PETROLOGY OF MONADNOCK MT., VT.

by

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Chairman, Departmental Committee on Graduate Students

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ABSTRACT

Samples were collected from Monadnock Mountain, Vermont, using Chapman's[1] geologic map. Twelve samples had their major phases analysed and had modes made of them. Eleven samples had whole rock analysis performed. Computer modeling showed that there are no direct fractional crystalization relationships but whole rock data and iron to magnesium ratios show a relationship between the essexite, the transition rock, the quartz syenite, and the granite.

Thesis Supervisor: John S. Dickey

Title: Associate Professor of Earth and Planetary Sciences

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CHAPTER 1

INTRODUCTION

Monadnock Mountain, named by early settlers after Mount Monadnock in southwestern New Hampshire, is the northern most intrusion of the White Mountain magma series.

The intrusion is located predominantly on the west side of the Connecticut River in Vermont opposite Colebrook, New Hampshire. A small extension of the intrusion outcrops across the river just south of Colebrook as two small hills (1460 and 1600 ft. high), separated by Simms Stream. Monadnock Mountain itself is a broad 3140 ft. conical peak with steeply dipping tangential and radial joints, some of which have sulfide mineralization. It has a radial drainage pattern which terminates with Mill Brook on the southwestern side, the Connecticut River at 1000 ft. on the east, and with Willard Stream intrenched on the northern flank. Willard Stream cuts off a small portion of the intrusion on the north which forms a hill of 1760 ft. just east of Tódd Hill. The southeastern part of Monadnock Mountain is terminated in a very steep slope facing the river.

The whole intrusion is approximately ten square miles: four miles along its northwest axis by approximately 2.5 miles along its northeast axis.

The country rock is the Gile Mountain formation which is middle Ordovician in age. The rock is a dark grey schist interbedded with lenticular aggregates of quartz.

BACKGROUND

In 1929, John E. Wolff[2] constructed a rough topographic map of the area and an approximate geologic map. He reports the optical properties of the ferrosilicates and describes a quartz-nordmarkite, which forms most of the exposed intrusion, an essexite, and various dikes.

In 1954, further investigation of the mountain was reported by Randolph W. Chapman[1] who spent five weeks mapping the area. His paper describes the major rock types, the structure of the stock, and a passive stoping model of emplacement. Wolff's paper gives chemical analysis for the quartz-nordmarkite, probably Chapman's quartz-syenite, the essexite, and an amphibole phenocryst from the essexite. The latter is obviously kaersutite and not typical of the groundmass hornblende as Chapman mistakenly assumed.

CONTACT RELATIONSHIPS

The goal of my research was to relate the different rock types of the Monadnock complex. No attempt was made to remap the intrusion. Instead, using Chapman's map, representative samples were collected and analysed by microprobe.

The map, Figure 1, is based on Chapman's map with minor additions and alterations. Figure 2 gives the age relations and the symbols for the rock types.

An essexite body forms a bench along the southeast slope of the mountain. Its eastern contact with the quartz monzonite is sharp while its contact with the main body of quartz syenite is gradational, but syenitic dikes do intrude the essexite at various locations. The transition rock has gradational boundaries only, but is intruded by various dikes.

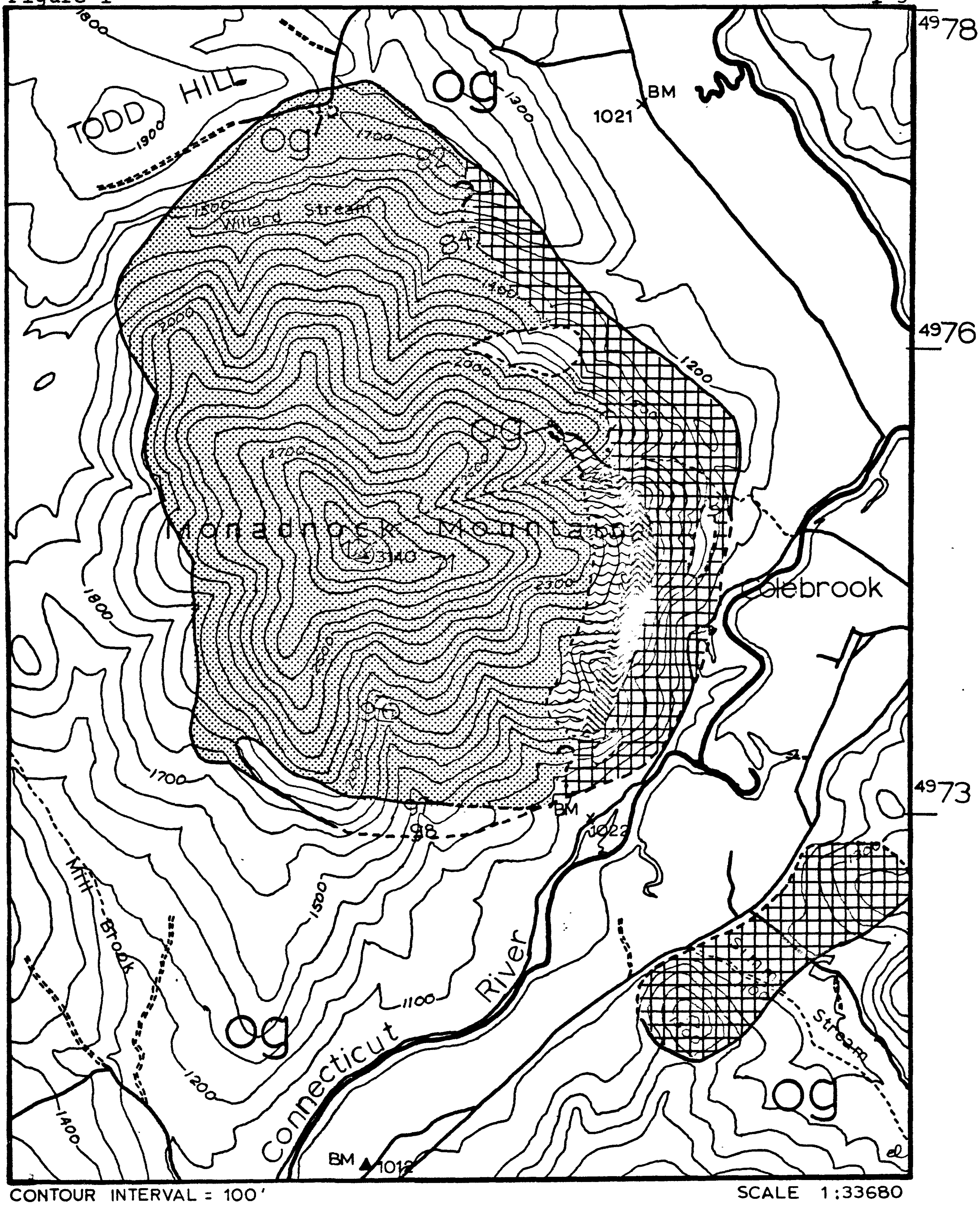
The major portion of the intrusion is composed of quartz syenite which is intruded by granite in the south. The contact between the quartz syenite and the quartz monzonite is not well exposed and not distinct because of the similarity of the rocks. The only diagnostic characteristic, the color of the feldspars, is often hard to distinguish in an iron-stained, weathered specimen. The quartz monzonite intrudes the essexite and is intruded by the eastern granite bodies.

The quartz syenite has an intrusive contact with the syenite porphyry which is located south of the summit, and the dark monzonite which is located northeast of the summit in Willard Stream at location 84 in Figure 1. Inclusions of a diorite are found in quartz syenite and the quartz monzonite. The largest of these inclusions is located just east of the summit of the hill and just north of Willard Stream.

Inclusions of country rock are common throughout the complex; large inclusions occur at the northern end of the transition rock and near the northern contact. The contact with the country rock in detail is irregular with dikes from the intrusion penetrating the country rock and a large number of xenoliths near the contact.

No strong contact metamorphism is apparent around Monadnock Mountain. This is most unusual, especially in light of the well-developed contact aureole around Mt. Ascutney[3] which is a similar intrusion of the White Mountain magma series further south. Perhaps the most spectacular contact metamorphic rocks are not exposed. The southeastern contact of the intrusion and the country rock is covered by alluvium, as is the northwest contact of the hills on either side of Simms Stream. It seems reasonable to assume that the two are joined because of the similarity of rock type and the lack of any other intrusive complex nearby.

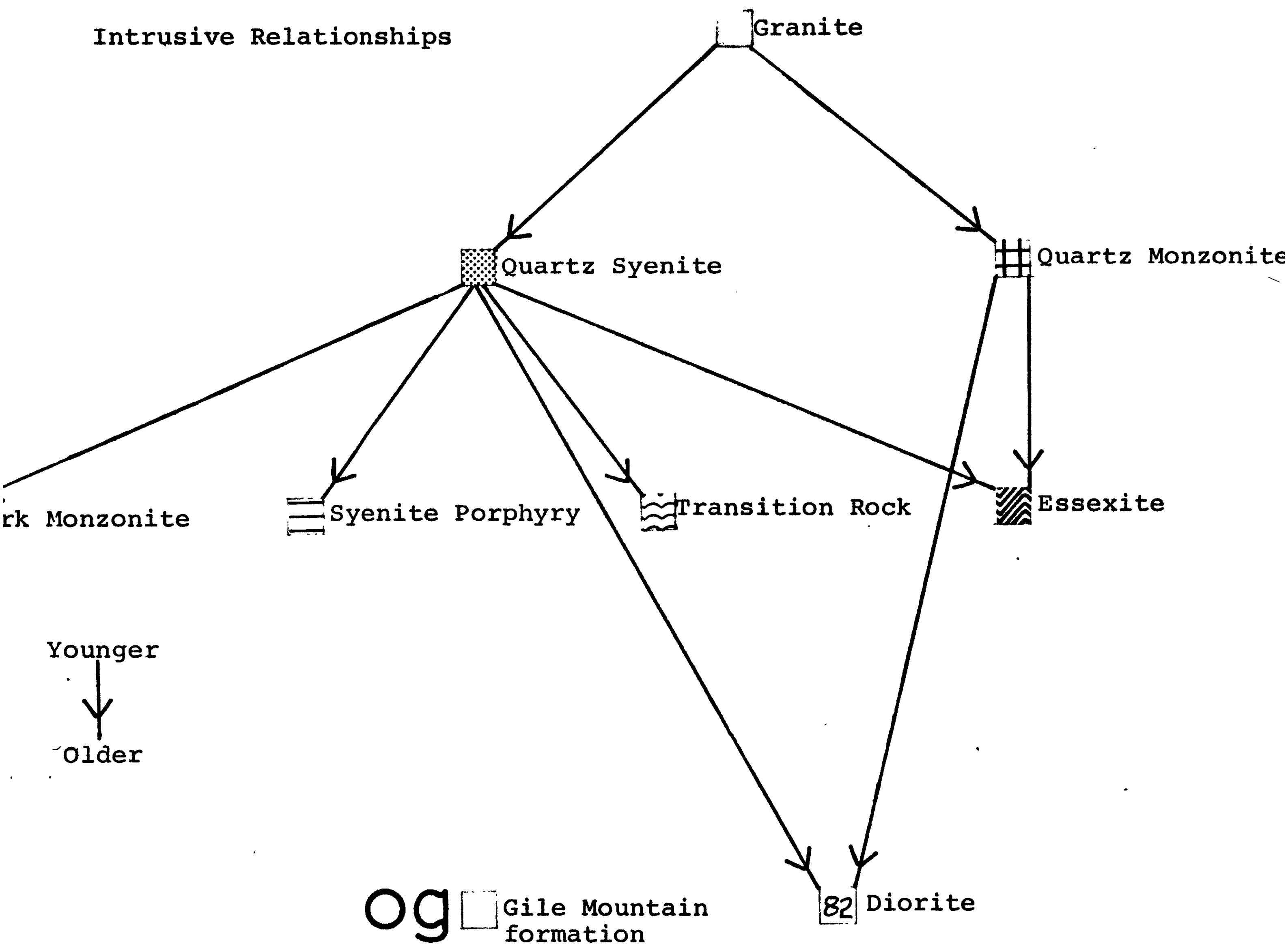
Figure 1



CONTOUR INTERVAL = 100'

SCALE 1:33680

Intrusive Relationships



CHAPTER 2

PETROGRAPHIC DESCRIPTIONS

Essexite

The grey and black essexite is allotriomorphic and even grained except for a few large crystals of salite and plagioclase.

In some samples, there are aggregates of feldspar. Rare megacrysts of kaersutite are found that are up to 8 cm on their long axis and about 2 cm across. These megacrysts contain inclusions of opaques and plagioclase. The plagioclase is euhedral (0.35 by 0.15 mm). The kaersutite is red-brown pleochroic and has an overgrowth of biotite, hornblende, and salite. Apatite and zircon, the next minerals to form, are euhedral (0.2mm). Subhedral crystals (0.04-0.5mm) of magnetite and illmenite probably crystalized next as they form inclusions in the later phases. Plagioclase and salite are the next minerals to form.

Plagioclase forms zoned subhedral laths (0.75 by 3mm), many with sericitized cores. Some contain inclusions of apatite and opaques, and all have overgrowths of albite. These laths occur as clumps throughout the rock.

The original crystal shape of the salite was subhedral (3-1mm), but the thick overgrowths of biotite and hornblende obscure the shape. Some crystals are totally altered to biotite, hornblende, and chlorite. The crystals are slightly pleochroic and golden in color, with inclusions of opaques, apatite, and plagioclase.

The rare interstitial material is composed of anhedral oligoclase (0.15-0.75mm), orthoclase (0.2-0.6mm), and opaques. Sphene is present as anhedral crystals (0.4mm) and has inclusions of biotite and quartz.

Biotite and hornblende occur as anhedral (0.05-3.5mm) intergrowths throughout the rock, and, in some places, totally replace the salite. The biotite and hornblende have inclusions of all the other phases present in the rock, particularly opaques. The biotite is reddish-brown and pleochroic. The hornblende is light green and pleochroic. Composition, done by electron microprobe, of the various phases and a mode for two samples are given in the Appendix.

Transition Rock

The transition rock is a grey, fine grained rock with medium grained light and dark euhedral phenocrysts. It is much more variable in composition and texture than the essexite. Orthoclase varies from non-existent, as in the essexite, to almost twelve percent.

Subhedral magnetite (0.07-0.5mm) and apatite (0.07mm) are the earliest formed crystals. Subhedral phenocrysts of plagioclase(2 by 1mm) contain inclusions of opaques. The size of the subhedral salite varies greatly depending on the sample (0.5-1.5mm). The salite contains inclusions of opaques and is heavily altered to chlorite. Subhedral to anhedral sphene (0.5-0.7mm) is abundant in some samples.

Anhedral crystals (0.6mm) of orthoclase occur in some sections. Anhedral biotite and hornblende are common throughout, and, in some places, are intergrown. They contain very few inclusions, unlike their counterparts in the essexite. The biotite is the same optically as the biotite in the essexite, but the hornblende is greener.

Anhedral oligoclase (0.2-0.35mm) is the groundmass feldspar. Its occurence is from 62 to 6 percent, and the amount is inversely proportional to the amount of orthoclase. Interstitial anhedral quartz (0.05-0.7mm) is more abundant in samples with high orthoclase content. The overall rock texture is allotriomorphic and the average grain size among samples varies between 0.3mm and 0.6mm. A mode and the compositions of the phases present are in the Appendix.

Quartz Syenite

The quartz syenites range from true syenites to granites. It is always pink. The quartz syenite has varying amounts of mafics and the oligoclase perthite ratio is variable. Orthoclase phenocrysts are common, with the amount of phenocrysts varying between rocks. They are generally subhedral and can be as large as 2mm and often have inclusions of plagioclase. The rest of the feldspars are oligoclase and perthite. The oligoclase is lenticular and subhedral in shape (0.5-0.2 by 2.7-0.7mm). The perthite is anhedral to subhedral (0.9-0.4mm).

Subhedral magnetite (0.15mm) is common to rare depending upon the sample. Sphene and calcite are sometimes present in small amounts. Anhedral (0.35mm) biotite is always present; it has dark brown to light brown pleochroism and much of it is altered to chlorite.

Subhedral crystals (0.3mm) of hornblende are sometimes present, but are often totally altered to chlorite. Quartz is always present as anhedral interstitial crystals (0.1-0.7mm). The Appendix shows compositions of the individual phases and modes for two quartz syenites. The overall texture of the quartz syenite is hypidiomorphic.

Granite

The pink granite's major feldspar is perthite, with some samples containing minor amounts of albite. The perthite tends to be subhedral (0.5-1.8mm). Intergrowths of euhedral opaques (0.05-0.7mm), biotite, and hornblende vary from common to rare depending on the sample. The hornblende is dark green and pleochroic. It is subhedral (0.1-0.7mm) and often occurs as aggregates with opaques. The subhedral biotite (0.5mm), much of which is altered to chlorite, always occurs as intergrowths with opaques. Apatite, sphene, allanite, and zircon are assessories. They are euhedral and generally associated with the mafic minerals. Quartz is always interstitial and anhedral (2-0.1mm). The texture of the rock is hypidiomorphic-granular. Tables of the rock forming minerals and a mode for two samples of the southern granite body are given in the Appendix.

The granite body northeast of the summit is very different from the other three. It was never observed in outcrop by Chapman or me, and was mapped by the presence of float alone. It is a medium grained, white rock that is approximately one-third sodic plagioclase, one-third microcline, and one-third quartz with minor biotite and muscovite. Because of its granitic nature, it is assumed to postdate the quartz syenite and the quartz monzonite.

Quartz Monzonite

The quartz monzonite is a medium grained white rock with dark blebs of mafics. The perthite of the quartz monzonite is anhedral (2.8-0.7mm). The plagioclase is subhedral to anhedral and the same size as the orthoclase.

Biotite, hornblende, and opaques are often intergrown and occur in clumps through the rock. The biotite has a deep, red-brown to yellow-brown pleochroism, and contains inclusions of opaques, zircon, and apatite. The biotite is anhedral (0.5-1.3mm). Like the biotite, the hornblende, which is dark green and pleochroic, contains inclusions of zircon, opaques, and apatite. It tends to be subhedral to anhedral (0.7-0.5mm).

Opaques are rarely found, except as small inclusions in the biotite or hornblende. Quartz is always interstitial, and, therefore, anhedral (1.2-0.4mm). The overall texture of the rock is hypidiomorphic-granular. A table of chemical analysis and a mode are in the Appendix.

Syenite Porphyry

The syenite porphyry is a medium grey rock, with large euhedral phenocrysts of plagioclase, medium grain sized phenocrysts of mafics (many of which are totally altered to chlorite), and an aphanitic groundmass. The rock also contains dark inclusions which resemble the diorite.

The plagioclase phenocrysts are euhedral to subhedral except where they occur as aggregates--here, they are intergrown and rounded. Most have overgrowths of albite, and vary greatly in size. The smaller the size of the phenocrysts, the more sodic they are. Some of the large plagioclase phenocrysts have inclusions of opaques, diopside, sphene, and biotite: the opaques are subhedral (0.05mm); the sphene is anhedral (0.2mm); and the diopside is subhedral (0.25mm). The biotite appears to be secondary.

Smaller phenocrysts of diopside, hornblende, and biotite are common. The colorless, nonpleochroic, subhedral diopside phenocrysts (1.2-0.4mm) have overgrowths of biotite and hornblende, and inclusions of opaques. Some are totally altered to chlorite. Most of the light green and pleochroic hornblende seems to be a secondary mineral formed from the alteration or late stage disequilibrium of diopside. The anhedral biotite phenocrysts (0.4mm) are dark brown in color and pleochroic.

These phenocrysts sit in a groundmass of predominantly orthoclase with lesser biotite. Sphene, albite, hornblende, quartz, and apatite are present in minor quantities. The groundmass is even grained and anhedral (0.15-0.1mm). The Appendix gives the composition of the various phases and a mode.

Dark Monzonite

The dark monzonite is a light grey fine grain rock, and has a peculiar texture, i.e., crystals of feldspar are 0.05mm to 1.75mm and all sizes in between. The plagioclase tends to be in subhedral laths (0.05-0.5 by 1.5mm), with larger size crystals predominating. The groundmass consists mainly of perthite. It is generally anhedral in shape, except for the very large crystals which are subhedral (0.05-1.75mm).

Magnetite, sphene, biotite, and hornblende occur throughout the groundmass. The sphene is generally euhedral (0.15mm), the magnetite is subhedral (0.25mm), the anhedral biotite (0.25mm) is brown and pleochroic, and the light green, pleochroic hornblende is subhedral (0.25mm). Apatite and quartz are present, but rare. A mode and the chemical composition of the different phases are in the Appendix.

Diorite

The diorite is a dark to light grey fine grained rock. Its texture is allotriomorphic, but it contains rare phenocrysts of diopside. The opaques were probably the first mineral to crystallize as they are found as anhedral inclusions (0.1mm) in the phenocrysts. The phenocrysts of diopside (1.25mm) were subhedral, but are now extensively altered to hornblende. The diopside phenocrysts seem identical to the clear and non-pleochroic groundmass pyroxene (0.35mm). The diopside in the groundmass is very irregular in shape and is probably a remnant of the phenocrysts. Hornblende in this rock is not primary, but found only as alterations of diopside, and has a light green to clear pleochroism.

The sphene present is subhedral to anhedral (0.2mm). The anhedral biotite (0.1-0.4mm) in the diorite has dark brown to yellow pleochroism. The groundmass is predominantly oligoclase with minor orthoclase. The oligoclase forms laths, when possible, but is generally anhedral in crystal shape (0.4-0.1mm). The orthoclase is anhedral (0.4-0.1mm). A mode and the compositions of the phases present are in the Appendix.

CHAPTER 3

EXPERIMENTAL

Representative samples of the rock types were thin sectioned and the major mineral phases in the thin section were electron microprobed, using a fully automated Materials Analysis Company electron microprobe.[4] The correction method of Albee and Ray[5] which is a modified version of the Bence and Albee[6] correction method was used. The probe was operated at an accelerating voltage of 15 KV with a beam current of about 0.02μA, and counted for 30 sec. or 30,000 counts.

Modes of the thin sections were done optically. Rock slabs of the samples were stained with a saturated solution of sodium cobaltinitrite to distinguish the potassium feldspar from the plagioclase. Finally, qualitative major element analyses of these samples were done by mixing ground portions of these samples with equal weight portions of lithium tetraborate, melted at 1000^{o}C, and quenched on a piece of aluminum. The glasses were then probed using a standard (G-2) that was prepared in the same manner. The Appendix lists the standards used with the microprobe. The following samples were studied in this manner: the quartz syenite (samples 71, 72); the southern granite body (samples 97, 98); the syenite porphyry (sample 90); the dark monzonite (sample 84); the diorite (sample 82); the quartz monzonite (sample 31); and the transition rock (samples 39, 76). The minerals of samples 37 and 33 of the essexite were analysed and a glass was made of sample 33 only. No major element analysis was obtained for sample 37 as it contained a large megacryst of kaersutite which is not typical of the whole rock. Optical microscope slides and stained rock slabs were prepared and studied for many other samples. The locations of the samples electron microprobed are listed in Figure 1. The Appendix lists the analysis of the mineral phases, the modes of the samples probed, and the major element composition of the samples. The method of obtaining major element data was not very successful. For some undetermined reason, the silica data was erratic. The standard glass was analysed between groups of analyses. The error in the silica data for the standard was used to correct the analyses, and then the analyses were normalized to 100 percent. The normalization was required because some of the glasses were clearly not half rock, half lithium tetraborate. This was caused by the presence of water in the lithium tetraborate caused by exposure to air. Also, the aluminum and sodium data tended to be erratic, but to a lesser degree. Therefore, the whole rock data is not used for anything but trends.

DATA

Feldspar diagrams were plotted from the probe data for the minerals (see Appendix). They are given in molar percentages using orthoclase and anorthite because the sodium data tends to be more erratic than potassium or calcium because of a greater counting error. The tie lines are between end members of a specific average, and, therefore, the analysis of that average lies near or on that line. If the average has end members that vary from a straight line, then a triangle was used. Perthite compositions were calculated by averaging the albite and orthoclase parts of the perthite using the mode data. The calculated perthites are represented as squares on these diagrams. These were calculated from the averages that are on the right and left bottom corners, the most sodium and potassium rich feldspars. The wide tie lines are between the co-existing feldspars.

Figure 3 shows the most anorthite rich feldspar in each rock. In the quartz monzonite, this is the core of a zoned crystal. The most anorthite rich plagioclase in the quartz syenites is an inclusion in an orthoclase phenocryst. The feldspar graphed for the syenite porphyry is from the largest plagioclase phenocryst probed. The feldspar shown for the granites is from the albite portion of the perthite. The trend to the granite is meaningless because the feldspars listed are not primary feldspars. If a more representative feldspar is graphed for the quartz monzonite and for one of the quartz syenites, as in Figure 4, then the dark monzonite and the light monzonite would be included in the trend.

Figure 5 shows the compositions of the pyroxenes. The essexite, transition rock pyroxene trend is the same shape as the pyroxene trend in the Kap Edvard Holm intrusion,[7] a slowly cooled intrusion of alkali-basalt in eastern Greenland. The trend is at a higher

$CaSiO_3$ concentration than the Kap Edvard Holm pyroxene trend, but this is not unusual because acidic rocks tend to have trends elevated in $CaSiO_3$.

The Appendix lists the iron to magnesium ratio for the mafic silicates and the whole rock. Figure 6 plots the whole rock iron to magnesium ratio against the iron to magnesium ratio of the mafic silicates. There is a trend from the essexite through the transition rock to the quartz syenite and then on to the granite. The dark and quartz monzonites are clearly off of the trend. The syenite porphyry and the diorite lie off of the trend also.

Variation diagrams were made from the whole rock data, Figures 7-13. The diorite lies off of the trend in most of the diagrams. The sodium diagram, Figure 12, shows only how bad the sodium data is. The poor quality of the sodium data may be from loss of sodium during heating as well as a greater counting error.

CONCLUSION

Wright and Doherty's[8] program for modeling fractional crystalization was used to model the possible fractional relationship between the different rock types. No direct parent daughter relationships were observed. This does not mean that the rock types are not related by fractional crystalization, but that if they are, the phases that precipitated are not present at this level of erosion, and, therefore, could not be accounted for in the program.

From the iron to magnesium ratic and the contact relationships

(Figure 2), it appears that the essexite, the transition rock, the quartz syenite, and the granite are related and that the quartz monzonite, the dark monzonite, the syenite porphyry, and the diorite are not directly related to the others. This conclusion may be erroneous since the whole rock data suggests that only the diorite is clearly not related.

It seems probable that the liquids that produced the essexite, the transition rock, the quartz syenite, and the southern granite body are fractionates of a high titanium alkali basalt magma. This seems likely because of the presence of kaersutite megacrysts in the essexite and because when the whole rock trends are extrapolated to lower silica concentrations, the resultant rock type is a high titanium alkali basalt.

The quartz monzonite seems to be a later intrusion that formed a ringdike along the east side of the mountain. How the granites that intrude it are related to the rest of the intrusion is not known. The dark monzonite and the syenite porphyry are early intrusions that were intruded by the quartz syenite. The diorite is probably the oldest rock type as it is found as inclusions in all the other igneous rocks, except the dark monzonite.

This synthesis of the intrusion is simplistic and the intrusion is certainly more complex. Trace element data, dates on the rock types, more samples studied in detail, better whole rock data, and a thorough mapping of the area would clarify the relationships between the rock types.

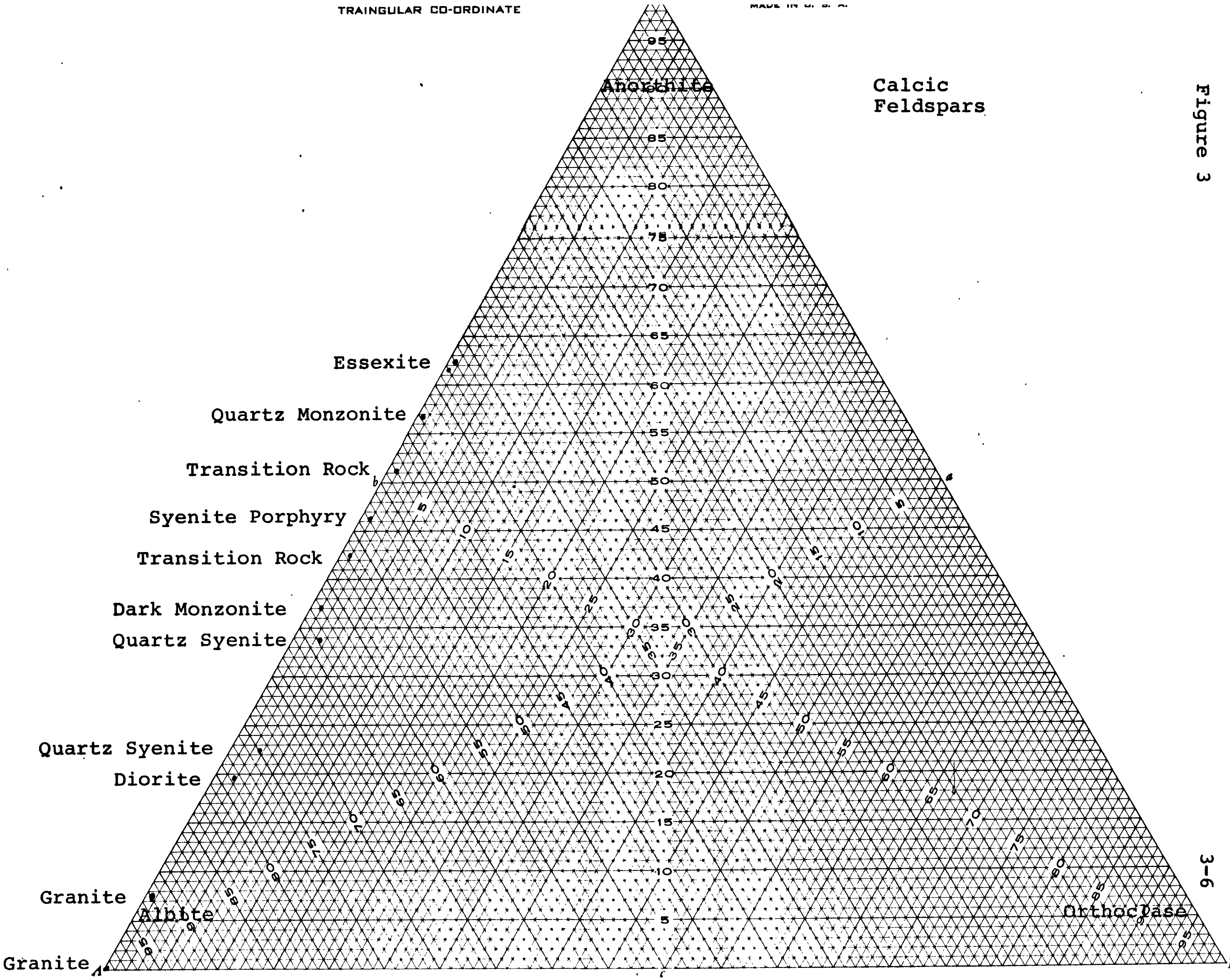
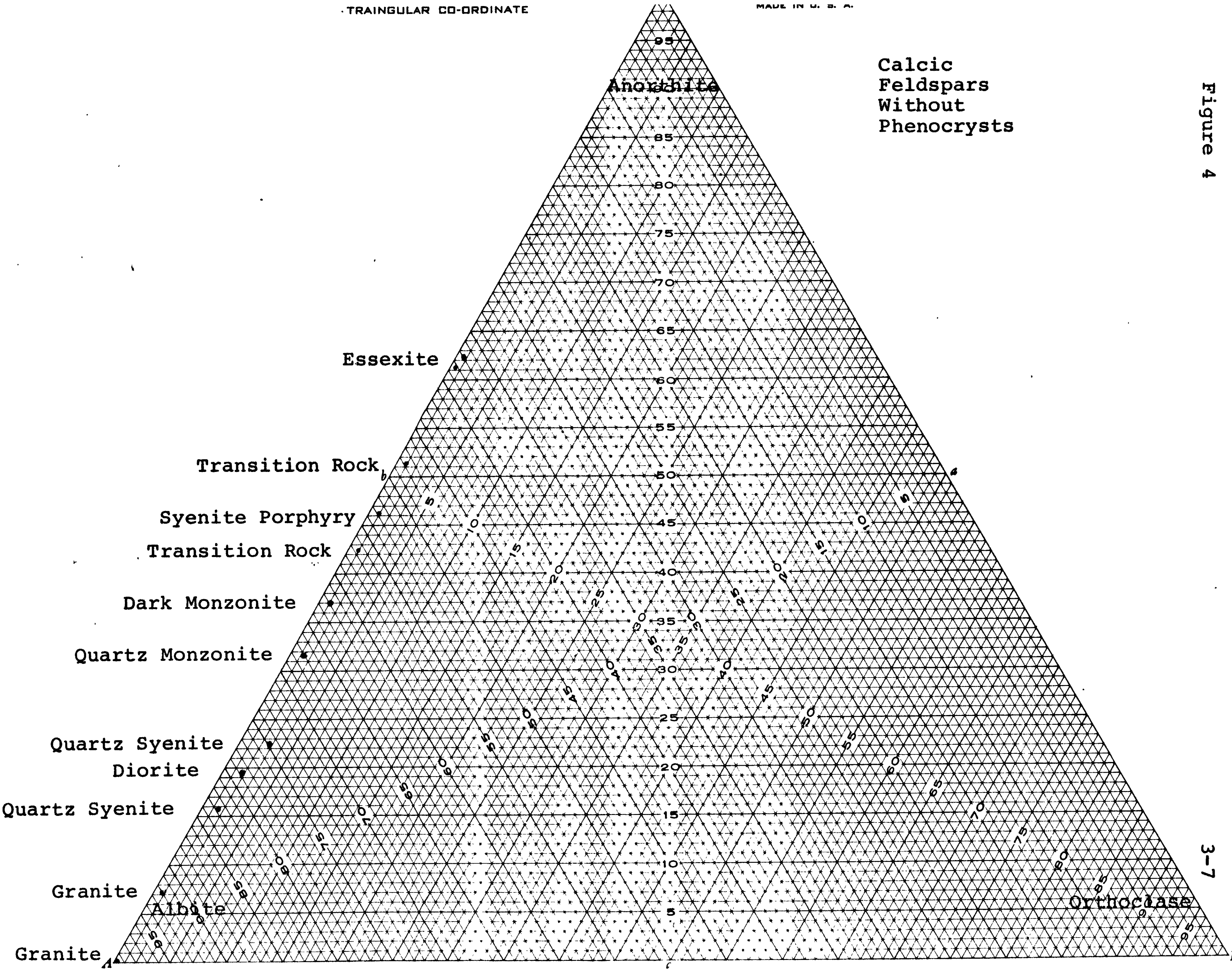

TRAINGULAR CO-ORDINATE
Anorthite
Calcic
Feldspars
Essexite
Quartz Monzonite
Transition Rock
Syenite Porphyry
Transition Rock
Dark Monzonite
Quartz Syenite
Quartz Syenite
Diorite
Granite
Albite
Granite
Orthoclase
A
B
C

Figure 3


TRAINGULAR CO-ORDINATE
MADE IN U. S. A.
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Anorthite
Essexite
Transition Rock
Syenite Porphyry
Transition Rock
Dark Monzonite
Quartz Monzonite
Quartz Syenite
Diorite
Quartz Syenite
Granite
Albite
Granite
Orthoclase

Figure 4

Figure 5

Pyroxenes

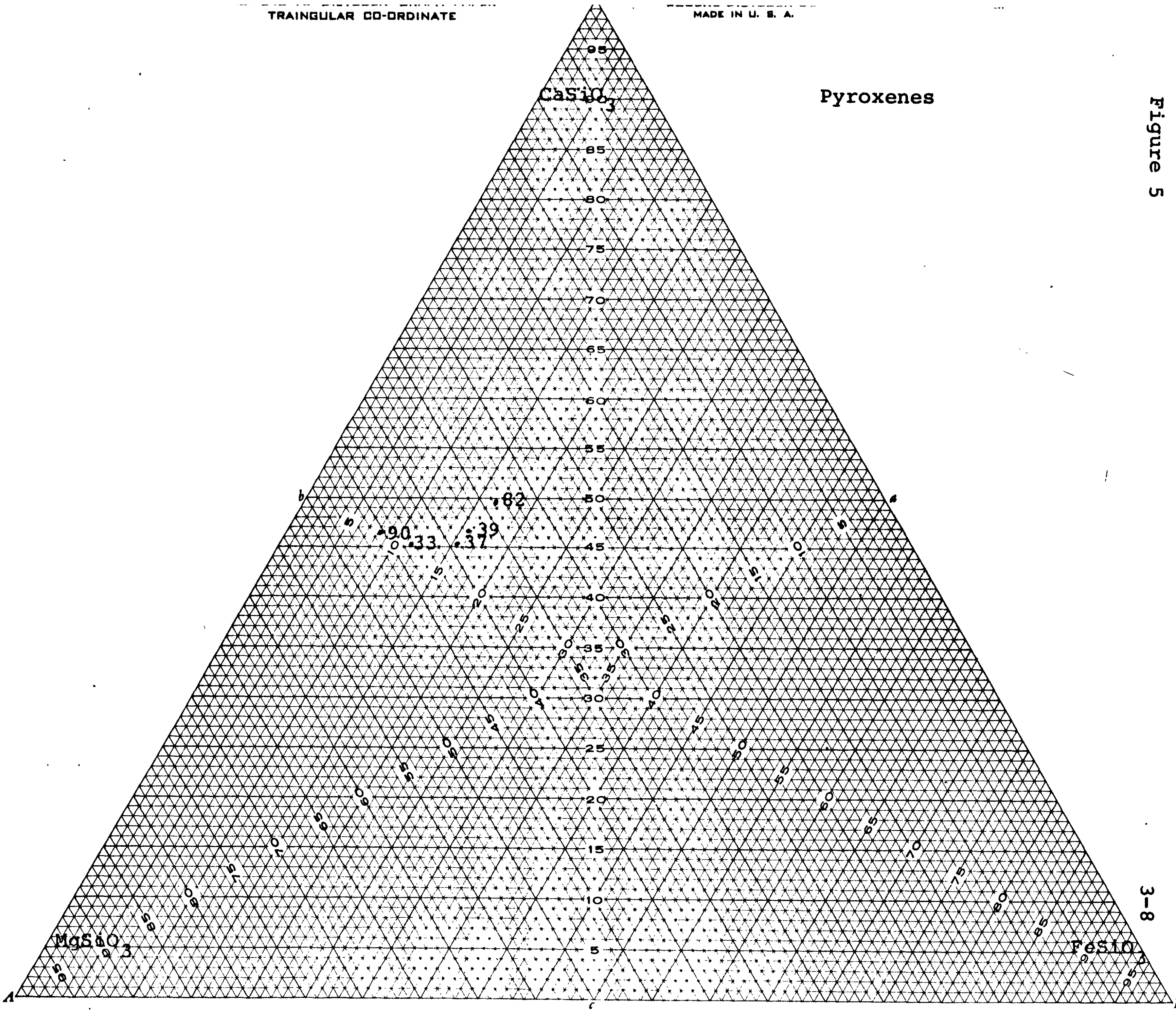
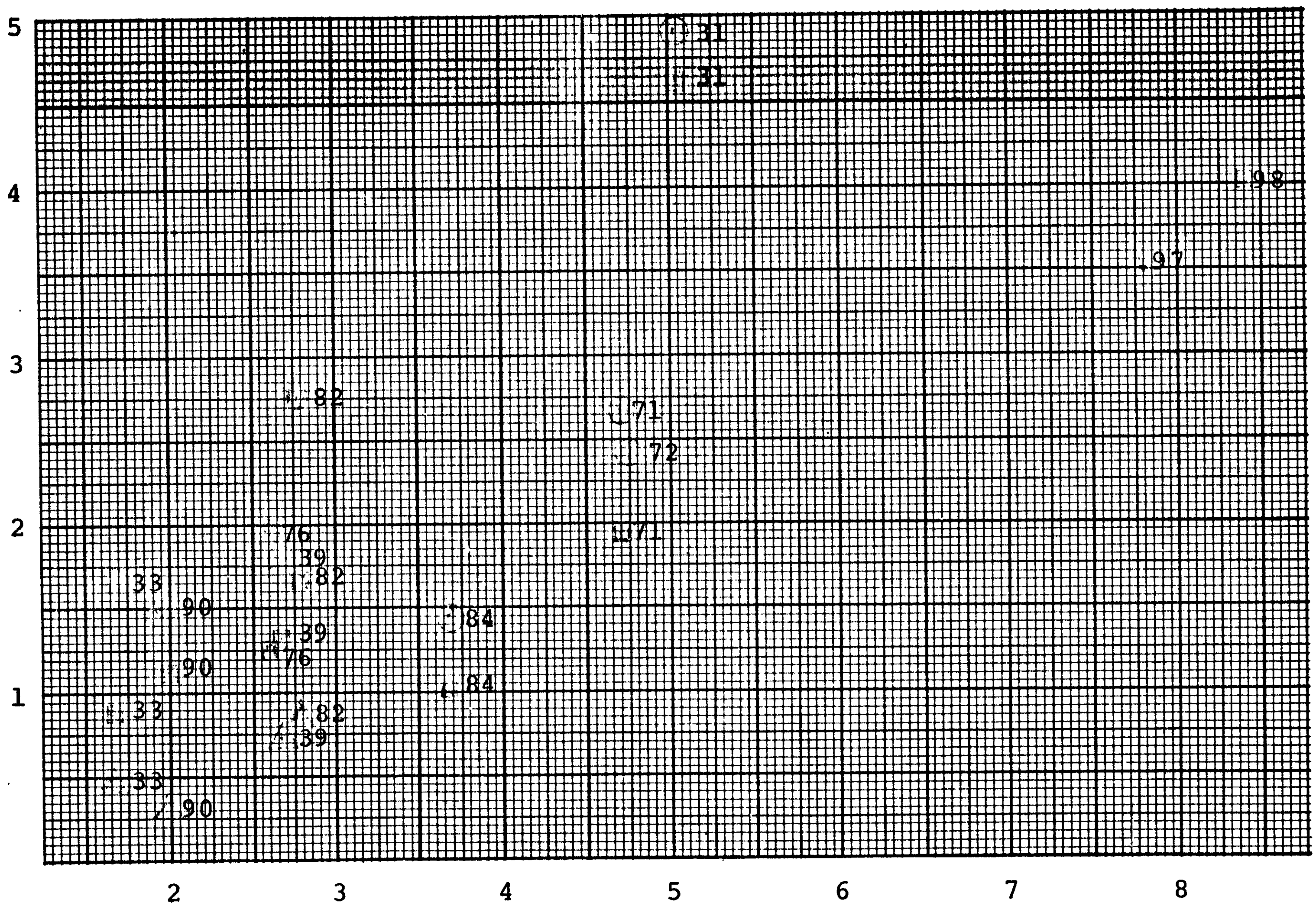


Figure 6

Iron to Magnesium Ratios



Fe/Mg for Minerals

Fe/Mg for Whole Rock

biotite
hornblende
pyroxene

Figure 7

Whole Rock Variation Diagram for Titanium

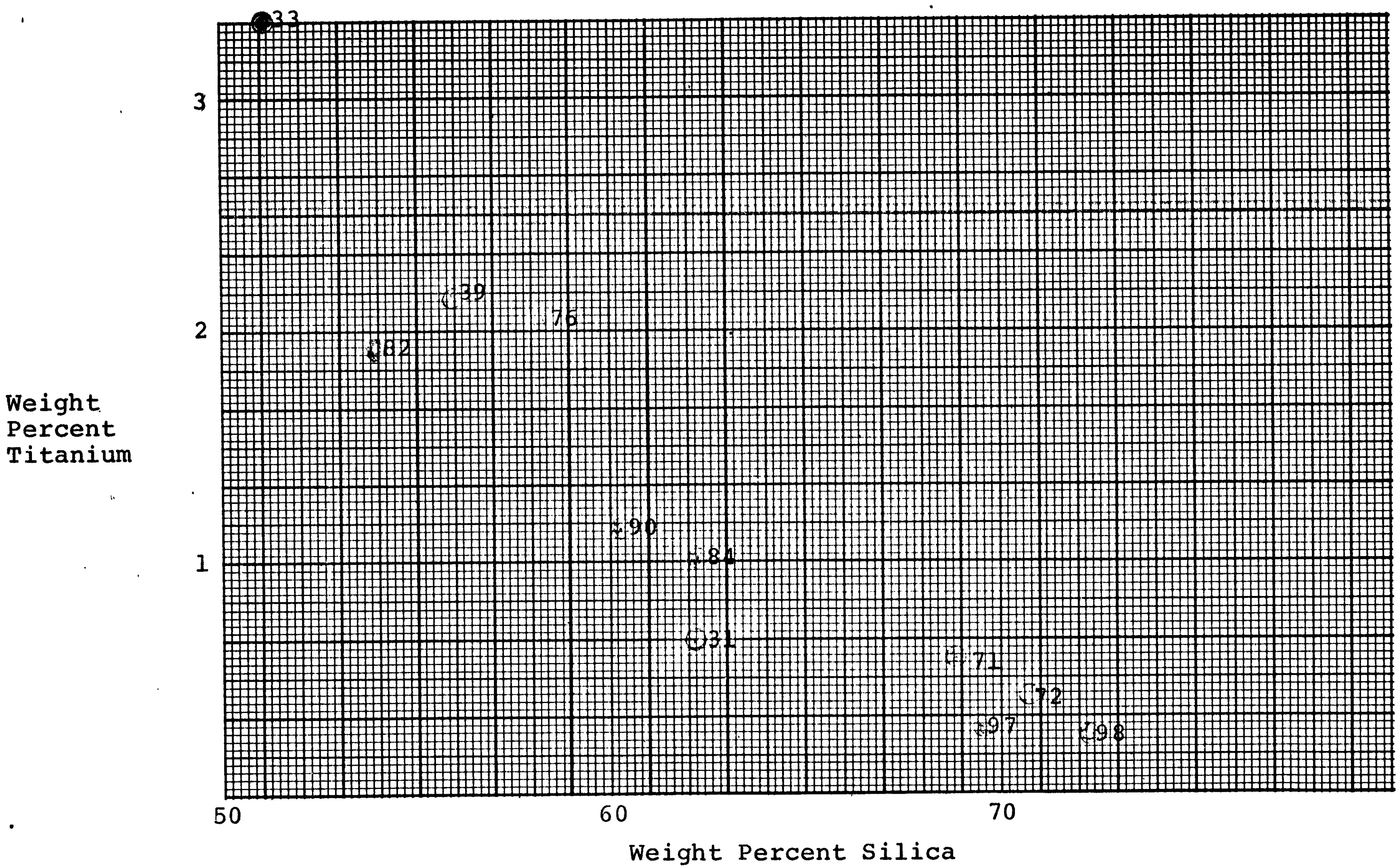


Figure 8

Whole Rock Variation Diagram for Aluminum

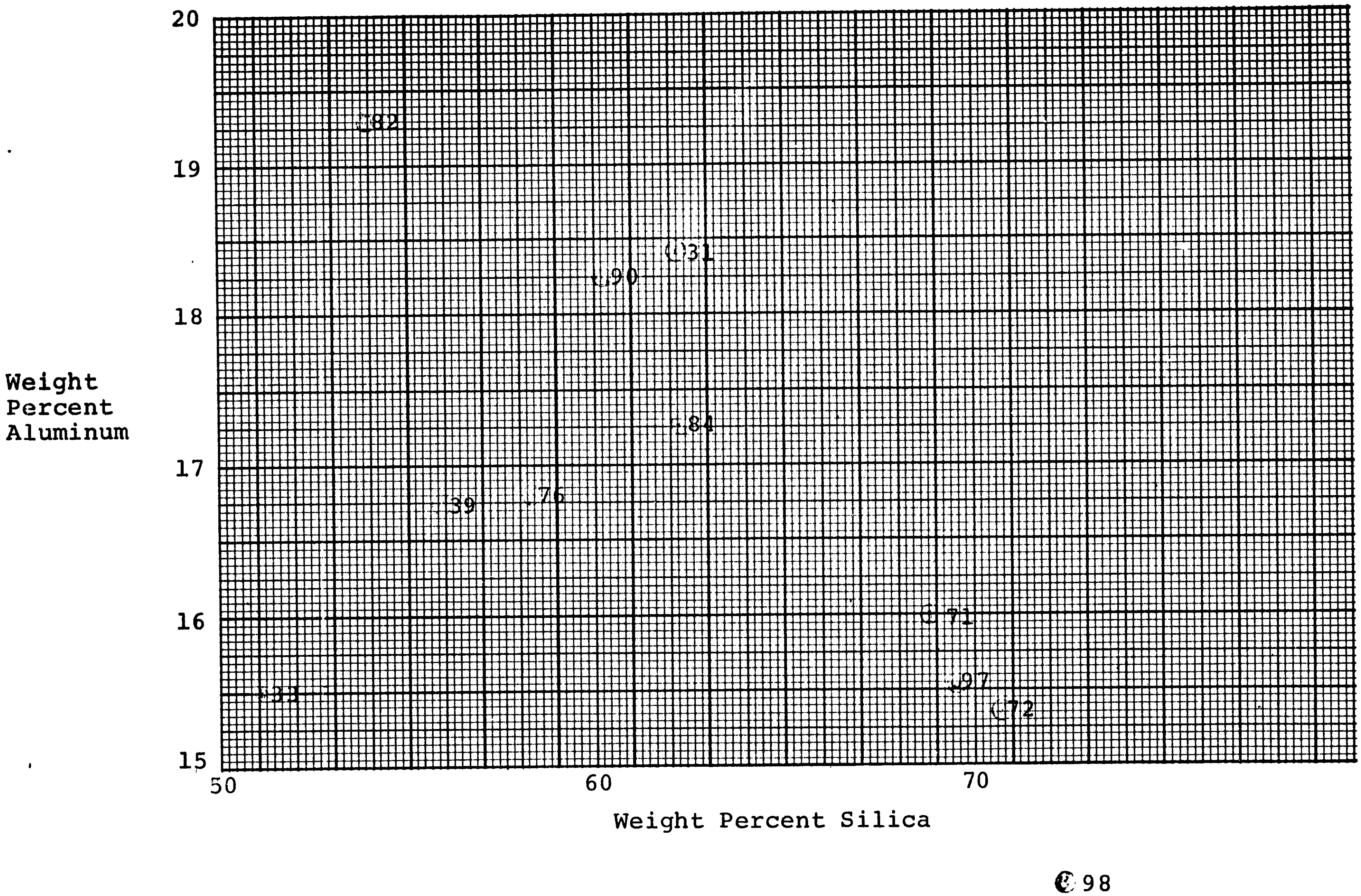


Figure 9

Whole Rock Variation Diagram for Iron

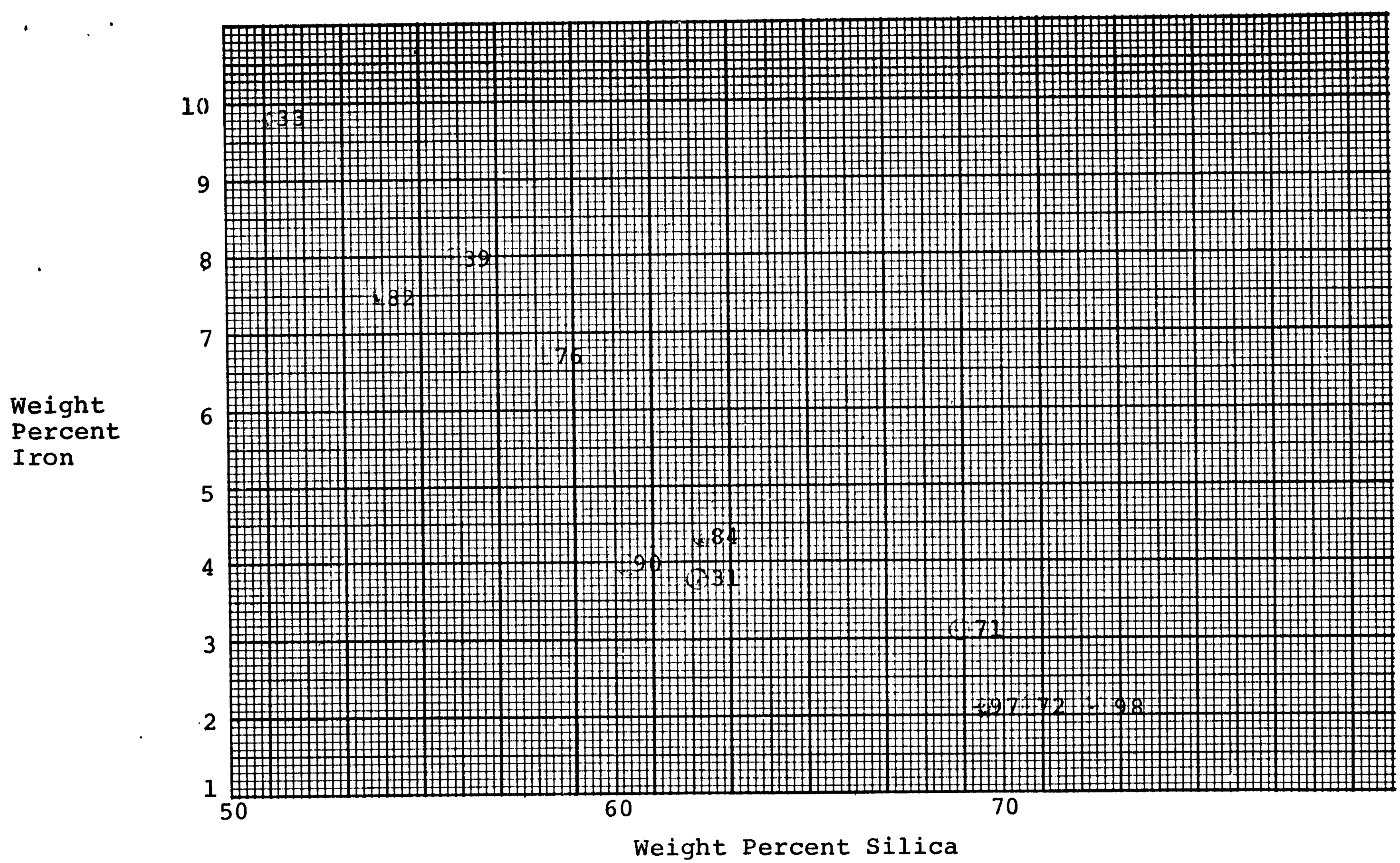
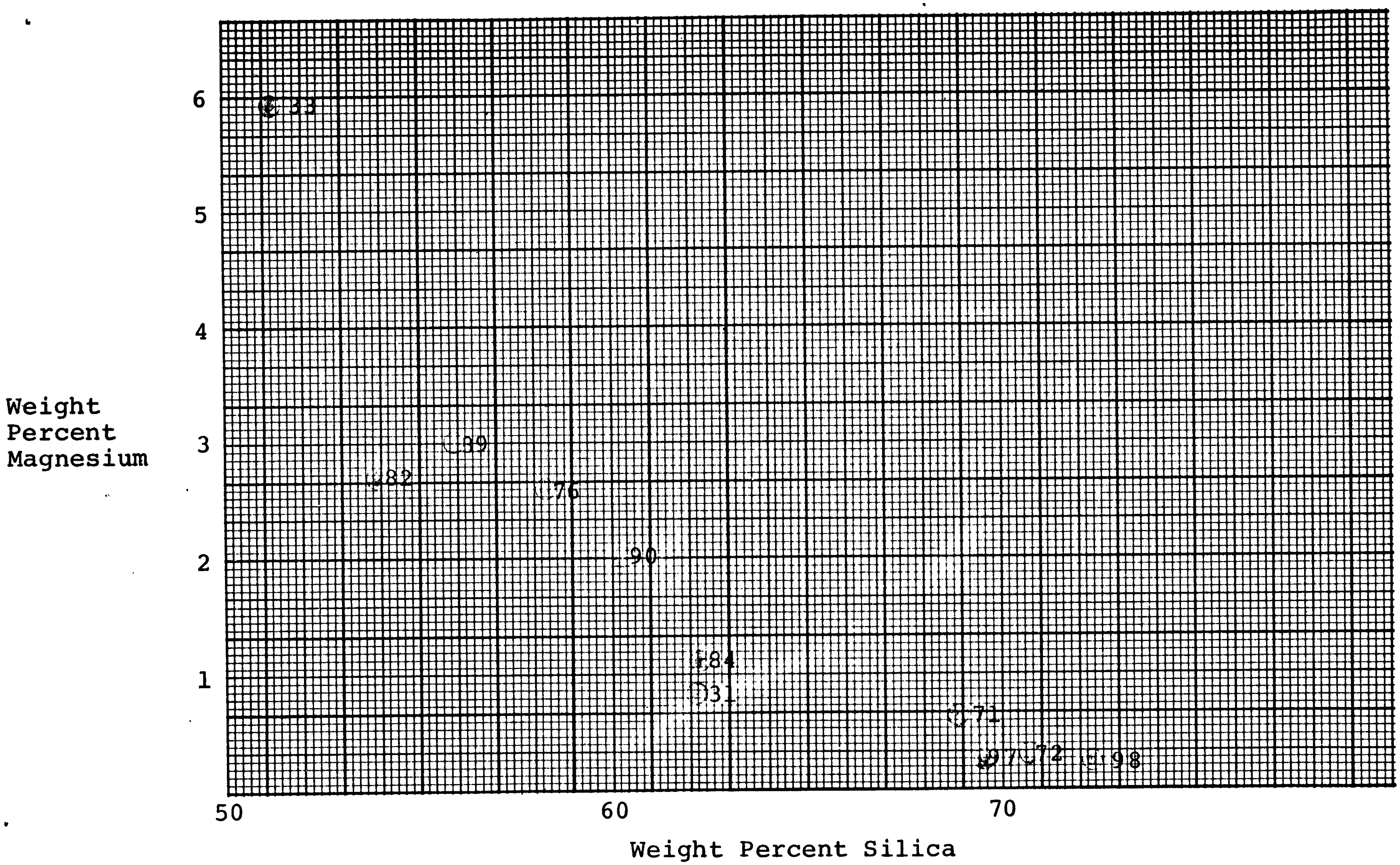
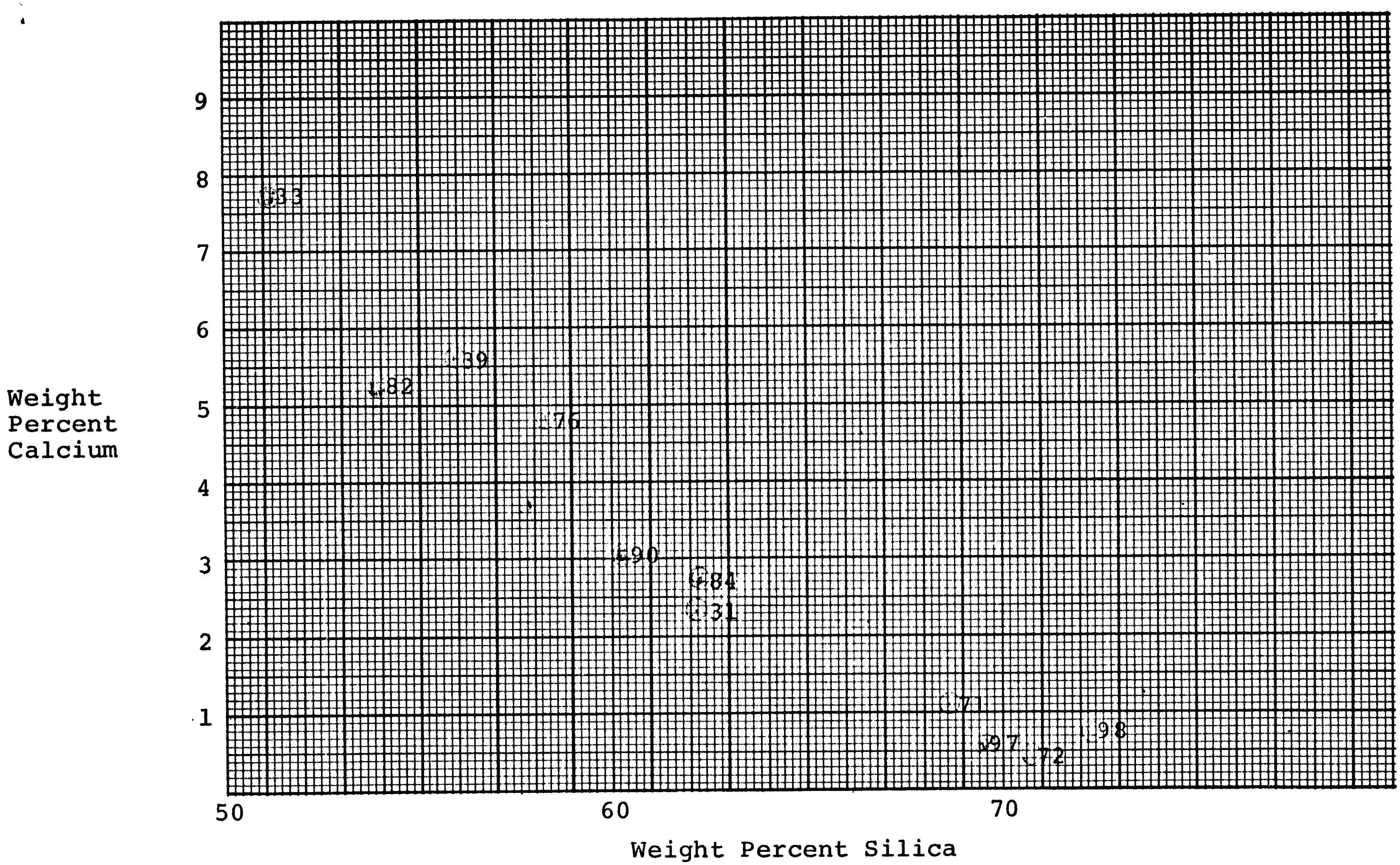


Figure 10

Whole Rock Variation Diagram for Magnesium



Whole Rock Variation Diagram for Calcium



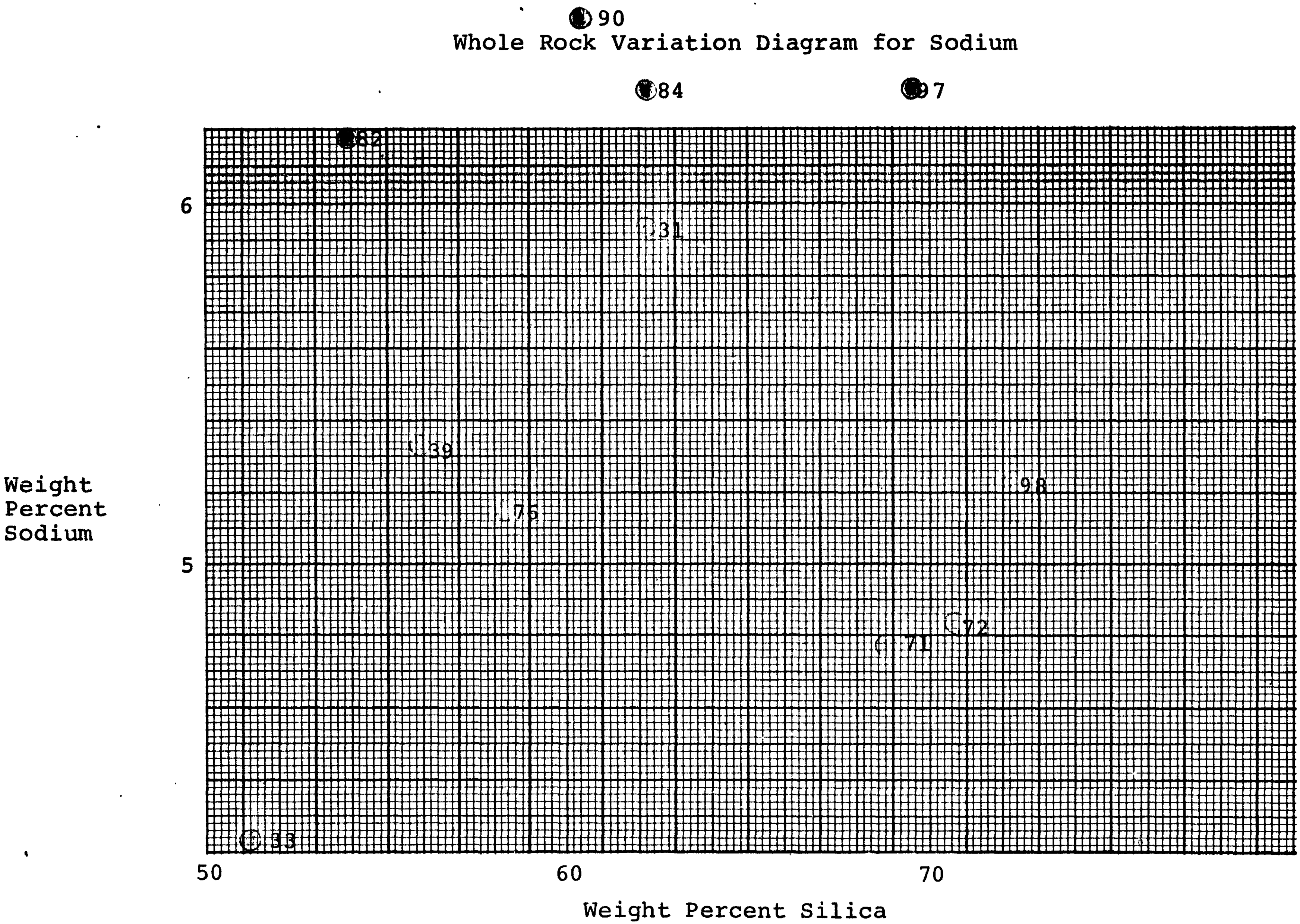
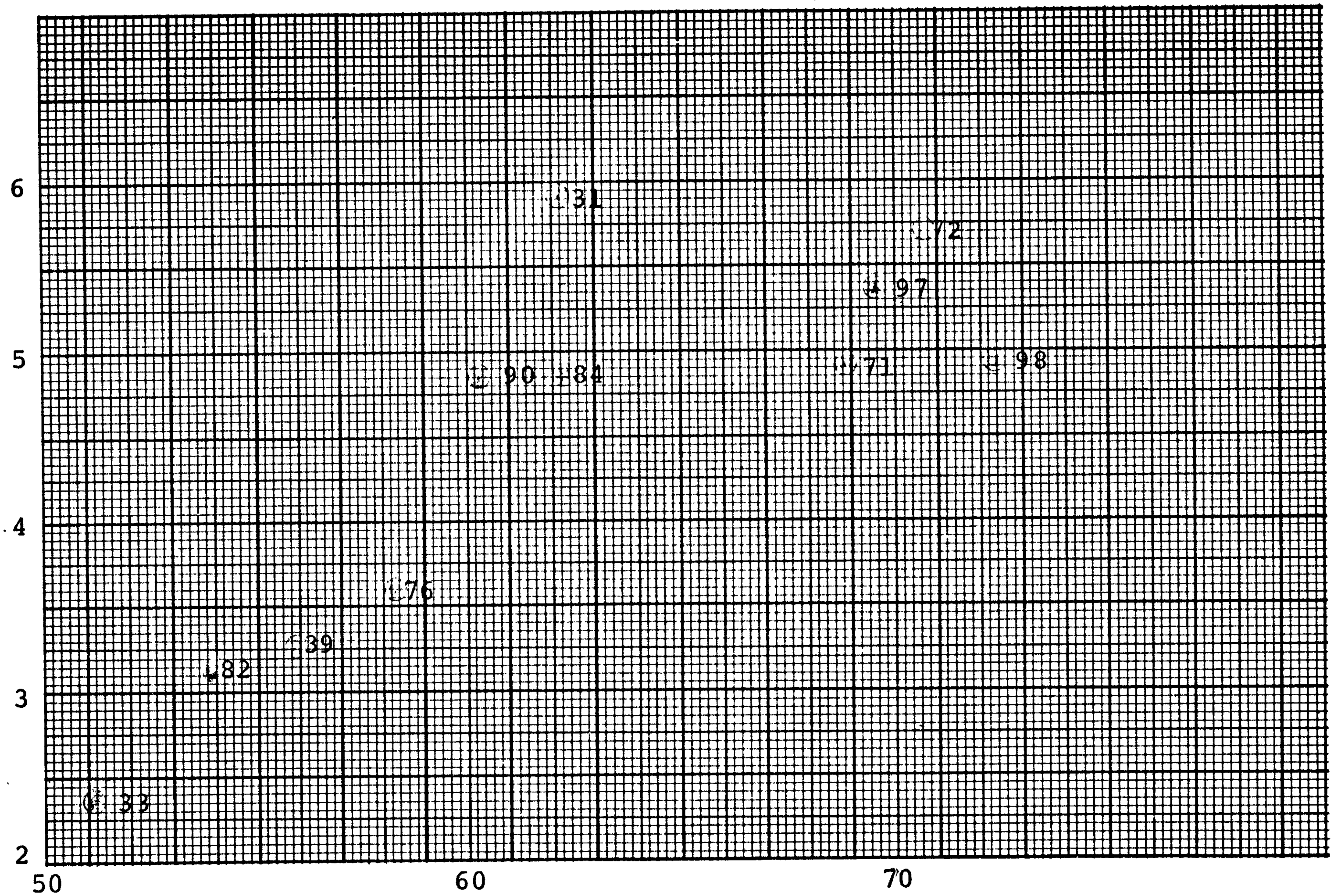

Whole Rock Variation Diagram for Sodium
90
84
97
62
31
39
98
76
72
71
33
6
5
Weight
Percent
Sodium
50
60
70
Weight Percent Silica

Figure 12

Figure 13

Whole Rock Variation Diagram for Potassium

Weight Percent Potassium



Weight Percent Silica

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APPENDIX

SAMPLE 37: ESSEXITE

	A	SD	B	SD	C	SD	D	SD	E	SD
SiO_2	52.21	.66	39.25	.98	48.98	.71	36.49	.77	54.76	1.43
TiO_2	.26	.32	5.61	2.09	1.08	.20	3.71	.53	.05	.01
Al_2O_3	.89	.71	13.26	1.15	4.82	.28	13.63	.25	28.61	1.01
*FeO	9.06	1.03	11.04	1.57	14.64	.25	19.65	.97	.22	.07
MgO	13.97	.50	12.68	1.12	14.45	.22	12.36	.90	.00	.01
CaO	22.26	.74	12.47	1.25	11.17	.31	.10	.40	10.86	1.14
Na_2O	.64	.05	1.94	.15	1.39	.18	.12	.03	5.40	.68
K_2O	.03	.01	1.53	.28	.52	.04	9.32	.18	.14	.03
TOTAL	99.32	5 analyses	97.80	15 analyses	97.05	7 analyses	95.39	10 analyses	100.04	15 analyses
MODE	6.7				16.7		18.8		17.2	

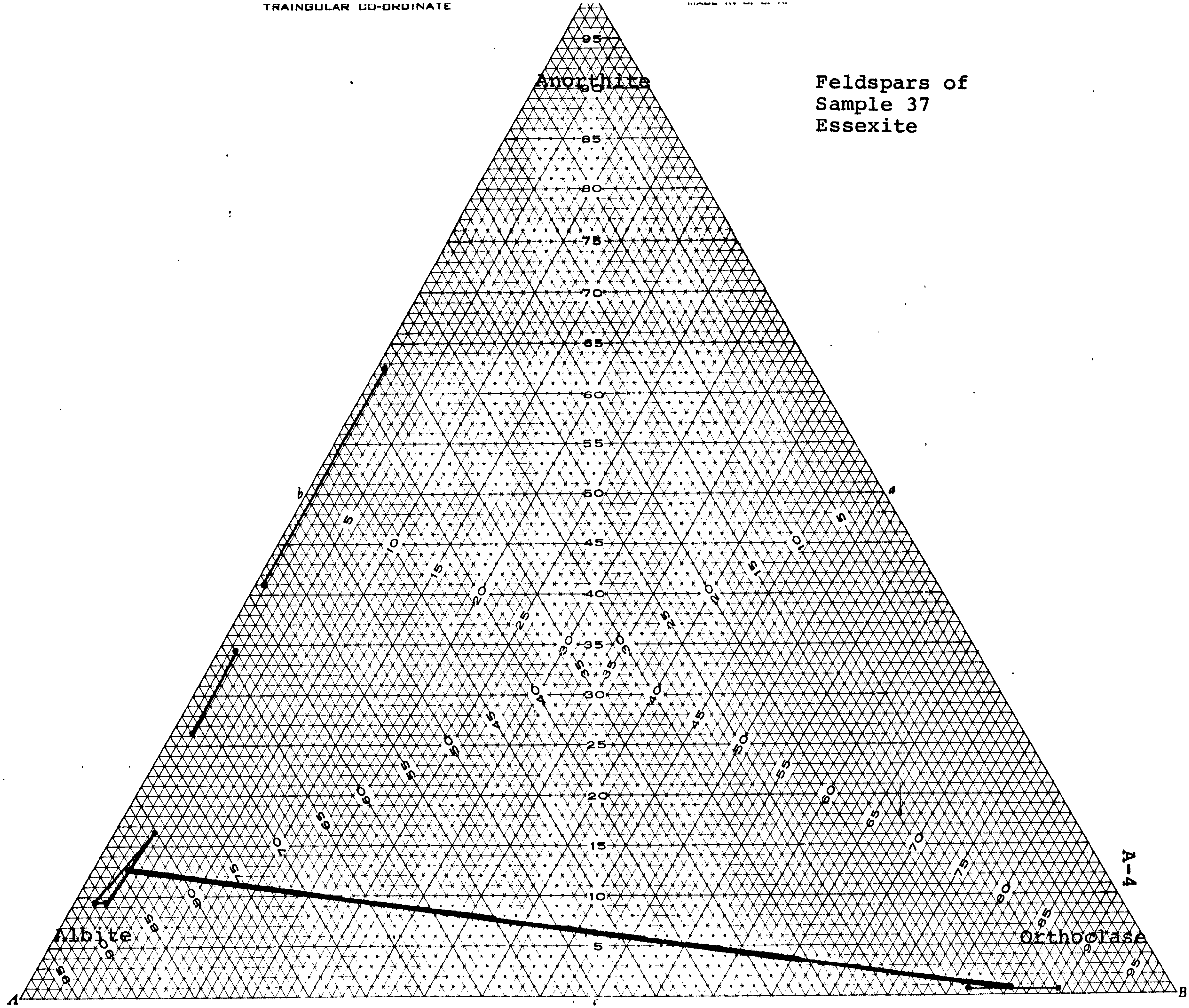
A = Salite
B = Kaersutite
C = Hornblende
D = Biotite
E = Large Plagioclase Crystals
F = Smaller Plagioclase Crystals
G = Oligoclase Groundmass
H = Orthoclase
I = Quartz

* Total iron expressed as FeO

SAMPLE 37 (continued)

F	SD	G	SD	H	SD	I			
60.78	.90	65.43	1.23	65.31	.51	96.57			
.02	.01	.00	.00	.00	.01	.00			
73.80	1.34	21.74	.94	18.11	.21	.03			
.23	.05	.23	.06	.18	.02	.00			
.00	.01	.01	.02	.00	.00	.00			
6.18	.65	2.60	.45	.10	.01	.01			
8.19	.27	10.04	.60	1.40	.26	.01			
.30	.06	.53	.44	14.65	.35	.01			
99.50	6 analyses	100.58	13 analyses	99.75	7 analyses	96.64			
		31.8		.5		.1	.5	7.7	100
							sphene	opaques	Total

Feldspars of
Sample 37
Essexite



SAMPLE 33: ESSEXITE

	A	SD	B	SD	C	D	E	SD	F	SD
SiO_2	.29	.36	.16	.11	.27	13.39	49.65	1.71	51.56	1.41
TiO_2	.25	.19	45.75	1.16	.02	15.52	1.50	.38	.67	.22
Al_2O_3	.39	.19	.68	.78	.04	.48	5.11	1.52	3.81	.86
Cr_2O_3	.89	.07	.00	.00			.02 (5 analyses)	.03	.00 (4 analyses)	.00
*FeO	88.82	1.27	48.47	.62	.16	1.73	7.01	1.08	14.01	.91
MgO	.16	.11	.22	.06	.04	.63	14.90	.89	15.66	.57
CaO	.08	.07	.04	.01	52.59	24.96	21.65	.54	11.76	.22
Na_2O	.00	.00	.00	.00	.24	.08	.70	.22	1.12	.30
K_2O	.00	.00	.00	.00	.02	.06	.02	.01	.35	.10
TOTAL	90.88	3 analyses	95.32	2 analyses	53.38	94.04	100.56	10 analyses	98.94	11 analyses
MODE	5.5 (opaques)				.5	.8	2.1		19.5	

A = Magnetite
B = Illmenite
C = Calcite
D = Sphene

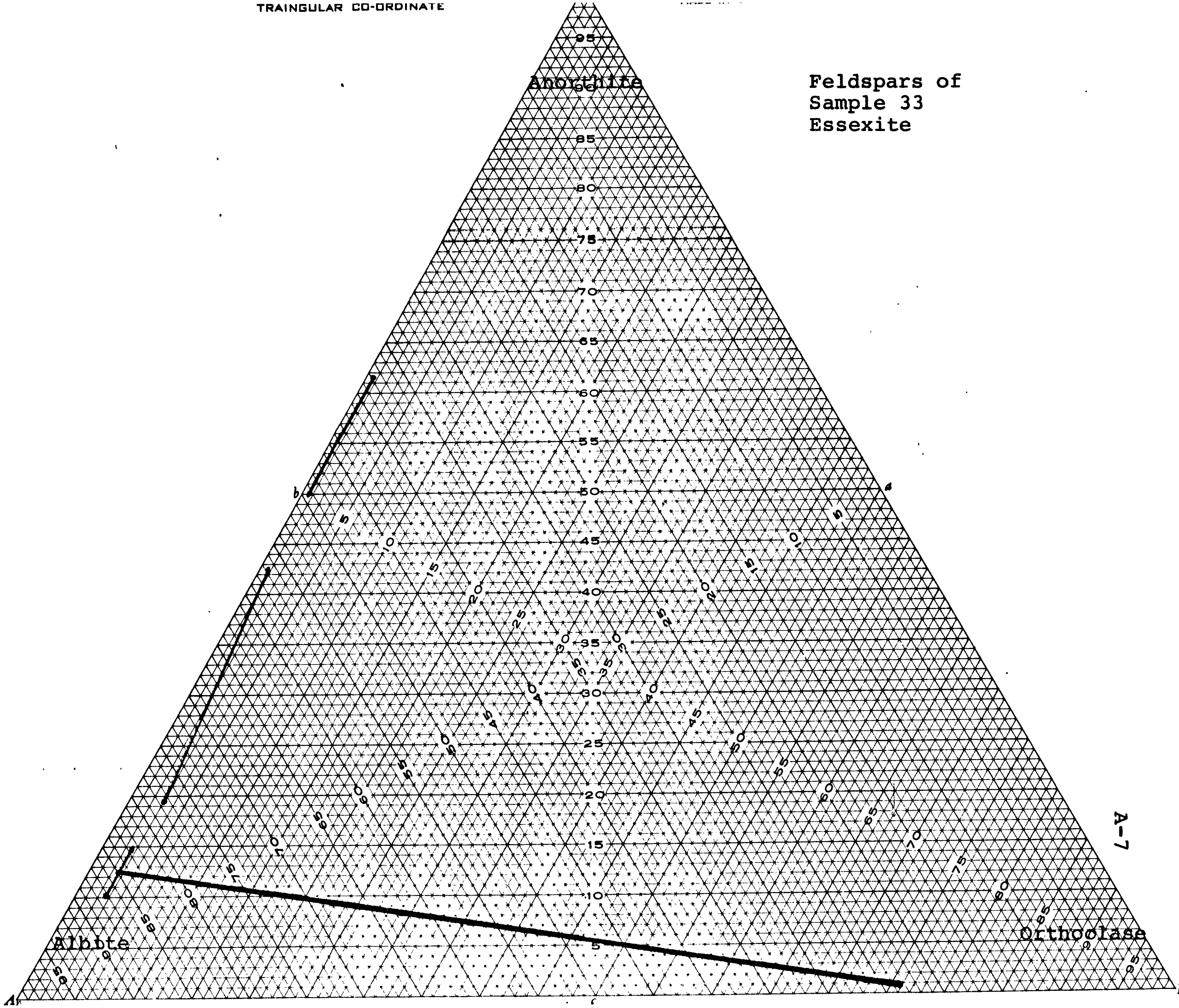
E = Salite
F = Hornblende
G = Biotite
H = Large Plagioclase Phenocrysts

I = Small Plagioclase Phenocrysts
J = Oligoclase, groundmass
K = Orthoclase

* Total iron expressed as FeO

SAMPLE 33 (continued)

G	SD	H	SD	I	SD	J	SD	K	
36.96	.34	54.28	.93	60.36	2.72	64.86	1.26	65.12	
3.69	.52	.07	.02	.02	.05	.01	.02	.04	
13.62	.16	29.04	.51	24.69	1.94	22.00	.98	18.12	
.10	(1 analysis)	.02	(1 analysis)						
20.69	.45	.22	.11	.23	.08	.22	.05	.19	
12.44	.48	.02	.01	.01	.01	.01	.01	.02	
.11	.03	11.34	.69	6.32	2.02	2.79	.32	.18	
.10	.07	5.46	.51	8.33	.89	10.30	.52	2.59	
9.31	.37	.18	.17	.30	.17	.55	.18	12.90	
97.02	11 analyses	100.63	9 analyses	100.29	5 analyses	100.74	10 analyses	99.15	
18.8		17.3				35.0		.5	100 TOTAL


Anorthite
Feldspars of
Sample 33
Essexite
Albite
Orthoclase

SAMPLE 76: TRANSITION ROCK

	A	SD	B	C	SD	D	SD	E	SD	F	SD
SiO_2	.17	.04	.08	29.52	.51	49.13	1.93	36.64	.52	26.83	.40
TiO_2	.43	.11	47.75	36.00	.49	.54	.21	3.44	.45	.05	.01
Al_2O_3	.26	.01	.08	1.29	.13	3.87	1.17	12.72	.47	17.92	1.78
*FeO	89.47	1.08	45.74	1.95	.09	16.67	.48	21.65	.46	30.72	4.67
MgO	.06	.01	.07	.04	.01	12.95	.55	11.02	.59	12.70	2.14
CaO	.10	.02	.07	27.05	1.13	11.18	.22	.09	.02	.08	.06
Na_2O	.00	.00	.07	.03	.04	1.06	.31	.07	.05	.01	.01
K_2O	.07	.01	.04	.02	.00	.43	.14	9.15	.14	.06	.01
TOTAL	90.56	2 analyses	93.90	95.90	2 analyses	96.43	8 analyses	94.80	7 analyses	88.37	2 analyses
MODE		3.1 opaques		2.7		5.3		13.1			

A = Magnetite
B = Illmenite
C = Sphene
D = Hornblende

E = Biotite
F = Chlorite
G = Plagioclase
H = Oligoclase Groundmass

I = Orthoclase

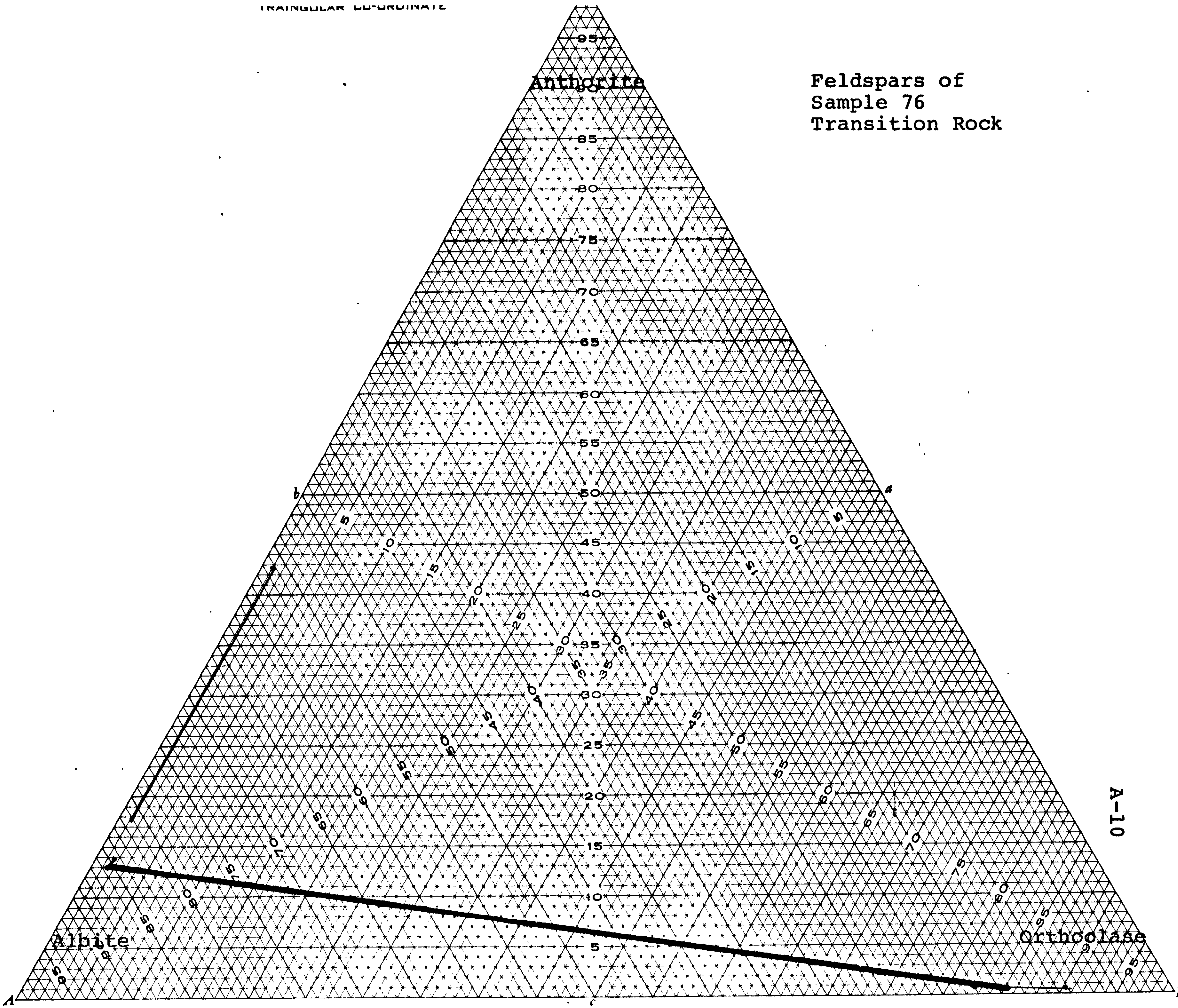
* Total iron expressed as FeO

SAMPLE 76 (continued)

G	SD	H	SD	I	SD		
60.27	2.92	65.17	1.38	64.99	.49		
.04	.03	.00	.00	.01	.01		
24.96	1.91	21.77	.31	18.27	.39		
.18	.05	.16	.05	.17	.05		
.02	.05	.01	.01	.01	.01		
6.53	2.00	2.84	.08	.01	.03		
7.94	1.28	10.37	.34	1.36	.27		
.23	.08	.31	.09	14.57	.41		
100.17	17 analyses	100.67	4 analyses	99.48	9 analyses		
54.8		6.3		11.7		3.0 quartz	100 TOTAL

TRAINGULAR CO-ORDINATE

Feldspars of
Sample 76
Transition Rock



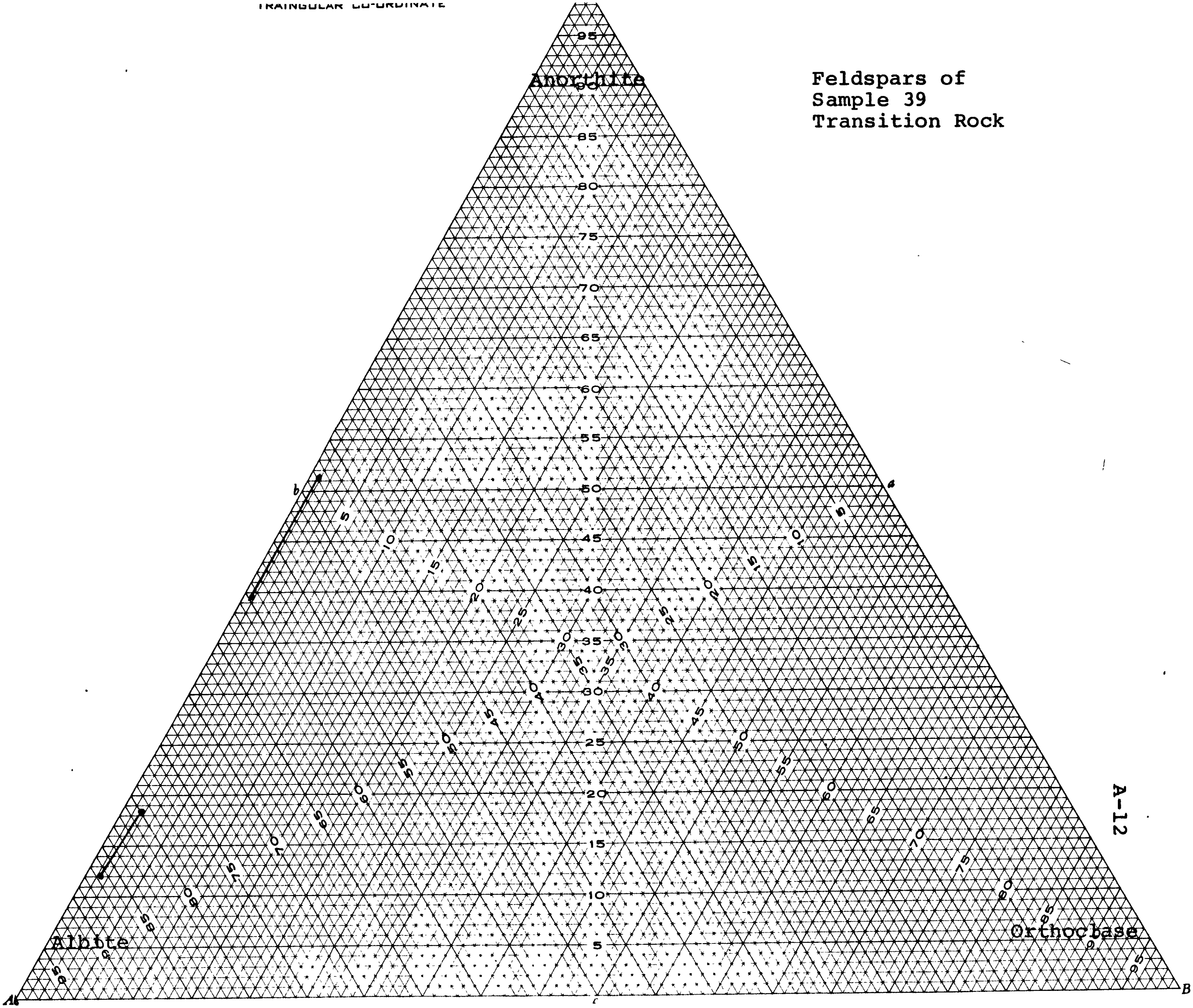
SAMPLE 39: TRANSITION ROCK

	A	SD	B	C	SD	D	SD	E	SD	F	SD	G	SD	
SiO_2	.52	.17	29.63	51.97	1.11	49.29	1.88	38.28	.62	55.42	.84	65.31	2.29	
TiO_2	.08	.01	35.75	.47	.38	.70	.22	3.12	.38	.09	.03	.01	.01	
Al_2O_3	.20	.20	1.26	1.21	.89	4.55	.93	13.53	.36	27.96	.47	21.31	.37	
* FeO	.38	.09	1.99	9.68	.84	16.86	.95	20.79	.31	.15	.05	.17	.03	
MgO	.07	.02	.04	13.05	.78	12.80	.72	11.69	.52	.01	.03	.00	.01	
CaO	52.70	.51	27.69	22.61	1.20	11.55	.29	.09	.03	9.93	.53	2.55	.25	
Na_2O	.25	.03	.03	.66	.19	1.28	.30	.09	.05	6.28	.39	10.95	.14	
K_2O	.06	.01	.05	.04	.01	.50	.16	9.01	.23	.17	.02	.26	.12	
TOTAL	54.26	3 analyses	96.43	99.69	23 analyses	97.53	9 analyses	94.60	8 analyses	100.01	14 analyses	100.56	5 analyses	
MODE			.5	3.9		9.8		12.7		7.5		62.4	3.2 (opaques)	100

A = Calcite
B = Sphene
C = Salite
D = Hornblende
E = Biotite
F = Plagioclase Phenocrysts
G = Groundmass Oligoclase

* Total iron expressed as FeO

Feldspars of
Sample 39
Transition Rock



SAMPLE 72: QUARTZ SYENITE

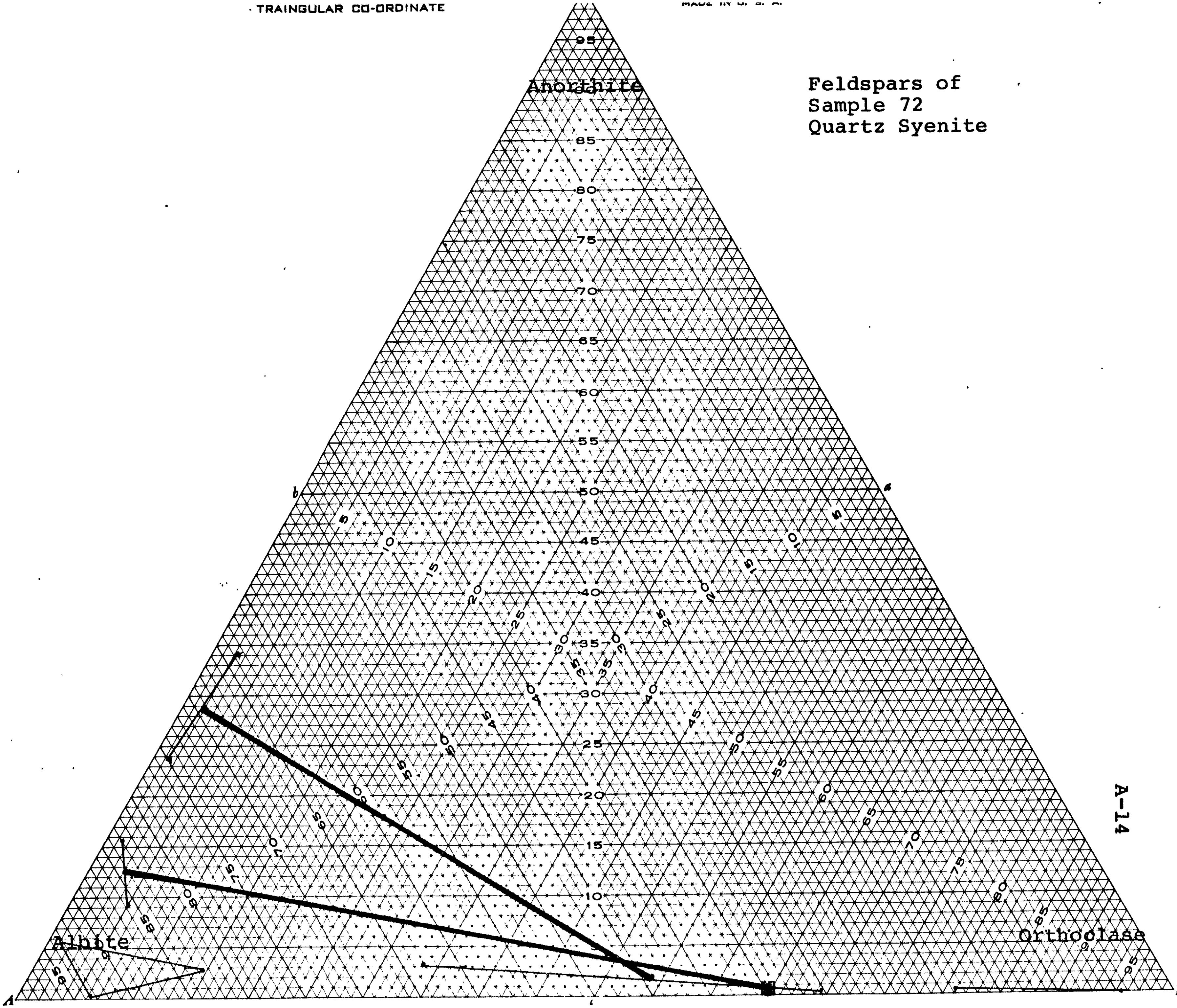
	A	SD	B	SD	C	SD	D	E	SD	F	SD	G	SD	H	
SiO_2	35.52	.43	24.67	.53	65.74	.58	59.69	65.08	1.30	66.82	1.37	64.92	.00	96.36	
TiO_2	4.50	.32	.12	.01	.02	.02	.05	.00	.00	.00	.00	.01	.01	.01	
Al_2O_3	12.88	.13	19.90	.92	19.18	.50	24.84	21.75	.89	20.34	.57	18.78	.50	1.66	
* FeO	23.02	.77	32.05	2.02	.17	.05	.25	.22	.05	.36	.24	.15	.08	2.35	
MgO	9.47	.72	9.31	1.63	.01	.01	.00	.01	.01	.09	.09	.01	.02	.34	
CaO	.08	.00	.04	.01	.34	.18	7.11	2.60	.45	.40	.36	.07	.05	.03	
Na_2O	.21	.03	.02	.03	4.94	1.01	7.42	10.13	.27	10.87	.83	1.11	.62	.01	
K_2O	9.14	.15	.05	.04	9.49	1.62	.40	.55	.23	1.01	.95	15.20	.84	.11	
TOTAL	94.80	7	86.16	5	99.89	19	99.76	100.34	7	99.89	6	100.25	11	100.97	
MODE	3.8		(.9) opaque		1.3			19.7		15.2		39.8		19.3	100

A = Biotite
B = Chlorite
C = Orthoclase Phenocryst
D = Plagioclase Inclusion in Phenocryst
E = Oligoclase Groundmass
F = Albite, part of Perthite
G = Orthoclase, part of Perthite
H = Quartz

* Total iron expressed as FeO

TRAINGULAR CO-ORDINATE

Feldspars of
Sample 72
Quartz Syenite



A-14

SAMPLE 71: QUARTZ SYENITE

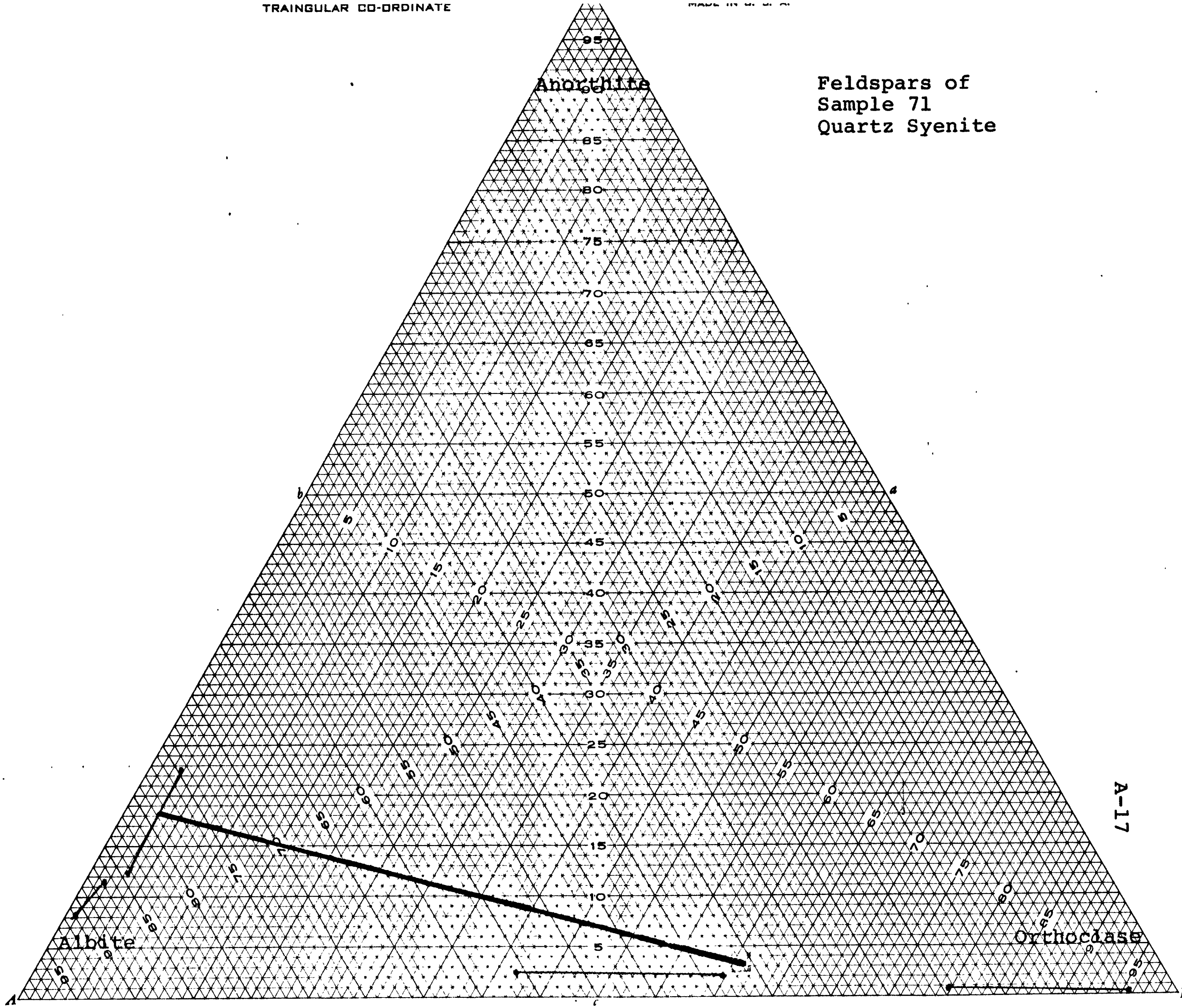
	A	SD	B	C	D	E	SD	F	SD	G	SD
SiO_2	.28	.04	.47	.56	30.54	43.73	.56	34.60	1.08	28.05	.83
TiO_2	.44	.14	96.19	.08	23.81	1.64	.04	3.87	.34	.70	.13
Al_2O_3	.31	.22	.54	.05	6.47	6.55	.18	12.37	.18	15.39	.32
*FeO	98.31	.93	1.78	.64	7.62	19.50	.35	24.10	.61	26.91	.46
MgO	.04	.04	.28	.10	2.30	10.02	.38	8.96	.55	14.56	.46
CaO	.09	.07	.01	51.97	22.12	10.23	.08	.01	.02	.04	.50
BaO				.17							
Na_2O	.01	.01	.02	.27	.14	2.19	.09	.08	.04	.03	.00
K_2O	.07	.01	.07	.04	.26	.85	.03	8.68	.66	.18	.01
TOTAL	90.55	4 analyses	99.36	53.89	93.19	94.71	12 analyses	92.67	9 analyses	85.36	2 analyses
MODE	2.3					.2		4.8			

A = Magnetite
B = Rutile
C = Calcite
D = Sphene
E = Hornblende
F = Biotite
G = Chlorite
H = Orthoclase Phenocrysts
I = Albite, Groundmass
J = Albite, Part of Perthite
K = Orthoclase, Part of Perthite
L = Quartz

* Total iron expressed as FeO

SAMPLE 71 (continued)

H	SD	I	SD	J	SD	K	SD	L	
65.37	1.24	62.67	.56	66.25	1.01	64.78	1.29	99.41	
.04	.02	.01	.02	.00	.00	.02	.01	.06	
18.91	.26	21.90	.99	21.06	.12	18.08	.24	.21	
.20	.03	.25	.07	.23	.06	.22	.07	.55	
.01	.01	.01	.01	.01	.01	.02	.01	.05	
.50	.11	3.44	.88	2.13	.32	.11	.04	.02	
.57	.34	.01	.02	.00	.00	.13	.09	.00	
5.75	.48	10.80	.60	11.68	.33	1.53	.61	.04	
8.95	.69	.38	.13	.23	.06	14.83	.89	.00	
100.30	19	99.47	8	101.59	4	99.72	6	100.34	
13.3		33.9		9.6		22.6		13.3	100 Total



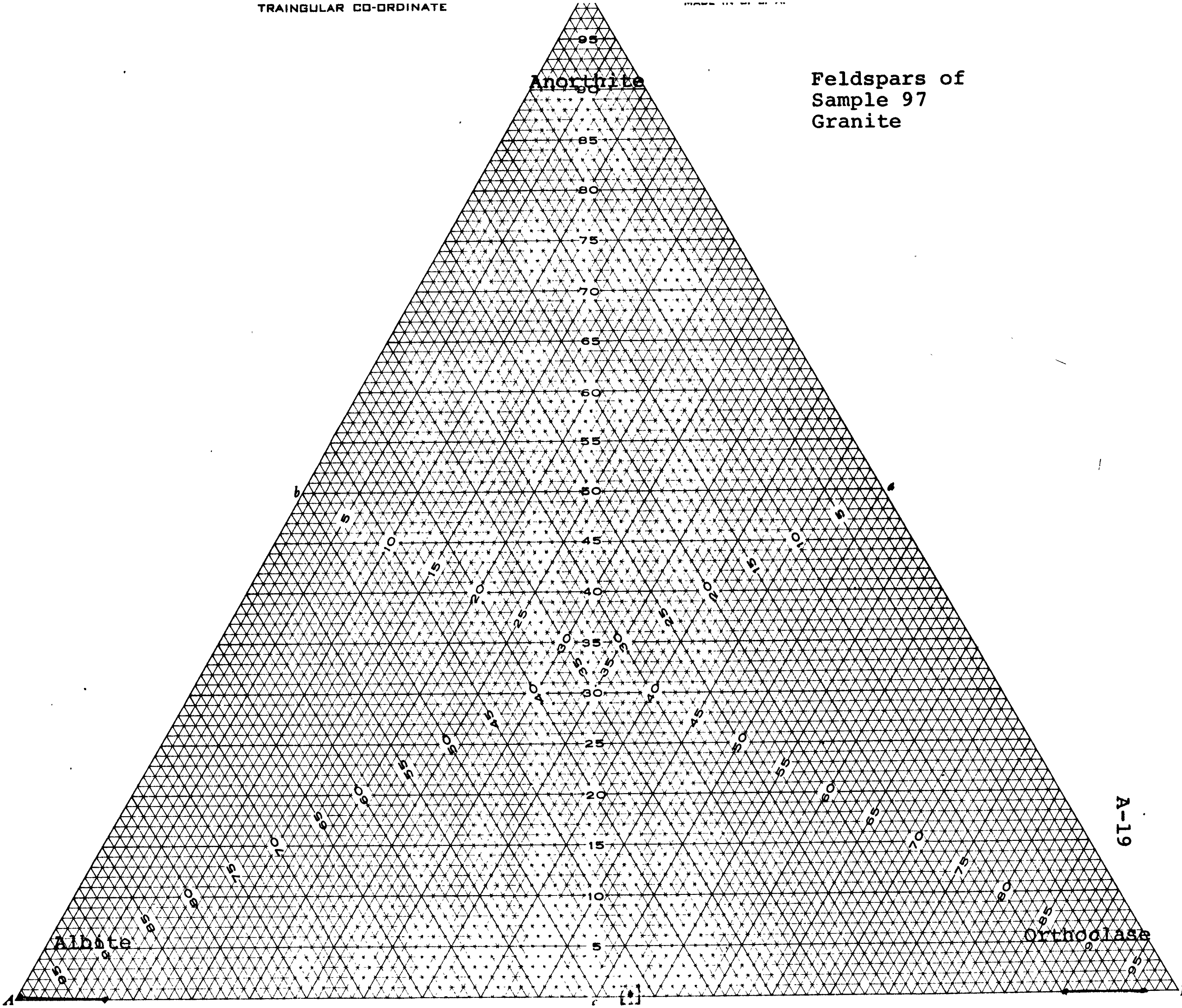
Feldspars of
Sample 71
Quartz Syenite

SAMPLE 97: GRANITE

	Magnetite	SD	Hornblende	SD	Albite, part of Perthite	SD	Orthoclase, part of Perthite	SD			
SiO_2	.12	.11	46.22	.88	69.38	1.26	65.15	.75			
TiO_2	2.37	1.00	.91	.07	.00	.00	.00	.00			
Al_2O_3	.22	.06	3.83	.51	18.73	.91	17.62	.65			
*FeO	87.17	.35	23.99	.79	.25	.12	.18	.05			
MgO	.00	.01	6.79	.33	.00	.00	.00	.00			
CaO	.01	.01	8.40	.17	.05	.07	.00	.00			
Na_2O	.00	.00	2.39	.15	11.16	.43	.46	.21			
K_2O	.05	.01	.84	.10	.35	.42	15.95	.35			
TOTAL	89.94	5 analyses	93.37	6 analyses	99.92	14 analyses	99.36	9 analyses			
MODE	1.6				34.0		44.4		1.1 biotite	18.9 quartz	100

* Total iron expressed as FeO

Feldspars of Sample 97 Granite



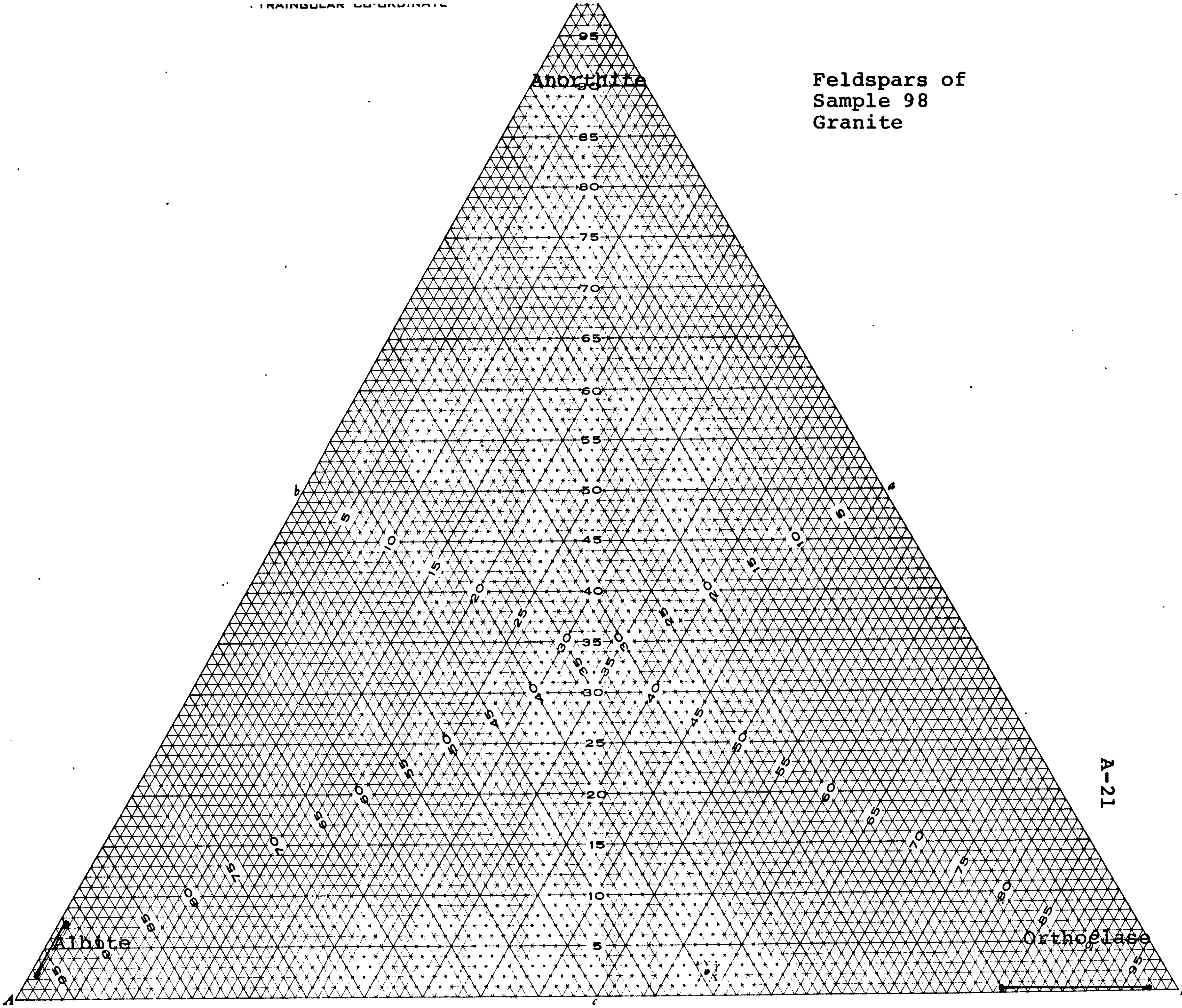
SAMPLE 98: GRANITE

	A	SD	B	SD	C	SD	D	SD	E	SD	F	SD	G	
SiO_2	.25	.17	.28	.10	28.57	.32	42.98	.56	68.06	1.00	65.45	.88	94.08	
TiO_2	2.34	.29	.19	.01	3.34	.14	1.31	.05	.00	.00	.01	.01	.02	
Al_2O_3	.47	.11	.13	.04	9.79	.21	6.71	.26	20.20	.24	18.22	.22	.47	
*FeO	88.08	1.95	57.50	.35	15.27	.62	24.88	.17	.12	.04	.15	.07	2.48	
MgO	.07	.02	.13	.00	.57	.02	6.16	.13	.01	.01	.03	.02	.31	
CaO	.14	.01	.09	.01	8.81	.15	10.36	.08	1.11	.27	.09	.02	.20	
Na_2O	.01	.01	.26	.08	.14	.02	2.21	.12	10.80	.33	.58	.37	.06	
K_2O	.07	.01	.06	.01	.07	.02	1.05	.12	.19	.04	15.67	.56	.13	
TOTAL	91.43	2 analyses	58.64	3 analyses	66.57	4 analyses	95.66	5 analyses	100.49	13 analyses	100.70	10 analyses	97.75	
MODE			1.9				.9		24.4		43.8		28.8	100

A = Magnetite
B = Pyrite
C = Allanite
D = Hornblende
E = Albite, part of Perthite
F = Orthoclase, part of Perthite
G = Quartz

* Total iron expressed as FeO

Feldspars of
Sample 98
Granite



SAMPLE 31: QUARTZ MONZONITE

	A	B	SD	C	SD	D	SD	E	SD
SiO_2	.42	41.54	.81	34.88	.60	53.36	.63	62.22	1.46
TiO_2	.02	1.72	.38	3.94	.38	.04	.02	.00	.00
Al_2O_3	.07	7.72	.66	12.69	.25	28.44	.23	23.27	.65
*FeO	.86	25.91	.31	28.02	.46	.15	.01	.12	.03
MgO	.03	5.25	.28	6.03	.33	.00	.01	.00	.00
CaO	54.20	10.20	.11	.10	.03	11.10	.40	4.86	.78
BaO									
Na_2O	.17	2.02	.19	.08	.03	5.46	.24	9.21	.63
K_2O	.05	1.04	.08	8.36	.23	.13	.03	.27	.07
TOTAL	55.84	95.61	11 analyses	94.11	19 analyses	98.69	3 analyses	99.95	8 analyses
MODE	.2	2.6		4.3				36.1	

A = Calcite
B = Hornblend
C = Biotite
D = Core of Plagioclase Crystal

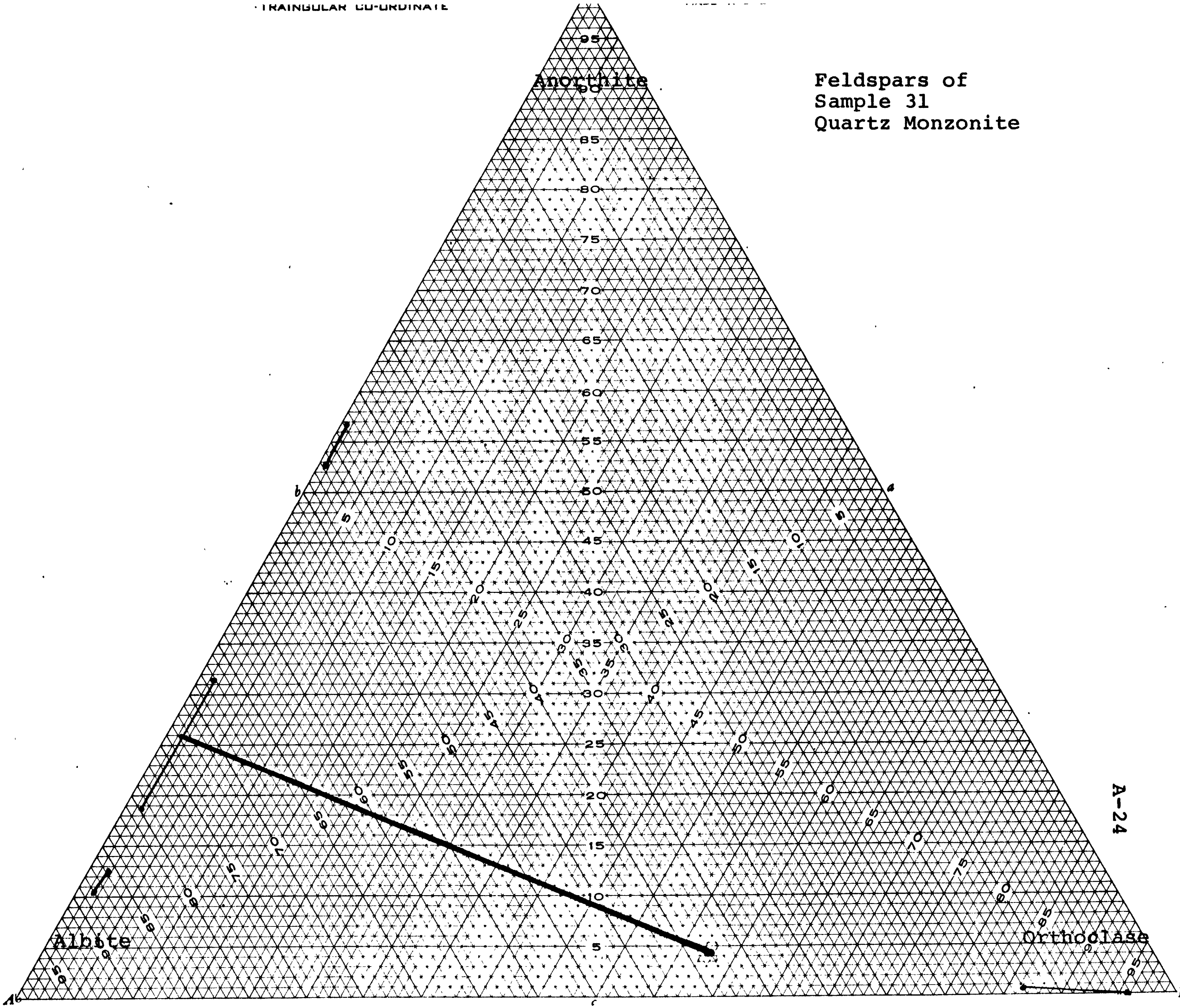
E = Oligoclase
F = Albite, part of Perthite
G = Orthoclase, part of Perthite
H = Quartz

* Total iron expressed as FeO

SAMPLE 31 (continued)

F	SD	G	SD	H	SD	
65.47	.44	64.19	.27	97.55	.23	
.00	.00	.00	.00	.00	.00	
21.36	.12	18.01	.11	.04	.01	
.16	.11	.06	.05	.21	.18	
.00	.00	.00	.01	.00	.00	
2.47	.15	.05	.02	.02	.01	
		.33	.15			
10.62	.25	1.06	.28	.00	.00	
.28	.03	15.05	.39	.01	.00	
100.36	7 analyses	98.75	16 analyses	97.83	2 analyses	
16.6		31.9		7.6	.7 opaques	100

Feldspars of
Sample 31
Quartz Monzonite



SAMPLE 90: SYENITE PORPHYRY

	A	SD	B	C	D	SD	E	SD	F	SD	G	SD
SiO_2	.08	.04	.20	.56	50.33	.18	48.79	1.70	36.60	.69	56.81	.61
TiO_2	.29	.01	48.85	.03	.83	.21	.76	.16	3.30	.45	.06	.02
Al_2O_3	.27	.13	.16	.05	4.86	.18	4.08	.68	12.63	.38	26.99	.34
*FeO	88.33	.01	45.37	.21	4.92	.48	15.23	.42	18.99	.72	.21	.07
MgO	.01	.01	.09	.05	15.61	.68	13.45	.57	12.49	.80	.03	.40
CaO	.05	.03	.08	52.50	21.16	.37	11.17	.14	.05	.02	8.86	.42
Na_2O	.00	.00	.00	.17	1.05	.31	1.70	.22	.12	.03	6.46	.20
K_2O	.03	.04	.04	.05	.01	.01	.56	.09	9.49	.27	.21	.03
TOTAL	89.06	2 analyses	94.80	53.63	98.77	5 analyses	95.74	5 analyses	93.64	6 analyses	99.63	13 analyses
MODE		1.6 opaques			2.4		5.6		7.1			

A = Magnetite
B = Illmenite
C = Calcite

D = Diopside
E = Hornblende
F = Biotite

G = Largest Plagioclase Phenocryst
H = Plagioclase Phenocrysts

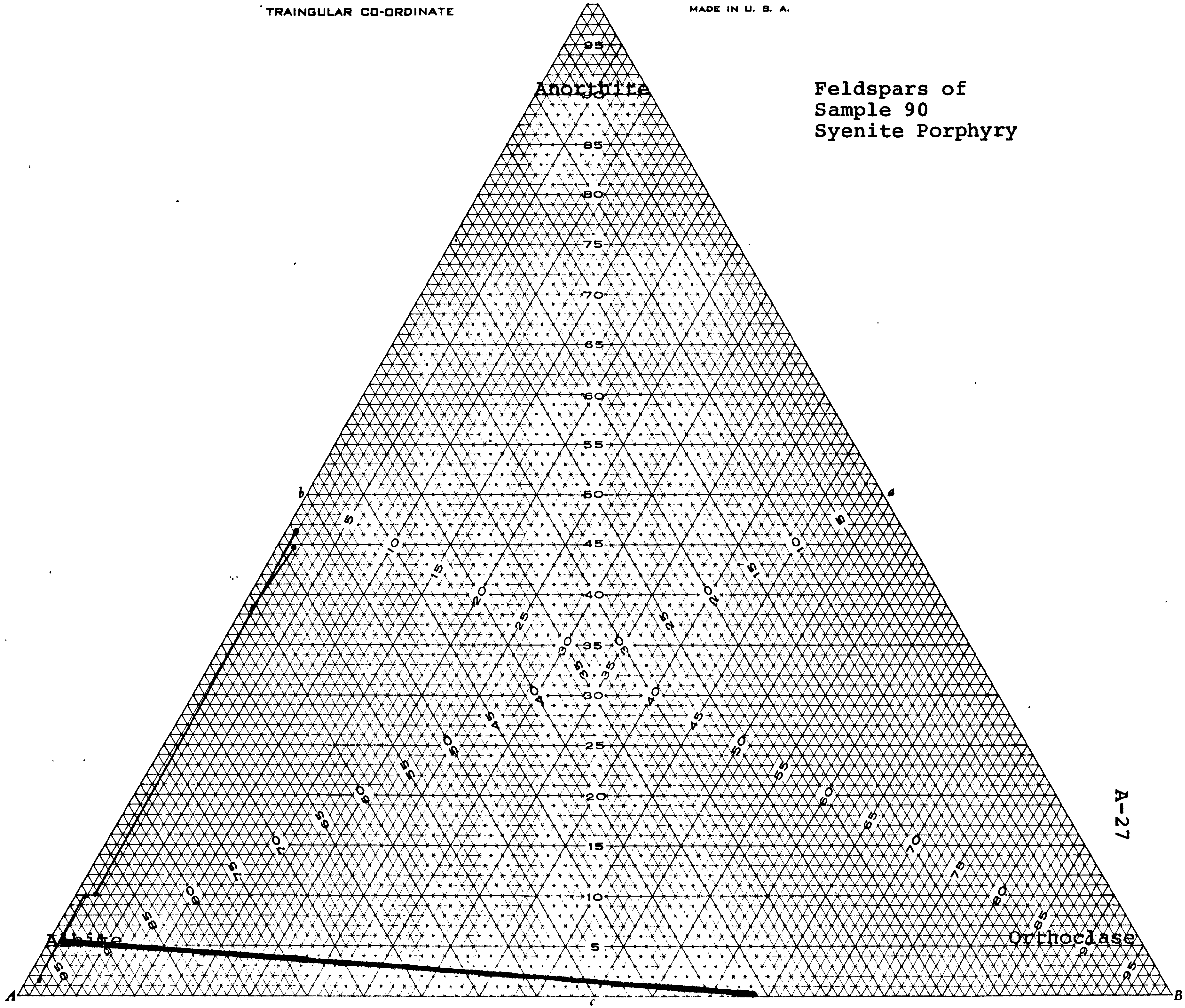
I = Small Plagioclase Phenocrysts
J = Orthoclase Groundmass
K = Quartz

* Total iron expressed as FeO

SAMPLE 90 (continued)

H	SD	I	SD	J	K		
61.53	2.88	66.82	.88	64.95	99.02		
.01	.02	.00	.01	.00	.00		
23.63	1.85	20.86	.74	18.56	.05		
.14	.06	.18	.08	.18	.07		
.01	.02	.01	.01	.01	.01		
5.14	2.09	1.56	.59	.08	.00		
8.75	1.18	11.08	.40	1.38	.00		
.27	.05	.19	.06	14.35	.03		
99.48	8 analyses	100.70	17 analyses	99.52	99.17		
32.3					50.3	.6 sphene	100 Total

Feldspars of
Sample 90
Syenite Porphyry



SAMPLE 84: DARK MONZONITE

	A	SD	B	SD	C	SD	D	SD
SiO_2	.36	.09	29.35	.42	49.37	.83	37.67	.64
TiO_2	.33	.05	35.67	1.51	.89	.08	2.95	.18
Al_2O_3	.24	.06	1.09	.19	4.32	.34	12.42	.32
*FeO	88.29	1.94	2.06	.44	14.83	.36	12.80	.28
MgO	.09	.02	.05	.03	14.19	.48	18.61	.34
CaO	.16	.10	27.97	.73	11.11	.11	.12	.07
Na_2O	.00	.03	.08	.05	1.71	.14	.12	.03
K_2O	.14	.16	.05	.04	.55	.06	9.34	.53
TOTAL	89.63	4 analyses	96.32	7 analyses	96.97	22 analyses	94.02	15 analyses
MODE	1.7		1.8		3.8		4.9	

A = Magnetite
B = Sphene
C = Hornblende
D = Biotite

E = Andesine
F = Albite, part of Perthite
G = Orthoclase, part of Perthite

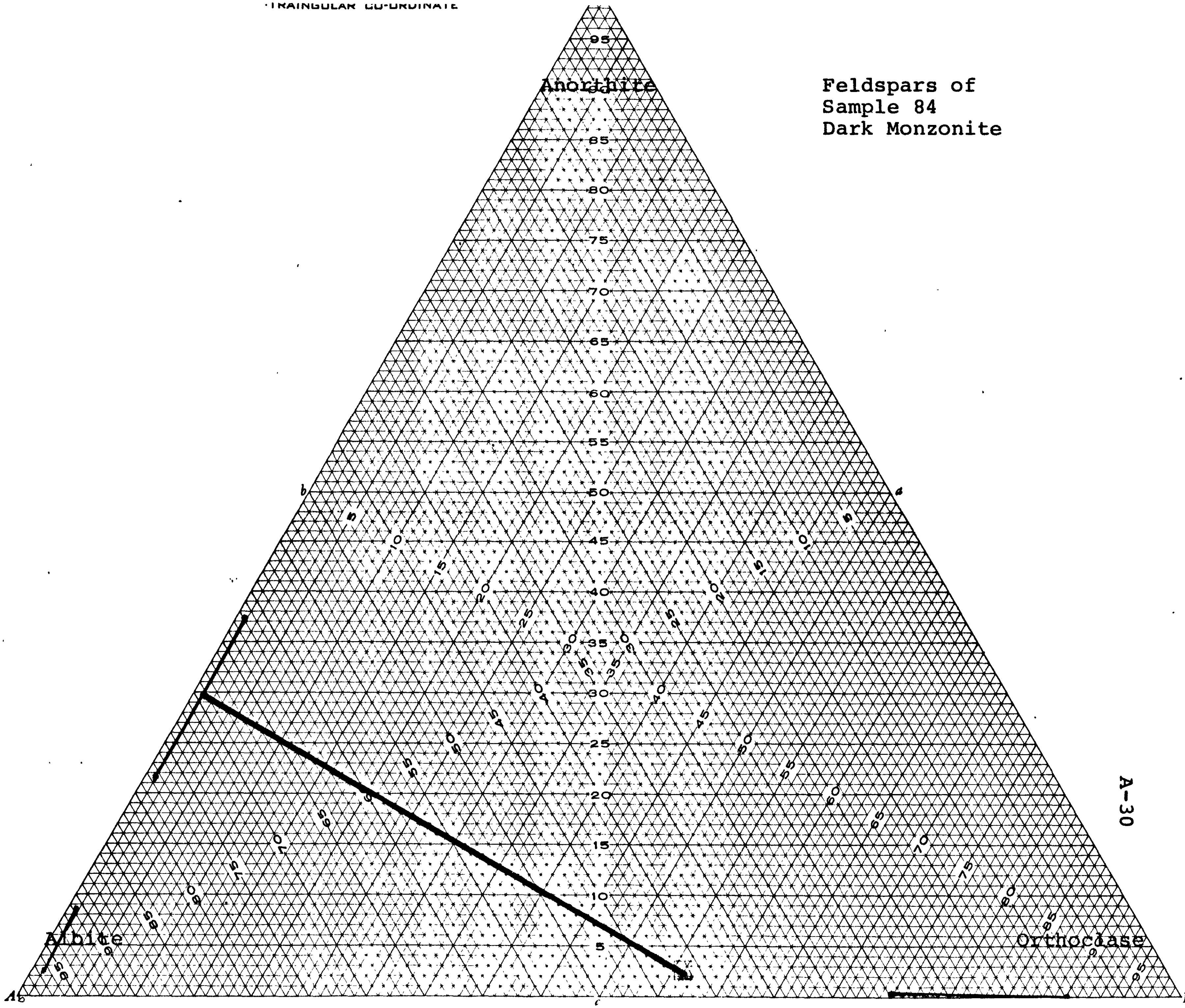
* Total iron expressed as FeO

SAMPLE 84 (continued)

E	SD	F	SD	G	SD		
60.40	2.30	66.84	1.18	65.74	.52		
.01	.01	.00	.00	.01	.01		
25.10	1.07	20.56	.42	18.32	.19		
.09	.05	.15	.03	.16	.01		
.00	.00	.00	.00	.00	.01		
6.62	1.26	1.46	.41	.02	.03		
7.78	.81	10.73	.37	1.62	.59		
.17	.05	.22	.05	14.35	1.10		
100.17	8 analyses	99.96	10 analyses	100.22	8 analyses		
42.3		14.4		29.8		1.3 quartz	100

TRAINGULAR CO-ORDINATE

Feldspars of
Sample 84
Dark Monzonite



SAMPLE 82: DIORITE

	A	SD	B	SD	C	D	E	SD
SiO_2	.24	.00	.31	.19	.38	30.05	52.30	.37
TiO_2	51.92	1.65	.18	.01	.06	37.59	.11	.07
Al_2O_3	.12	.02	.15	.08	.05	1.62	.62	.30
* FeO	41.66	.40	56.56	.78	.38	.84	10.29	.42
MgO	.08	.00	.13	.01	.04	.01	11.81	.28
CaO	.32	.20	.13	.04	57.83	29.04	24.28	.59
Na_2O	.06	.01	.30	.06	.10	.10	.42	.20
K_2O	.11	.04	.07	.02	.04	.06	.03	.01
TOTAL	94.51	4 analyses	57.83	5 analyses	58.89	99.31	99.86	10 analyses
MODE		2.1 (opaques)				.4	6.5	

A = Illmenite
B = Pyrite
C = Calcite
D = Sphene

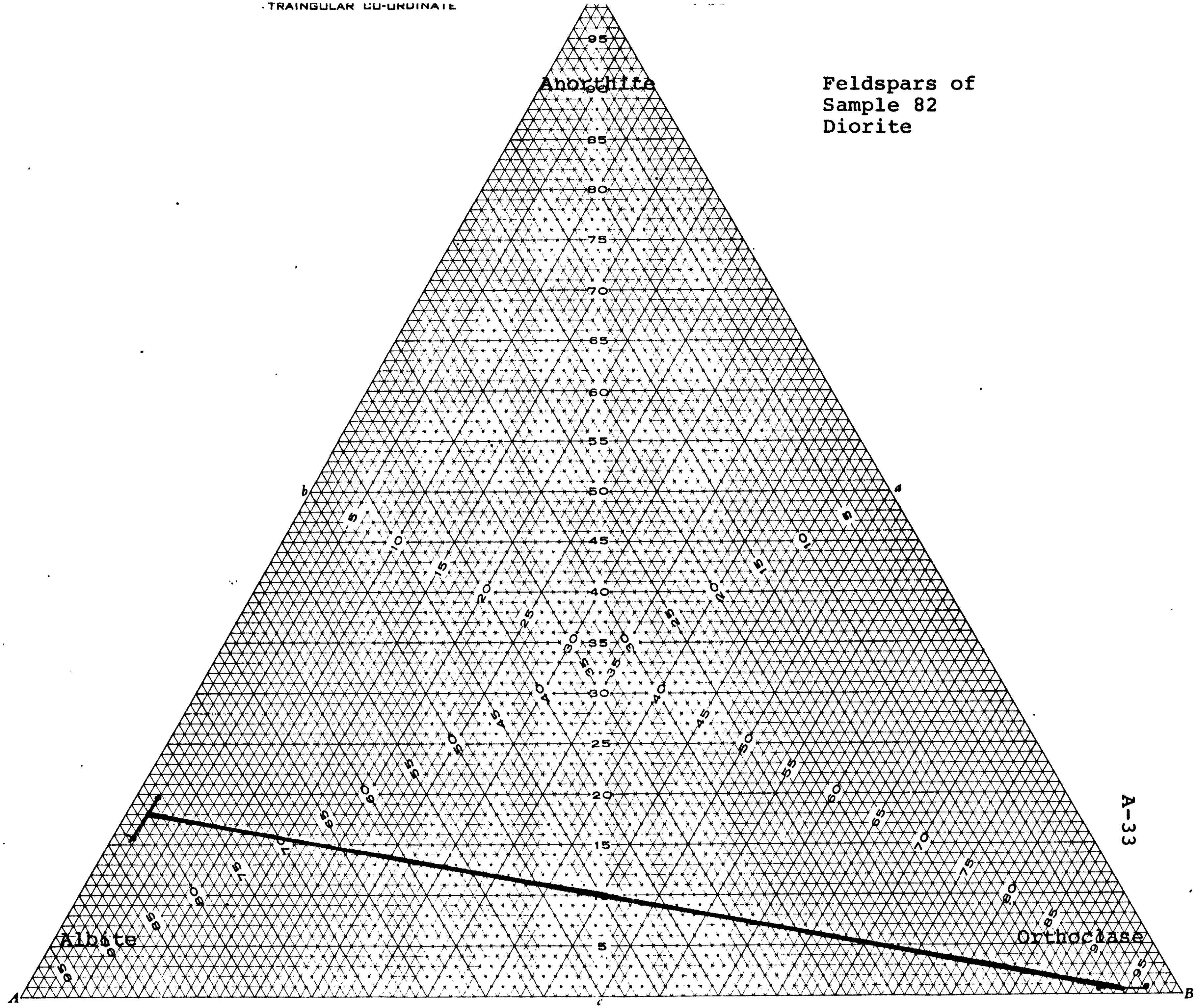
E = Salite
F = Hornblende
G = Biotite
H = Oligoclase

I = Orthoclase

* Total iron expressed as FeO

SAMPLE 82 (continued)

F	SD	G	SD	H	SD	I	SD	
49.72	1.08	35.25	1.18	63.99	.24	63.68	.89	
.22	.10	4.43	.30	.01	.02	.07	.00	
3.65	.69	13.47	.25	22.48	.17	18.68	.49	
18.52	.84	23.68	.36	.15	.03	.20	.10	
11.14	.76	8.60	.22	.02	.01	.01	.01	
12.36	.49	.11	.03	3.73	.43	.11	.05	
.57	.04	.12	.04	9.31	1.33	1.27	.31	
.28	.06	9.89	.19	.37	.05	15.45	.83	
96.46	3 analyses	95.55	12 analyses	100.06	4 analyses	99.47	3 analyses	
3.6		31.2		48.9		7.3		100


Feldspars of
Sample 82
Diorite
Anorthite
Albite
Orthoclase

ELECTRON MICROPROBE

STANDARDS

	DIJD 35 Pyroxene Glass[1]	Mn Ilmenite[2]	Orthoclase Glass[3]	Watson Standard[4]	52-NL-11 Chromite[5]	G-2[6]
SiO_2	56.88		64.39	46.75		69.81
TiO_2		51.61				.50
Al_2O_3	8.82		18.58	18.90	19.41	15.55
Cr_2O_3					44.50	
FeO		45.41		19.95	22.10	2.38
MnO		1.50				.03
MgO	12.10	.025			12.30	.76
CaO	16.83					1.95
BaO			.82	6.06		
Na_2O	5.36		1.14			4.11
K_2O			14.42	6.27		4.55
P_2O_5						.15
TOTAL	99.99	98.77	99.35	97.93	98.31	99.78

1 - used for Na, Mg, Al, Si, and Ca
2 - used for Fe and Ti
3 - used for K
4 - used for Ba
5 - used for Cr
6 - used for whole rock

WHOLE ROCK CHEMICAL ANALYSES

	33	SD	39	SD	76	SD	71	SD	72	SD
SiO_2	51.17	.62	55.88	.50	58.27	.27	68.83	1.01	70.72	.39
TiO_3	3.33	.10	2.16	.03	2.04	.00	.59	.01	.43	.02
Al_2O_3	15.51	.34	16.75	.03	16.80	.42	16.00	.20	15.36	.25
* FeO	9.82	.31	8.00	.23	6.73	.06	3.10	.13	2.13	.17
MgO	5.82	.18	3.01	.21	2.61	.04	.66	.01	.45	.05
CaO	7.76	.10	5.62	.06	4.81	.03	1.11	.03	.44	.00
Na_2O	4.24	.23	5.33	.44	5.15	.13	4.78	.15	4.83	.39
K_2O	2.26	.06	3.26	.15	3.60	.09	4.92	.07	5.71	.15
Total	100.02	6 analyses	100.01	3 analyses	100.01	2 analyses	99.99	2 analyses	100.07	5 analyses

* Total iron expressed as FeO

WHOLE ROCK ANALYSES (continued)

97	SD	98	SD	31	SD	90	SD	84	SD	82	SD
69.56	.17	72.26	.00	62.19	.27	60.26	.13	62.23	.64	53.91	.75
.28	.03	.25	.03	.65	.03	1.14	.04	1.01	.05	1.92	.07
15.54	.19	14.23	.26	18.43	.40	18.24	.51	17.26	.25	19.36	.30
2.11	.04	2.10	.21	3.78	.11	3.96	.01	4.37	.14	7.50	.21
.27	.03	.25	.03	.75	.06	2.00	.14	1.19	.08	2.71	.13
.58	.04	.74	.07	2.33	.05	3.05	.05	2.74	.07	5.26	.07
6.31	.05	5.23	.19	5.94	.23	6.51	.30	6.31	.09	6.18	.41
5.36	.03	4.94	.01	5.92	.07	4.85	.25	4.88	.08	3.14	.02
100.01	4 analyses	100.00	2 analyses	99.99	5 analyses	100.01	2 analyses	99.99	5 analyses	99.98	5 analyses

IRON TO MAGNESIUM RATIOS
FeO/MgO

	Pyroxene	Horneblende	Biotite	Whole Rock
Essexite (37)	.649	1.013	1.590	-----
Kaersutite from (37)	----	.871	-----	-----
Essexite (33)	.470	.895	1.663	1.656
Transition Rock (39)	.742	1.317	1.778	2.658
Transition Rock (76)	----	1.287	1.961	2.519
Quartz Syenite (71)	----	1.946	2.690	4.697
Quartz Syenite (72)	----	----	2.431	4.733
Granite (97)	----	3.533	-----	7.815
Granite (98)	----	4.039	-----	8.400
Quartz Monzonite (31)	----	4.935	4.647	5.040
Syenite Porphory (90)	.315	1.132	1.520	1.980
Dark Monzonite (84)	----	1.045	1.454	3.672
Diorite (82)	.871	1.662	2.753	2.768