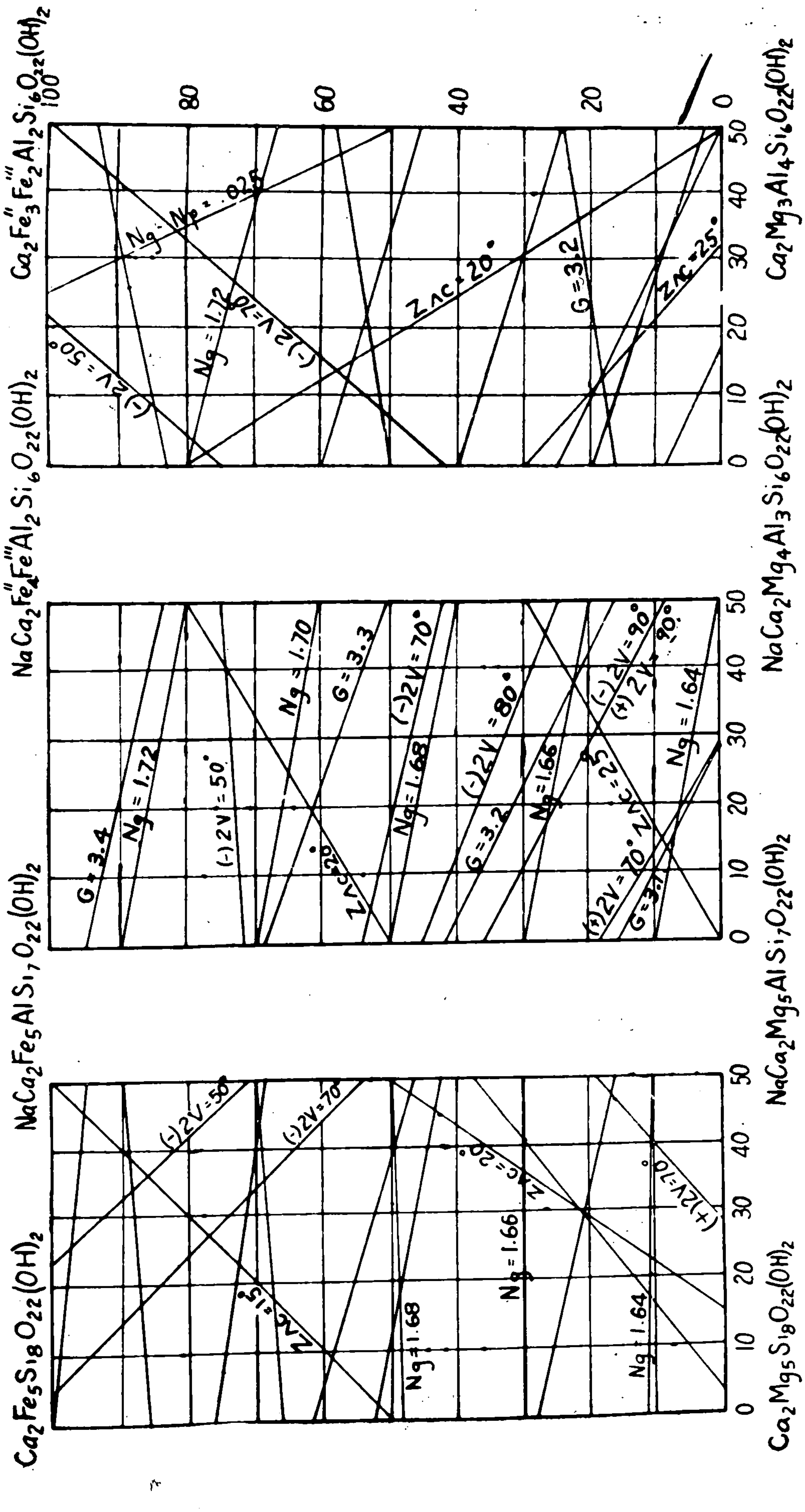
Fig. 60

The Physical Properties of the Calciferous Amphiboles (Winchell 1945) The Partial Prism.



. Physical properties of calciferous hornblendes.

FIG. 60.



Ca2Fe3''Fe2'''Al2Si6O22(OH)2
Ca2Mg3Al4Si6O22(OH)2
NaCa2Fe4''Fe'''Al2Si6O22(OH)2
NaCa2Mg4Al3Si6O22(OH)2
NaCa2Fe5AlSi7O22(OH)2
NaCa2Mg5AlSi7O22(OH)2
Ca2Fe5Si8O22(OH)2
Ca2Mg5Si8O22(OH)2
100
80
60
40
20
0
10
30
50
Ng - Np = .025
Ng = 1.72
(-)2V = 70
(-)2V = 50°
Z ∧ c = 20°
G = 3.2
Z ∧ c = 25°
G = 3.4
(-)2V = 50°
Ng = 1.70
G = 3.3
(-)2V = 70°
Ng = 1.68
(-)2V = 80°
Ng = 1.66
(-)2V = 90°
(+)2V = 90°
Ng = 1.64
(+)2V = 70°
G = 3.1
(-)2V = 50
(-)2V = 70
Z ∧ c = 15
Ng = 1.68
Ng = 1.66
Z ∧ c = 20°
Ng = 1.64
(+)2V = 70

FIG. 61

Fig. 62

The Relationship between the Ng Refractive Index and Al(4).

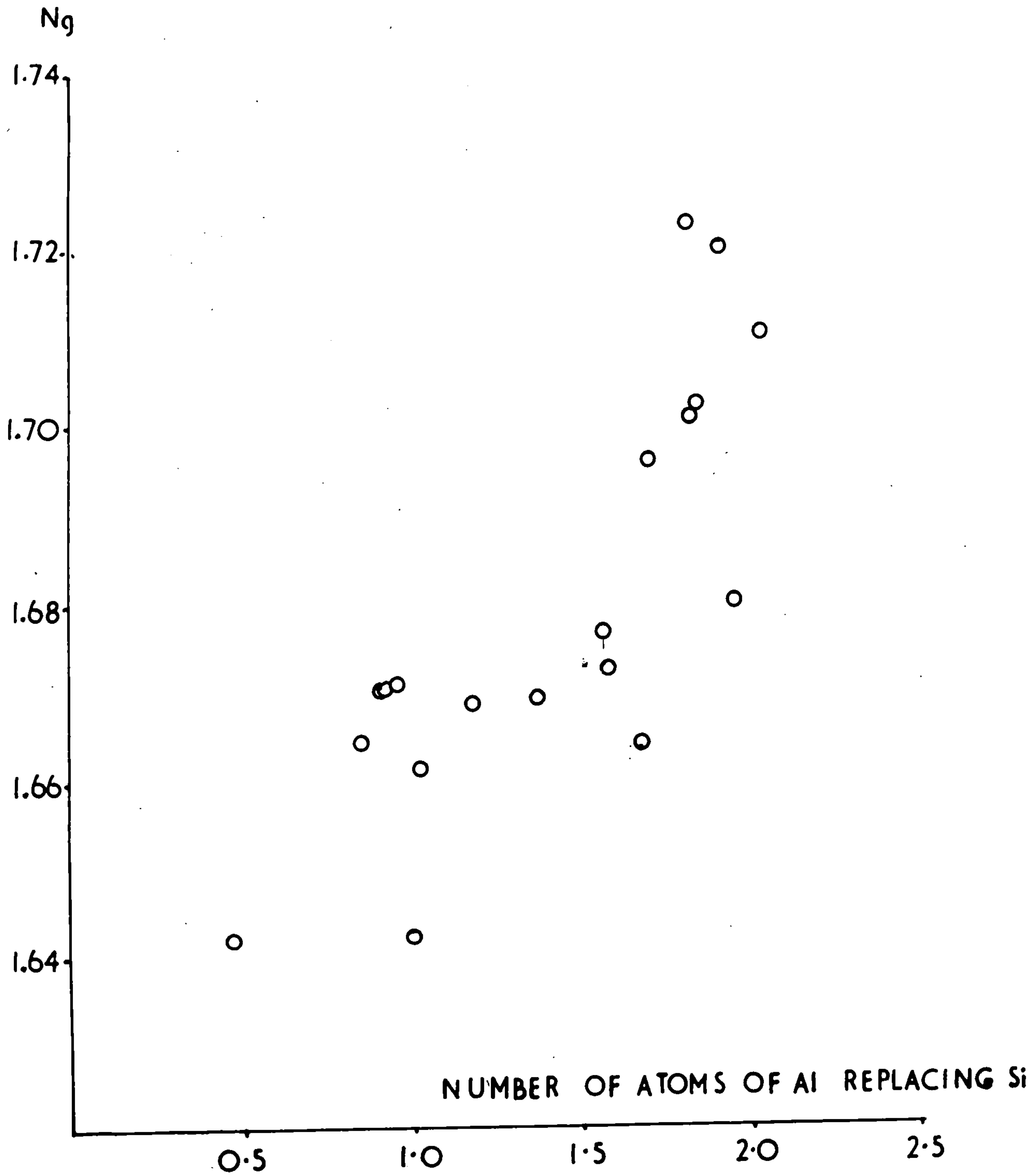

Ng
1.74
1.72
1.70
1.68
1.66
1.64
NUMBER OF ATOMS OF Al REPLACING Si
0·5
1·0
1·5
2·0
2·5

FIG. 62

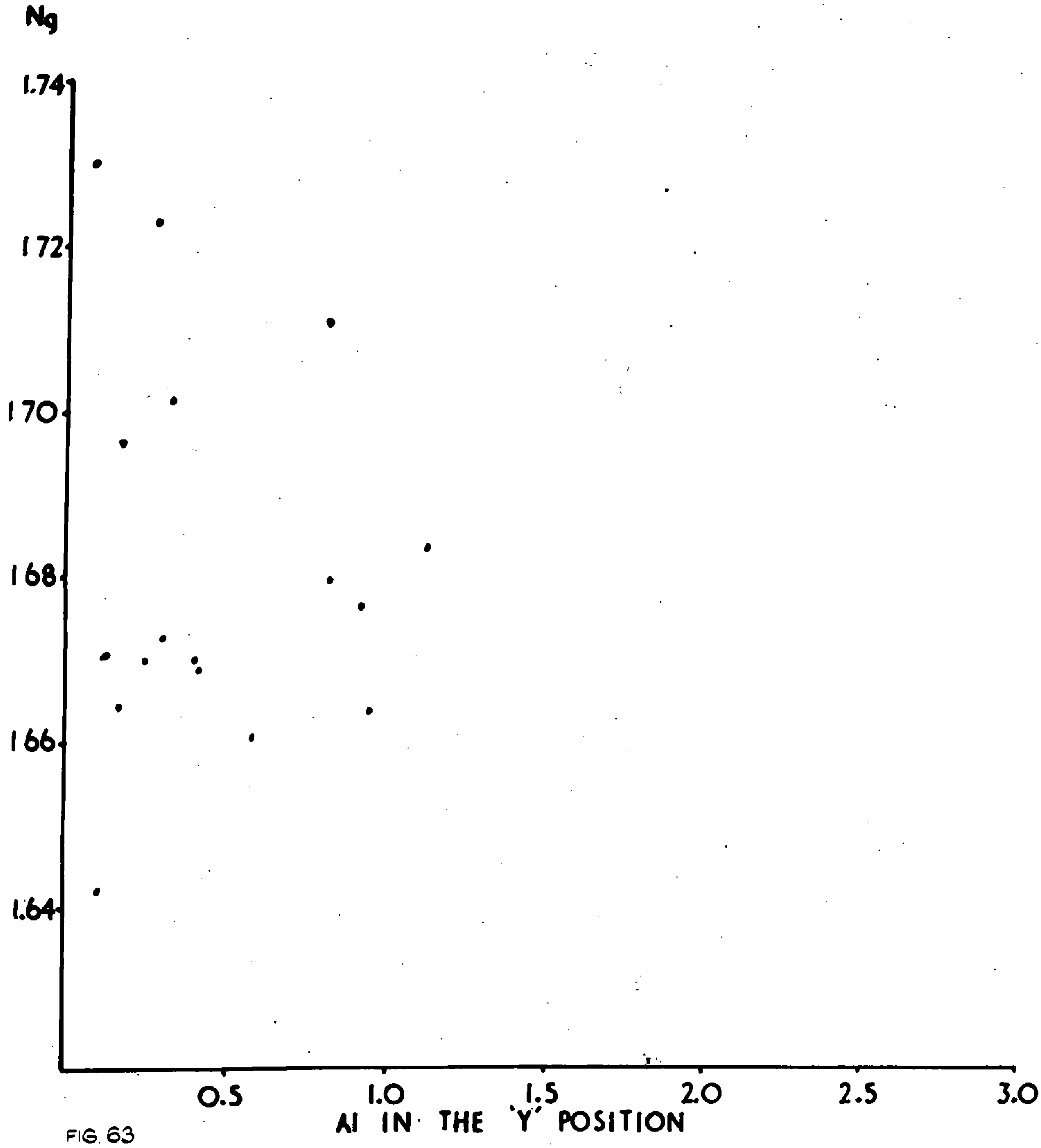


FIG. 63

Fig. 64

Two Axial Diagrams for Study of Sesqui-oxides in the Hornblende Series (Sundius 1946)

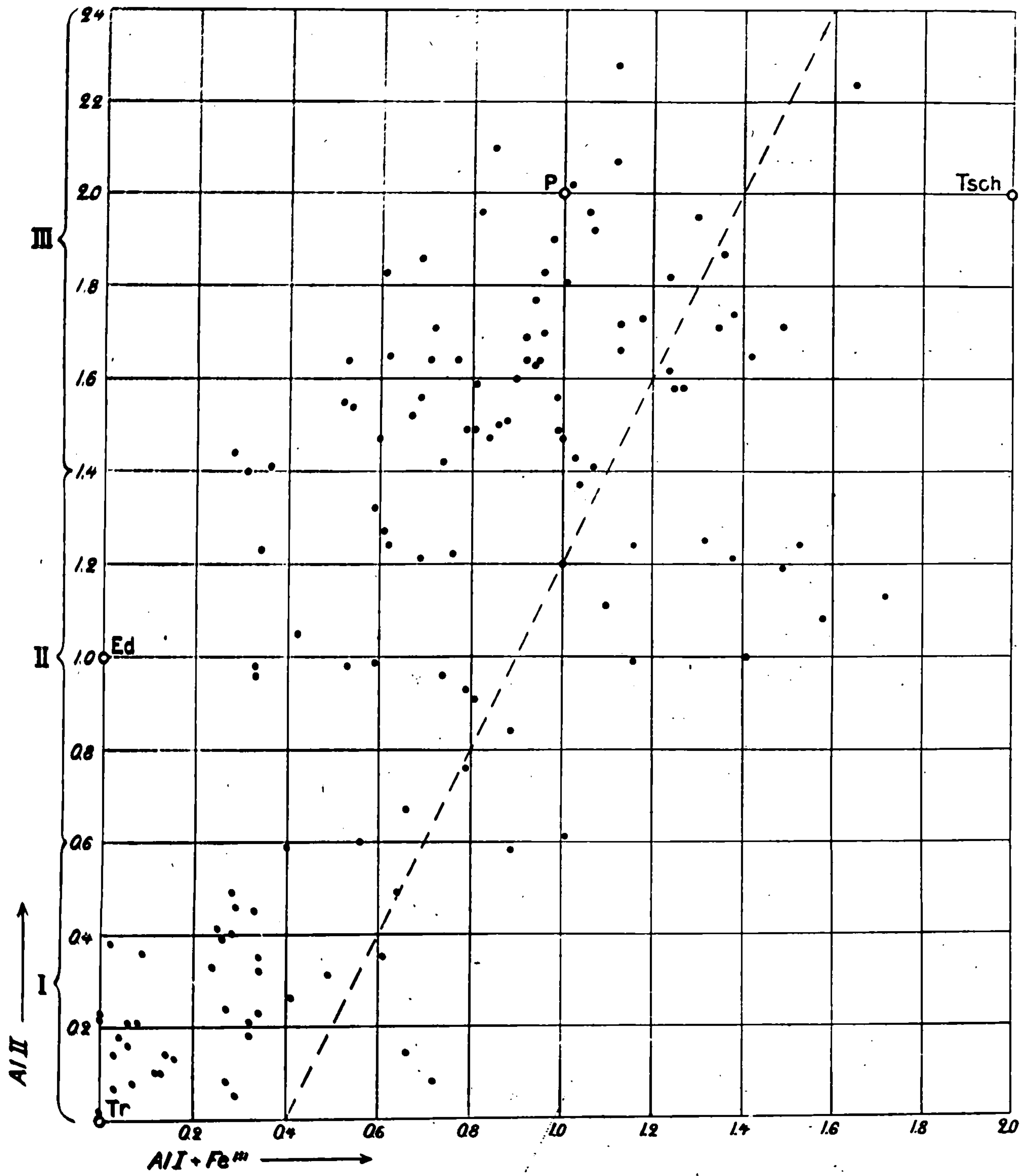

2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
III
II
I
P
Tsch
Ed
Tr
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
Al/II
Al I + Fe'''

FIG. 64

Fig. 65

Refractive Index Values at Various Sesqui-oxide Levels. (Sundius 1946)

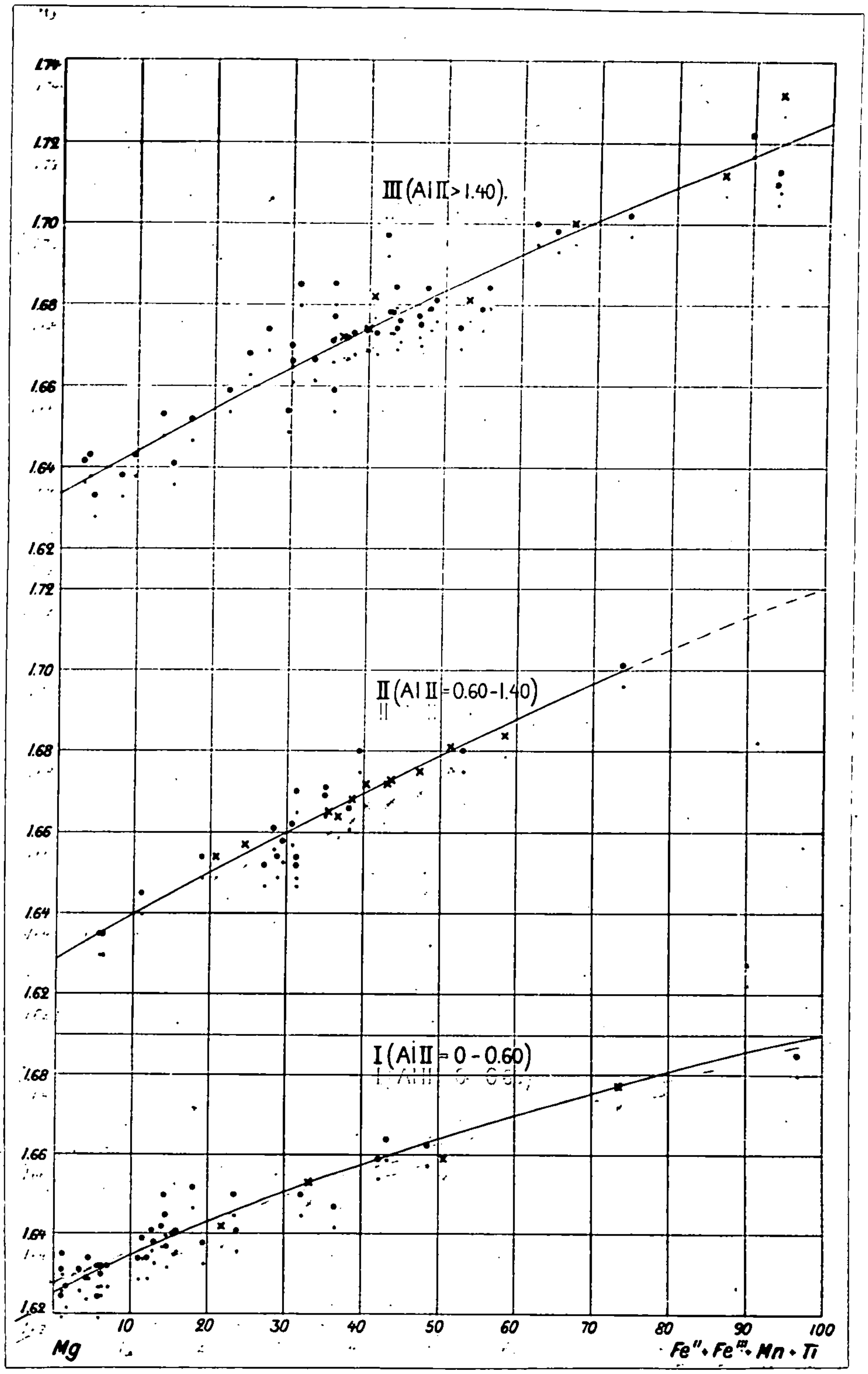

1.74
1.72
1.70
1.68
1.66
1.64
1.62
III (Al II > 1.40).
1.72
1.70
1.68
1.66
1.64
1.62
II (Al II = 0.60-1.40)
1.68
1.66
1.64
1.62
I (Al II = 0 - 0.60)
10
20
30
40
50
60
70
80
90
100
Mg
Fe''+ Fe'''+ Mn + Ti

FIG. 65

Fig. 66

Showing the Relationship of Ti+Fe''' to Various Contents of Al(ii) and Fe'' (Sundius 1946)

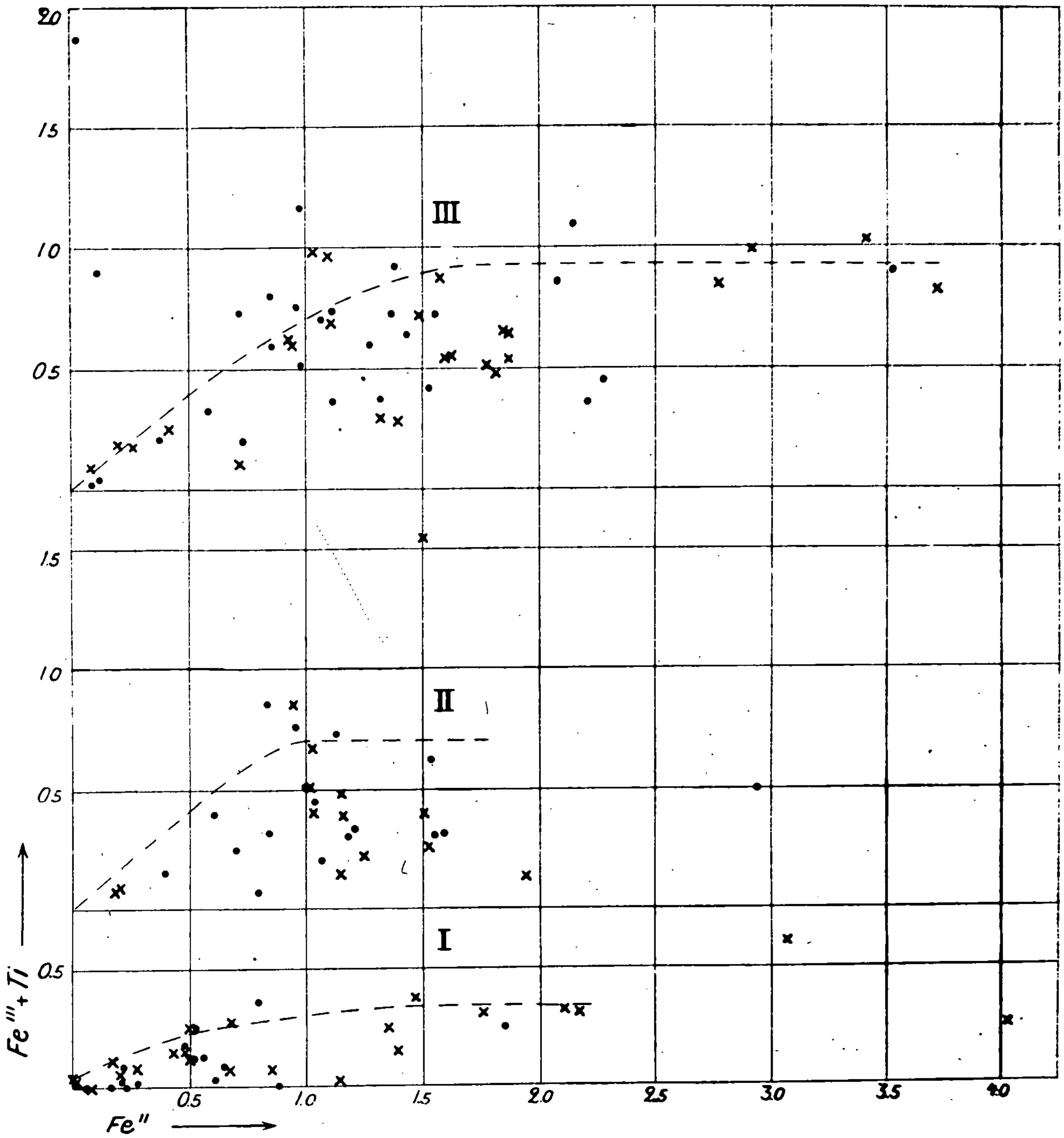


FIG. 66.

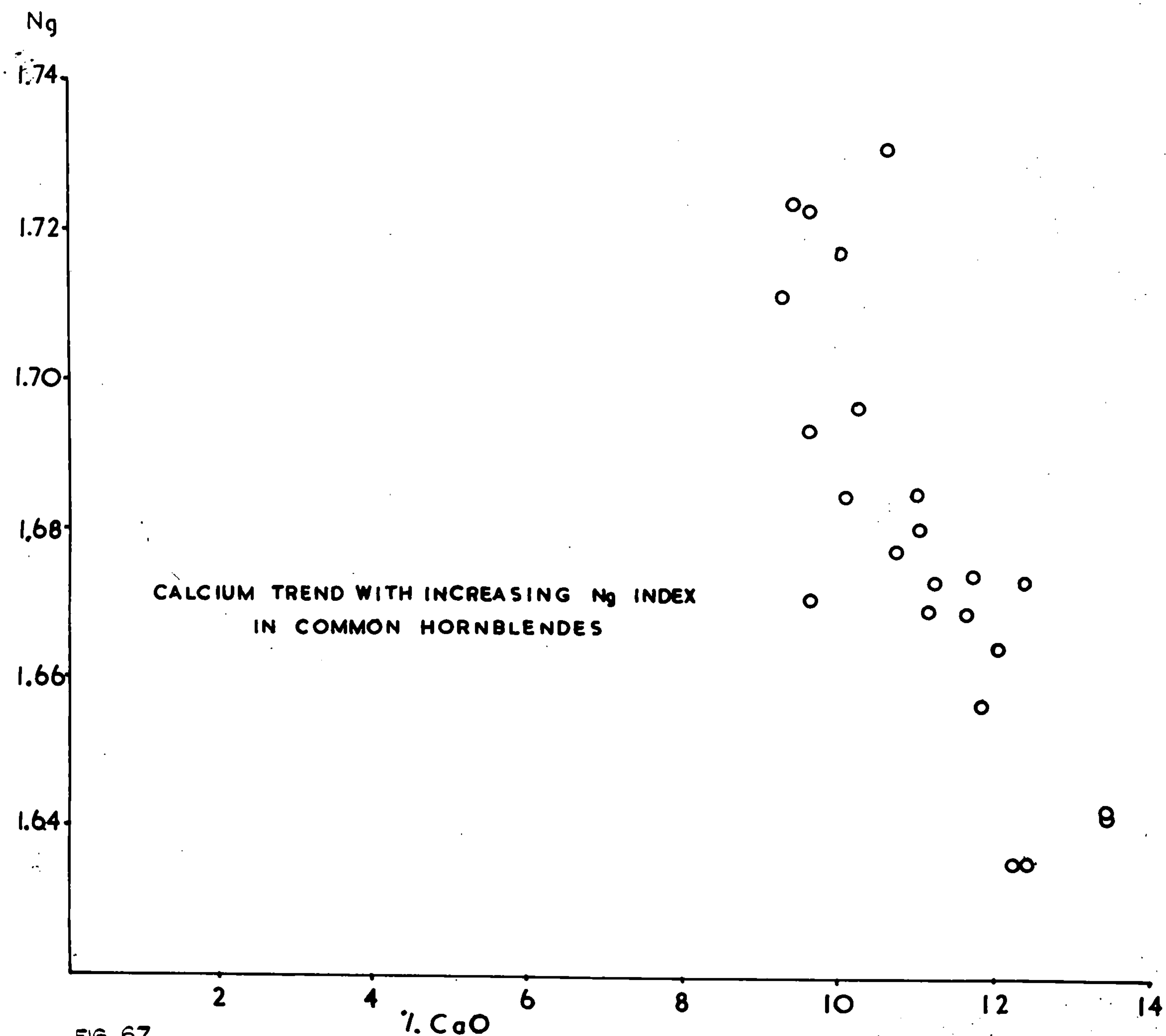
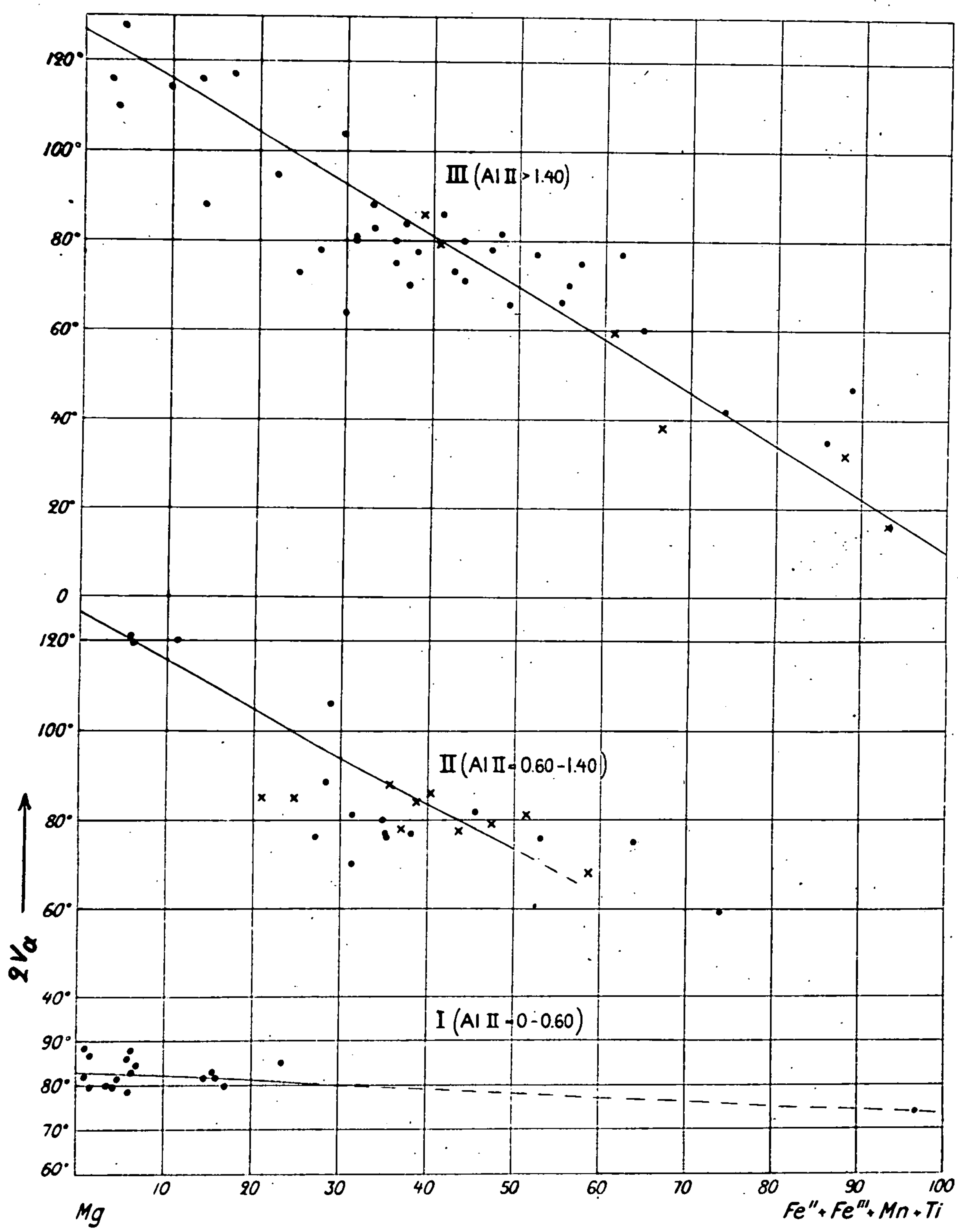

Ng
1.74
1.72
1.70
1.68
1.66
1.64
2
4
6
8
10
12
14
% CaO
CALCIUM TREND WITH INCREASING Ng INDEX
IN COMMON HORNBLENDES

FIG. 67.

Fig. 68

The Relationship between Axial Angle, Al(ii) and Heavy Ion Content (Sundius 1946)



120°
100°
80°
60°
40°
20°
0
III (Al II > 1.40)
120°
100°
80°
60°
40°
II (Al II = 0.60 - 1.40)
90°
80°
70°
60°
I (Al II = 0 - 0.60)
2 Vα
10
20
30
40
50
60
70
80
90
100
Mg
Fe'' + Fe''' + Mn + Ti

FIG. 68.

Fig. 69

Illustrating the break in Optical Properties between the Tremolite Series and the Common Hornblendes (Sundius 1946)

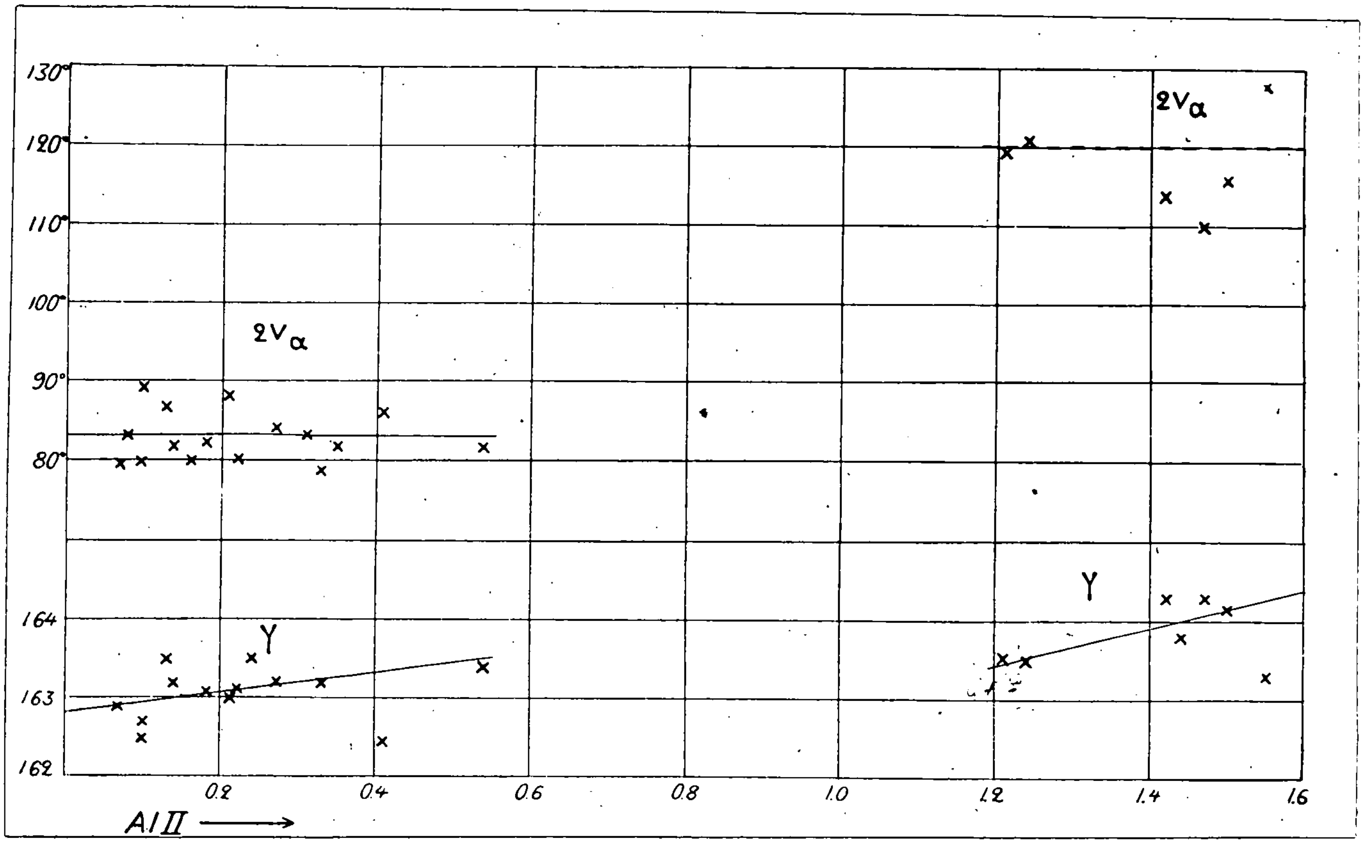
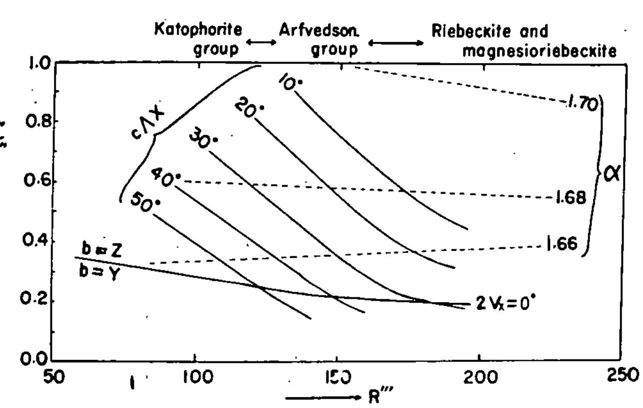
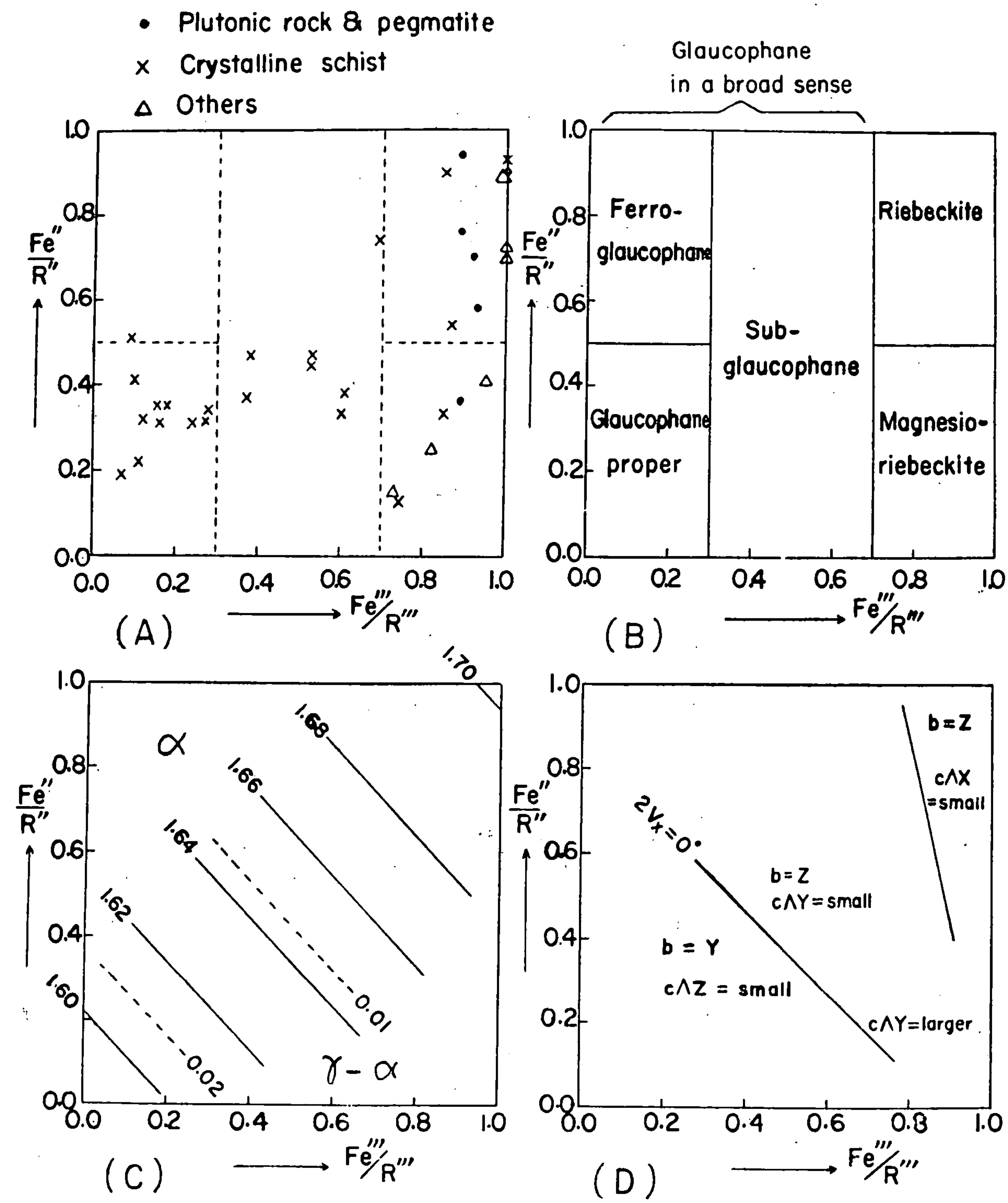


FIG. 69.



The approximate relation between the compositions and optical properties of amphiboles of the riebeckite-arfvedsonite-katophorite series, excluding glaucophane.

FIG. 70.



The Fe'''/R''' and Fe''/R'' ratios in amphiboles of the riebeckite-glaucophane group. (A) compositions, (B) nomenclature, (C) refractive indices, (D) optic orientation.

FIG. 34/71

Fig. 72

Writer's Suggested Method for Identification of Alkali Amphiboles.

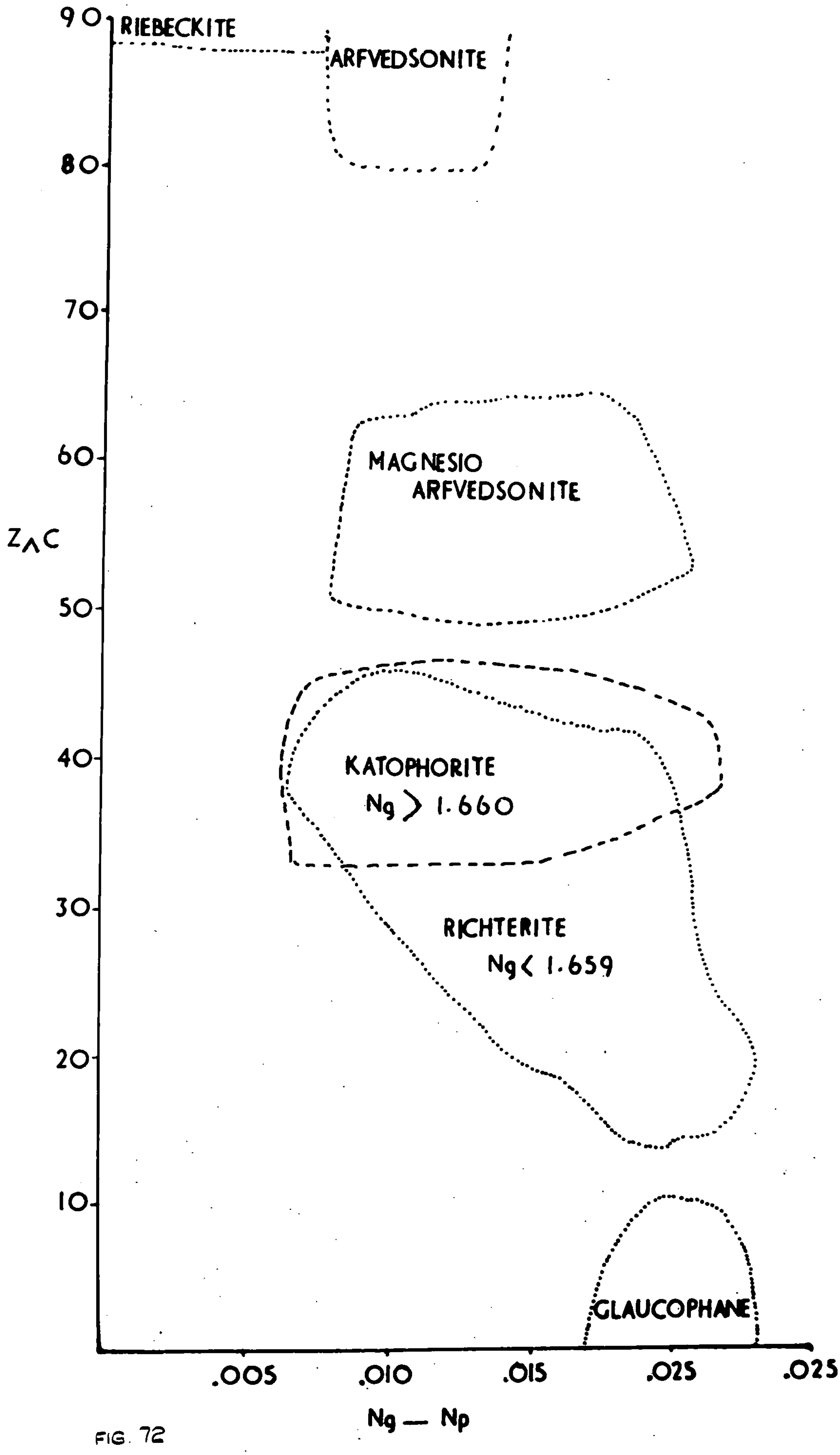

90
80
70
60
50
40
30
20
10
Z∧C
RIEBECKITE
ARFVEDSONITE
MAGNESIO
ARFVEDSONITE
KATOPHORITE
Ng > 1.660
RICHTERITE
Ng < 1.659
GLAUCOPHANE
.005
.010
.015
.025
.025
Ng — Np

FIG. 72

Fig. 73

Graph showing the Relationship between d-space and % Al_2O_3 Content in the Hornblende Series.

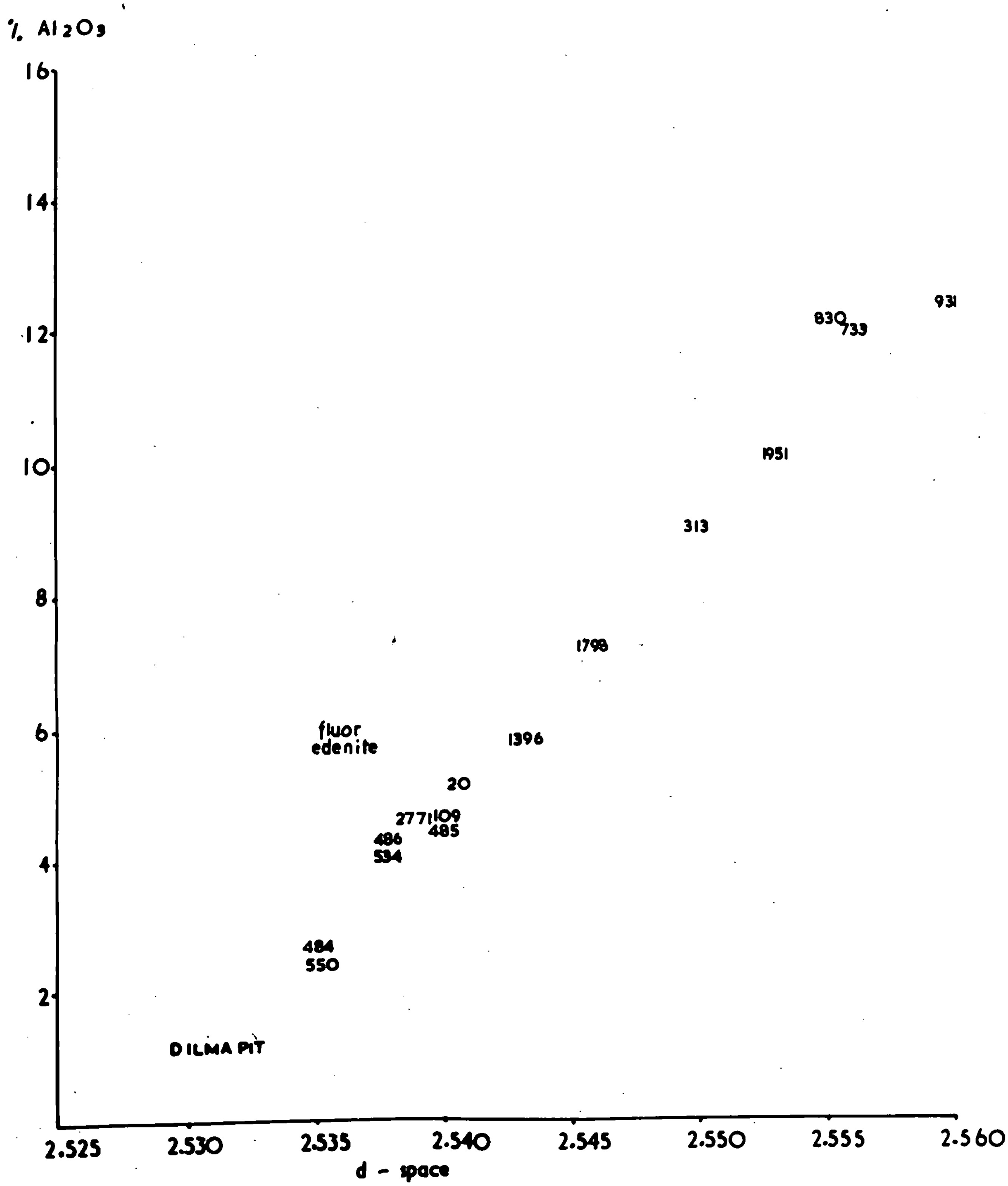

% Al_2O_3
16
14
12
10
8
6
4
2
931
830
733
1951
313
1798
1396
fluor
edenite
20
2771
109
485
486
534
484
550
DILMA PIT
2.525
2.530
2.535
2.540
2.545
2.550
2.555
2.560
d - space

FIG. 73

Fig. 74

Graphs showing the Relationship between d-space and % SiO_2 and Mgo Content.

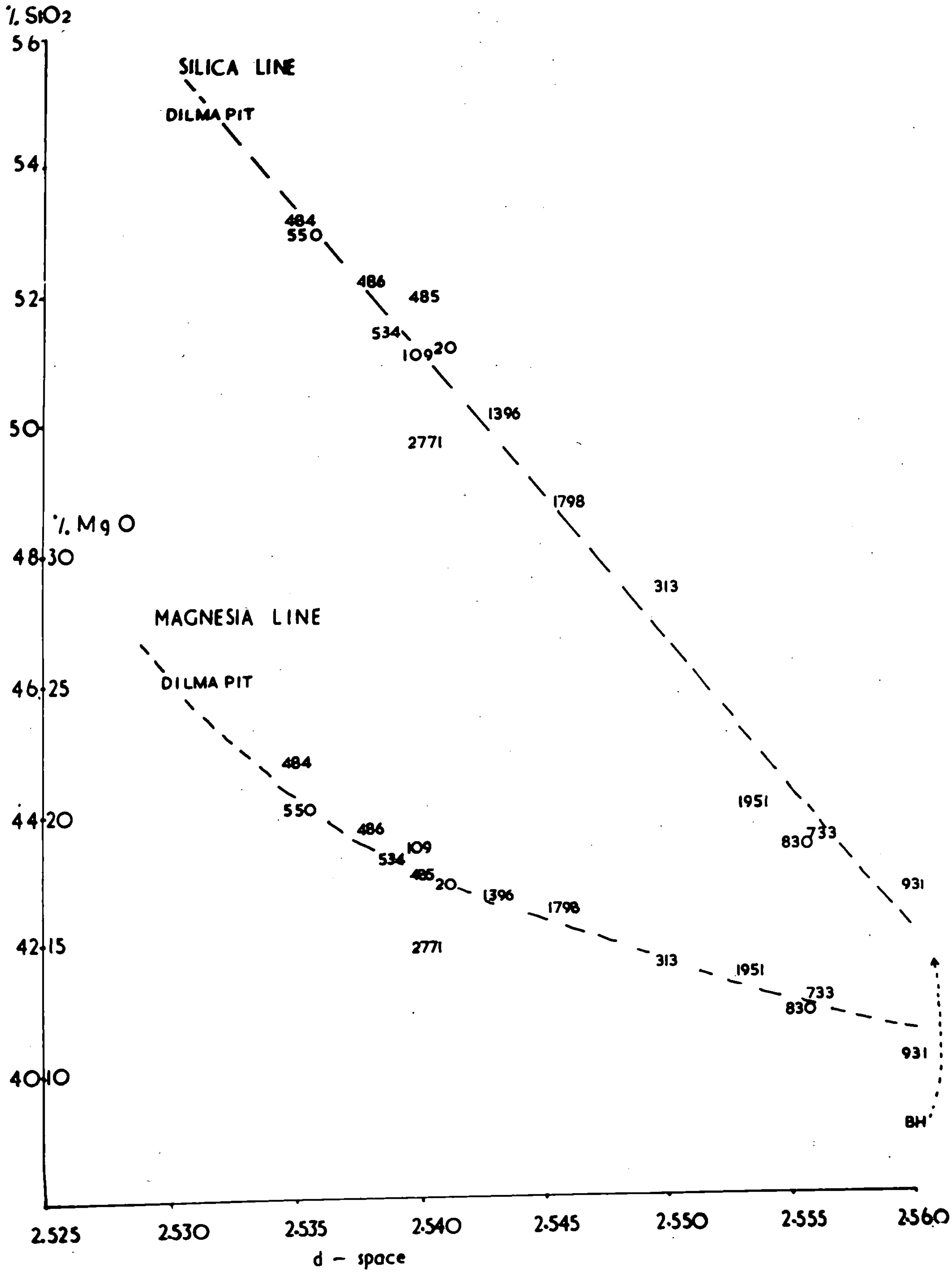

% SiO2
56
54
52
50
48
46
44
42
40
SILICA LINE
DILMA PIT
484
550
486
485
534
109
20
1396
2771
1798
313
1951
830
733
931
% MgO
30
25
20
15
10
MAGNESIA LINE
DILMA PIT
484
550
486
109
534
485
20
1396
1798
2771
313
1951
733
830
931
BH
2.525
2.530
2.535
2.540
2.545
2.550
2.555
2.560
d – space

FIG. 74.

Fig. 75

Graphs showing the Relationship between d-space and % FeO and % (Na_2O+K_2O) Content.

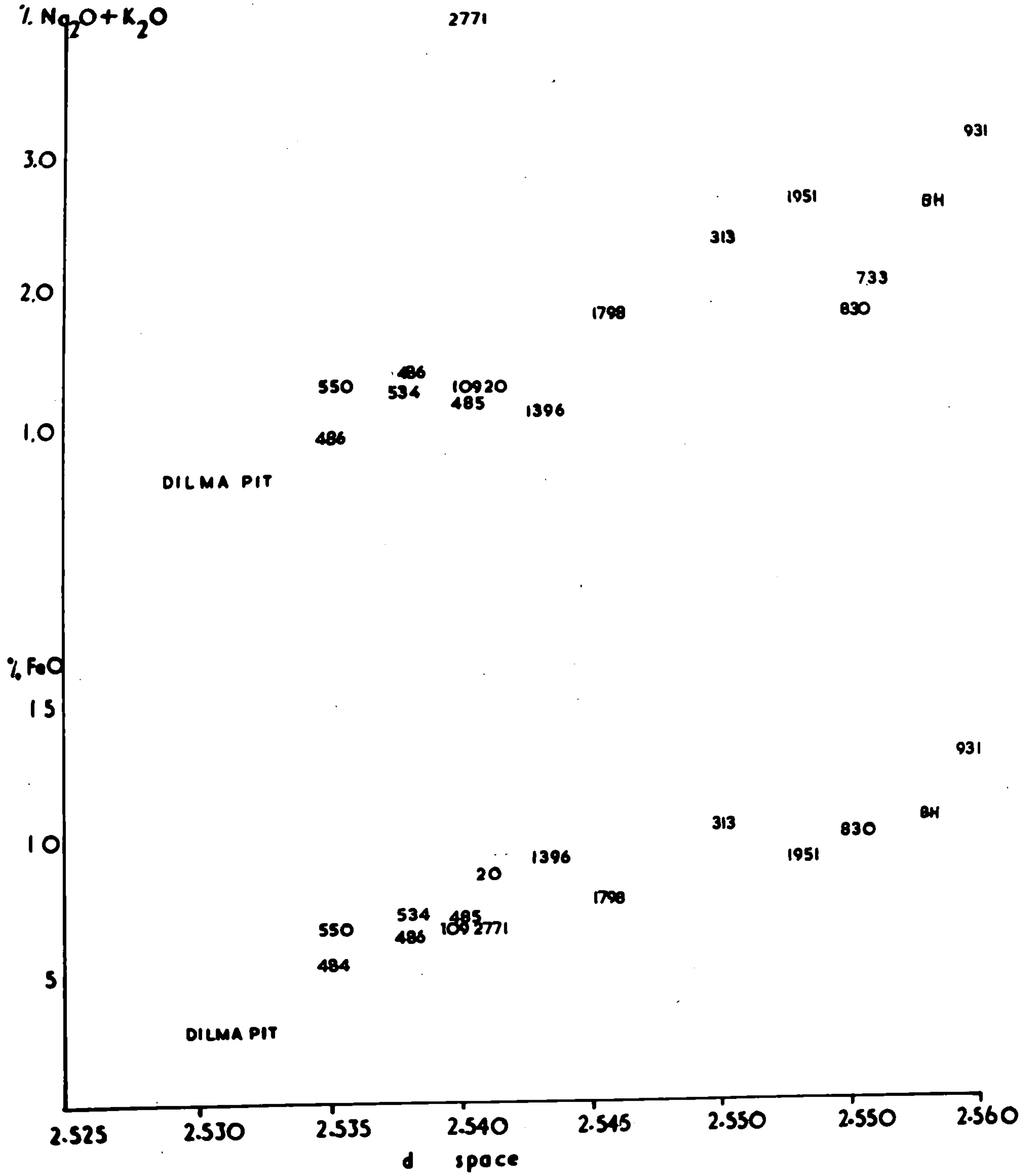

% Na2O+K2O
2771
3.0
931
1951
BH
313
2.0
733
830
1798
486
550
534
10920
485
1396
1.0
486
DILMA PIT
% FeO
15
931
313
830
BH
10
1396
1951
20
1798
534
485
550
486
109 2771
5
484
DILMA PIT
2.525
2.530
2.535
2.540
2.545
2.550
2.550
2.560
d space

FIG. 75

Fig. 76

Graph showing the Relationship between d-space and Si (in atomic proportions)

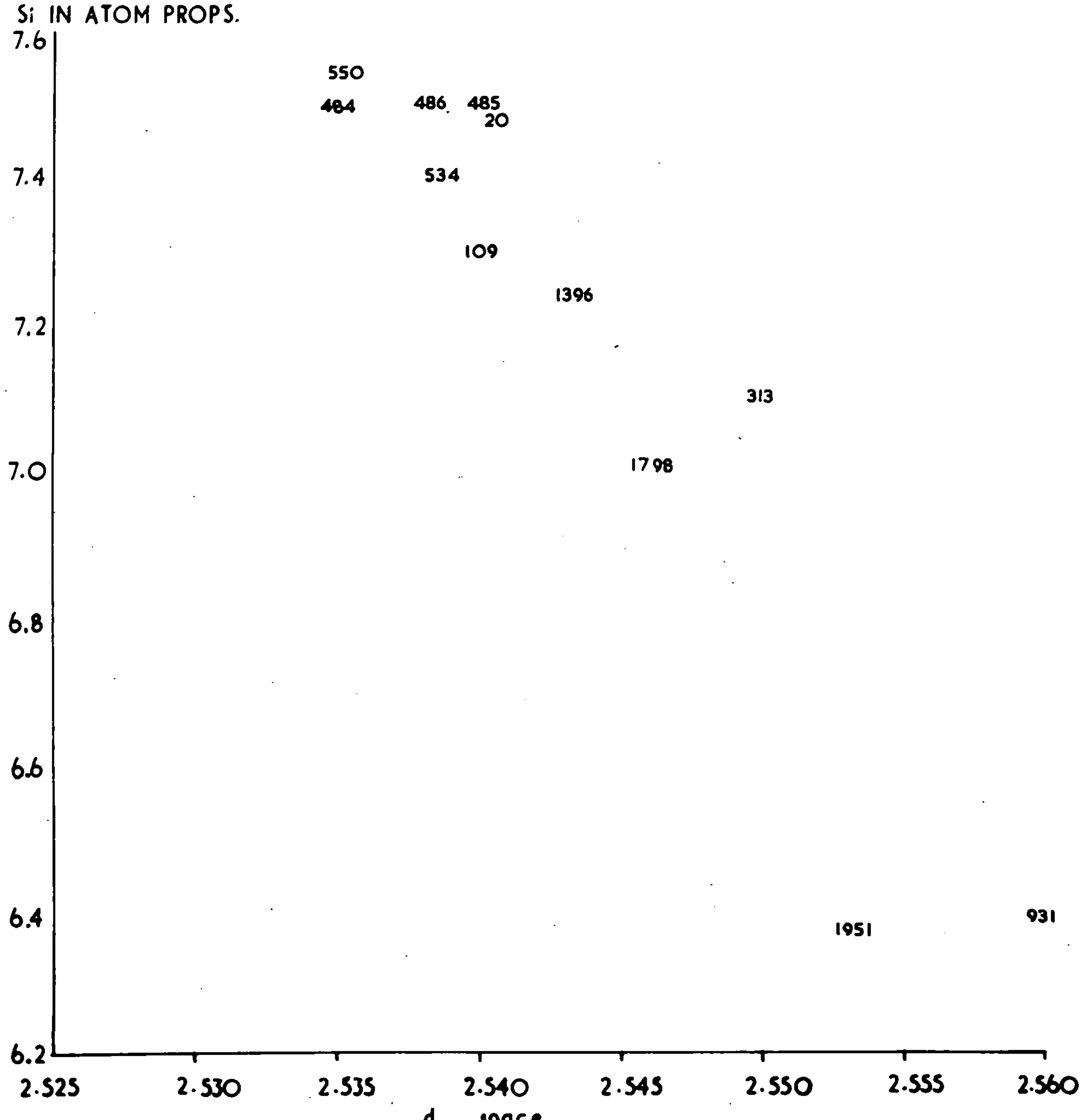

Si IN ATOM PROPS.
7.6
7.4
7.2
7.0
6.8
6.6
6.4
6.2
550
484
486
485
20
534
109
1396
313
1798
1951
931
2.525
2.530
2.535
2.540
2.545
2.550
2.555
2.560
d space

FIG. 76.

APPENDIX 1

ADDITIONAL STATISTICAL DATA.

ADDITIONAL DATA FOR MULTIPLE REGRESSION EQUATIONS.

	Common Hornblende.	Tremolite Series.
E(Ng x S.G)	214.404446	100.610853
E(Ng x (Fe))	135.21891	26.95112
E(Ng x Np)	110.768936	53.082842
E(Ng x (2V))	58.24105383	32.47543720
E(Ng x ($Z_\wedge c$))	21.09740079	9.63298600
E(Ng x Si)	434.00380	253.90211
E(Ng x ((Fe) Al))	270.30724	39.46639
E(Ng x Mg)	179.36136	141.12768
E(Np x S.G)	211.74056	99.120428
E(Np x (Fe))	133.46348	204.19532
E(Ng x Np)	-	-
E(Np x (2V))	57.52138501	31.9934597
E(Np x ($Z_\wedge c$))	20.83871185	9.4908147
E(Np x Si)	428.60906	205.12907
E(Np x ((Fe) Al))	266.87239	38.89814
E(Np x Mg)	177.19263	139.2578
E(S.G x (Fe))	261.01316	50.63583
E(S.G x (Fe) Al)	519.67214	74.1081
E(S.G x (2V))	110.87424942	60.6350273
E(S.G x ($Z_\wedge c$))	40.26153122	17.9937191
E(S.G x Mg)	340.13228	263.24982
E(S.G x (Mg))	-	-
E(S.G xSi)	828.87811	473.93413

ADDITIONAL DATA FOR MULTIPLE REGRESSION EQUATIONS.

	Common Hornblende.	Tremolite Series.
E((Fe) x (Fe) + Al)	384.0436	25.2538
E((Fe) x Mg)	162.9743	64.5958
E((Fe) x (Mg))	-	98.5944
E((Fe) x Si)	509.15650	125.67990
E((Fe) x ($Z_{\wedge}c$))	23.6331772	4.853548
E((Fe) x (2V))	62.3824063	16.164033
E((Fe) x (Na+K))	-	5.5582
E((2V) x Z c)	11.1473384906	5.80609515
E(2V x Si)	222.8507074	153.064162
E2V x (Fe) + Al	131.6454101	23.678456
E(2V x Mg)	101.0244209	85.169084
E(2V x (Na+K))	-	7.263718
E(2V x (Mg))	-	126.699157
E($Z_{\wedge}c$ x Si)	81.7233097	45.37892
E($Z_{\wedge}c$ x Mg)	35.5483011	25.185643
E($Z_{\wedge}c$ x (Na+K))	-	2.106163
E($Z_{\wedge}c$ x (Mg))	-	37.499198
E($Z_{\wedge}c$ x (Fe) + Al)	48.2882334	7.072733

APPENDIX 2.

EXAMPLE OF METHODS OF CALCULATION OF REGRESSION EQUATIONS

AND

OTHER STATISTICAL DATA

KEY.

X_1 = Ng

X_2 = Np

X_3 = D

X_4 = Sin $Z_\wedge c$

X_5 = Sin 2V

Y = (Fe" + Fe"' + Mn + Ti)

1. EX_1^2 = Sum of squares of Ng values. (Table 8 and Appendix 1) Similarly for EX_2^2 EX_3^2 etc.

2. Correction term in this case is the square of the sum of the Ng values. (Similarly for X_2 X_3 etc.) divided by the number of Ng values.

3. The products e.g. $EX_1 X_2$ are similarly derived and the correction terms are products of sums divided by number of values.

4. $Ex_1 x_2$ etc. are differences and represent sums of squares and products of deviations from the means.

5. $(Ex_1)^2(Ey)^2$ etc. are the denominators of the correlation coefficients 'r' the numerators being the values from Step 4.

6. The simultaneous equations are then built with the 'r' values in the manner indicated by t he example.

HORNBLENDE SERIES, REDUCTION OF DATA FOR SIMULTANEOUS EQUATIONS.

X_1

	EX_1^2	Correction	Ex_1^2	Ex_1^2
X_1	112.167109	112.141260	.025849	.1608

X_2

	EX_2^2	Correction	Ex_2^2	Ex_2^2
X_2	109.388993	109.36579	.023203	.15232

X_3

	EX_3^2	Correction	Ex_3^2	Ex_3^2
X_3	410.056677	409.568000	.488677	.69907

X_4

	EX_4^2	Correction	Ex_4^2	Ex_4^2
X_4	4.258997	3.980531	.278466	.52774

X_5

	EX_5	Correction	Ex_5^2	Ex_5^2
X_5	32.44060	30.40437	2.03523	1.4266

Y

	EY^2	Correction	Ey^2	Ey^2
Y	216.5470	106.2401	56.3069	7.5040

HORNBLENDE SERIES, REDUCTION OF DATA FOR SIMULTANEOUS EQUATIONS.

X_2

	EX_1X_2	Correction	Ex_1x_2	$(Ex_1^2)(Ex_2^2)$	r_1
X_1	110.768936	110.744830	.024106	.02449	.9843

X_3

	EX_1X_3	Correction	Ex_1x_3	$(Ex_1)^2(Ex_3)^2$	r_2
X_1	214.404446	214.311620	.092826	.1124	.8259

X_4

	EX_1X_4	Correction	Ex_1x_4	$(Ex_1)^2(Ex_4)^2$	r_3
X_1	21.097400	21.127749	-.030348	.08486	-.3576

X_5

	EX_1X_5	Correction	Ex_1x_5	$(Ex_1)^2(Ex_5)^2$	r_4
X_1	58.24105	58.39098	-.14993	.2294	-.6536

Y

	EX_1Y	Correction	Ex_1y	$(Ex_1)^2(Ey)^2$	r_5
X_1	135.21891	134.05046	1.16845	1.2066	.9683

HORNBLENDE SERIES, REDUCTION OF DATA FOR SIMULTANEOUS EQUATIONS.

			X_3		
	EX_2X_3	Correction	Ex_2x_3	$(Ex_2)^2(Ex_3)^2$	r6
X_2	211.74056	211.64293	.097637	.1065	.9168

			X_4		
	EX_2X_4	Correction	Ex_2x_4	$(Ex_2)^2(Ex_4)^2$	r7
X_2	20.838711	20.864657	-.025945	.08039	-.3227

			X_5		
	EX_2X_5	Correction	Ex_2x_5	$(Ex_2)^2(Ex_5)^2$	r8
X_2	57.52138	57.66458	-.14319	.2173	-.6590

			Y		
	Ex_2Y	Correction	Ex_2Y	$(Ex_2)^2(Ey)^2$	r9
X_2	133.46348	132.38121	1.08227	1.1430	.9469

HORNBLENDE SERIES, REDUCTION OF DATA FOR SIMULTANEOUS EQUATIONS.

	EX_3X_4	Correction	X_4 Ex_3x_4	$(Ex_3)^2(Ex_4)^2$	r^{10}
X_3	40.261530	40.37695	-.11542	.3689	-.3129

	EX_3X_5	Correction	X_5 Ex_3x_5	$(Ex_3)^2(Ex_5)^2$	r^{11}
X_3	110.87424	111.59157	-.71732	.9973	-.7193

	EX_3Y	Correction	Y Ex_3Y	$(Ex_3)^2(EY)^2$	r^{12}
X_3	261.0131	256.1819	4.8312	5.2458	.9210

	EX_4X_5	Correction	X_5 Ex_4x_5	$(Ex_4)^2(Ex_5)^2$	r^{13}
X_4	11.147338	11.1001170	.0472214	.7529	.6272

	EX_4Y	Correction	Y Ex_4y	$(Ex_4)^2(Ey)^2$	r^{14}
X_4	23.6331	25.2555	-1.6223	3.9602	-.4097

	EX_5Y	Correction	Y Ex_5y	$(Ex_5)^2(Ey)^2$	r^{15}
X_5	62.38240	69.79971	-7.4173	10.7052	-.6929

COMMON HORNBLENDES: Simultaneous and Regression Equations for (Fe) in Atomic Proportions on Physical Properties.

Simultaneous Equations (derived from Reduction of Data)

	Ng	Np	D	Z.c	2V		Fe
Ng	+.1	+.09843	+.08259	-.03576	-.06536	=	+.09683
	L						
Np	+.09843	+.1	+.09168	-.03227	-.06590	=	+.09469
	L						
D	+.08259	+.09168	+.1	-.03129	-.07193	=	+.09210
	L						
Z.c	-.-3576	-.03227	-.03129	+.1	+.06272	=	-.04970
	L						
2V	-.06536	-.06590	-.07193	+.06272	+.1	=	-.06929

(Reduced by a factor of 10 for computer.)

Solutions given by computer.

-4.4703808336 = a   partial regression coefficients.
6.9495669087 = b
-2.1274607100 = c
-0.2705730651 = d
-0.3955553821 = e

Regression Equations:

$$(Fe'' + Fe''' + Mn + Ti) = (Fe) = 411.21 - 208.75 Ng + 340.55 Np - 22.79 D - 3.83 \sin Z.c - 2.05 \sin 2V$$

Correlation Coefficient:

$$R_{Fe} = 0.915$$

Standard Error of the Estimate:

$$S.E._{(Fe)} = .515 \text{ atoms.}$$

Correlation Coefficient: "R"

$$R^2 = ry_1\, a + ry_2\, b + ry_3\, c + ry_4\, d + ry_5\, e$$

by substitution $R = \sqrt{.838} = .\underline{\underline{915}}$ (Maximum correlation is 1.0)

R is calculated firstly to enable consideration to be given to the usefulness of the regression equation.

Regression Equation:

$$(Fe) = \overline{Fe} + a\frac{\sqrt{Ey^2}}{\sqrt{Ex_1{}^2}}(Ng-\overline{Ng}) + b\frac{\sqrt{Ey^2}}{\sqrt{Ex_2{}^2}}(Np-\overline{Np}) + c\frac{\sqrt{Ey^2}}{\sqrt{Ex_3{}^2}} + d\frac{\sqrt{Ey^2}}{\sqrt{Ex_4{}^2}} + e\frac{\sqrt{Ey^2}}{\sqrt{Ex_5{}^2}}$$

by substitution from simultaneous equation and reduction of data.

$$Fe = 411.21 - 208.75Ng + 340.55Np - 22.790 - 3.83 \operatorname{Sin} Z \wedge c - 2.05 \operatorname{Sin} 2V$$

Standard Error of Estimate:

$$\sqrt{\frac{(1 - R^2)\, Ey^2}{n - m}} \text{ by substitution } = .515$$

n = number of sample

m = number of parameters

COMMON HORNBLENDES. Simultaneous and Regression Equations for (Fe)+Al, Mg and Si in Atomic Proportions on Physical Properties.

Simultaneous Equations.

	Ng	Np	D	$Z \wedge c$	2V	Fe		(Fe)+Al	Mg	Si
Ng	+.1	+.09843	+.08259	-.03576	-.06536	+.09683	=	+.09400	-.09663	-.05559
	L									
Np	+.09843	+.1	+.09168	-.03227	-.06590	+.09469	=	+.09295	-.09492	-.05546
	L									
D	+.08259	+.09168	+.1	-.03129	-.07193	+.09210	=	+.09076	-.09417	-.05466
	L									
$Z \wedge c$	-.03576	-.03227	-.03129	+.1	+.06272	-.04970	=	-.05048	+.03996	-.106366
	L									
2V	-.06536	-.06590	-.07193	+.06272	+.1	-.06929	=	-.0658	+.06767	-.08918
	L									
Fe	+.09683	+.09469	+.09210	-.04970	-.06929	+.1	=	+.09315	-.09597	-.05166

Reduced by a factor of 10 for computer.

Solutions:

(Fe)+Al	Mg	Si
-0.8482347716	0.4602100234	4.4842276253
1.3386004537	-0.5589338585	-5.0688003215
-0.2707048741	0.1821008245	0.6462166752
-0.1453277567	-0.1455006438	0.8041386006
0.0483780172	0.1116705605	-2.9182168545
0.6959373818	-0.0387190430	-2.2765717169

Regression Equations:

$$(Fe)+Al = -45.43Ng + 78.74Np - 3.61D - 2.54(\sin Z \wedge c) + .30\sin 2V + .83(Fe) - 39.74$$

$$Mg = 21.85Ng - 27.38Np + 1.89D - 2.07\sin Z \wedge c - .56\sin 2V - 1.00Fe + 9.63$$

$$Si = 67.20Ng - 86Np + 2.3D + 3.8\sin Z \wedge c - 5.19\sin 2V - .76Fe + 21.61$$

Correlation Coefficients:

$R_{(Fe)+Al} = .939$

$R_{Mg} = .99$

$R_{Si} = .92$

Standard Error of the Estimate:

$R_{(Fe)+Al} = .538$ atoms.

$R_{Mg} = .18$ atoms.

$R_{SiO_2} = .172$ atoms.

TREMOLITE SERIES: Simultaneous and Regression Equations for (Fe) in Atomic Proportions on Physical Properties.

Simultaneous Equations:

	Ng	Np	D	Z∧c	2V		Fe
Ng	+.1	+.09141	+.05984	-.09073	-.05549	=	+.07578
	L						
Np	+.09141	+.1	+.07701	+.02300	-.06195	=	+.08651
	L						
D	+.05985	+.07701	+.1	+.01543	+.04063	=	+.08271
	L						
Z∧c	-.09073	+.023	+.01543	+.1	-.007349	=	+.01354
	L						
2V	-.05549	-.06195	+.04063	-.007349	+.1	=	+.04383

Reduced by a factor of 10 for computer.

Solutions

-0.1168195896
-0.4505201085
1.4731118539
-0.1320347089
-0.5138489746

Regression Equation:

(Fe''+Fe'''+Mn+Ti) = (Fe) = 33.860 - 6.202Ng - 22.746Np + 12.876D - 1.767(SinZ∧c) - 25.301(Sin2V).

Correlation Coefficient = .97334 (1.00 = absolute correlation).

TREMOLITE SERIES: Simultaneous and Regression Equations for Mg, Si and (Fe)+Al in Atomic Proportions on Physical Properties.

Simultaneous Equations.

	Ng	Np	D	$Z \wedge c$	2V	Fe		MgO	Si	(Fe)+Al
Ng	+.1	+.09141	+.05985	-.09073	-.05549	+.07578	=	-.07860	-.03728	+.08122
	L									
Np	+.09141	+.1	+.07701	+.0230	-.06195	+.0865	=	-.08033	-.05022	+.09102
	L									
D	+.05985	+.07701	+.1	+.01543	+.04063	+.08271	=	-.06022	-.07302	+.08684
	L									
$Z \wedge c$	-.09073	+.02300	+.01543	+.1	-.007349	+.01353	=	-.01353	-.01286	+.007383
	L									
2V	-.05549	-.06195	+.04063	-.007349	+.1	-.04383	=	+.04255	+.03847	-.04619
	L									
Fe	+.07578	+.08651	+.0827	+.01353	-.04383	+.1	=	-.09255	-.04867	+.09505

Reduced by a factor of 10 for computer.

Solutions.

Mg	Si	(Fe)+Al
0.11926625895	-0.13642164730	0.10615192772
0.12744572033	-0.80460230625	0.33127991369
-0.19301711123	0.55268364124	-0.02647826180
0.11015178921	-0.14412427155	0.01783329007
0.28097609595	-0.59328453038	0.09725838073
-0.85825982695	-0.38486418755	0.64558084246

Regression Equations:

$$Mg = 8.70Ng + 8.86Np - 2.32D + 2.03(\sin Z \wedge c) + 19.05(\sin 2V) - 1.18(Fe) - 35.12$$

$$Si = 48.93 - 3.36Ng - 18.32Np + 2.18D - 0.8\sin Z \wedge c - 13.51\sin 2V - .17Fe$$

$$(Fe)+Al = 7.19Ng + 21.40Np - .29D + .31(\sin Z \wedge c) + 61.11(\sin 2V) + .83(Fe) - 105.54$$

Correlation Coefficients.

$R_{Mg} = .905$

R_{Si} = not significant

$R_{(Fe)+Al} = .967$

Standard Error of the Estimate.

$S.E._{Mg} = .339$ atoms.

$S.E._{(Fe)+Al} = .187$ atoms.

TREMOLITE SERIES: Simultaneous and Regression Equations for (Mg) and Na+K in Atomic Proportions on Physical Properties.

Simultaneous Equations.

	Sin2V	$SinZ_{\wedge}c$	Fe		(Mg)	Na+K
Sin 2V	+.1	-.007349	+.01358	=	-.01323	-.03504
	L					
$SinZ_{\wedge}c$	-.007349	+.1	-.04383	=	+.04074	-.01974
	L					
Fe	+.01353	-.04383	+.1	=	-.09176	-.02376

Reduced by a factor of 10 for computer.

Solutions given by computer.

(Mg)	Na+K
-0.00782231126	-0.32948234355
0.00664434058	-0.37902882815
-0.91302942682	-0.35914937426

Regression Equations:

(Mg+Ca+Na+K) = (Mg) = .48(Sin2V) - .15($SinZ_{\wedge}c$) - 1.34Fe * 7.54

(Na+K) = not significant

Correlation Coefficients:-

$R_{(Mg)}$ = .91619 (correlation is almost wholly with (Fe) see above equation)

$R_{(Na+K)}$ = not significant

Standard Error of the Estimate.

$S.E._{Mg}$ = .316 atoms

HORNBLENDE SERIES: Simultaneous and Regression Equations for (Fe) in Atomic Proportions on Physical Properties.

Simultaneous Equations:

	Ng	Np	D	$Z_{\wedge}c$	2V		(Fe)
Ng	+.1	+.09844	+.08674	-.01893	-.06652	=	+.09598
	L						
Np	+.09844	+.1	+.09310	-.01330	-.06534	=	+.96554
	L						
D	+.08674	+.09310	+.1	-.01429	-.07031	=	+.09316
	L						
$Z_{\wedge}c$	-.01893	-.01330	- .01429	+.1	+.03808	=	-.02515
	L						
2V	-.06652	-.06534	-.07031	+.03808	+.1	=	-.06777

Reduced by a factor of 10 for computer.

Solutions:

9.132493992
11.675324974
4.413976915
0.247174916
0.844567427

Regression Equation:

$$(Fe''' + Fe'' + Mn + Ti) = (Fe) = 397.25Ng - 498.90Np + 44.19D + 4.07 (\sin Z_{\wedge}c) + 5.03 (\sin 2V) + 14.48.$$

Correlation Coefficient:

$$R_{(Fe)} = .894$$

Standard Error of the Estimate:

$$S.E._{Fe} = .538 \text{ atoms.}$$

HORNBLENDE SERIES: Simultaneous and Regression Equations for (Fe)+Al in Atomic Proportions on Physical Properties.

Simultaneous Equations.

	Ng	Np	D	Sin $Z_\wedge c$	2V	Fe		(Fe)+Al
Ng	+.1	+.09844	+.08674	-.01893	-.06625	+.09598	=	+.09430
	L							
Np	+.09844	+.1	+.09310	-.01330	-.06534	+.09414	=	+.09542
	L							
D	+.08674	+.09310	+.1	-.01429	-.07031	+.09316	=	+.09160
	L							
$Z_\wedge c$	-.01893	-.01330	-.01429	+.1	+.03808	-.02515	=	-.02002
	L							
2V	-.06652	-.06534	-.07031	+.03808	+.1	-.06777	=	r.06208
	L							
Fe	+.09598	+.09414	+.09316	-.02515	-.06777	+.1	=	+.09157
	LL							

Reduced by a factor of 10 for computer.

Solutions:

-0.6491581247
1.4280526135
-0.1650874380
-0.0810818564
0.0322167856

0.3496299236

Regression Equations:

$$(Fe)+Al = -44.08Ng + 96.10Np - 25.79D - 2.06\ (\sin Z_\wedge c)$$
$$+ .30\ (\sin 2V) + .55Fe - .50$$

Correlation Coefficient:

$$R_{(Fe)+Al} = .96$$

Standard Error of the Estimate.

$$S.E._{Fe} = .538 \text{ atoms.}$$

APPENDIX 3

X-RAY POWDER DATA.

1. The three strongest lines of each pattern are indicated by the superscripts 1, 2, 3 against the abbreviations for intensity.

2. 'd' spacings in Ångstrom units were obtained using the tables of Parrish and Irwin (1953) in which the Bragg values for the wavelengths are used.

3. All the patterns were obtained with Fe filtered Co. radiation by the method of Straumanis in an 11.4 cm. diameter camera. The exception is the Dilma pit chrome tremolite (Dunham and others 1958) which was obtained with Ni filtered Cu radiation in a 9cm. camera by the Van Arkel method.

NOTE. 'd' spacing at 3.12Å approximately is very similar in intensity to Line at 2.54Å. By visual methods it is often difficult to estimate whish is the stronger.

B.L. 1396		B.L. 931		B.L. 733	
d.	I	d.	I	d.	I
9.08	M	9.05	W	9.06	W
8.48	S [1]	8.45	S [1]	8.47	S [1]
5.11	W	4.93	W	5.12	VVW
5.10	M			5.05	MW
4.53	M	4.53	W	4.53	MW
4.23	VW	4.25	VVW	4.22	VVW
3.98	VVW	4.06	VVW	4.03	VVW
3.88	M-W	3.90	W	3.90	W
3.39	MS	3.40	MS	3.40	M
3.28	M	3.29	M	3.28	M
3.12	M-S	3.13	S	3.12	S
2.95	M	2.95	M	2.95	S
2.80	W	2.82	W	2.81	W
2.71	S [2]	2.71	S [2]	2.73	S [2]
2.59	M	2.60	MS	2.60	MS
2.543	S [3]	2.560	S [3]	2.556	S [3]
2.382	VVW	2.392	VW		
2.340	M	2.347	M	2.344	M
2.280	W	2.300	MW	2.295	M-W
2.214	VVW	2.231	VW	2.225	VVW
2.161	M	2.170	M	2.164	M
2.045	MW	2.055	W	2.052	W

2.017	MW	2.030	MW	2.026	M
1.968	VVW				
1.936	VVW				
1.888	VVW			1.888	VVW
1.867	MW	1.875	VW	1.873	W
1.846	VVW	1.858	VVW	1.852	VVW
1.811	VVW	1.816	VW	1.814	W
1.748	VVW	1.764	VW	1.748	VW
1.718	VVW	1.702	VW		
1.689	MW	1.688	VW	1.692	MW
1.651	M	1.656	M	1.654	M
1.635	VW			1.640	VW
1.621	W	1.623	W	1.620	W
1.582	M	1.585	M	1.590	SM
1.559	VW	1.564	VW	1.560	VW
1.535	VW	1.546	W	1.542	VW
1.519	M	1.529	MW	1.525	M
1.506	W	1.510	W	1.507	W
1.474	VVW	1.479	VW	1.476	W
1.448	VVW	1.462	VW	1.460	W
1.439	M	1.445	S	1.441	S
1.366	MW	1.373	M	1.370	M
1.342	VW	1.344	M	1.352	M
1.197	W	1.204	W	1.200	W
1.164	VVW	1.168	W	1.163	VW
1.148	VVW	1.154	VW	1.151	VW
1.123	VVW	1.140	W	1.121	VVW

1.113	VVW	1.118	VVW	1.099	VVW
1.078	W	1.083	W	1.080	W
1.051	W	1.054	W	1.052	W
1.046	W	1.049	W	1.047	W
1.029	W	1.031	W	1.029	W
1.024	W	1.016	VVW	1.020	VVW
.984	VW	1.004	VVW	1.004	VVW
.977	VW	.99	W	.99	W
.976	VW	.983	W	.981	W
.969	VVW	.953	VVW	.973	VVW
.950	VW	.937	VVW	.951	VW
.922	VW	.919	VW	.934	VVW
.921	VW	.913	W	.924	VVW
.911	W	.911	VVW	.915	W
.909	VW			.913	VW
.901	VVW			.911	VVW
				.909	VVW
				.904	VVW
				.902	VVW

B. L. 1798		B. L. 1951		B. L. 830	
d.	I	d.	I.	d.	I.
9.06	M	9.05	M	9.01	W
8.42	S [1]	8.42	S [1]	8.43	S [1]
5.10	VW	5.07	VW	4.91	VW
4.91	MW	4.90	MW	4.14	VW
4.51	MW	4.52	MW	4.52	MW
4.21	VW	4.20	VW	4.22	VVW
3.98	VVW				
3.88	MW	3.90	V	3.90	VW
3.33	MS	3.37	MS	3.38	MS
3.27	M	3.27	M	3.27	M
3.10	MS	3.12	S [2]	3.13	S
2.94	M	2.95	M	2.95	M
2.80	W	2.80	VW	2.82	W
2.71	S [2]	2.70	S [3]	2.68	S [2]
2.60	M	2.60	M	2.60	M. S
2.546	MS [3]	2.553	M. S	2.555	S [3]
2.384	VVW	2.378	VVW		
2.341	M	2.342	M	2.342	M
2.290	W	2.291	W	2.295	M. W
2.217	VVW	2.232	VW	2.223	VW
2.162	M	2.166	M	2.166	M
2.045	W	2.050	W	2.053	W
1.199	VW	1.198	VW	1.199	W
1.161	VVW	1.163	VW	1.166	VW

1.148	VVW	1.149	VW	1.148	VW
1.124	VVW				
1.107	VVW			1.111	VVW
1.079	W	1.065	VW	1.080	VW
		1.051	W	1.050	VVW
1.048	W	1.046	VVW	1.046	VVW
1.030	VW	1.027	W	1.028	W
1.026	VW			1.019	VVW
1.006	VVW	.987	W	1.001	VVW
.986	W	.980	VW	.990	VW
.980	VW			.986	VW
.979	VW			.981	VW
.973	VW	.950	VVW	.978	VW
.951	VVW			.951	VW
.933	VVW	.933	VVW	.922	VW
.921	VVW	.921	VVW	.921	VVW
.913	VVW	.914	VVW	.914	VVW
.911	MW	.912	VVW	.913	VW
.909	VVW	.910	VVW	.910	VW
.902	VVW				

LY 313		LY 109		LY 486	
d.	I	d.	I	d.	I
9.00	MW	9.16	M	8.95	MW
8.45	S [1]	8.45	S [1]	8.40	S [1]
5.70	VW	5.12	W	5.09	W
4.91	W	4.84	MW	4.87	MW
4.53	MW	4.63	MW	4.51	MW
4.27	VVW	4.37	W	4.21	W
4.03	VW	4.06	MW	4.01	VW
3.90	W	3.53	VW	3.88	MW
3.39	MS	3.40	MS	3.38	MS
3.28	M	3.28	M	3.28	MW
3.11	MS	3.12	MS	3.12	S [2]
2.95	MW	2.95	M	2.94	MW
2.80	VW	2.81	VW	2.80	VW
2.71	MS [2]	2.71	S [2]	2.71	S [3]
2.60	MS	2.60	M	2.60	M
2.550	S [3]	2.540	S [3]	2.538	S
2.383	VVW	2.382	VVW	-	-
2.333	M	2.340	MW	2.364	M
2.288	MW	2.281	W	2.278	W
		2.213	VW	2.212	VW
2.164	M	2.162	M	2.162	MW
2.049	MW	2.045	MW	2.043	W
2.019	M	2.016	MW	2.015	MW
1.971	VVW	1.952	VVW	1.967	VVW
1.938	VVW	1.933	VVW	1.936	VVW

1.890	VVW	1.889	VVW	1.894	VVW
1.869	VW	1.865	W	1.868	VW
1.847	VVW	1.845	VW	1.845	VW
1.811	W	1.810	VVW	1.815	VW
1.750	W	1.749	VVW	1.751	VW
1.695	W	1.685	W	1.689	W
1.680	W			1.677	VVW
1.652	MW	1.650	MW	1.652	MW
1.621	W	1.617	W	1.621	W
1.587	MW	1.581	M	1.584	MW
1.560	VW	1.562	VVW	1.500	VVW
1.538	VW	1.538	VW	1.538	VVW
1.523	MW	1.516	W	1.518	MW
1.508	VW	1.504	W	1.507	W
1.477	VW	1.472	VVW	1.472	VW
1.459	VW	1.454	VVW	1.456	VW
1.441	M	1.438	M	1.443	M
1.369	MW	1.363	MW	1.368	MW
1.342	W			1.345	W
1.199	W	1.195	MW	1.199	MW
1.163	VW	1.159	VW	1.161	VW
1.149	VVW	1.133	VVW	1.147	VVW
				1.124	VVW
1.115	VVW	1.110	VW	1.110	VVW
1.079	W	1.074	VW		

1.050	VW	1.049	VW		
1.046	VW	1.045	VW		
1.030	VW	1.030	VVW		
1.014	W	1.022	VW		
1.009	WW	1.005	VVW		
.986	M	.983	VW		
.980	W	.980	VW	.979	VVW
.977	VW	.974	VW	.975	VVW
.969	VVW				
.951	VW			.950	VVW
.933	VVW	.936	VVW	.934	VVW
.930	VVW	.931	VVW	.932	VVW
.912	VVW	.919	VVW	.930	VVW
		.909	M	.910	M
		.907	VW		
.904	VVW			.900	VW
.901	VVW	.901	VW		

LY	484	LY	485	LY	20
d.	I.	d.	I.	d.	I.
9.10	MW	9.07	M	9.03	M
8.34	S [1]	8.40	S [1]	8.44	S [1]
5.08	VW	5.08	W	5.08	VW
4.88	W	4.89	MW	4.89	VW
4.50	W	4.44	MW	4.53	MW
4.22	VVW	4.22	W	4.23	VVW
		4.00	VVW	4.01	VVW
3.87	W	3.87	MW	3.89	MW
3.38	M	3.38	MS	3.39	M
3.27	M	3.28	M	3.28	MW
3.12	MS	3.12	S [2]	3.13	MS
2.94	M	2.94	MS	2.94	MW
2.80	VW	2.81	VW	2.88	VVW
2.71	S [2]	2.70	S [3]	2.71	S [2]
2.59	M	2.62	M	2.60	M
2.535	S [3]	2.540	MS	2.541	S [3]
2.377	VVW	2.374	VVW	2.383	VVW
2.333	MW	2.367	M	2.343	MW
2.276	VW	2.282	W	2.285	VW
2.210	VW	2.213	VVW	2.261	VVW
2.161	M	2.162	M	2.163	MW
2.042	WM	2.041	MW	2.098	W
2.014	MW	2.015	MW	2.016	W
1.970	VVW	1.969	VVW	1.955	VVW
1.932	VVW	1.927	VVW	1.916	VVW

		1.890	VVW	1.890	VVW
1.865	W	1.865	VW	1.867	W
1.841	VVW	1.840	VVW	1.843	VVW
1.813	VVW	1.811	VVW	1.815	VVW
1.748	VVW	1.748	VVW	1.779	VVW
1.688	W	1.687	W	1.690	W
1.648	MW	1.650	MW	1.654	MW
1.636	VVW	1.633	VVW		
1.617	W	1.618	W	1.621	W
1.580	MW	1.581	MW	1.584	M
1.558	VW	1.559	VVW	1.562	VVW
1.534	VW	1.534	VW	1.540	VW
1.514	MW	1.518	W	1.521	MW
1.504	MW	1.505	W	1.508	VVW
1.469	VVW	1.472	VVW	1.481	VVW
1.455	VVW	1.455	VVW	1.464	VVW
1.438	M	1.441	MS	1.441	M
1.364	MW	1.365	M	1.367	MW
		1.343	W	1.343	W
1.195	MW	1.197	MW	1.200	MW
1.159	W	1.159	VW	1.161	MW
1.146	VVW	1.149	VVW		
1.124	VVW	1.123	VW		
1.110	VVW	1.111	VVW		
1.088	VVW	1.078	VW	1.079	VW

1.05	VVW	1.050	W	1.051	VW
1.046	WM	1.047	WM	1.047	VW
1.031	VVW	1.031	VW	1.031	VW
1.021	VVW	1.028	VVW	1.028	VW
		.986	VW	.985	VVW
.983	W	.980	VVW	.981	VVW
.98	W	.978	VVW	.979	VVW
.974	VVW	.976	VVW	.976	VVW
.968	VVW	.954	VVW	.950	VVW
.950	VVW	.952	VVW		
.934	W	.934	VVW	.933	VVW
.929	VVW	.930	VVW		
.920	VVW	.920	VVW	.920	VVW
.910	M	.910	VVW	.911	M
		.909	VVW	.909	VVW
		.902	VVW		
.90	VVW	.90	VVW		

LY 550		LY 534		Dilma Pit B.	
d.	I.	d.	I.	d.	I.
9.16	MW	9.11	W		
8.39	S [1]	8.34	S [1]	8.44	S [1]
5.04	W				
4.87	W	4.86	W	4.90	S
4.51	W	4.46	W	4.54	S
4.21	W	4.25	VW	4.16	W
4.00	VW				
3.87	W	3.89	W	3.88	S
3.38	MS	3.38	M	3.36	M
3.26	M	3.24	W	3.26	W
3.12	MS	3.10	M-S	3.09	M
2.93	M	2.94	M	2.92	M
2.80	VVW	2.78	VVW		
2.70	S [2]	2.70	S [2]	2.70	S [2]
2.59	MS	2.58	M	2.60	W
2.534	S [3]	2.538	S [3]	2.53	S [3]
2.383	VW				
2.333	M	2.331	M	2.31	M
2.292	MW	2.283	MW		
2.254	MW	2.257	VVW		
2.187	VW	2.158	M	2.16	W
2.071	W	2.042	MW		
2.024	MW	2.012	MW	2.01	W
1.992	VVW	1.966	VVW		
1.951	VVW	1.928	VVW		

1.911	VVW	1.883	VVW		
1.862	MW	1.861	W	1.86	VW
1.844	VVW	1.844	VVW		
1.810	VVW	1.809	MW	1.805	W
1.746	VVW	1.741	VVW		
1.707	VVW	1.718	VVW		
1.686	W			1.681	W
1.647	MW	1.746	MW	1.642	W
1.633	VW				
1.615	MW	1.612	W	1.612	W
1.580	M	1.585	M		
1.556	VW	1.557	VVW		
1.534	VW	1.535	VW		
1.518	MW	1.516	M		
1.503	VW	1.500	VW	1.507	M
1.470	VVW	1.473	VVW		
1.452	VVW	1.454	VVW		
1.438	M	1.436	M	1.432	W
1.364	MW	1.364	M	1.360	VW
		1.345	M		
		1.198	MW	1.197	VW
1.155	W	1.163	VVW		
1.141	VVW	1.148	VVW		
1.119	VW	1.115	VVW		
1.108	VW	1.101	VVW		
1.074	W	1.079	W		

1.059	VW	1.061	VVW		
1.048	MW	1.044	W	1.046	VW
1.029	VW	1.028	MW	1.027	VW
1.024	VW	1.017	VVW		
.985	W	.988	VW		
.978	W	.985	VW	.979	W
.974	VVW	.977	VVW		
.949	VVW	.948	VW		
.920	VVW	.928	VVW		
		.920	VVW		
.910	MS	.913	VVW		
.909	VVW	.912	M	.908	W
.904	VVW	.910	VVW		
		.901	VVW		

TABLE 17

ANALYSES OF GHANA AMPHIBOLES

AND

ANALYSES OF AMPHIBOLES FROM DR. B. LEAKE.

No.	LY542	LY109	LY484	LY313	LY308	LY20	LY485	LY534
SiO_2	47.60	51.10	53.2	47.50	45.90	51.00	52.20	51.40
Al_2O_3	17.78	4.7	2.7	9.00	13.39	5.02	4.51	4.10
TiO_2	.68	0.30	0.10	0.43	0.82	0.29	0.23	3.21
Fe_2O_3	.87	1.80	0.86	2.00	1.50	2.66	2.42	1.18
FeO	8.65	6.80	5.26	10.50	11.50	8.74	6.80	7.10
MnO	.18	0.11	0.10	0.19	0.29	0.20	0.11	0.25
MgO	7.70	18.70	22.00	14.00	8.60	17.20	17.50	18.30
CaO	12.18	12.49	12.76	12.54	14.59	13.06	13.25	12.70
Na_2O	2.06	1.20	0.65	1.36	1.45	0.94	0.91	0.90
K_2O	.93	0.12	0.34	1.07	0.36	0.40	0.37	0.40
H_2O^+	.45	2.03	1.53	0.91	1.71	0.65	1.28	0.54
H_2O^-	.26	-	-	-	-	-	-	
P_2O_5	-	-	-	-	-	-	-	
Total	99.34	99.35	99.50	99.50	100.11	100.16	99.58	100.08

Analyst
W. Layton

TABLE 17

ANALYSES OF GHANA AMPHIBOLES

AND

ANALYSES OF AMPHIBOLES FROM DR. B. LEAKE.

(cont.)

No.	LY486	LY550	931	1798	1396	1951	830	733
SiO_2	52.10	53.2	42.85	48.80	50.31	44.05	43.53	43.61
Al_2O_3	4.35	2.4	12.59	7.30	5.89	10.05	12.23	12.03
TiO_2	0.29	0.57	1.57	0.50	0.43	1.48	1.27	1.49
Fe_2O_3	1.51	1.29	1.14	3.39	2.48	4.83	4.56	as Fe_2O_3 15.95
FeO	6.10	6.70	13.36	7.88	9.25	9.43	10.28	
MnO	0.13	0.12	0.44	0.23	0.25	0.23	0.36	0.46
MgO	19.50	20.20	10.42	16.20	16.70	13.75	12.35	12.71
CaO	12.51	12.21	11.66	11.75	11.04	11.45	11.26	10.91
Na_2O	0.82	0.90	1.88	1.14	0.91	1.85	1.21	1.26
K_2O	0.61	0.48	1.33	0.75	0.23	0.90	0.75	0.90
H_2O^+	1.24	1.51	2.31	2.12	2.16	2.08	2.27	2.04
H_2O^-			-	-	-			
P_2O_5			0.03	0.02	0.01	0.22	0.05	0.10
Total		99.58	99.52	100.08	99.93	100.32	100.12	101.46

Analyst
B. Leake.

TABLE 17

ANALYSES OF GHANA AMPHIBOLES AND AMPHIBOLES FROM LEAKE.

RECALCULATED ON BASIS 24 (O,OH,F).

No.	542	109	484	313	308	20	485	534
Si	6.91	7.30	7.50	7.10	6.77	7.48	7.50	7.40
$Al^{(4)}$	1.09	0.70	.44	0.90	1.23	0.52	0.5	0.60
$Al^{(6)}$	1.99	0.08	-	0.68	1.09	0.33	0.26	0.13
Ti	0.07	0.06	0.08	0.04	0.01	0.03	0.02	0.35
Fe'''	0.08	0.20	0.08	0.17	0.16	0.29	0.26	0.12
Fe''	1.06	0.80	0.65	1.25	1.41	0.77	0.82	0.85
Mn	0.01	0.02	0.01	0.02	0.03	0.03	0.01	0.02
Mg	1.69	3.96	4.65	3.12	1.89	3.80	3.80	3.95
Ca	1.90	1.90	1.90	1.97	2.30	2.07	2.06	1.94
Na	0.68	0.32	0.23	0.34	0.48	0.26	0.26	0.28
K	0.16	0.08	0.05	0.02	0.05	0.01	0.05	0.06
(OH)	0.24	1.92	1.52	0.91	1.60	0.63	1.2	0.52

TABLE 17

ANALYSES OF GHANA AMPHIBOLES AND AMPHIBOLES FROM LEAKE.

RECALCULATED ON BASIS 24 (O,OH,F).

(cont.)

No.	486	550	931	1798	1396	1951	830
Si	7.50	7.55	6.39	7.00	7.22	6.35	6.32
Al$^{(4)}$	0.50	0.39	1.61	1.00	0.78	1.65	1.68
Al$^{(6)}$	0.22		0.58	0.24	0.21	0.05	0.40
Ti	0.04	0.06	0.17	0.05	0.04	0.02	0.15
Fe'''	0.07	0.07	0.06	0.36	0.26	0.32	0.50
Fe''	0.73	0.80	1.65	0.94	1.12	1.13	1.24
Mn	0.02	0.02	0.05	0.03	0.02	0.05	0.04
Mg	4.20	4.25	2.33	3.49	3.61	2.96	2.72
Ca	1.93	1.84	1.86	1.81	1.72	1.78	1.75
Na	0.23	0.12	0.54	0.33	0.24	0.50	0.32
K	0.05	0.04	0.26	0.14	0.04	0.15	0.14
(OH)	1.19	1.48	2.32	1.96	2.08	1.99	2.4

TABLE 17

PHYSICAL PROPERTIES OF GHANA AMPHIBOLES.

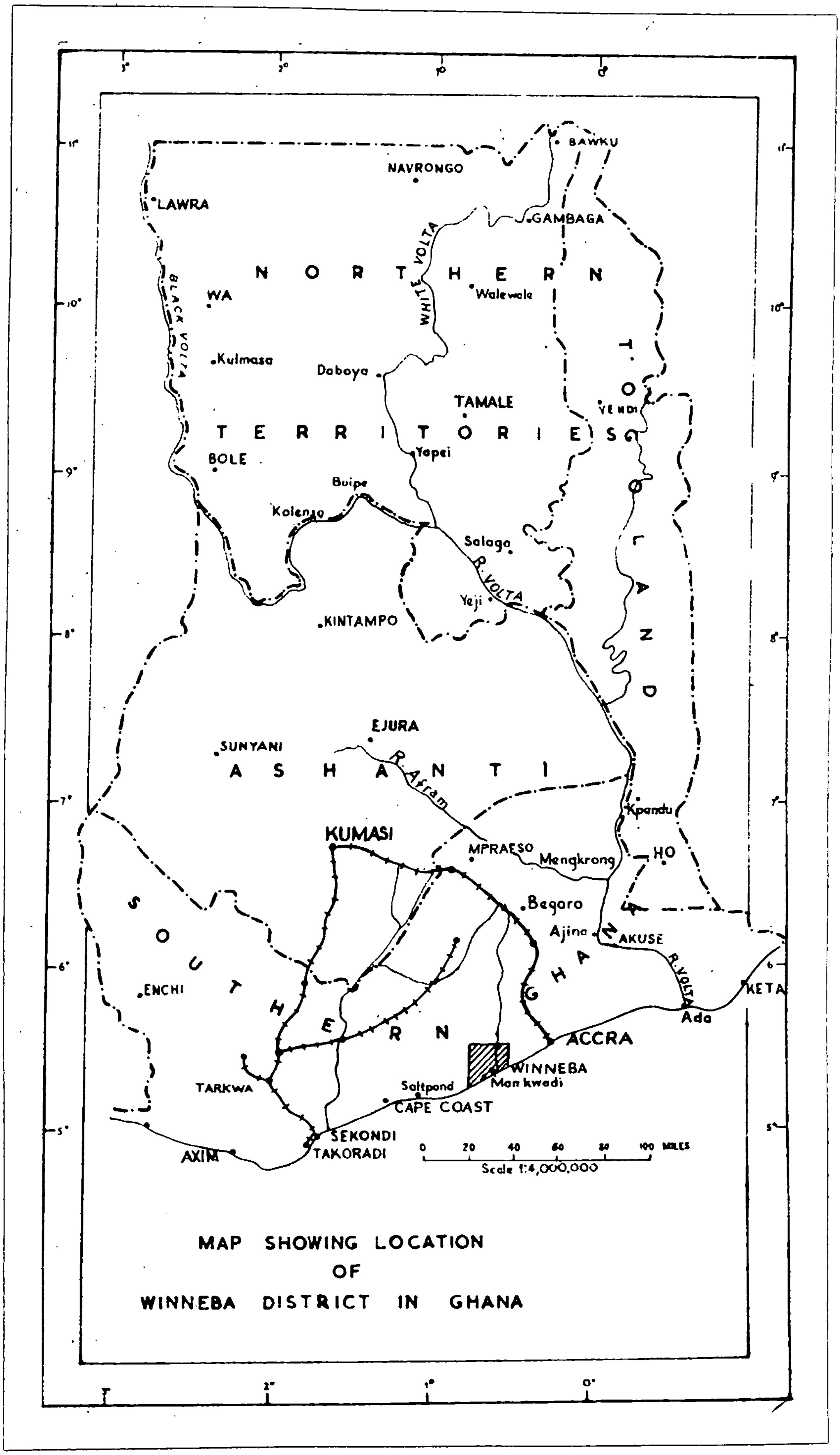
No.	542	109	484	313	308	20
Ng	1.670	1.633	1.640	1.670	1.665	1.652
Nm	1.660	1.620	1.628	1.661	1.654	1.642
Np	1.656	1.615	1.623	1.656	1.649	1.6330
2V meas.	65	86	74	89	66	88
2V calc.	65.8	84.8	68	72	68.8	86
Ng-Np	.014	.018	.017	.015	.016	.019
$Z_\wedge c$	15°	12°	15°	15°-17°	15°	16°
S.G.	3.15	2.90	3.03	3.15	3.10	3.10
X	yellow	colourless	colour-less	yellowish	very pale yellow	yellow
Y	green	very pale green	pale yellowish green	green	green	pea green
Z	blue-green	pale bluish	v.p. bluish green	dark bluish green	blue-green	brilliant sea green

TABLE 17

PHYSICAL PROPERTIES OF GHANA AMPHIBOLES.

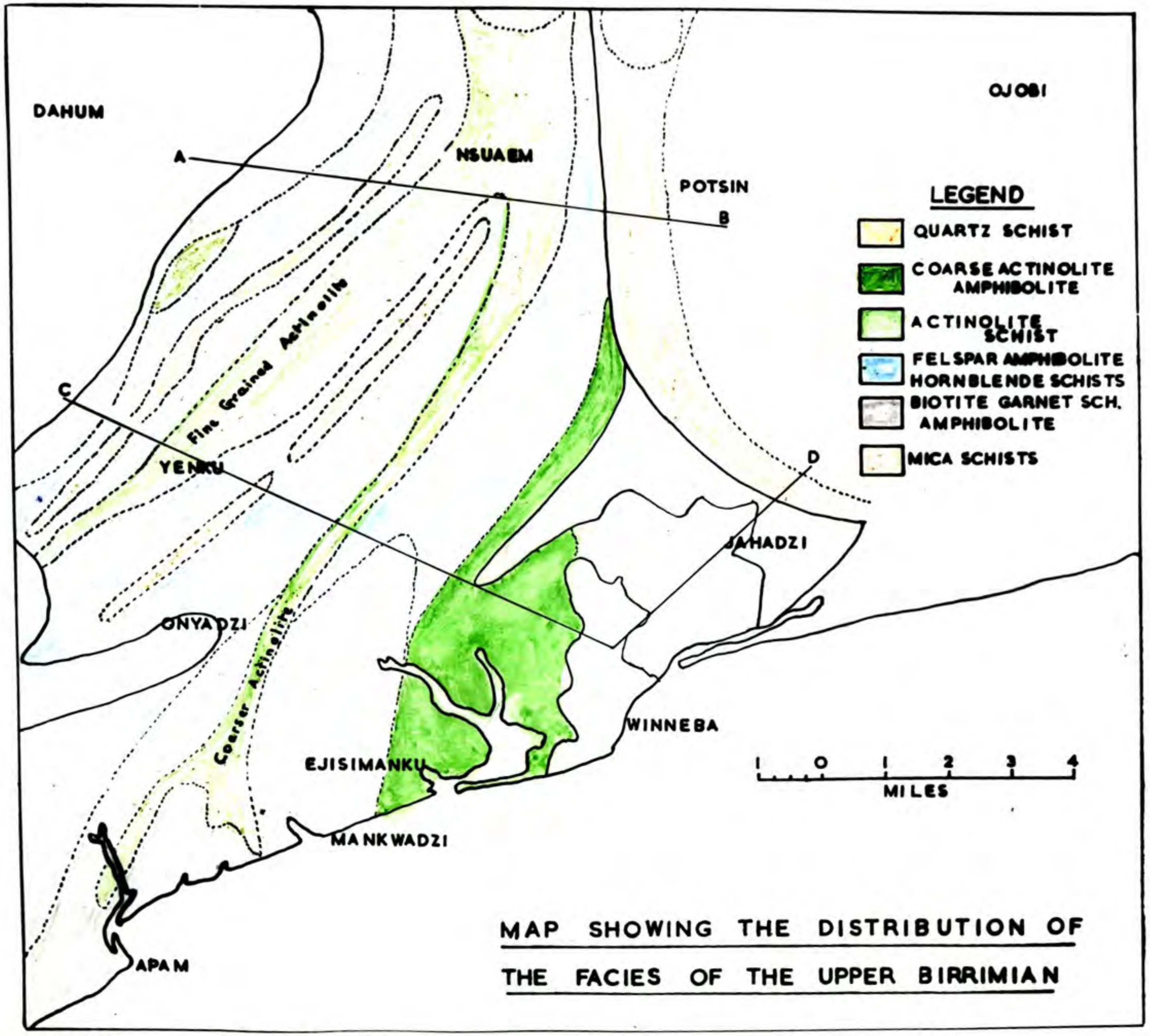
(cont.)

No.	485	534	486	550
Ng	1.634	1.672	1.645	1.645
Nm	1.620	1.662	1.632	1.636
Np	1.622	1.6560	1.622	1.629
2V meas.	78	69	79	72.5
2V calc.	88	73.8	81.5	70.4
Ng-Np	.012	.016	.023	.016
$Z \wedge c$	25°-27°	15°	10°-15°	21°-26°
S.G.	3.11	3.22	3.11	3.11
X	colourless	pale yellow	pale yellow	pale yellow
Y	v. pale	green	pale green	pale green
Z	pale bluish green	blue green	pale bluish	bluish green



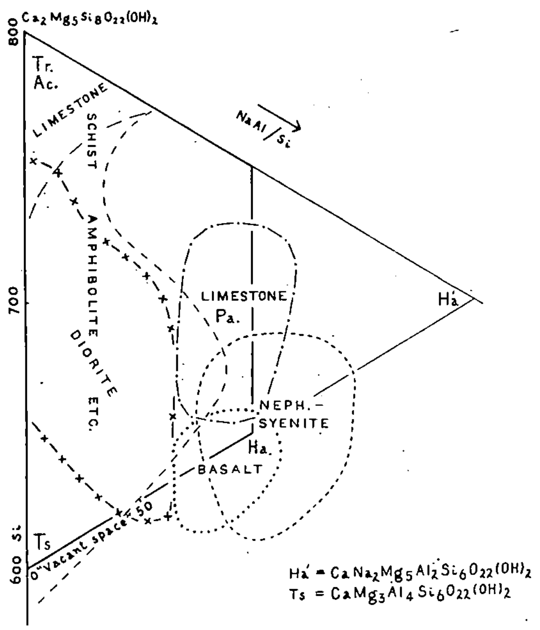
NORTHERN TERRITORIES
TOGOLAND
ASHANTI
SOUTHERN GHANA
BAWKU
NAVRONGO
LAWRA
GAMBAGA
WHITE VOLTA
BLACK VOLTA
WA
Walewale
Kulmasa
Daboya
TAMALE
YENDI
BOLE
Yapei
Buipe
Kolenso
Salaga
R. VOLTA
Yeji
KINTAMPO
EJURA
SUNYANI
R. Afram
KUMASI
MPRAESO
Mengkrong
Kpandu
HO
Begoro
Ajina
AKUSE
ENCHI
KETA
Ada
ACCRA
WINNEBA
Mankwadi
Saltpond
CAPE COAST
TARKWA
SEKONDI
TAKORADI
AXIM
0 20 40 60 80 100 MILES
Scale 1:4,000,000
MAP SHOWING LOCATION OF WINNEBA DISTRICT IN GHANA

FIG. 77



MAP SHOWING THE DISTRIBUTION OF THE FACIES OF THE UPPER BIRRIMIAN

FIG. 78



Approximate limits of composition of amphiboles derived from various rocks.

FIG. 79.

TABLE 18a

ANALYSES OF BIRRIMIAN ROCKS, PARENTS FOR ANALYSED AMPHIBOLES.

Analyst W. Layton.

	LYR485	LYR313	LYR484	LYR550	LYR109	LYR308
SiO_2	52.30	49.01	54.0	50.0	47.80	48.10
Al_2O_3	5.43	14.20	6.49	9.0	7.84	15.55
TiO_2	.52	.82	.65	.80	.54	1.01
Fe_2O_3	1.67	.09	1.29	2.41	1.37	.62
FeO	5.04	10.70	4.40	5.70	6.8	11.65
MnO	.17	.14	.13	.04	.23	.55
MgO	15.79	6.45	14.99	11.50	20.70	7.09
CaO	15.45	13.70	13.99	16.40	12.25	11.19
Na_2O	1.38	2.05	1.65	.96	.64	1.52
K_2O	.602	1.53	1.09	.42	.12	.48
H_2O^+	.75	1.32	.76	2.87	2.17	2.18
H_2O^-	-	-	-	-	-	-
P_2O_5	-	-	-	.15	-	-
TOTAL	99.10	100.1	99.44	100.25	100.46	99.94

TABLE 18b

ANALYSES OF BIRRIMIAN ROCKS, PARENTS FOR ANALYSED AMPHIBOLES.

Analyst W. Layton.

	LYR534	LYR542	LYR20	LYR486	LYR734
SiO_2	50.50	49.50	52.90	60.50	59.10
Al_2O_3	12.15	16.05	9.05	11.57	16.55
TiO_2	.96	.71	.72	.06	.11
Fe_2O_3	.95	1.95	1.96	.31	.45
FeO	10.25	6.80	5.54	3.84	4.40
MnO	.23	.09	.14	.14	.08
MgO	5.06	4.86	9.30	7.79	1.62
CaO	15.75	13.99	14.48	10.39	10.05
Na_2O	1.82	2.54	2.19	1.93	2.86
K_2O	.72	.84	2.28	3.25	4.1
H_2O^+	2.1	1.66	1.28	.51	.94
H_2O^-	-	-	-	-	-
P_2O_5	-	-	-	-	-
TOTAL	100.49	98.99	99.84	100.29	100.26

TABLE 18c

		A	B	C	D
	SiO_2	43.54	71.05	66.19	56.89
	Al_2O_3	8.70	16.51	17.74	9.61
	CaO	5.12	3.36	2.84	4.72
	MgO	21.80	0.91	0.98	2.92
	MnO	0.39	0.05	0.03	11.05
	BaO	0.02	0.05	0.17	0.03
	TiO_2	0.44	0.33	0.57	0.50
Total	H_2O	5.39	0.42	-	1.60
	K_2O	0.08	1.20	4.06	-
	Na_2O	1.48	4.54	4.42	.32
	Fe_2O_3	3.36	0.96	1.04	5.43
	FeO	10.27	1.58	2.37	7.54
	Totals	100.59	100.96	100.41	100.16

Analyst L. A. Cook.

A - Actinolite Amphibolite LY 942

B - Eastern Migmatite gneiss LY 943

C - Winneba Granite LY 941

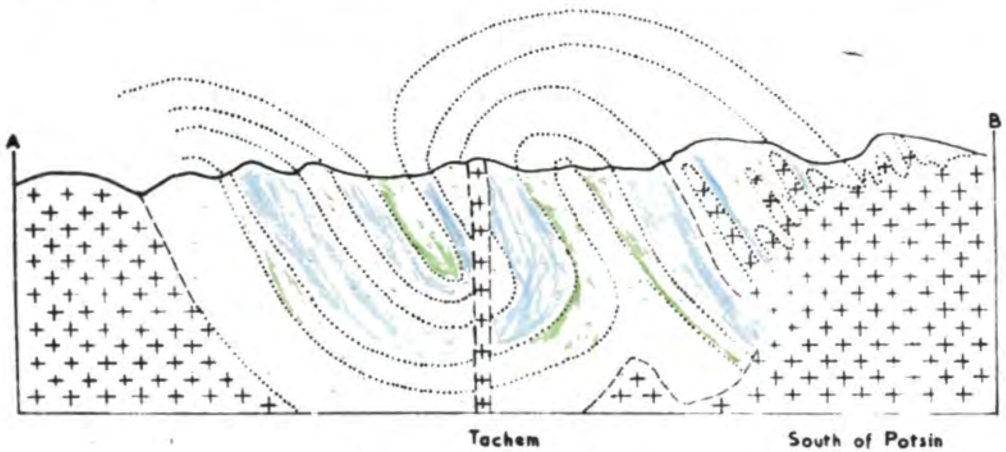
D - Gondite LY 936

TABLE 19

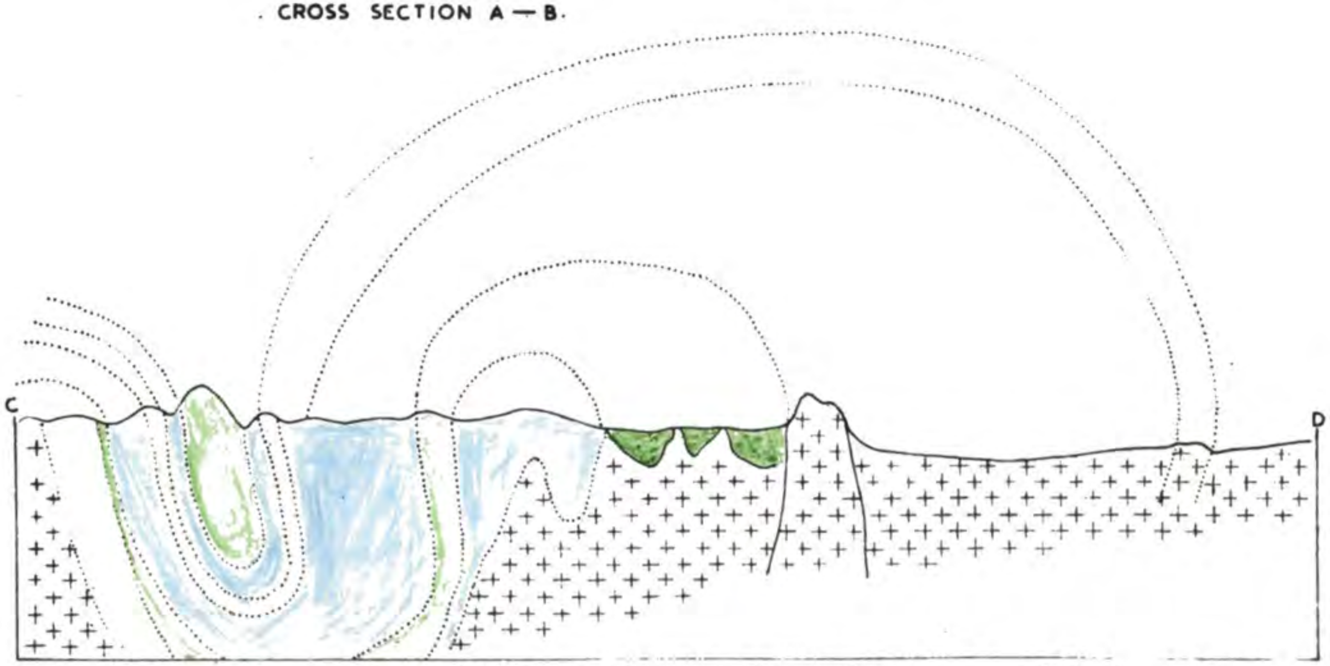
Analyses of Basalts for Comparison with Birrimian Greenstones and Actinolite Schists.

Type	Al_2O_3	MgO	SiO_2
Deccan trap basalt	13.58	5.46	50.61
Limestone	.81	7.90	-
Kimberlite	4.6	28.6	35.4
Melilite basalt	10.2	20.0	30.5
Hawaiian	17.33	.16	61.69
Hawaiian Olivine basalts	13.18	9.72	48.35

SEMI DIAGRAMATIC SECTIONS ACROSS THE BIRRIMIAN SERIES SHOWING THE RELATIONSHIP BETWEEN THE VARIOUS QUARTZ SCHIST BANDS.



CROSS SECTION A — B.



CROSS SECTION C — D

FIG. 79a.

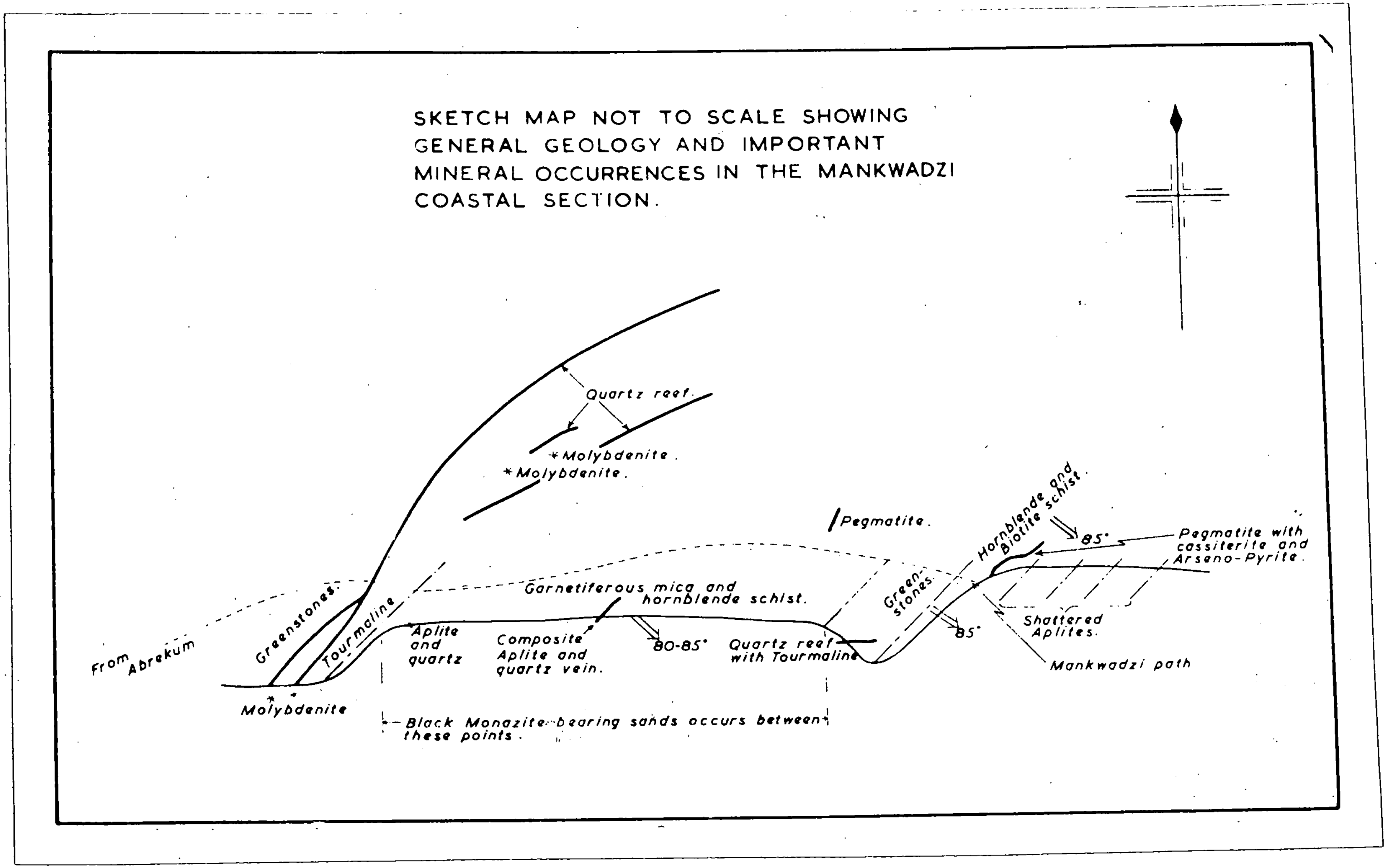
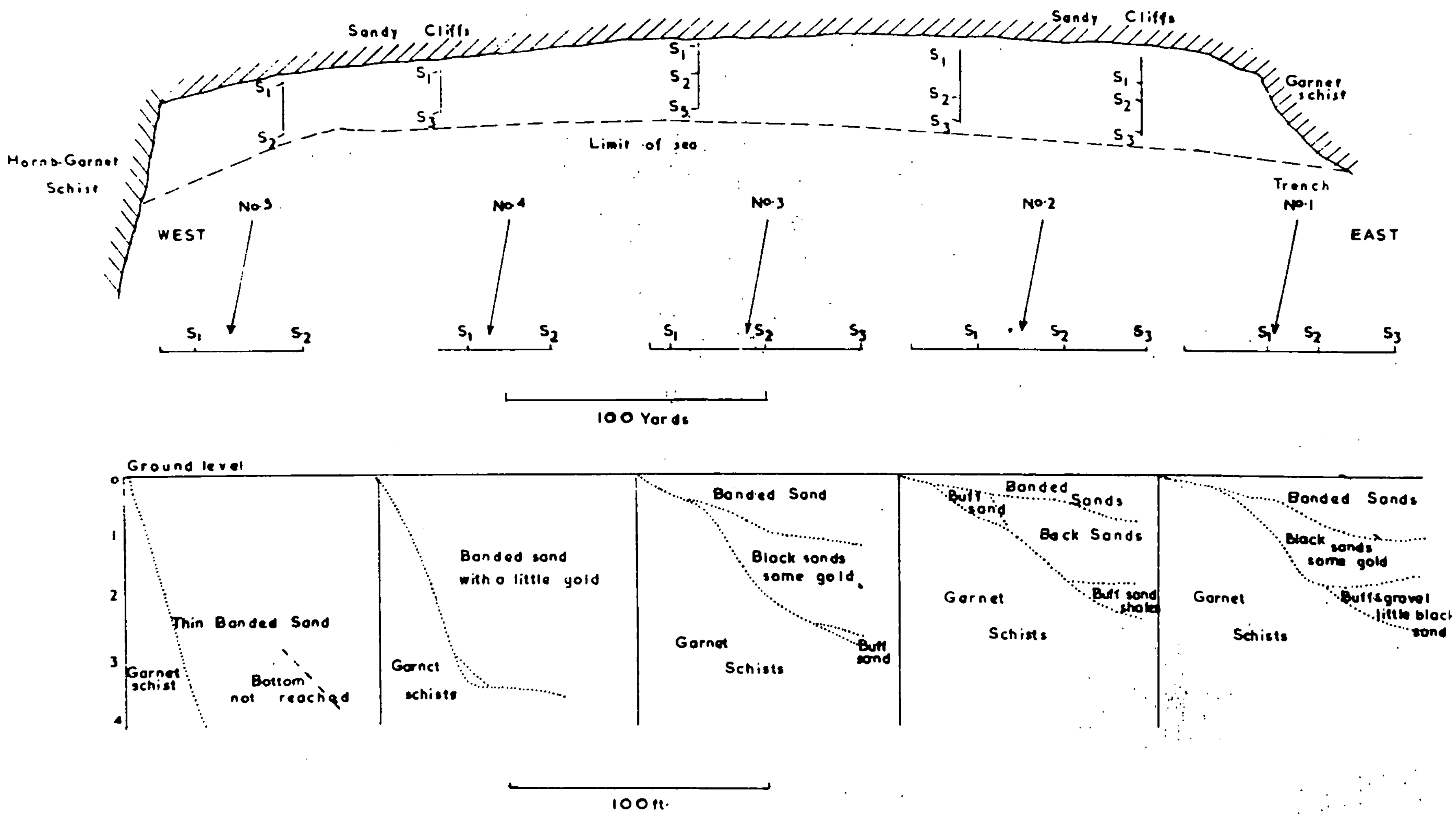

SKETCH MAP NOT TO SCALE SHOWING GENERAL GEOLOGY AND IMPORTANT MINERAL OCCURRENCES IN THE MANKWADZI COASTAL SECTION.
Quartz reef.
*Molybdenite.
*Molybdenite.
Pegmatite.
Hornblende and Biotite schist.
85°
Pegmatite with cassiterite and Arseno-Pyrite.
Greenstones.
Garnetiferous mica and hornblende schist.
Greenstones.
Tourmaline
Aplite and quartz
Composite Aplite and quartz vein.
80-85°
Quartz reef with Tourmaline
85°
Shattered Aplites.
Mankwadzi path
From Abrekum
Molybdenite
Black Monazite-bearing sands occurs between these points.

FIG. 80.



PLAN OF TRENCHES IN SANDY BAY BETWEEN MANKWADZI AND ABREKUM

FIG. 81

The accuracy of the rapid methods determined by single analyses of W1 and G1

	W1 a	W1 b	W1 c	1 a	1 b	1 c	2 a	2 b	2 c	3 a	3 b	3 c
SiO_2	52·9	53·4	0·9	55·9	55·3	1·1	58·9	59·2	0·5	61·9	62·5	1·0
TiO_2	1·1	1·1	0	0·95	0·98	3·2	0·83	0·85	2·4	0·70	0·72	2·8
Al_2O_3	14·8	14·7	0·7	14·6	14·4	1·4	14·5	14·1	2·8	14·3	13·8	3·5
Fe_2O_3	1·3	1·3	0	1·2	1·3	8·3	1·2	1·3	8·3	1·1	1·2	9·1
FeO	8·8	8·8	0	7·6	7·6	0	6·4	6·3	1·6	5·3	5·1	3·8
MnO	0·18	0·14	22	0·16	0·14	12·5	0·14	0·10	28	0·11	0·12	9·1
MgO	6·7	6·7	0	5·7	5·9	3·5	4·8	4·4	8·3	3·9	4·0	2·6
CaO	11·0	10·8	1·8	9·5	9·3	2·1	8·1	8·1	0	6·6	6·8	3·0
Na_2O	2·1	2·4	14	2·3	2·6	13	2·5	2·7	8·0	2·7	3·1	15
K_2O	0·65	0·70	7·7	1·4	1·5	7·1	2·1	2·2	4·8	2·8	2·9	3·6
P_2O_5	0·14	0·15	7·1	0·13	0·12	7·7	0·13	0·13	0	0·12	0·12	0
H_2O^+	0·55	0·60	0	0·52	0·5	0	0·50	0·5	0	0·47	0·4	20
Fe*	11·1	11·1	0	9·7	9·7	0	8·4	8·3	1·2	7·0	6·9	1·4
Total	100·2	100·8	0·6	100·0	99·6	0·4	100·1	99·9	0·2	100·0	100·8	0·8

	4 a	4 b	4 c	5 a	5 b	5 c	6 a	6 b	6 c	G1 a	G1 b	G1 c
SiO_2	64·9	64·4	0·8	68·0	68·0	0	71·0	71·0	0	73·0	72·5	0·7
TiO_2	0·58	0·60	3·4	0·46	0·49	6·5	0·33	0·35	6·1	0·25	0·26	4·0
Al_2O_3	14·2	14·3	0·7	14·0	14·4	2·8	13·9	13·3	4·3	13·8	14·0	1·4
Fe_2O_3	1·0	1·1	10	0·91	0·98	7·7	0·84	0·81	3·6	0·79	0·76	3·8
FeO	4·1	4·0	2·4	2·9	2·9	0	1·8	1·7	5·6	1·0	0·94	6·0
MnO	0·09	0·07	22	0·07	0·06	14	0·04	0·03	25	0·03	0·02	33
MgO	2·9	2·9	0	2·0	2·0	0	1·1	1·1	0	0·45	0·46	2·2
CaO	5·2	5·1	1·9	3·8	3·6	5·3	2·3	2·2	4·3	1·4	1·5	7·1
Na_2O	2·8	3·2	14	3·0	3·2	6·7	3·2	3·4	6·2	3·4	3·8	12
K_2O	3·5	3·7	5·7	4·2	4·1	2·4	5·0	4·8	4·0	5·4	5·4	0
P_2O_5	0·12	0·10	17	0·11	0·10	9·1	0·10	0·08	20	0·10	0·08	20
H_2O^+	0·44	0·6	50	0·42	0·5	25	0·39	0·5	25	0·37	0·4	0
Fe*	5·6	5·5	1·8	4·2	4·2	0	2·8	2·7	3·6	1·9	1·8	5·3
Total	99·8	100·1	0·3	99·9	100·3	0·4	100·0	99·3	0·7	100·0	100·1	0·1

Columns *a* are the calculated figures for W1 and G1 and six dilutions of W1 in G1. The figures for W1 in G1 are the consensus means given in *U.S. Geol. Survey Bull.* 980 Tables 19 and 20, p. 41 (FAIRBAIRN *et al.*, 1951), modified to include the revised figures for SiO_2 and Al_2O_3 (FAIRBAIRN, 1953).
Columns *b* are the results of single analyses of W1, G1, and the mixtures 1–6.
Columns *c* are the per cent differences between columns *a* and *b*.
Fe* denotes total Fe expressed as Fe_2O_3.

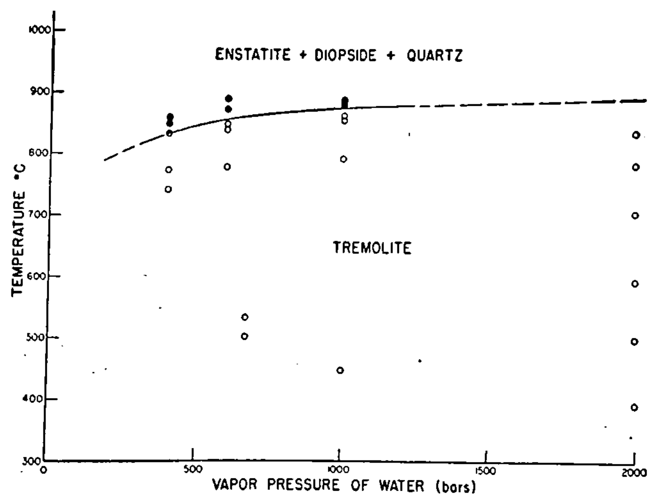
TABLE 20

Comparison of precision of rapid methods and conventional methods

	Granite M149–G1 type, 1 analyst, 6 determinations			Granite G1 American Standard, 7 analysts, 1 laboratory*			Diorite T13, 1 analyst, 6 determinations			Diabase W1 American Standard, 6 analysts, 1 laboratory*		
	$\bar{x}$	C	E	$\bar{x}$	C	E†	$\bar{x}$	C	E	$\bar{x}$	C	E†
SiO_2	73·4	0·46	0·19	72·64	0·31	0·12	55·9	0·38	0·16	52·66	0·64	0·26
TiO_2	0·21	6·0	2·5	0·25	11·2	4·2	1·0	7·8	3·2	1·03	4·15	1·7
Al_2O_3	14·2	3·5	1·4	14·13	1·22	0·46	18·4	2·5	1·0	14·87	3·23	1·3
Fe_2O_3	0·55	6·8	2·8	0·86	19·3	7·3	1·6	6·8	2·8	1·41	33·4	13·6
FeO	0·94	2·7	1·1	1·06	5·72	2·2	4·3	1·5	0·60	8·91	1·82	0·74
MnO	0·04	11·2	4·6	0·03	30·5	11·5	0·08	3·5	1·4	0·17	15·6	6·4
MgO	0·80	1·5	0·60	0·44	9·90	3·7	3·4	2·9	1·2	6·51	6·00	2·4
CaO	0·94	0·95	0·39	1·34	6·53	2·5	5·5	0·81	0·33	10·95	0·83	0·34
Na_2O	4·1	1·9	0·77	3·43	6·23	2·4	4·6	1·7	0·69	2·20	5·72	2·3
K_2O	4·2	2·8	1·2	5·43	3·83	1·4	2·7	3·3	1·4	0·68	7·06	2·9
P_2O_5	0·09	8·6	3·5	0·10	23·4	8·8	0·39	1·6	0·66	0·15	18·7	7·6
H_2O^+	1·0	11·8	4·8	0·31	26·7	10·1	1·1	16·3	6·6	0·45	10·5	4·3
Fe°	1·6	2·8	1·1	2·04	9·30	3·5	6·3	1·4	0·58	11·30	3·92	1·6

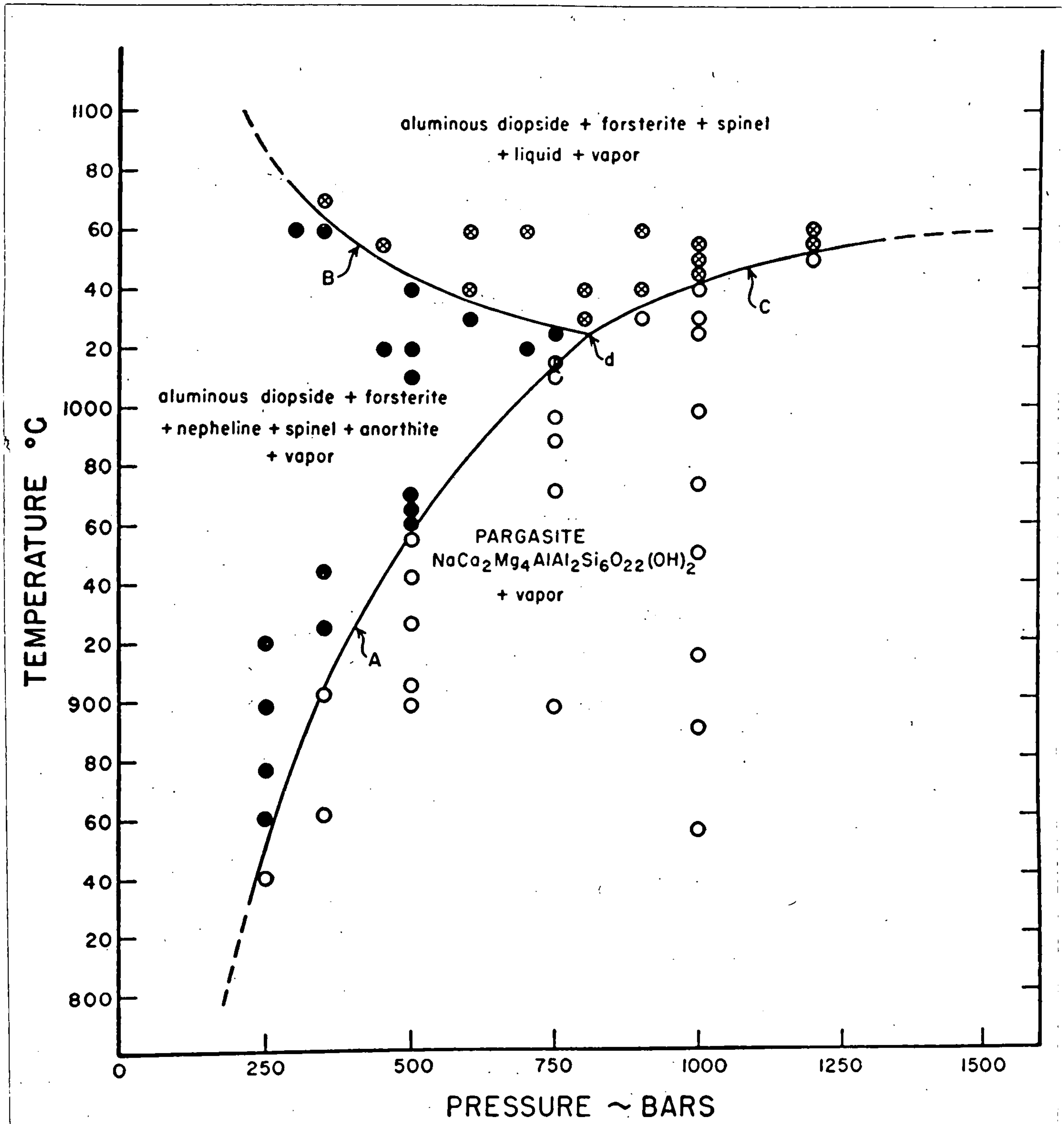
* U.S. Geological Survey Laboratory. Figures for $\bar{x}$ and C taken from Table 17, p. 38 *U.S. Geol. Surv. Bull.* 980.
† Calculated from $E = C/\sqrt{n}$ on the basis $n = 7$ (granite) and $n = 6$ (diabase).
$\bar{x}$ = arithmetic mean.
C = relative deviation of a single observation.
E = relative error of the mean.
Fe° denotes total Fe expressed as Fe_2O_3.

TABLE 21.



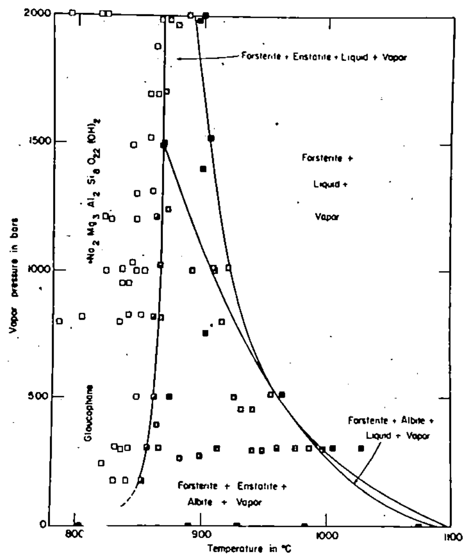
The univariant equilibrium curve for the reaction tremolite ⇌ 3 enstatite + 2 diopside + quartz + vapor.

FIG. 82



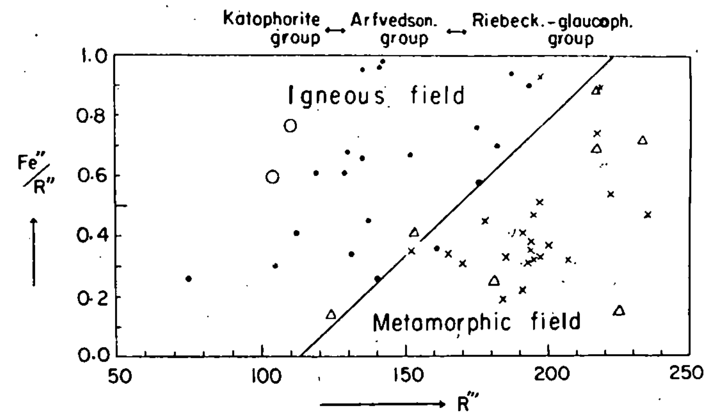
The stability field of the magnesian hornblende pargasite

FIG. 84



Preliminary P_{vapor}-T diagram for the composition $Na_2O \cdot 3MgO \cdot Al_2O_3 \cdot 8SiO_2$ with excess water.

FIG. 85



The relation between the compositions and modes of occurrence of amphiboles of the riebeckite-arfvedsonite-katophorite series. Glaucophane is included. The open circles represent amphiboles of volcanic rocks, the points those of plutonic rocks and pegmatites, the crosses those of crystalline schists, and the triangles those of ironstones and others.

FIG. 86

Chemical analyses of hornblendes from the Nakoso and Gosaisyo-Takanuki districts.

	Zone C					Zone B				
	1	2	3	4	5	6	7	8	9	10
SiO_2	42.94	45.62	42.44	43.20	44.36	40.96	44.03	42.62	44.07	44.60
Al_2O_3	12.56	8.87	12.50	12.44	11.69	11.70	12.33	12.75	12.37	12.12
TiO_2	1.89	1.13	3.09	1.65	1.26	0.99	0.46	0.53	1.70	0.87
Fe_2O_3	1.83	2.85	2.07	3.21	1.29	5.32	3.33	6.01	0.18	2.72
FeO	13.42	16.09	12.38	10.10	16.63	13.30	13.27	14.00	10.23	16.21
MgO	10.84	10.13	11.43	13.27	9.71	11.06	12.17	8.52	14.20	8.89
MnO	0.29	0.32	0.30	0.21	0.43	0.69	0.41	0.33	0.18	0.37
CaO	11.31	11.42	10.90	11.36	11.82	12.72	10.82	11.65	12.42	10.78
Na_2O	1.99	1.27	2.21	2.72	0.79	1.06	1.59	1.28	1.00	0.98
K_2O	0.35	0.33	0.14	0.40	0.50	1.27	0.23	0.55	0.30	0.50
$H_2O(+)$	2.23	1.92	1.94	1.38	1.67	1.50	1.32	1.91	2.85	2.03
$H_2O(-)$	0.22	0.16	0.15	0.07	0.12	0.06	0.07	0.12	0.03	0.11
F	n.d.	n.d.	n.d.	n.d.	n.d.	0.13	n.d.	n.d.	n.d.	n.d.
P_2O_5	n.d.	n.d.	0.23	0.07	0.12	n.d.	0.07	n.d.	n.d.	0.21
Total	99.87	100.11	99.78	100.08	100.39	100.76	100.10	100.27	99.53	100.39
α_D	1.659	1.662	1.653	1.654	1.650	1.663	1.657	1.665	1.656	1.660
γ_D	1.688	1.687	1.676	1.680	1.679	1.686	1.675	1.683	1.673	1.682
$2V_x$	76°	68.5°	84°	83°	79°	44°	74°	65.5°	82°	63°
$c \wedge Z$	26°	23°	15°	19°	15°	25°	18°	20°	19°	15°
X	p. brown	p. yellow	p. yellow	v. p. yellow	v. p. yellow	yellow	v. p. yellow	p. yellow	v. p. yellow	colorless
Y	brown	greenish brown	sepia-brown	green-yellowish brown	yellow-greenish brown	d. yellowish green	l. green	green	p. yellow-brownish green	l. green
Z	brown	greenish brown	sepia-brown	greenish brown	yellow brownish green	bluish green	l. bluish green	greenish blue	bluish green	l. bluish green

Note: In No. 2 β=1.674; In No. 1 Sp. gr.=3.164. p.=pale, v.p.=very pale, l.=light, d=deep.

TABLE 22.

	Zone C					Zone B			
	1	2	3	4	5	6	7	8	9
Si	6.377	6.800	6.277	6.291	6.573	6.128	6.443	6.361	6.453
Al^{IV}	1.623	1.200	1.723	1.709	1.427	1.872	1.557	1.639	1.547
Al^{VI}	0.575	0.358	0.455	0.425	0.615	0.191	0.570	0.604	0.588
Fe^{+3}	0.205	0.320	0.231	0.352	0.144	0.598	0.367	0.674	0.019
Ti	0.211	0.126	0.344	0.181	0.141	0.111	0.051	0.059	0.187
Fe^{+2}	1.666	2.005	1.531	1.230	2.060	1.663	1.623	1.747	1.252
Mg	2.398	2.249	2.519	2.878	2.143	2.465	2.653	1.894	3.097
Mn	0.037	0.040	0.037	0.026	0.054	0.087	0.051	0.042	0.022
Ca	1.799	1.823	1.727	1.772	1.876	2.038	1.695	1.862	1.948
Na	0.573	0.367	0.634	0.768	0.226	0.307	0.452	0.371	0.283
K	0.066	0.063	0.027	0.070	0.094	0.243	0.042	0.104	0.056

Note: P_2O_5 is neglected from the calculation.

TABLE 23.

Fig. 87

Suggested (Layton) Relationship of Composition to Colour in the Shido (1958) Amphiboles.

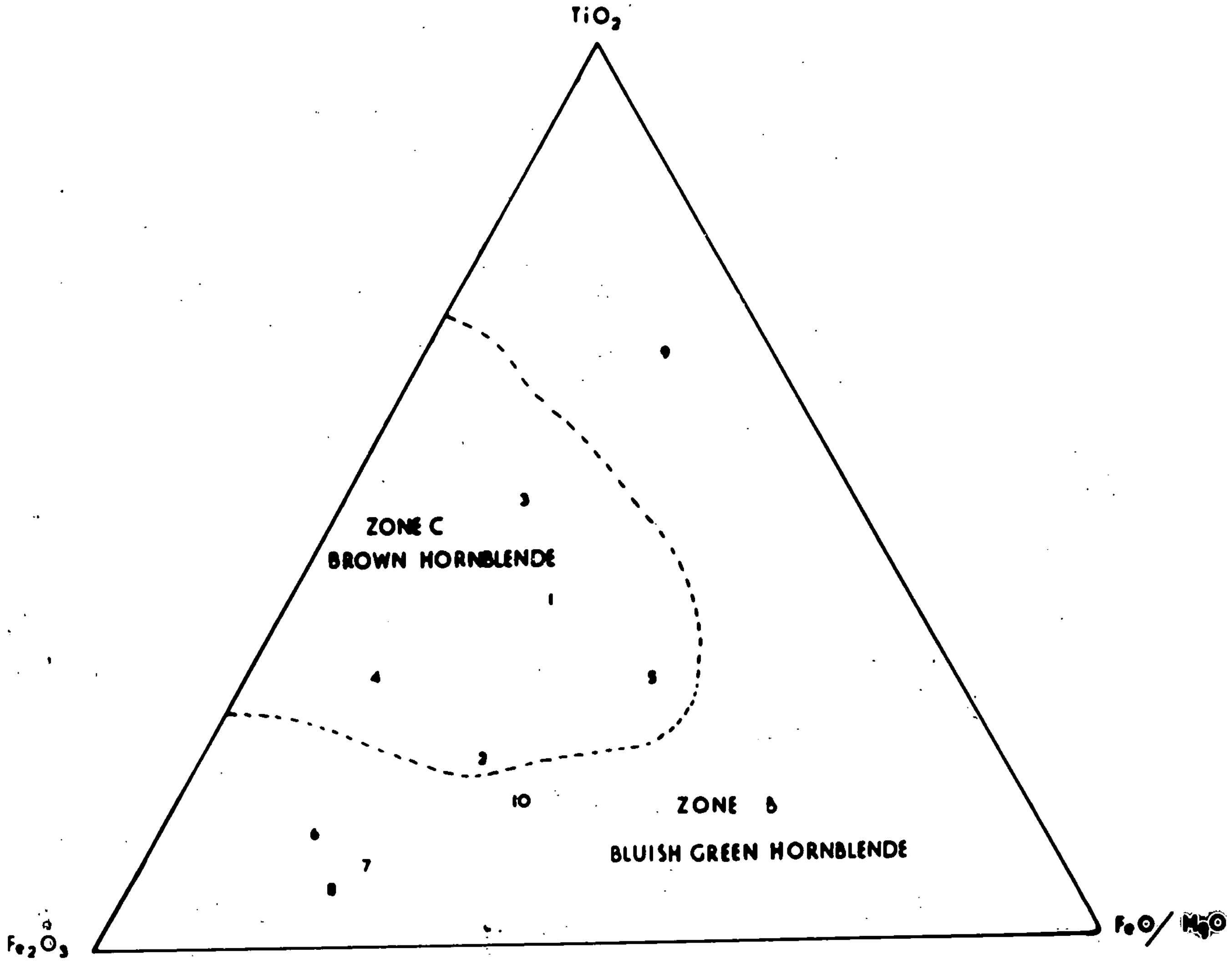
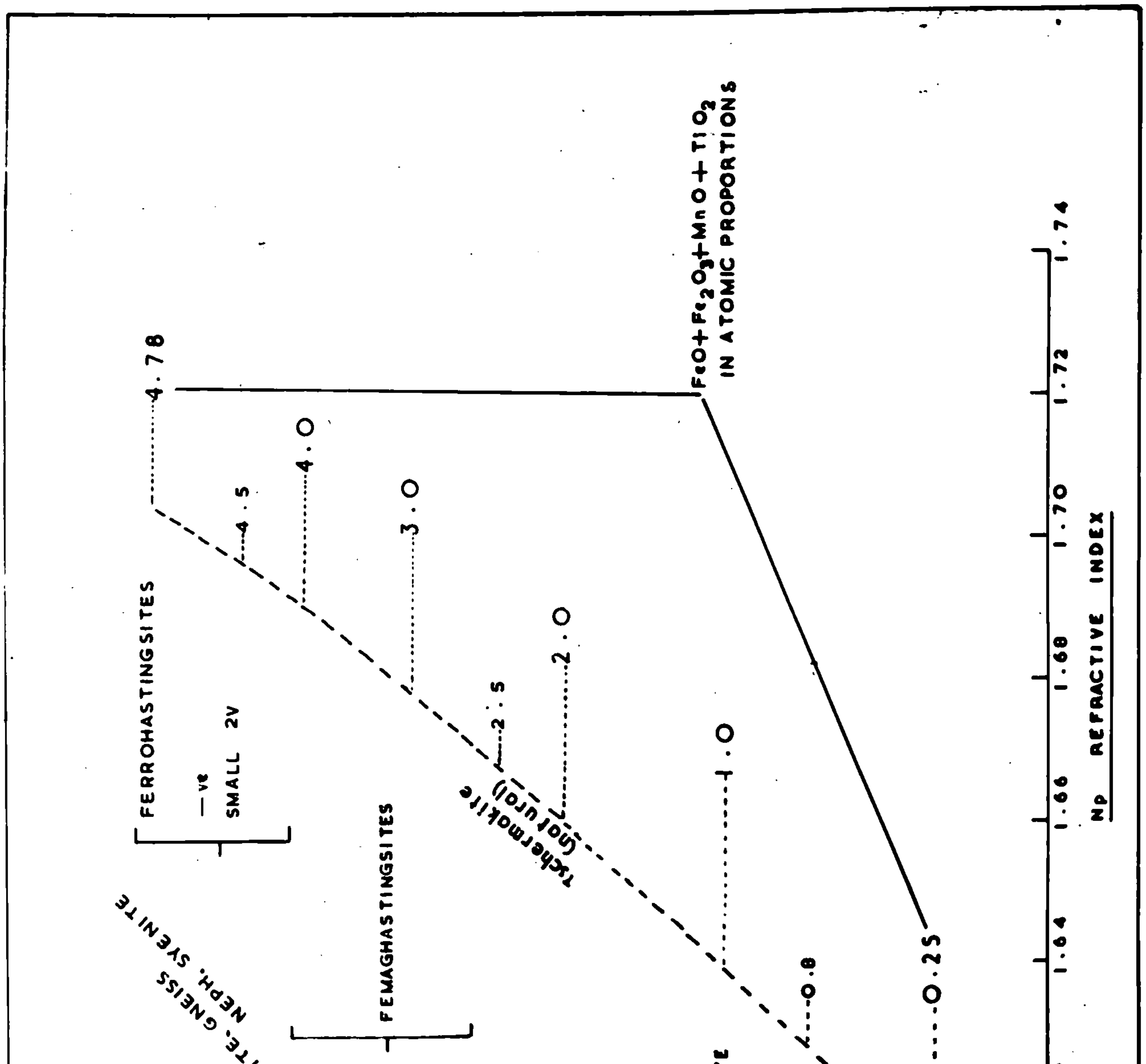

TiO2
ZONE C
BROWN HORNBLENDE
ZONE B
BLUISH GREEN HORNBLENDE
Fe2O3
FeO/MgO
1
2
3
4
5
6
7
8
9
10

FIG. 87

Fig. 88

Relationship between Iron Content, Refractive Index and Occurrence of the Common Hornblende Series.



Nm REFRACTIVE INDEX
1.74
1.72
1.70
1.68
1.66
1.64
1.62
1.60
Np REFRACTIVE INDEX
FeO+Fe2O3+MnO+TiO2
IN ATOMIC PROPORTIONS
4.78
4.0
4.5
3.0
2.0
2.5
1.0
0.8
0.25
FERROHASTINGSITES
—ve
SMALL 2V
FEMAGHASTINGSITES
PARGASITE
EDENITE
+ve
Tschermakite
(not ural)
GRANITE, GNEISS
NEPH. SYENITE
DIORITE
HORNBL. SCH.
AMPHIBOLITES
LIMEST. CONTACTS

FIG. 88.

Fig. 89

Relationship between Amphibole Composition and Occurrence in the Hornblende Series.

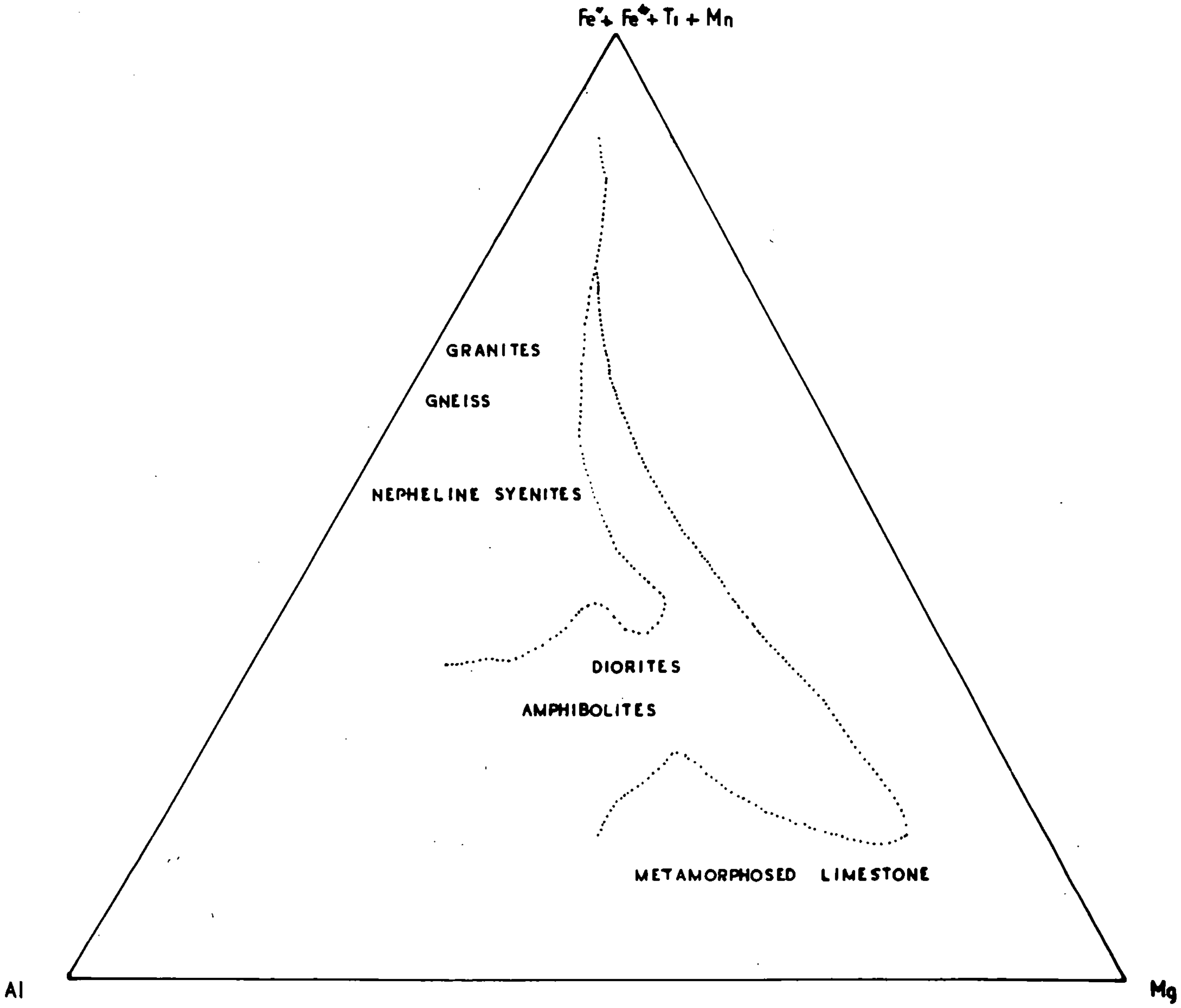
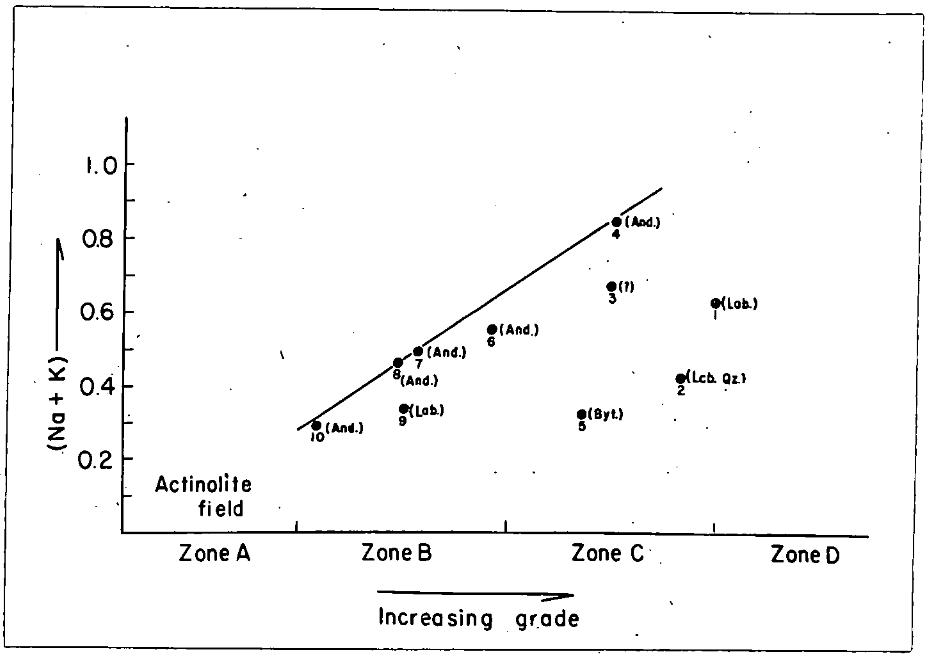

Fe'' + Fe''' + Ti + Mn
GRANITES
GNEISS
NEPHELINE SYENITES
DIORITES
AMPHIBOLITES
METAMORPHOSED LIMESTONE
Al
Mg

FIG. 89.

Fig. 90

Diagram to show Increasing Alkali Content with Increasing Metamorphic Grade (Shido 1958)



1.0
0.8
0.6
0.4
0.2
(Na + K)
(And.)
4
(?)
3
(Lab.)
1
(And.)
6
(And.)
7
8
(And.)
(Lcb. Qz.)
2
(Lab.)
9
(Byt.)
5
(And.)
10
Actinolite
field
Zone A
Zone B
Zone C
Zone D
Increasing grade

FIG. 90.

End members resulting from the various types of substitution and corresponding ordinary molecules.

End members						Ordinary molecules					
Denotation	Structural positions A	W	X+Y	Z		Name	Structural positions A	W	X+Y	Z	
Tiam		Ca_2	Mg_1Ti_4	Al_8	$O_{22}(OH)_2$	Titanoamphibole		Ca_2	Mg_1Ti_4	Al_8	$O_{22}(OH)_2$
Cum		Mg_2	Mg_6	Si_8	$O_{22}(OH)_2$	Cummingtonite		Mg_2	Mg_6	Si_8	$O_{22}(OH)_2$
Ce′	Ca_4	Ca_2	Mg_6	Al_8	$O_{22}(OH)_2$	Calcium-edenite	Ca	Ca_2	Mg_5	Al_2Si_6	$O_{22}(OH)_2$
St′	Na_2	Na_2	Mg_5	Si_8	$O_{22}(OH)_2$	Sodatremolite	Na	NaCa	Mg_5	Si_8	$O_{22}(OH)_2$
Ed′	Na_8	Ca_2	Mg_6	Al_8	$O_{22}(OH)_2$	Edenite	Na	Ca_2	Mg_5	Al_1Si_7	$O_{22}(OH)_2$
Gl		Na_2	Mg_3Al_2	Si_8	$O_{22}(OH)_2$	Glaucophane		Na_2	Mg_3Al_2	Si_8	$O_{22}(OH)_2$
Ts′		Ca_2	Al_5	Al_6Si_3	$O_{22}(OH)_2$	Tschermakite		Ca_2	Mg_3Al_2	Al_2Si_6	$O_{22}(OH)_2$
Tr		Ca_2	Mg_6	Si_8	$O_{22}(OH)_2$	Tremolite		Ca_2	Mg_5	Si_8	$O_{22}(OH)_2$

TABLE 24.

Calculation of the hornblende No. 1.

	Atomic ratio		Tiam	Cum	Ce′	St′	Ed′	Gl	Ts′	Tr	Remains
Z	Si	6.377	—	0.368	—	0.436	—	—	0.468	5.104	:0.001
	Al	1.623	0.422	—	—	—	0.421	—	0.780	—	—
Y	(Al, Fe^{+3})	0.780	—	—	—	—	—	—	0.780	—	—
	Ti	0.211	0.211	—	—	—	—	—	—	—	—
X	(Fe^{+2}, Mg, Mn)	4.009	0.053	0.230	—	0.273	0.263	—	—	3.190	—
W	(Fe^{+2}, Mg, Mn)	0.092	—	0.092	—	—	—	—	—	—	—
	Ca	1.799	0.106	—	—	—	0.105	—	0.312	1.276	—
	Na	0.109	—	—	—	0.109	—	—	—	—	—
A	(Na, K)	0.530	—	—	—	0.109	0.421	—	—	—	—

TABLE 25

Molecular proportions of the analysed hornblende from the central Abukuma regional metamorphic rocks.

	⟸ Metamorphic grade									
	Zone C					Zone B				
	1	2	3	4	5	6	7	8	9	10
Tiam	0.422	0.252	0.688	0.362	0.282	0.222	0.102	0.118	0.374	0.212
Cum	0.368	0.392	0.468	0.368	0.628	0.460	1.260	0.080	0.660	0.956
Ts′	1.248	1.185	1.098	1.243	1.214	1.262	1.499	2.045	0.971	1.224
Ce′	—	—	—	—	0.066	0.306	0.020	—	0.226	0.072
St′	0.436	0.316	0.624	0.544	—	—	—	0.472	—	—
Ed′	0.421	0.272	0.349	0.566	0.320	0.550	0.494	0.239	0.339	0.291
Tr	5.104	5.684	4.776	4.912	5.484	5.192	4.620	5.044	5.424	5.244

Note: The total of all the molecules in each hornblende is taken to be very close to 8.

TABLE 26.

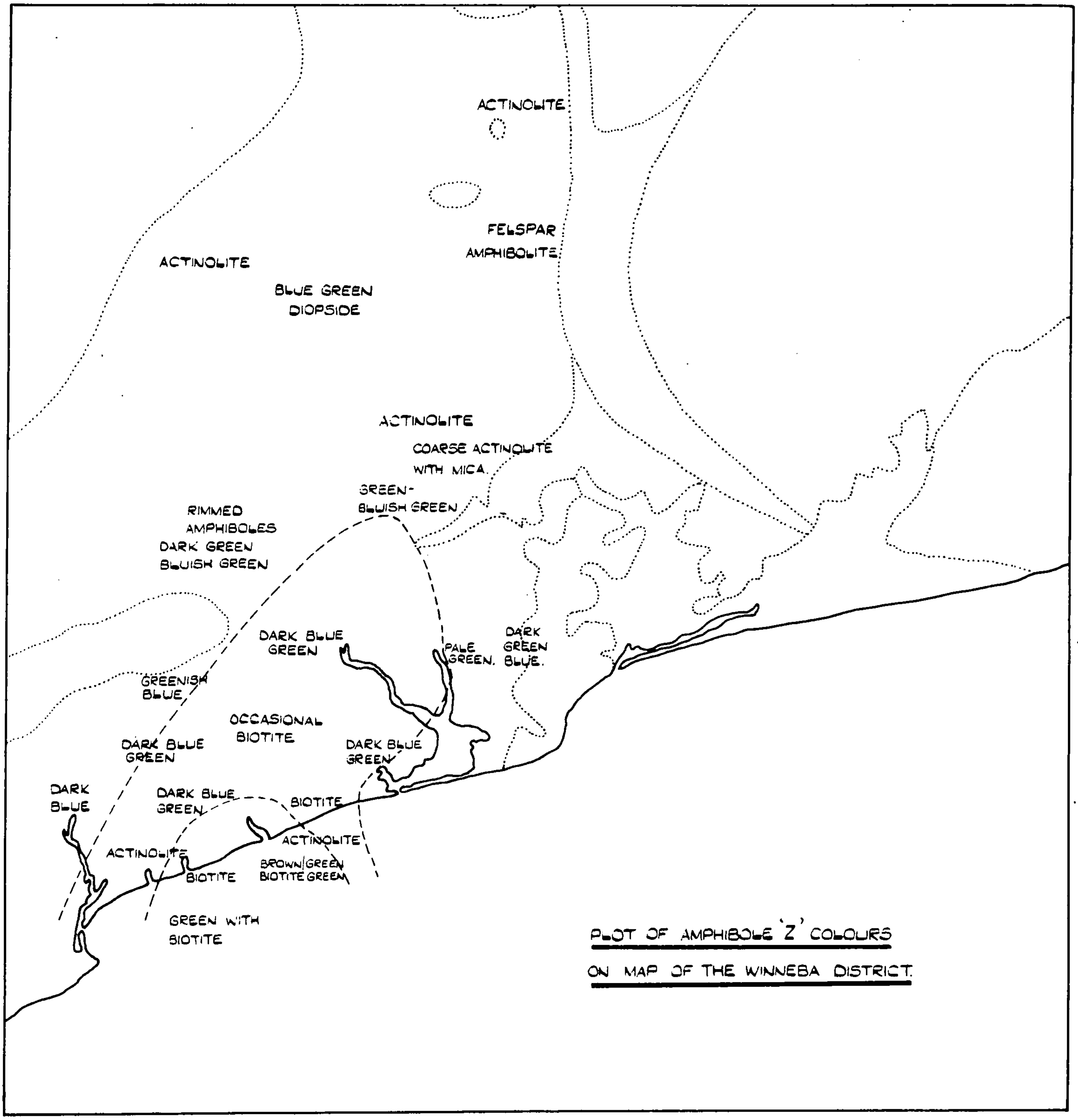

ACTINOLITE
FELSPAR
AMPHIBOLITE
ACTINOLITE
BLUE GREEN
DIOPSIDE
ACTINOLITE
COARSE ACTINOLITE
WITH MICA.
GREEN-
BLUISH GREEN
RIMMED
AMPHIBOLES
DARK GREEN
BLUISH GREEN
DARK BLUE
GREEN
PALE
GREEN.
DARK
GREEN
BLUE.
GREENISH
BLUE
OCCASIONAL
BIOTITE
DARK BLUE
GREEN
DARK BLUE
GREEN
DARK
BLUE
DARK BLUE
GREEN
BIOTITE
ACTINOLITE
ACTINOLITE
BROWN GREEN
BIOTITE GREEN
BIOTITE
GREEN WITH
BIOTITE
PLOT OF AMPHIBOLE 'Z' COLOURS
ON MAP OF THE WINNEBA DISTRICT

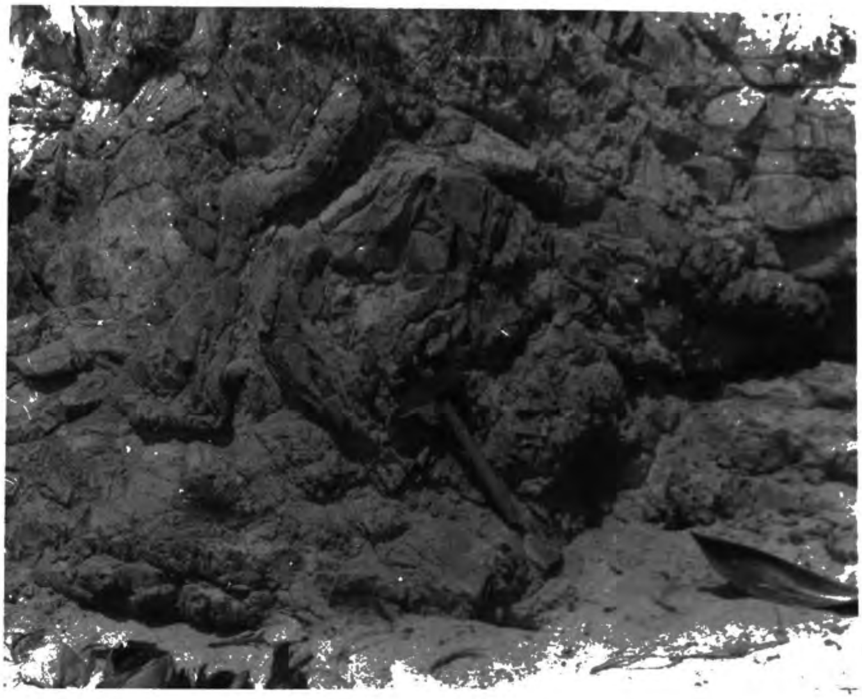
FIG. 91

Plate 1 A.

Recumbent Folding the the Togo Series West of Senya Beraku near a Wedge of Dahomeyan Gneiss.

Plate 1 B.

Strong Folding in Togo Series, West of Senya Beraku.



A

B

PLATE 1.

Plate 2 A

Large Pegmatite Exposure in the Coarse Amphibolite Zone near Winneba.

Plate 2 B

Quartz Crystal in Quartz Reef near Onyadzi, Winneba.

A

B.

PLATE 2

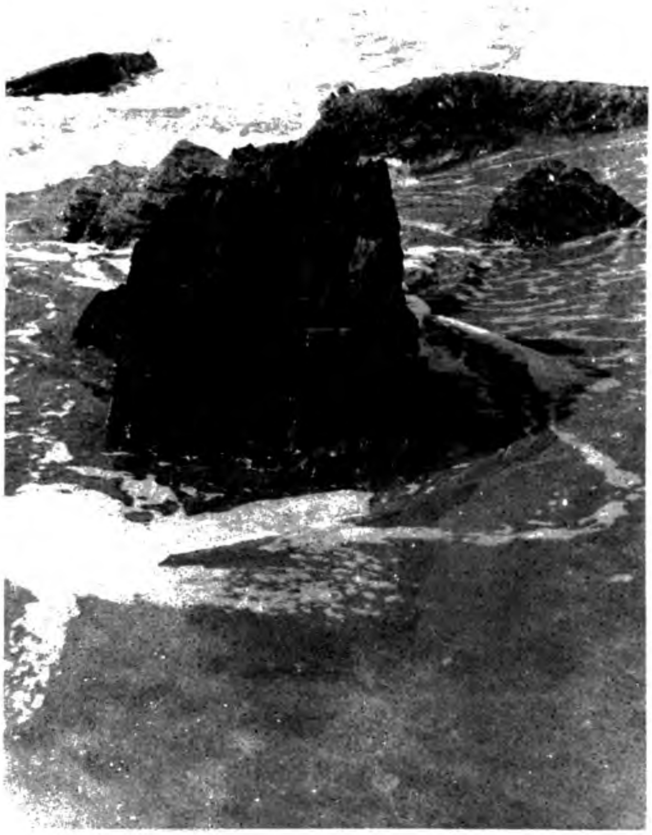
Plate 3 A

Composite Quartz-Aplite Dyke in the Sandy Cove between Mankwadzi and Abrekum.

Plate 3 B

Typical Shattering in the Aplites West of Mankwadzi Village.

A.



B.

PLATE 3

Plate 4 A

Cassiterite Bearing Pegmatite in Hornblende Biotite Schists West of Mankwadzi Village.

Plate 4 B

Typical Banding in the Ilmenite-Monazite Bearing Beach Sands West of Mankwadzi Village.

A.

B.

PLATE 4.

<u>Plate 5 A</u>

Typical Exposure of Graphic Pegmatite in Eastern Migmatite Gneiss along the Winneba-Accra Road.

<u>Plate 5 B</u>

Texture of the Graphic Pegmatites.

A.

B.

PLATE 5

Plate 6 A

Typical Banding in the Eastern Migmatites.

Plate 6 B

Typical Ptygmatic Folding in the Eastern Migmatite Gneiss near Mile 9 Accra Road.

A.

B.

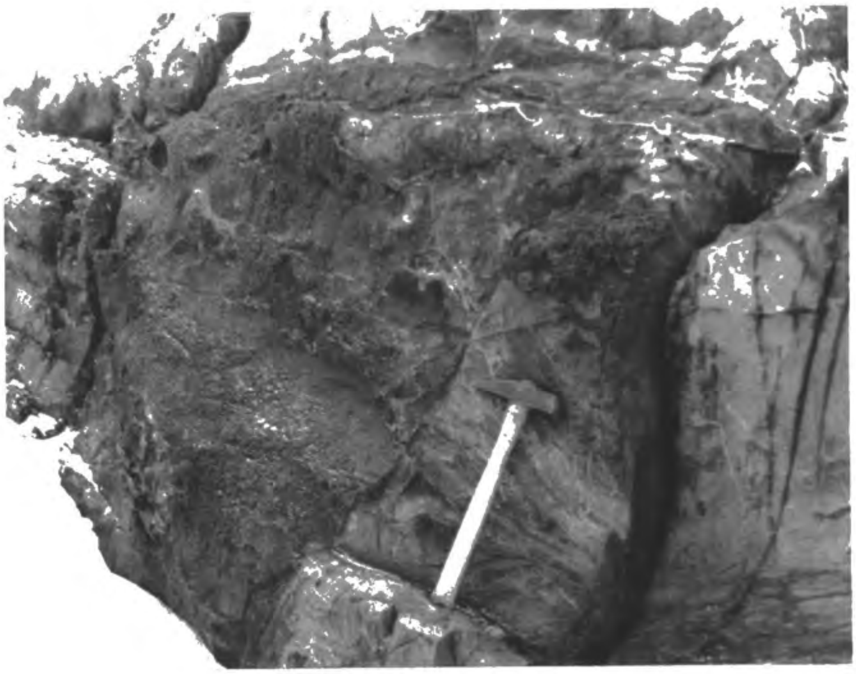
PLATE 6

Plate 7 A

Pillow Structure on the Beach West of Mankwadzi Village.

Plate 7 B

Typical Contact between Feldspar Amphibolites and Garnet Schists Winneba-Saltpond Road.



A.

B.

PLATE 7

Plate 8 A

Typical Winneba Granite Topography.

Plate 8 B

Porphyroblastic Texture of the Winneba Granite.

A.

B.

PLATE 8

Plate 9 A

Typical Flow Banding in the Winneba Granite Near Ateiti Village.

Plate 9 B

Ghosts in the Winneba Granite near Ateiti Village.

A.

B.

PLATE 9.

Plate 10 A

Thrust Faulting in Togo Quartzites. West of Senya Beraku.

Plate 10 B

Multiple Faulting Resulting in the Exposure
of the Probable Base of the Togo Quartzite.

A

B.

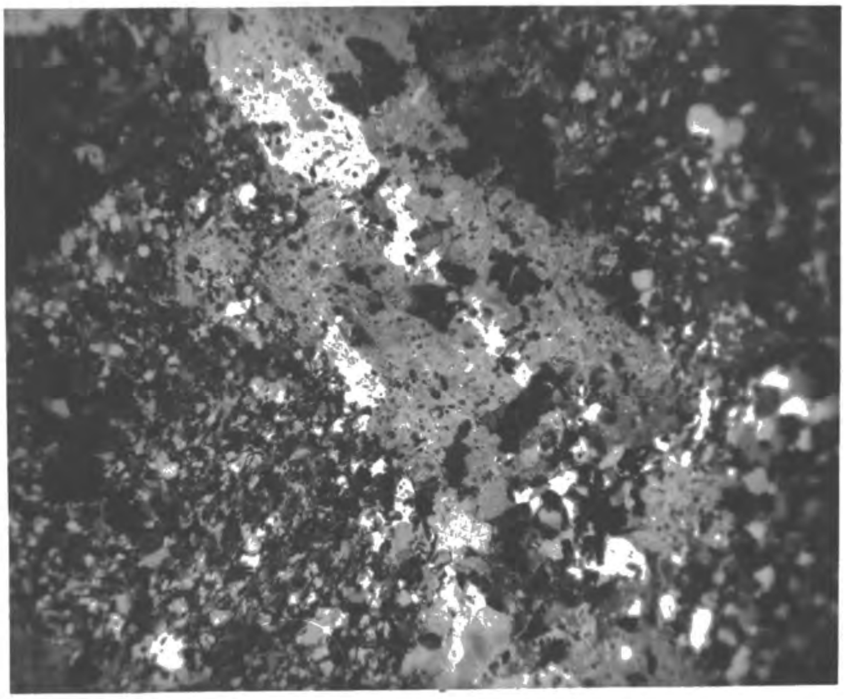
PLATE 10

Plate 11 A

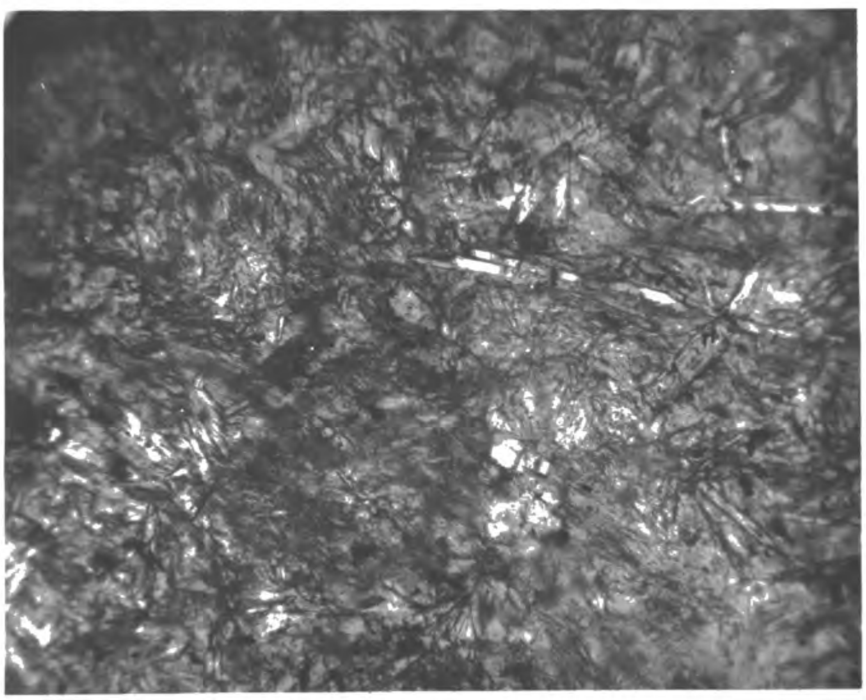
Typical Porphyritic Metamorphosed Lava. x70 Crossed Nicols.

Plate 11 B

Typical Actinolite Schist. x70 Crossed Nicols.



A.



B.

PLATE 11.

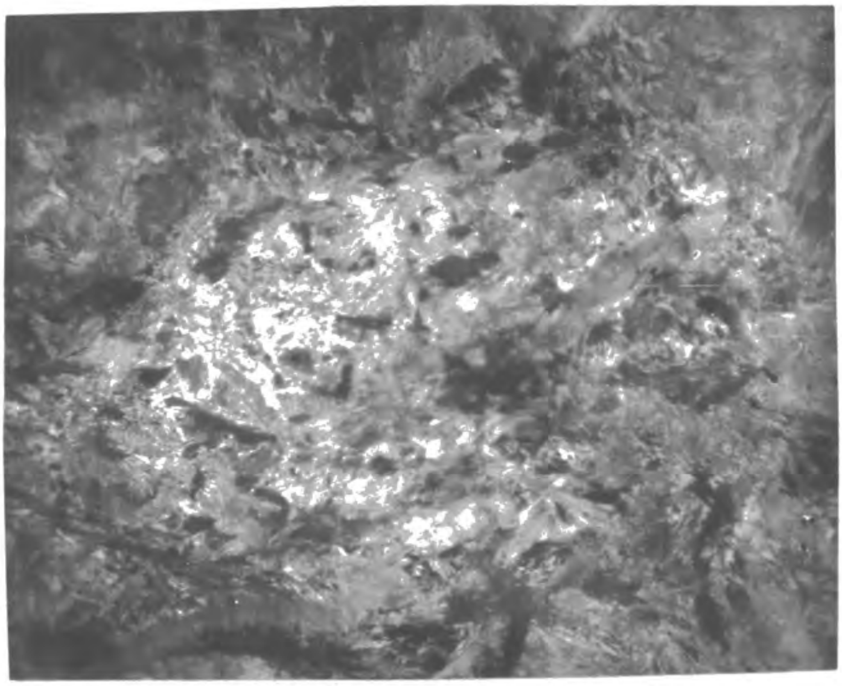
Plate 12 A

Hornblendite from zone of Coarse Amphibolites.
Note Large Hornblende Plates. z70 Crossed Nicols.

Plate 12 B

Actinolite Amphibolite. Note Mass of Actinolitic Hornblende.
x70 Crossed Nicols.

A.



B.

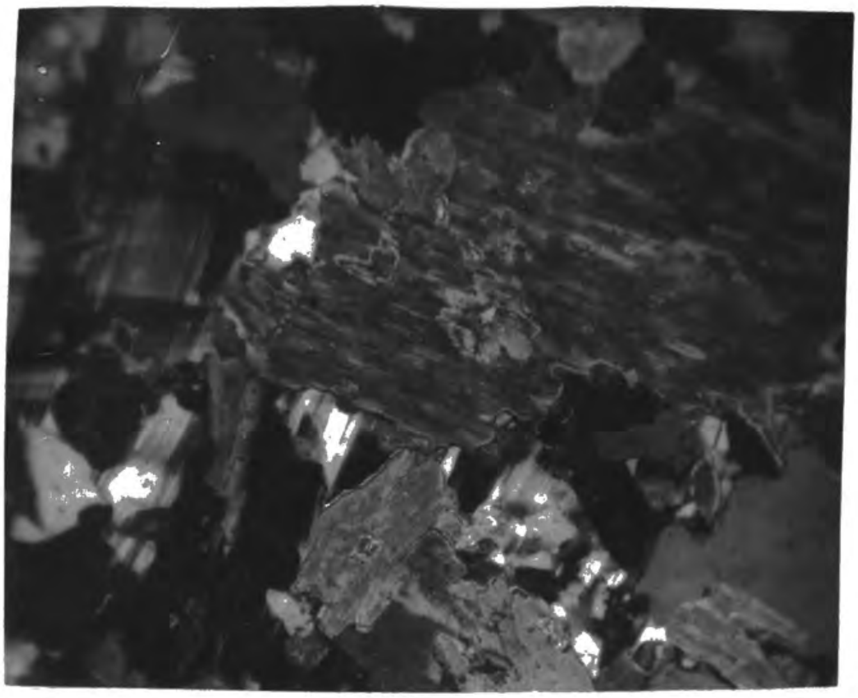
PLATE 12.

Plate 13 A

Typical Rimmed Amphibole in Zone of Coarse Amphibolite.
Note Granitic Contamination.
x70 Crossed Nicols.

Plate 13 B

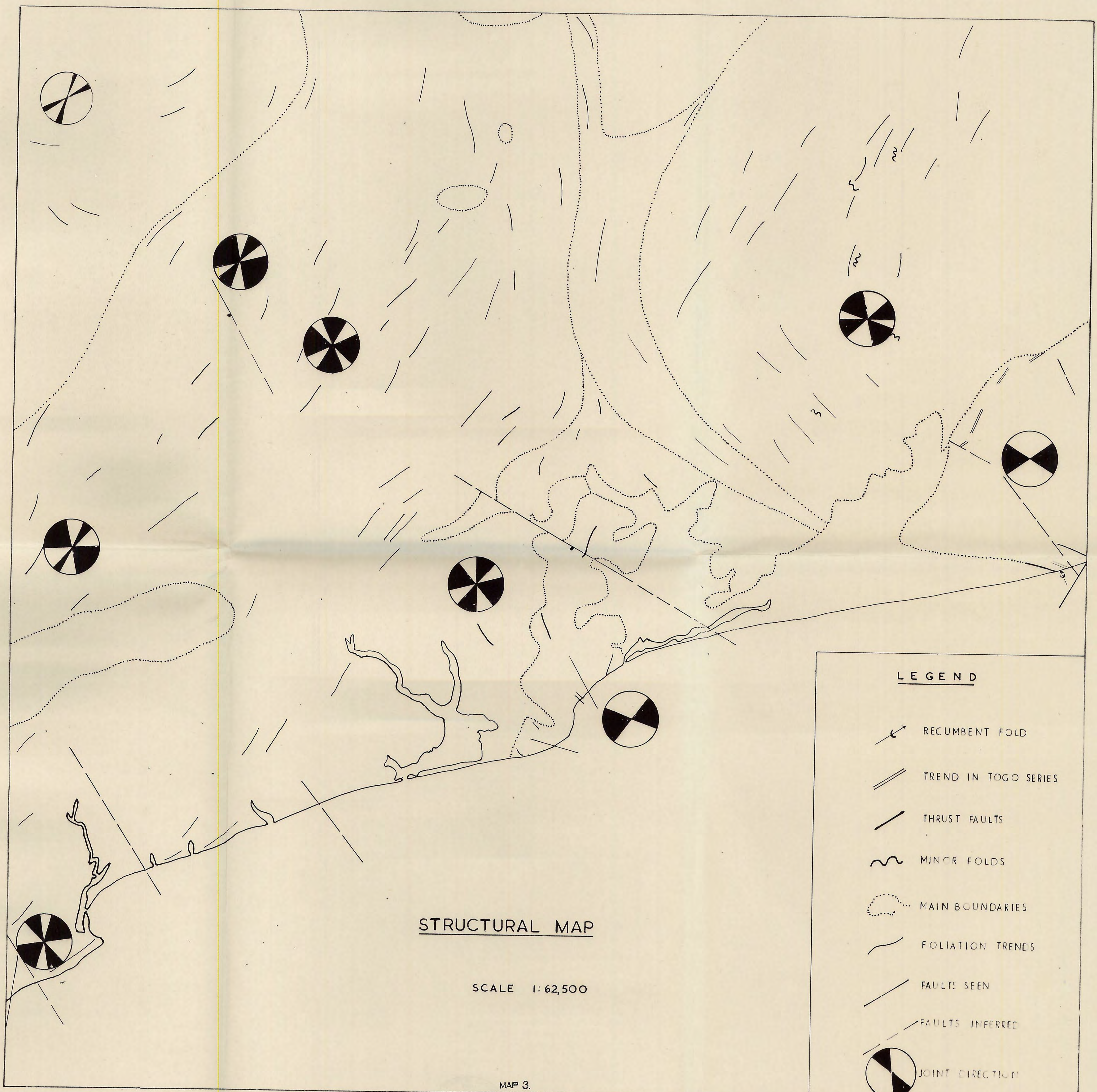
Rimmed Amphibole in the Coarse Amphibolite Zone.
x70 Ordinary Light.



A.

B.

PLATE 13.


STRUCTURAL MAP
SCALE 1: 62,500
LEGEND
RECUMBENT FOLD
TREND IN TOGO SERIES
THRUST FAULTS
MINOR FOLDS
MAIN BOUNDARIES
FOLIATION TRENDS
FAULTS SEEN
FAULTS INFERRED
JOINT DIRECTION
MAP 3.

MAP SHOWING THE DISTRIBUTION OF THE MAJOR PEGMATITES APLITES AND QUARTZ REEFS

MAP 2.

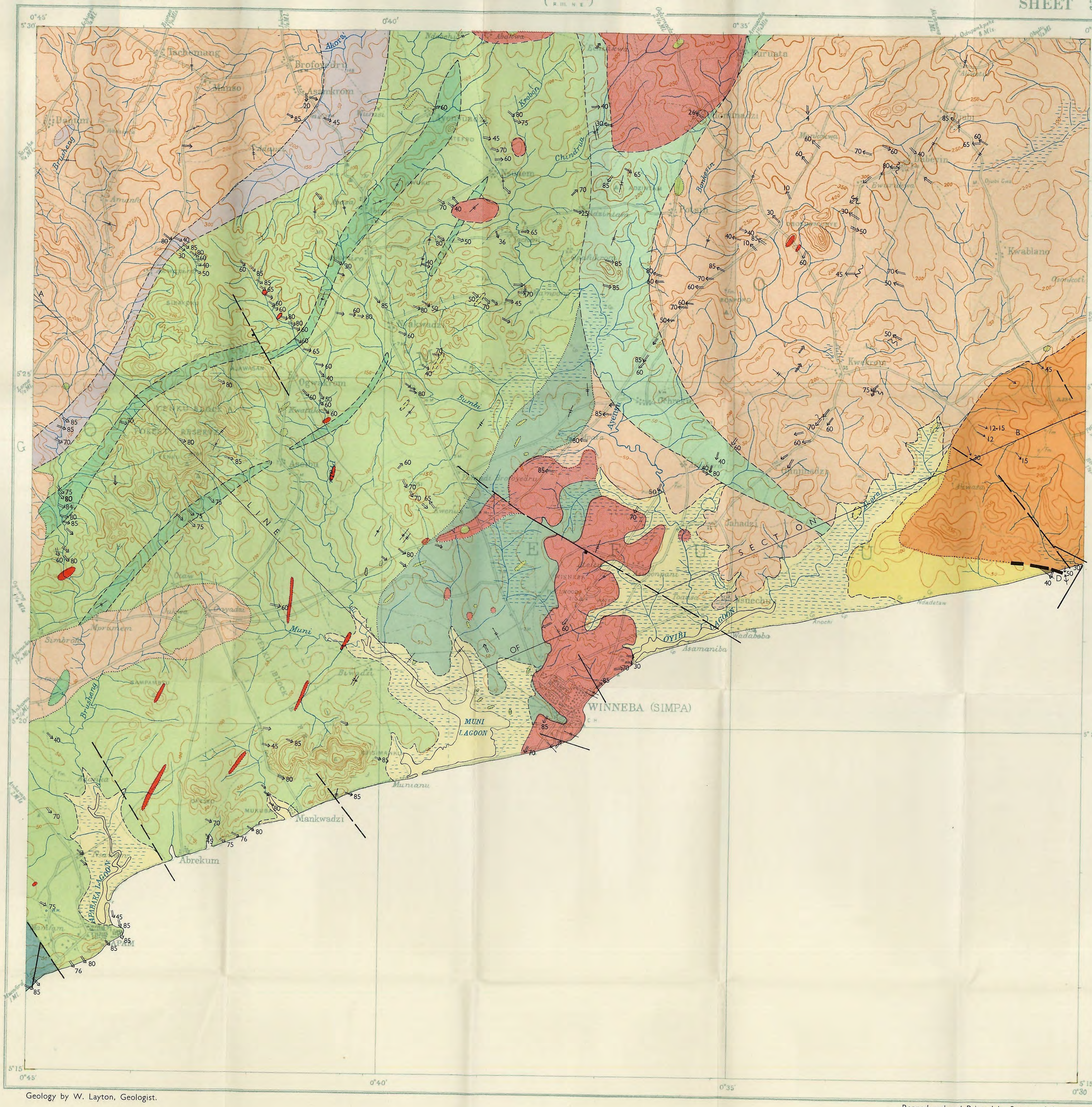
MAP I.

WINNEBA N.E.

(NORTH B 30 / B III. N.E.)

AFRICA 1:62,500.

SHEET 32.



LEGEND

RECENT ↑ TERTIARY
- Lagoonal deposits, raised beach sands.
- Boulder beds of uncertain age.

TOGO SERIES
- Quartzites.

TARKWAIAN?
- Quartz schists.

UPPER BIRRIMIAN
- A Greenstone series.
- Quartz schists.
- B Banded quartz and hornblende gneiss with lit-par-lit injection and pegmatite.
- Zone of coarse amphibolite.

LOWER BIRRIMIAN
- Mica schists.

DAHOMEYAN ?
- D Biotite gneiss.

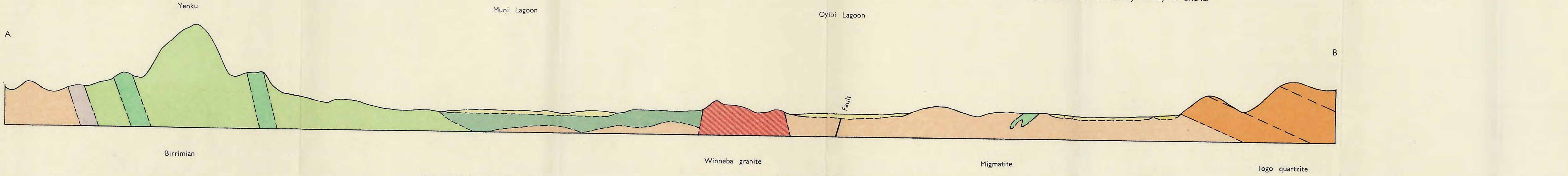
INTRUSIVES
- Basic Intrusives now hornblendites.
- Epidiorite dykes.
- Late orogenic granites.
- Early orogenic granites.

- Observable boundaries.
- Approximate boundaries.
- Inferred boundary or gradational contact.
- Boundary of outcrop.
- 70 Dip of bedding.
- 70 Dip of foliation.
- Faults.
- Inferred faults.
- Thrusts.
- Recumbent folds.
- Vertical foliation.

NOTE.
THE COLOURS OF A & B IN THE KEY ONLY, HAVE BECOME INTERCHANGED DURING PRINTING.

Geology by W. Layton, Geologist.

Reproduced and Printed by Survey of Ghana.



Horizontal Scale 1" = 1.014 miles

Vertical Scale 1" = 500 feet