

**PETROGRAPHY OF THE GOLD-BEARING VEIN ROCKS
FROM BISSETT AREA, SOUTHEASTERN MANITOBA**

**A Thesis Submitted to
The Faculty of Graduate Studies and Research
University of Manitoba**

**In Partial Fulfillment
of the Requirements for the Degree
Master of Science**

by

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ABSTRACT

Vein rocks were examined from the Bissett, Manitoba area, and 250 samples collected from 50 localities. Fifty-nine samples were chemically analysed for 26 elements, and thin sections were prepared from 20 samples.

Four generations of gold-bearing quartz injections are located in steeply dipping fractures, shears and faults. The veins occur mostly in rocks of the Rice Lake group (greenstones), in which the most favorable structural areas are noses and axial planes of anticlines.

The quartz in these veins exhibits a wide range of colors, textures and transparencies. Other minerals in the vein rocks include chlorite, epidote, carbonates, some feldspars and sulfides (mostly pyrite, arsenopyrite, chalcopyrite, galena and sphalerite). The vein rocks are surrounded by alteration zones.

Gold occurs as a native element associated with quartz and carbonates, or within country rocks. The greatest amounts occur as particles in the clear microcrystalline quartz. Some gold is disseminated in pyrite and arsenopyrite, and partially replaces them.

There is an enrichment of Si, Co, Cr, Cu, Pb and Ba, and a depletion of Zn, Ni, S, Mn, Zr, Ti, P, Li, Rb, and Sr in veins compared to either rocks that contain them or the equivalent average crustal rocks.

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CHAPTER I

INTRODUCTION

ACKNOWLEDGEMENTS

This study was suggested by Dr. A. Turek, of the Manitoba Department of Mines and Natural Resources, Geological Division, and was undertaken by the author as part of "Project Pioneer". This project, an investigation jointly sponsored by the Manitoba Department of Mines and Natural Resources and the Department of Earth Sciences at the University of Manitoba, includes petrological, geochemical and geophysical studies in the Bissett area of southeastern Manitoba (Davies, 1966).

Field work was conducted during the field seasons of 1967 and 1968. Chemical analyses were done in the Department of Earth Sciences, University of Manitoba, under the supervision of Mr. K. Ramlal.

The thesis was written under the supervision of Dr. A. C. Turnock, whose interest and valuable suggestions are gratefully acknowledged. Dr. D. T. Anderson was the second reader, and Dr. W. D. McRitchie was the outside reader.

The writer wishes to express his appreciation for the co-operation received from some of the property owners and residents of the area. Particular thanks are due to Mr. J.

C. Gibson, then the chief geologist-general manager of the San Antonio Gold Mines Limited, for information and assistance in the examination of the property. During the course of field work, the writer received useful suggestions and valuable criticisms from all members of "Project Pioneer" field party, especially from Drs. W. D. McRitchie, N. B. Church, A. Turek, and Messers J. Stephenson, F. Campbell and H. Zwanzig. The assistance of these men is deeply acknowledged.

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FIELD WORK AND LABORATORY METHODS

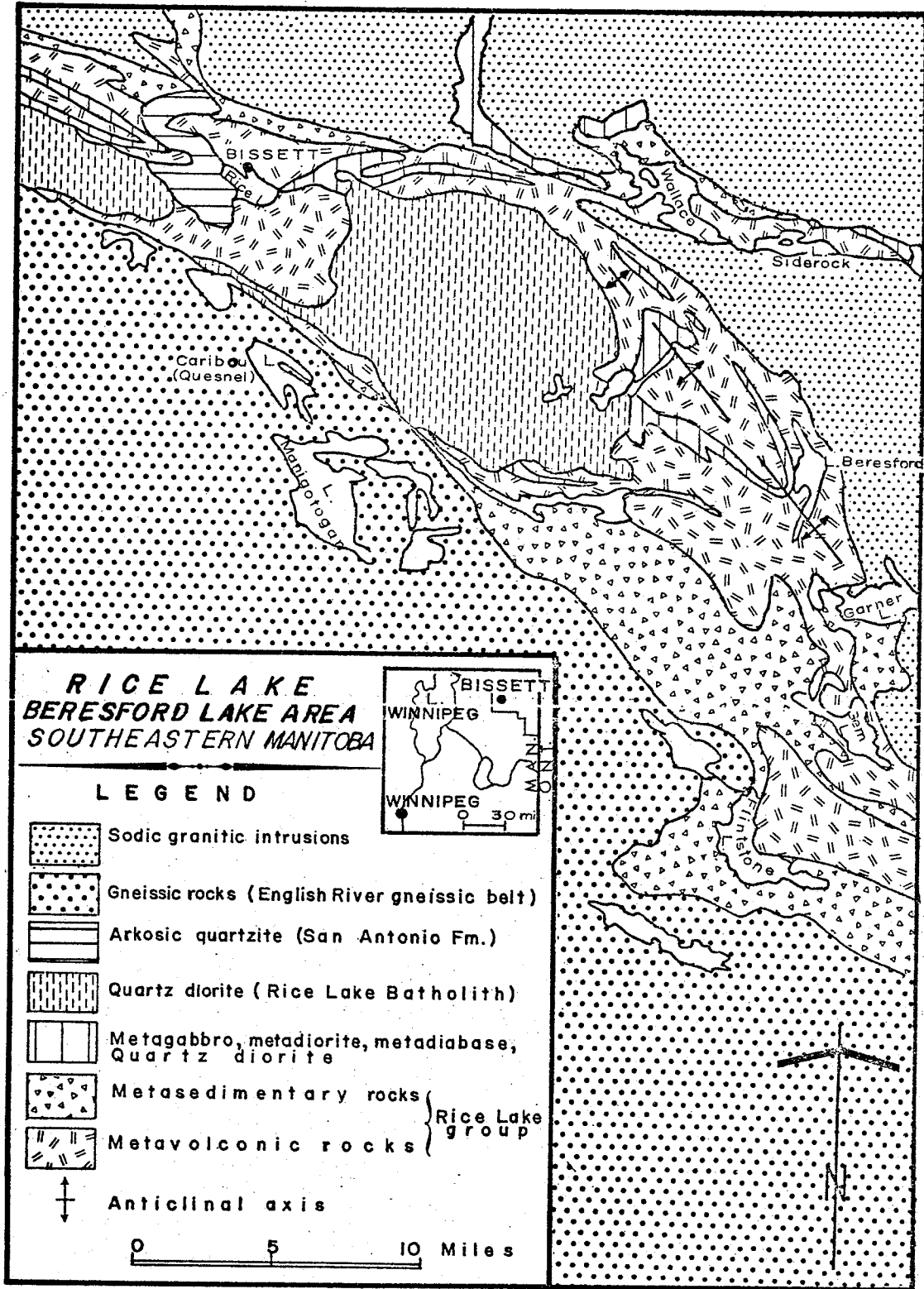
Only one accessible underground property, namely the San Antonio Gold Mine, was examined during field work. Samples of quartz were collected from veins representing rich, moderate and barren ore on various levels.

The samples from other shear zones were collected on the surface, and from waste dumps of abandoned mines and prospect pits. The adjacent country rocks were sampled in profiles at right angles to some shear zones.

In the laboratory, the barren and gold-bearing quartz were studied in hand specimens, thin and polished sections. Some samples were then crushed and prepared for chemical analysis. A summary of methods used in the chemical analytical laboratory is given in Appendix 2.

The petrology of the Rice Lake Greenstone belt has been described by Davies (1963) and Stockwell (1938). The location and general geology are shown in Figure 1, and a summary description is given in Appendix 1.

Figure 1. Location and general geology of "Project Pioneer" area.



CHAPTER II

THE VEIN ROCKS

DEFINITION

"Vein Rocks" are quartz-rich veins, lenses, or dikes; with other minerals and inclusions of wall-rock. Most of the veins have a well defined outline with a clear quartz filling. Others are silicified, mylonitized wall-rock. Some are of economic value because of their content of gold, but most of them have gold contents less than an economic value.

Most of the veins are surrounded by an alteration zone, which is a sheared and partly-altered zone of the wall-rock.

DISTRIBUTION

The distribution of major, minor, and barren mineralized veins is of great practical and scientific significance, especially in an area which was once a gold-producing district. Davies (1963) illustrated the distribution in a larger area, including the area of study, while Stockwell (1938) described all known quartz veins in the Rice Lake-Gold Lake, and Halfway Lake-Beresford Lake areas. He enumerated over 200 such features.

The distribution is: 1. Confined within a belt bounded by the Wanipigow-Siderock and Manigotagan faults (see

Figure 2), 2. Located mostly within the Rice Lake Group and the rocks intruded into it (see Figure 2), 3. Concentrated in the region of anticlinal axes and noses of the Beresford and Rice Lake folds (see Figure 2).

The distribution of veins in the area is shown in Figure 2. About 250 samples were collected from the 50 localities shown in Figure 3.

The veins of the "Pioneer" area occur within zones of fracturing and faulting in steeply dipping and metamorphosed volcanic, basic intrusive, and quartz diorite rocks, all of Archean age. The veins, like the structural features, occur essentially in all rocks of the area, but are concentrated in the more brittle and competent rocks.

MODE OF OCCURRENCE

The veins display a considerable variation in composition and shape. Some are up to 50 feet in width and continuous over distances of up to 1000 feet; some are discontinuous, occurring as stringers or lenses, and with branching veinlets.

The orientation pattern of the mineralized fractures of the region is similar to that of the major non-mineralized fractures and faults (see Figure 4). Also there is some distinction of shape and composition amongst the three sets, viz:

Figure 2: Distribution and Location of Quartz Veins

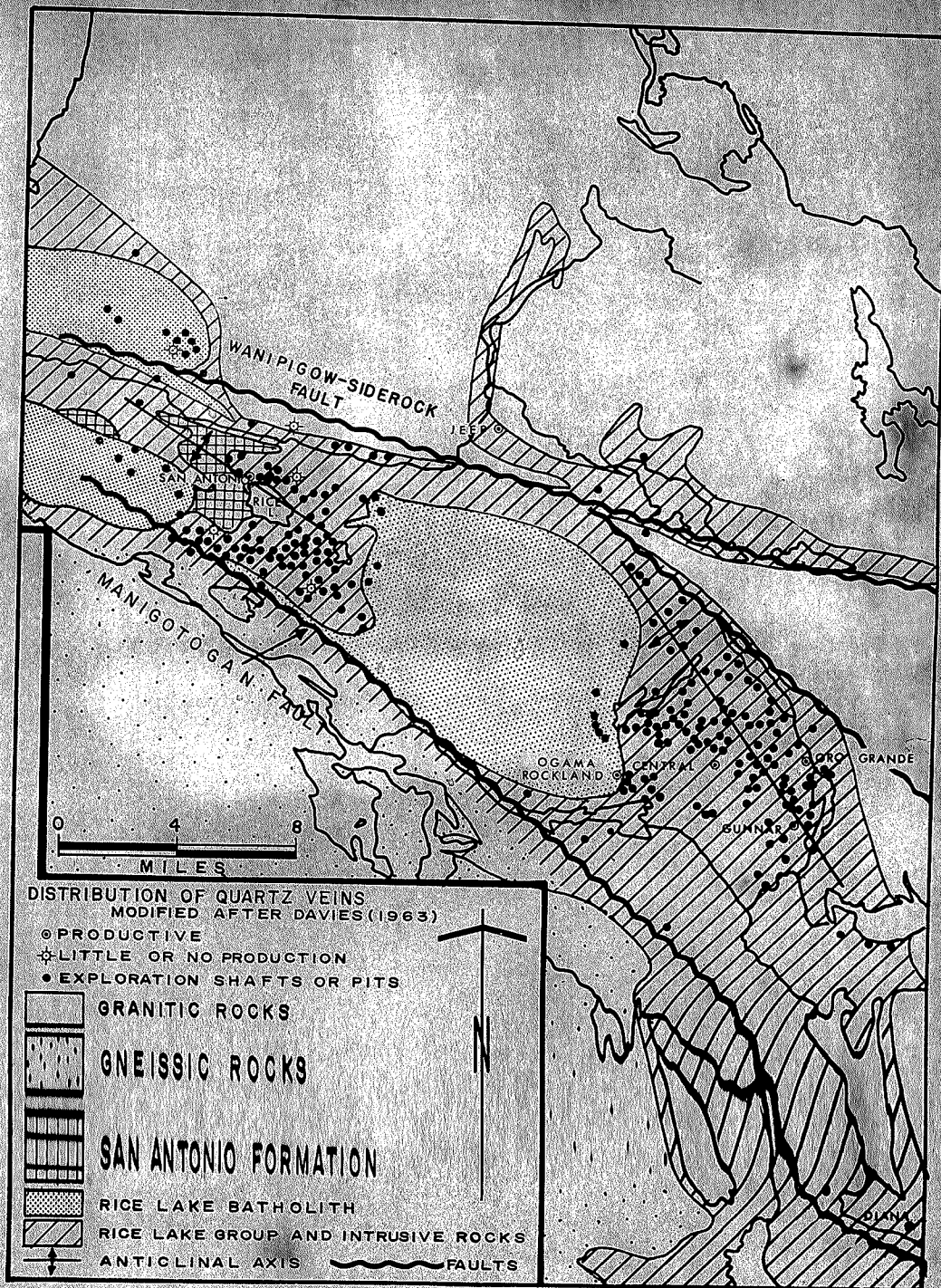
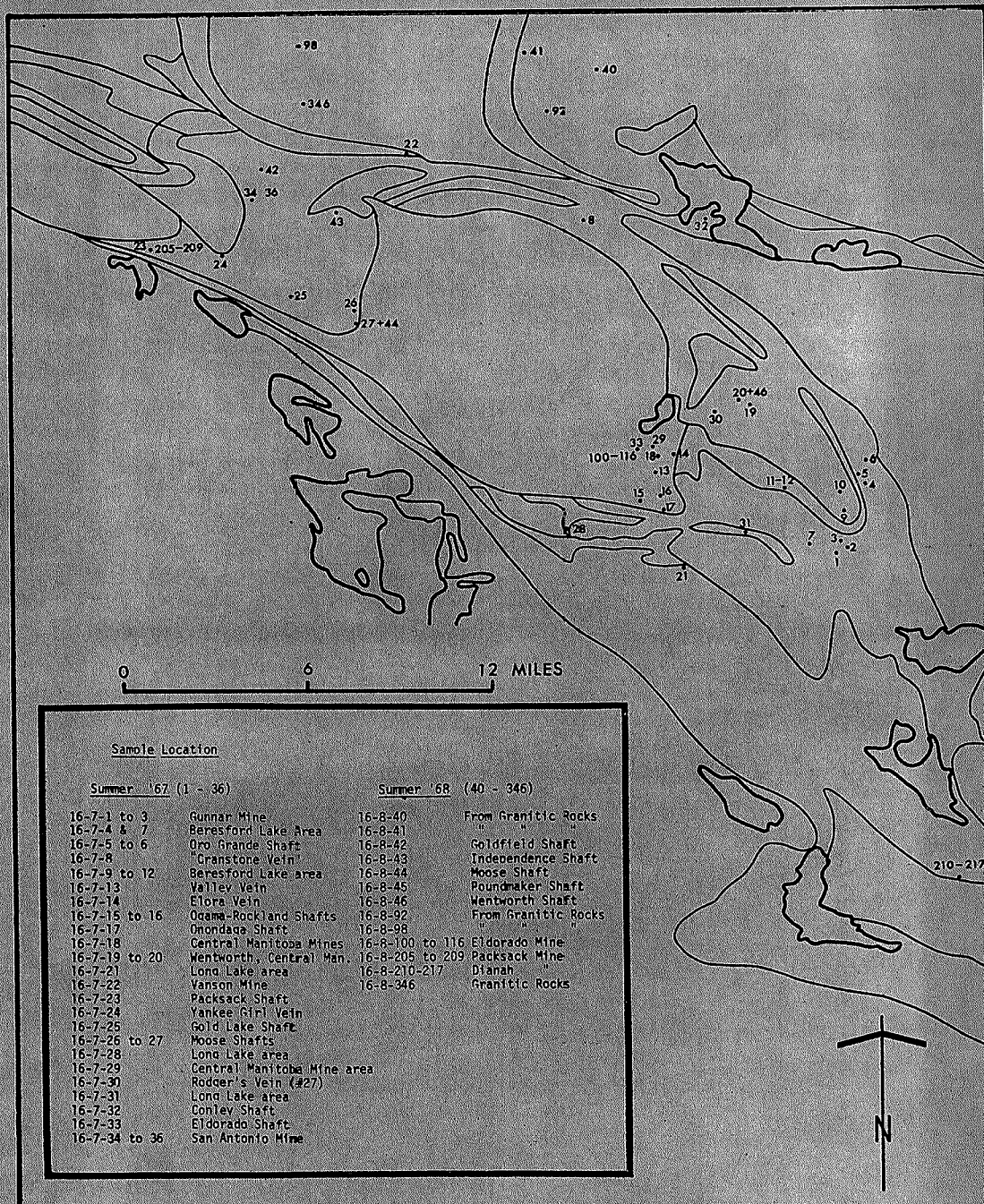


Figure 3. Sample Locations.



The numbers on the map are the third number in the identity-set-code of the legend.

1. The Northwest-Southeast Set

The poles to the strike and dip of the veins in this set make a strong concentration plot which is scattered between $s30^{\circ}W$ to $s80^{\circ}W$. The veins dip steeply to vertically to the northeast, see Figure 4a and 4b.

The Northwest set commonly exists as irregular quartz veinlets, displaying swelling and pinching in some locations. They follow fracture zones which are characterized by brecciation and a lack of shearing. It was also found by Stockwell (1938) that veins of this set are made up of sinuous, vein-like bodies of quartz.

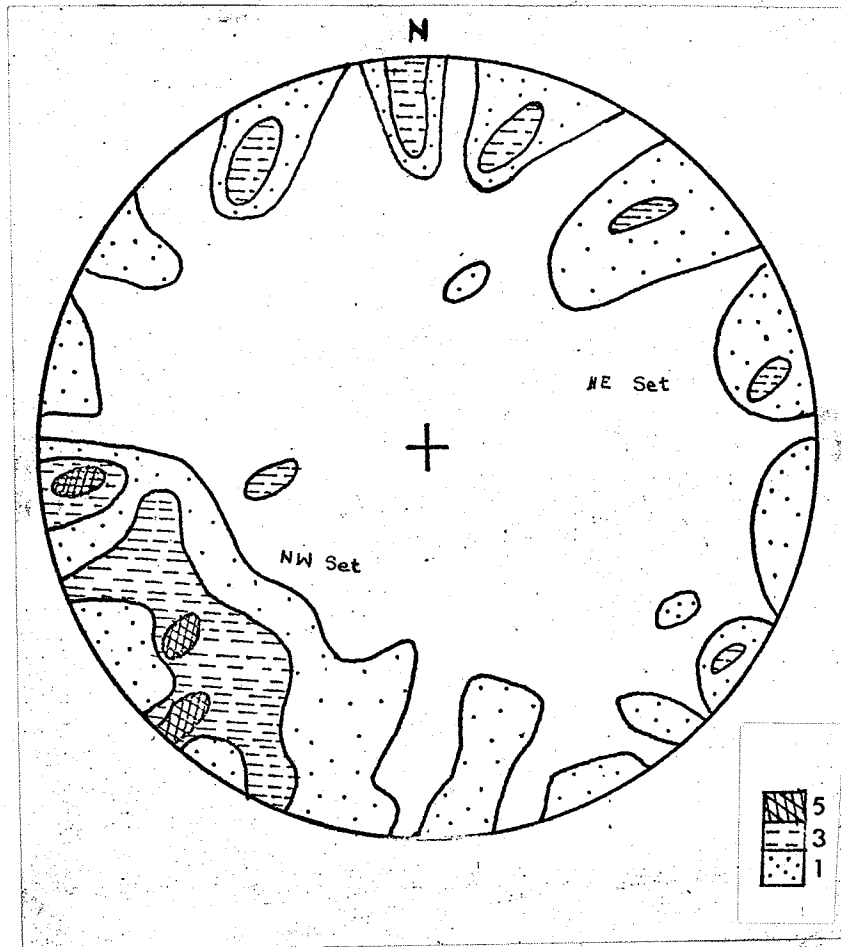
These veins were the largest and best ore producers at the following mines: San Antonio Gold Mine (#26 vein), Gunnar Gold Mine (#1 and #3 shears), and Central Manitoba Mine (the Kitchener vein). Veins of this set also, as a rule, make up nearly a half of the veins in these mines and other claims. It is the most prominent shear direction in the entire area.

2. The Northeast-Southwest Set

A stereo-net plot of poles to the attitude of veins of this set makes a poor concentration that is split up according to direction of dip, see Figure 4a and 4b. These veins commonly dip vertically or steeply to the northwest.

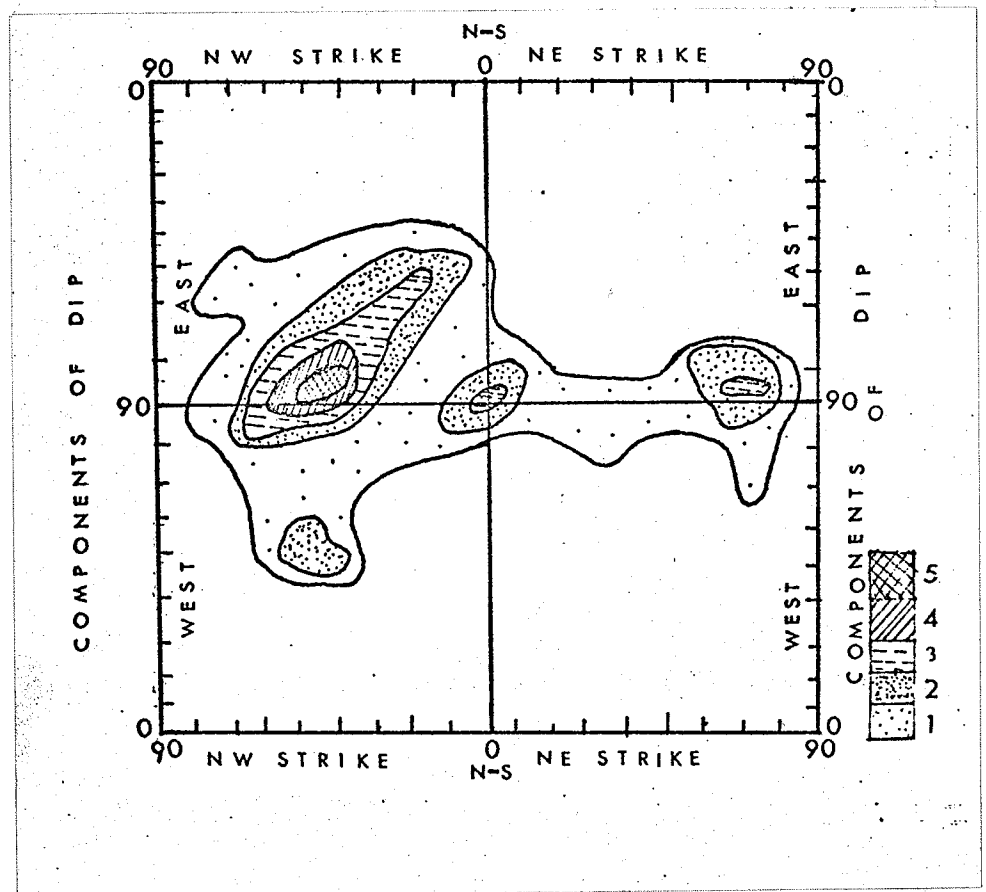
The Northeast set of veins is usually made up of a succession of lenticular quartz bodies. They follow shear

Figure 4a: Stereonet plot of poles to fractures, shears and faults.



250 Points

Figure 4b: Statistical plot of fractures, shears and faults.



250 Points

zones along which there has been differential movement of the walls with little or no displacement.

The second largest ore producer in the same mines, that is, #16 for San Antonio, #2 for Gunnar, and Eclipse #2 for Central Manitoba, were veins of the Northeast-Southwest set. The veins and lenses of this set constituted the second next abundant and significant shear direction in the area.

3. The North-South Set

The concentration of points representing poles to the strike and dip of members of this set is also poor, see Figure 4a and 4b. The veins dip steeply.

Although there were fewer veins and lenses of this set, small amounts of gold were produced from some claims with this shear direction. In most instances the north-south strike of the fractures changed abruptly to either of the sets already mentioned.

COMPOSITION

The veins may be either quartz, or a silicified and mylonitized country rock, with the minerals: quartz (at least 85%), carbonate, chlorite, sercite, epidote, rutile and tourmaline. Where "mineralization" is present, there may be pyrite, arsenopyrite, pyrrhotite, sphalerite, chalcopryite, galena, hematite, magnetite and gold. Vein rock chemical compositions are described in chapter III.

DESCRIPTION OF THE QUARTZ FROM THE VEINS

Physical Properties

In hand specimen, the color of quartz from the veins varies widely from colorless to black. The colors are affected by transparency, texture and luster (see table 2).

The predominant color is white, with the following varieties: The first variety, a milky white, forms the majority of the white specimens (see samples 31(2), 24(2)). Sample 31(2) is milky white, semi-opaque, and very coarsely crystalline; sample 24(2) also milky white, but it is semi-translucent and coarsely crystalline. They are both vitreous.

A second form of white specimens, displayed by samples 5, 7 and 22(2) is smoky white. Samples 5 and 7 are semi-translucent and dense. They all have a vitreous luster.

A third type is white to smoky, a variation of the smoky form. These specimens are coarsely crystalline, and with a vitreous luster. It is shown in samples 210 and 3(1), which are semi-translucent and sample 27(1) which is translucent.

A fourth and final variety of white quartz differs only in its texture, which is medium to coarse granular; the samples are translucent (see specimens 15(1), 41 and 92(3)).

The next most abundant color of the specimens is black. There are two varieties, the darkest of which is

Table 2: Summary of specimen colors and other physical features.

<u>Color</u>	<u>Transparency</u>	<u>Texture</u>	<u>Luster</u>	<u>Sample Numbers of Examples</u>
White	Translucent	Medium granular	Vitreous	41, 15, 92(3)
Milky white	Semi-opaque	Very coarse	Vitreous	31(2)
	Semi-translucent	Coarse	Vitreous	24(2)
Smoky white	Semi-translucent	Coarse	Vitreous	7, 5
Smoky white to grey	Translucent	Dense	Vitreous	22(2)
White to smoky	Semi-translucent	Coarse	Vitreous	210, 3(1)
	Translucent	Coarse	Vitreous	27(1)
Black	Semi-opaque	Coarse	Vitreous	22(3), 30(2), 18(1)
Dark grey	Semi-translucent	Medium to Coarse	Vitreous	30(1), 19(1), 46
Reddish-brown (pink)	Semi-opaque	Coarse	Vitreous	26(2), 44, 30(3)
Reddish to grey	Semi-translucent	Coarse	Vitreous	13(1)
Yellowish-brown	Semi-opaque	Medium to Coarse	Vitreous	3(1), 2(2), 32, 20(1)

opaque, coarsely crystalline and vitreous (see samples 18(1), 21(1), 22(3), and 30(2)). This variety also displays conchoidal fracture. The second variety, a dark grey, may vary in texture from aphanitic to coarse-grained, or it may be mixed up with veinlets of the white types (see samples 19(1), 30(1), and 46). The specimens can be opaque or translucent and have a vitreous luster.

The reddish-brown (pink) color in the specimens can be also subdivided by textural properties, ranging from medium to coarse-grained, and by degrees of transparency. It is composed of reddish-brown and reddish to grey varieties; examples of this type are specimens 26(2), 30(3), and 44.

Finally a yellowish-brown color is exhibited only by those specimens that were collected from the surface or prospect pits. They represent weathered equivalents of the other colors (see samples 2(2), 3(1), 20(1), and 32).

Megascopically, there are at least three characteristic textures in all the quartz of almost all colors. Some specimens are irregular medium to coarse-grained, as in samples 18(1), 19(1), 21(1), 30(2), and 210. Other samples: 27(2), 32(1), are fine-grained to aphanitic, or even so fine as to give the quartz a cherty appearance.

The third type is the granular (sugary) texture displayed by samples 15(1), 41, 92(3), 98(1), and 30(1).

The density of randomly selected specimens averaged 2.65gm/cc at room temperature and pressure.

An x-ray beam was passed through powdered samples of white specimens. Upon being exposed, the powders changed color to grey. This induced grey color is lost partially when the powder is left at room temperature and pressure; it is completely destroyed by heating.

The powder of black colored specimens was also heated at 1000°C for 10 hours. The black color changed to a light grey.

Age Relationships Between the Quartz Varieties

In his study of the Ogama-Rockland gold mine, Troop (1949) identified two principal ages of quartz injection in that mine: an early smoky quartz, and a later white quartz. Boyle (1954), working in a similar type of a greenstone belt in the North-West Territories, noted that the shear zones of the Yellowknife area contain quartz of two distinct ages: an older white quartz and a younger dark type.

During the course of field work, as many as four separate ages of quartz injections were identified by their cross-cutting relationships. Comparison of the age relationships of one area to another non-juxtaposed area is only considered to ^{be} speculation, even if the types of quartz observed have similar physical or chemical properties. Many of the milky white quartz veinlets cut across black quartz. The older black quartz is characteristically fine-grained to aphanitic and contains pyrite, chalcopyrite, and small amounts of gold.

However, there are also occurrences of the opposite relation in which veins of white quartz are cut by younger black quartz. This black quartz, however, is medium to coarse-grained and contains little or no sulphides and gold.

The younger white quartz is usually coarse-grained and shows evidence of brecciation with extreme undulatory (wavy) extinction. Three generations of younger white quartz were observed. The oldest type carries considerable gold and is crowded with solid inclusions of altered country rock, carbonates, and some amounts of pyrite, chalcopyrite, arsenopyrite, and iron oxides. It is dark white to colorless.

The second generation exhibits a green coloration which may be in the form of bands, patches or dots. This generation of quartz carries some sulphides and oxides, with small quantities of visible gold.

The youngest white quartz probably fills the surfaces of joint sets (Figure 5). This generation of quartz is characteristically medium to coarse, granular, and is milky white. It carries very little solid inclusions.

It is evident that the oldest quartz is black and that the youngest quartz in the area fills joint planes. It is postulated that after the deposition of both black and white quartz, there were two events: a period of shearing which affected the younger white, coarse-grained variety more than the older, fine-grained types. The

Figure 5: Youngest quartz filling the joint planes.
Locality #16-8-41.



Figure 6: Occurrence of gold (center) in pyrite crystals.
Locality #16-8-45. Scale 300x.



second event was the introduction of black and white quartz, plus mineralizing solutions.

OCCURRENCE OF GOLD

1. The greatest amounts of gold occur as particles in the clear microcrystalline quartz.

2. Some gold is disseminated within pyrite, arsenopyrite and chalcopyrite in a finely divided state, or as a partial replacement product of pyrite and arsenopyrite, see Figure 6.

3. Native gold also occurs as small segregations in adjacent country rocks, see Figure 7a.

4. Native gold also occurs as small grains in the carbonates, mostly calcite and ankerite, and near quartz, see Figure 7b.

Figure 7a: Small gold segregations (light) in the country rocks. Locality #16-7-23. Scale 30x.

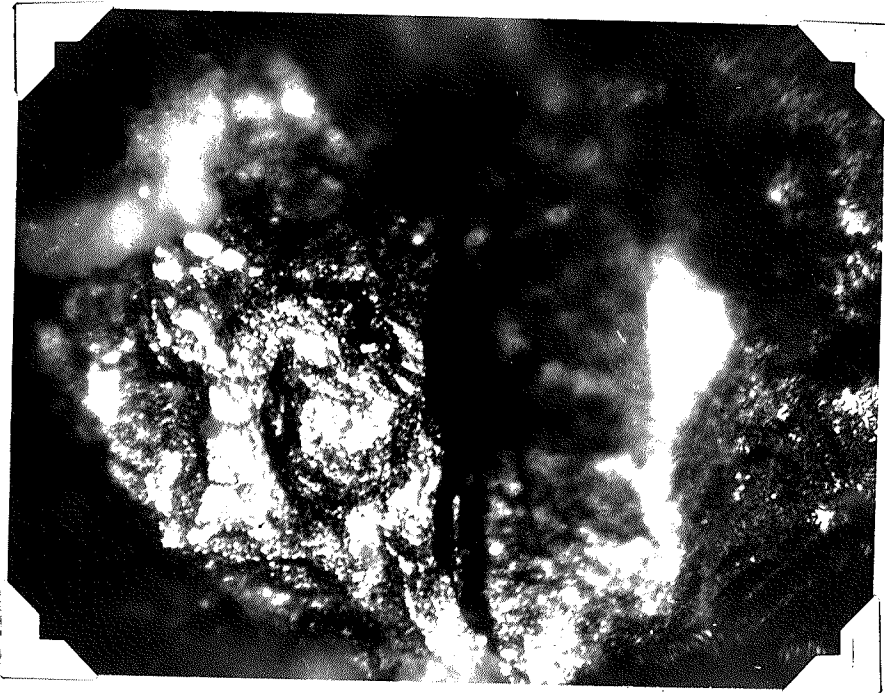
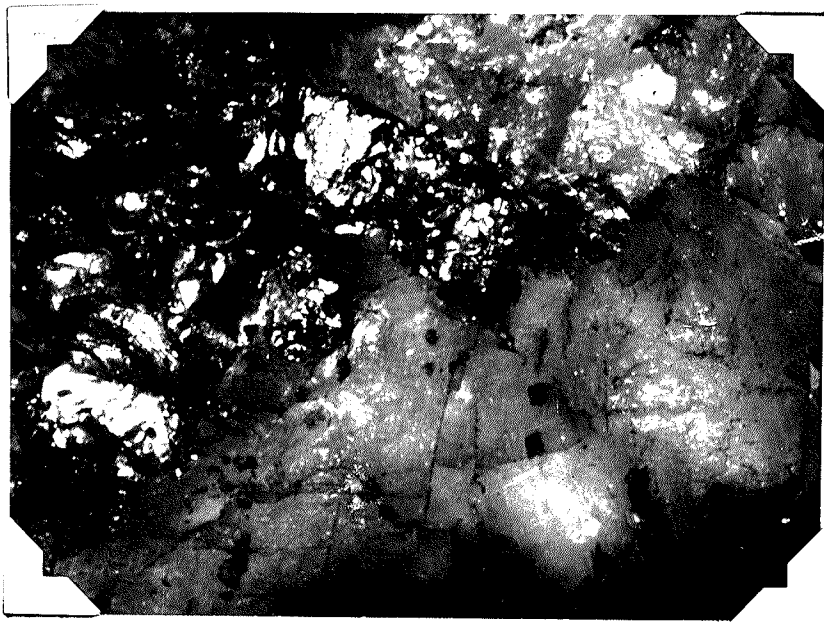


Figure 7b: Small grains of gold in carbonates and quartz. Locality #16-8-205. Scale 10x.



CHAPTER III

PETROLOGY

A petrographic study of the quartz from the veins was carried out in a search for a possible correlation between the type of vein material and the chemistry thereof. Several of the mines and shears zones were sampled across the strike and into the country rock.

THE QUARTZ CORES

Texture

The quartz from the vein cores is made up of medium to fine-grained euhedral and subhedral quartz showing extreme undulatory extinction, with some larger strained grains of quartz. Fine-grained quartz is invariably observed around grain boundaries of larger grains of quartz. This texture, also called "mortar structure" is illustrated in Figure 8a. In some specimens (e.g. #5), there is an alternation of grain sizes which defines a layered structure Figure 8b. In other samples, clear quartz not only exists as veinlets cross-cutting the grain boundaries, but also parallels them (sample #3(1)).

The major textural difference between the two generations of quartz, namely the early black-grey quartz and

Figure 8a: Texture of vein quartz-coarse, medium and fine.
Locality #16-7-28(1). Scale 100x.

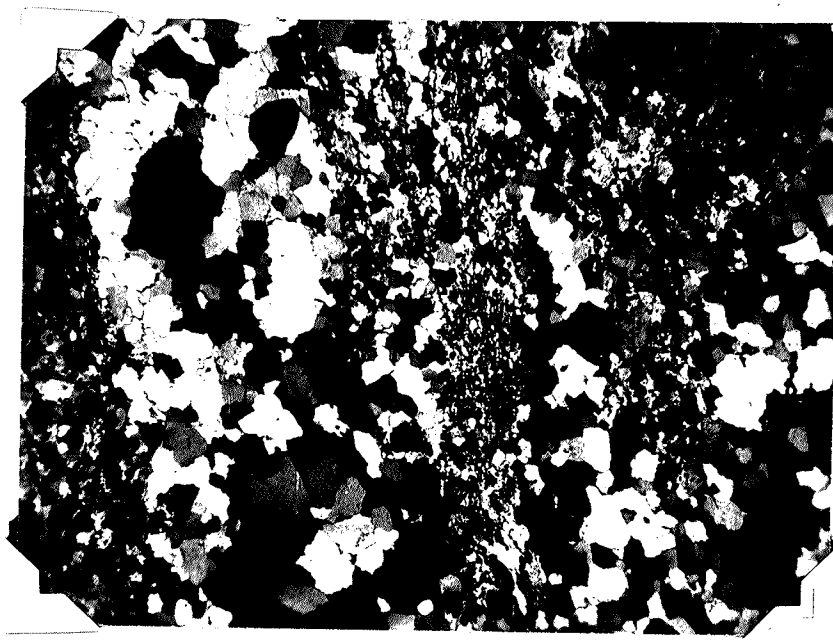
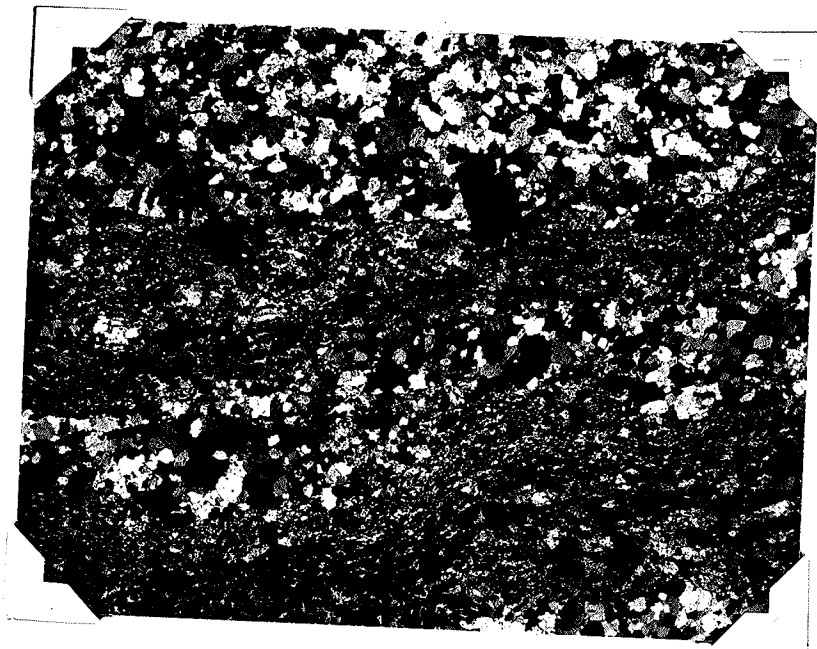


Figure 8b: "Microlayering" - Texture of vein quartz
Locality #16-7-5. Scale 20x.



the relatively late white quartz, is that the early quartz is fine to medium-sized and euhedral to subhedral, with patches of microcrystalline quartz, whereas the later white quartz is generally medium to coarse-grained, and has subhedral grains which also contain patches and veinlets of microcrystalline clear quartz.

Mineralogy

By far the most abundant mineral of the veins is quartz. It gives an excellent x-ray powder diffraction pattern of Low (α) quartz.

Optically, most grains give a uniaxial positive figure, but some of the strained crystals are pseudo-biaxial with a low $2V$ of about 10° . Extinction is parallel in euhedral grains, but is undulose in strained grains. Relatively unsheared grains may be flamboyant and euhedral to subhedral. These may be modified by shearing to give feathered small, lamellar-like needles, with broken and "dragged" grains.

Plagioclase feldspars are more common in the vein material than potash feldspars. The feldspars in fine-grained mixture with quartz are short and stubby, with fibrous terminations. The plagioclases are partly altered to sericite and zoisite (?), especially in the center of the grains. Feldspars within country rock inclusions in the vein material are not as altered as those in the quartz.

The amphiboles show peculiar microscopic structures, being composed of feathered needles and lamellae in a fine-grained mixture of quartzo-feldspathic material.

The predominant mica in the quartz cores is muscovite. In some of the grains it is accompanied by leucoxene, rutile and magnetite.

Biotite is rare, and most of it has been altered to very fine-grained chlorite.

A few grains of serpentine (or talc?) are scattered in the sections. They are thought to be alteration products.

X-ray powder photograph patterns reveal that the most common carbonate is calcite. Ankerite, magnesite, and siderite also occur. Also identified by x-ray methods were: azurite and malachite as weathering products.

Pyrite, arsenopyrite, chalcopyrite, sphalerite, pyrrhotite, galena were identified.

Hematite and magnetite were easily recognizable. Epidote, ilmenite, rutile, leucoxene were observed but not confirmed by x-ray analysis.

Rare occurrences of tourmaline, garnet and graphite were observed.

By far the most abundant native element is gold. Its occurrence is described in Chapter III. Traces of native copper were also present.

Micro-inclusions in quartz, solid and liquid, can display planar, linear or random orientations. The solid inclusions are serite-saussurite, chlorite, carbonates,

mica, rutile, tourmaline, graphite, with or without metallic oxides and sulfides. Liquid inclusions have been reported in a number of thin sections of quartz from Gold-seal, Wentworth (west), Cryderman and Independence shafts, by J. Stephenson (personal communications, 1969). These have been called secondary liquid inclusions because their location was such that they occur as veinlets having a linear alignment that cut across grain boundaries.

DESCRIPTION OF THE ALTERATION ZONES

Texture

The characteristic textures and structures are:

1. Mortar, augen, and flaser textures, where lenticles, needles, or "porphyroblasts" and "porphyroclasts" of uncrushed grains are scattered in a granulated, streaky matrix of the same material (chiefly quartzo-feldspathic).
2. Flow structures within the granulated quartzo-feldspathic matrix.
3. "Flinty-crush-rock" texture within fault and shear zones (microbrecciation), where there are veins of black or dark green crushed rock associated with faults and shears. The minerals all display strain shadows and fragmentation, especially in the quartz grains; this texture may be used to trace the extent of initial stages of dynamic deformation.
4. Mylonitic texture in which only a few scattered grains remain uncrushed. The grain-size of cataclastic

rocks determines whether the rock is to be referred to as a cataclasite, a mylonite, or an ultramylonite.

5. All vein rocks of the alteration zones are strongly foliated, Figure 9.

6. Poikiloblastic texture of porphyroblasts of quartz or feldspar containing inclusions of other minerals.

7. Relict texture or structure. Diabasic (ophitic) texture is still retained in some gabbroic rocks. Megascopic structures such as pillows, vesicles and amygdules may be preserved, vesicles being filled with quartz or calcite. Close to the edges of the granitic intrusions, there are zones rich in xenoliths, giving a relict igneous-inclusion structure.

Mineralogy

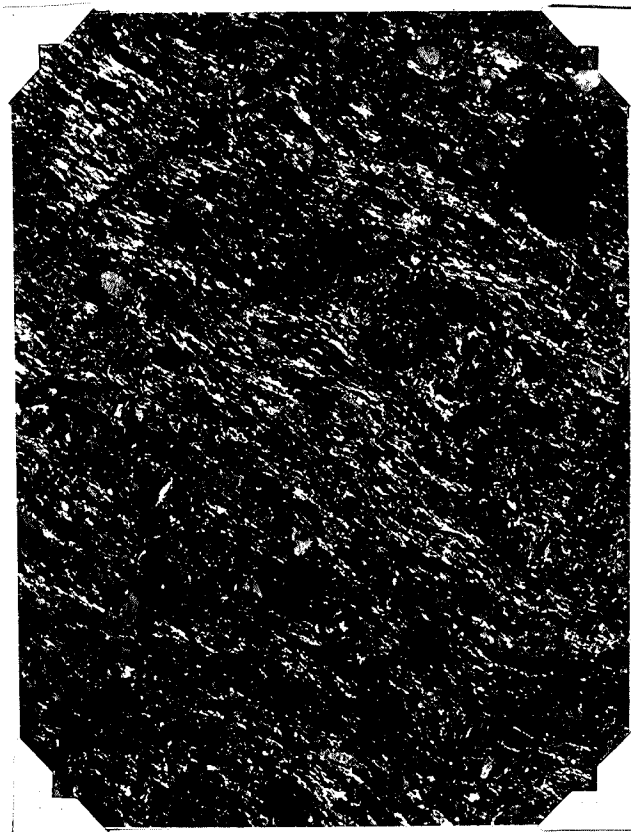
The mineralogy of the country rocks is dependent on the lithology as outlined in Figure 1. However, the most predominant minerals are green chlorite, sericite, zoisite, clinozoisite, epidote, muscovite, carbonate (mostly calcite, ankerite, azurite and malachite), graphite, quartz and feldspar. Fibrous amphiboles, biotite, leucoxene and rutile are irregularly distributed.

Metallic oxides and sulfides are rare.

Classification

The distribution of specific minerals within certain sections of similar alteration zones in Yellowknife greenstone-belt shear zones was used by Boyle (1959) to classify

Figure 9: Foliation in rocks of the alteration zones
Locality #16-7-15(1). Scale 20x.



them into three schist zones: (1) chlorite, (2) carbonate-chlorite, and (3) carbonate-sericite-schists. However, in the Bissett area, his zones (1) and (2) are not distinct, but are here together in an outer zone. The zones are:

1. The Chlorite-Carbonate Schist Zone (outer zone)

The outer zone is rich in chlorite and carbonates, with minor quartz, micas, feldspars, tourmaline, sericite, epidote, clinozoisite, and graphite. Sulphides, especially pyrite, pyrrhotite, arsenopyrite, chalcopyrite, sphalerite and galena, are uncommon and irregularly distributed.

This zone is interpreted to be a zone of chloritization, carbonatization, desilication and hydration of the country rock.

2. The Sericite-Saussurite Schist Zone (inner zone)

The inner zone is rich in quartz, sericite, clinozoisite, epidote, muscovite and graphite and contains minor carbonates, feldspars, tourmaline, rutile, leucoxene. Sulphides occur as in zone 1.

This unit is interpreted to be a zone of sericitization, saussuritization, silicification and oxidation of the country rock.

DESCRIPTION OF COUNTRY ROCKS

The wall (country) rocks have been subjected to dynamic, regional and retrograde (hydrothermal) metamorphism, probably of lower greenschist facies (Stockwell, 1938). They are fine-grained schists and granoblastites,

representing metamorphosed volcanic and sedimentary rocks.

The minerals are: quartz, plagioclase, potash feldspar, biotite, muscovite, amphiboles, sericite-saussurite, chlorite, carbonates, magnetite, epidote, rutile, tourmaline, and a few oxides and sulfides. Bulk chemical analyses of samples adjacent to veins at the Eldorado and Packsack mines are listed in Table 15, Appendix 5.

The minerals produced by retrograde metamorphism usually appear as needles within the fine-grained quartzofeldspathic matrix and around phenocrysts or clasts.

CHAPTER IV

CHEMICAL COMPOSITION OF VEIN MATERIAL

The samples are random or "grab" samples of different types of vein materials. Representative material was chosen for chemical analyses.

The methods of analysis are described in Appendix 2.

A. VEIN MATERIAL WITH BLACK QUARTZ (TABLE 5)

In general, the amounts of elements other than SiO_2 reflects the amount of minerals other than quartz in the sample. The contents of CaO and CO_2 may be assigned to calcite, and MgO , Al_2O_3 and H_2O to chlorite. The content of sulfides should be reflected in the amount of S.

In more than half of these samples (e.g. 19(1), 46 the amount of CO_2 is more than double that of CaO . It may be speculated that some of the excess CO_2 is derived from elemental carbon.

The origin of the color of black-grey quartz has been variously attributed to carbon (graphite) pigmentation (Boyle, 1954); and to tourmaline, trivalent iron, and lithium (Fronde1, 1963). Chemical composition of black-grey quartz (Table 5) is not characterized by the presence of large amounts of Fe^{3+} or Li, relative to their contents

Table 5: Analysis of Vein Rocks Containing Black Quartz

<u>Major Elements</u>	<u>16-7-7</u>	<u>16-7-18(1)</u>	<u>16-7-19(1)</u>	<u>16-8-44</u>	<u>16-8-46</u>
SiO ₂	80.55%	97.50%	97.25%	97.80%	97.70%
Al ₂ O ₃	6.30	0.59	0.19	0.25	0.26
Fe ₂ O ₃	2.76	0.67	0.61	0.47	0.97
FeO	0.40	0.28	0.48	0.20	0.02
MgO	0.74	0.04	0.05	0.09	0.05
CaO	4.60	0.40	0.20	0.18	0.22
Na ₂ O	0.24	0.03	0.02	0.03	0.12
K ₂ O	0.02	0.06	0.002	0.00	0.00
H ₂ O	0.58	0.10	0.09	0.12	0.08
CO ₂	3.44	0.12	0.64	0.25	0.44
TiO ₂	0.13	0.03	0.00	0.004	0.00
P ₂ O ₅	0.06	0.03	0.02	0.04	0.04
MnO	0.04	0.00	0.004	0.00	0.002

Table 5: Analysis of Vein Rocks Containing Black Quartz

<u>Trace Elements</u>	<u>16-7-7</u>	<u>16-7-18(1)</u>	<u>16-7-19(1)</u>	<u>16-8-44</u>	<u>16-8-46</u>
S	1350PPM	90PPM	7600PPM	1890PPM	194PPM
Ni	17	10	8	17	6
Cu	34	26	2850	1450	1400
Co	22	0	28	10	9
Zn	33	1	43	6	35
Pb	68	16	28	16	22
Zr	160	110	60	110	160
Cr	188	236	238	160	232
V	58	8	6	6	14
Sr	80	7	0	0	0
Rb	0	0	0	0	0
Li	1	1	0	2	2
Ba	400	100	400	600	232
Totals	100.03	100.19	99.55	100.77	100.18

Total includes all elements with pertinent correction.

in white quartz.

The color of most black-grey specimens was destroyed by heating at 1000°C overnight. It is also noted that a similar color was produced by gamma-rays passed through the powdered white-colored specimens for several hours.

B. VEIN MATERIAL WITH WHITE QUARTZ

The chemical analyses of vein rocks containing white quartz are listed in four groups: aphanitic, Table 6a; banded, Table 6b; coarse-grained, Table 6c; and granular, Table 6d.

The aphanitic and banded types (Table 6a and 6b) contain more sulfides than the coarse and granular groups (Tables 6c and 6d). The former are thereby enriched in S and Cu.

The principal constituents of all the white types are: Al, Fe³⁺, Ca, H₂O and CO₂. The white quartz is similar to the black quartz in trace element quantities of Mg, Na, P and Ti, (except a and b). Some amounts of Mn, Cu, K and S (except c and d) are also contained in the white quartz types. The other significant elements in small quantities are: Zr, Cr, Ba, Co (except c and d), Ni, Zn, Pb, V, Sr, Rb and Li.

White quartz from the vein material contains more Ti and K than black-grey quartz from the vein rocks, but comparable or larger amounts of these elements are found in other colored types.

One sample of vein material #16-7-3(1), Table 6a, was

Table 6a: Analysis of Vein Rocks Containing White Aphanitic Quartz

<u>Major Elements</u>	<u>16-7-27(2)</u>	<u>16-7-31(2)</u>	<u>16-8-44</u>	<u>Unknown</u>	<u>16-7-3(1)</u>
SiO ₂	97.30%	76.60%	97.80%	98.70%	98.45%
Al ₂ O ₃	0.21	2.66	0.25	0.11	0.36
Fe ₂ O ₃	0.80	3.55	0.47	0.43	0.12
FeO	0.72	1.76	0.20	0.20	0.44
MgO	0.01	1.98	0.09	0.01	0.02
CaO	0.21	4.93	0.18	0.20	0.13
Na ₂ O	0.016	0.87	0.03	0.009	0.03
K ₂ O	n.d.	0.10	0.00	0.00	0.01
H ₂ O	0.08	0.90	0.12	0.00	0.11
CO ₂	0.27	4.17	0.25	0.17	0.06
TiO ₂	n.d.	0.08	0.004	0.00	0.00
P ₂ O ₅	0.04	0.07	0.04	0.05	0.01
MnO	0.009	0.05	0.00	0.002	0.003

Table 6a: Analysis of Vein Rocks Containing White Aphanitic Quartz

<u>Trace Elements</u>	<u>16-7-27(2)</u>	<u>16-7-31(2)</u>	<u>16-8-44</u>	<u>Unknown</u>	<u>16-7-3(1)</u>
S	3100 PPM	29600 PPM	1890 PPM	520 PPM	2060 PPM
Ni	5	39	17	15	12
Cu	3300	35	1450	99	950
Co	0	17	10	8	4
Zn	2	46	6	6	900
Pb	0	30	16	19	32
Zr	600	0	110	0	0
Cr	256	255	160	125	192
V	19	0	6	17	10
Sr	0	27	0	0	0
Rb	0	0	0	0	0
Li	2	3	2	1	200
Ba	800	200	600	500	
Totals	100.31	99.22	100.77	99.99	100.07

Total includes all elements with pertinent correction.

Table 6b: Analysis of Vein Rocks Containing White Banded Quartz

<u>Major Elements</u>	<u>16-7-25(1)</u>	<u>16-7-30(1)</u>	<u>16-7-35(2)</u>	<u>16-7-36(2)</u>	<u>16-8-42</u>
SiO ₂	92.45%	96.05%	70.65%	96.10%	91.90%
Al ₂ O ₃	1.01	0.35	3.72	1.02	1.62
Fe ₂ O ₃	2.59	0.84	11.72	0.78	0.47
FeO	0.56	1.16	3.60	0.25	0.48
MgO	0.02	0.09	0.28	0.07	0.32
CaO	0.20	0.10	0.59	0.14	2.01
Na ₂ O	0.02	0.02	0.59	0.54	0.39
K ₂ O	0.29	0.00	0.83	n.d.	0.20
H ₂ O	0.18	0.15	0.32	0.35	0.25
CO ₂	0.59	0.51	0.86	0.65	1.98
TiO ₂	0.00	0.02	0.74	n.d.	0.004
P ₂ O ₅	0.03	0.06	0.18	0.05	0.05
MnO	0.003	0.005	0.005	0.009	0.02

Table 6b: Analysis of Vein Rocks Containing White Banded Quartz

<u>Trace Elements</u>	<u>16-7-25(1)</u>	<u>16-7-30(1)</u>	<u>16-7-35(2)</u>	<u>16-7-36(2)</u>	<u>16-8-42</u>
S	17700 PPM	5900 PPM	110500 PPM	390 PPM	1790 PPM
Ni	10	5	36	11	19
Cu	240	4100	72	23	1245
Co	152	0	98	8	14
Zn	1	48	14	39	9
Pb	18	18	0	12	21
Zr	510	150	0	160	0
Cr	288	170	218	304	223
V	30	8	94	6	12
Sr	7	0	10	7	37
Rb	0	0	30	0	1
Li	1	0	0	0	2
Ba	300	700	400	400	500
Totals	99.01	100.18	99.72	100.08	100.01

Total includes all elements with pertinent correction.

Table 6c: Analysis of Vein Rocks Containing White Coarse-Grained Quartz

<u>Major Elements</u>	<u>16-7-17(1)</u>	<u>16-7-16(2)</u>	<u>16-7-24(2)</u>	<u>16-7-36(2)</u>	<u>16-8-210</u>
SiO ₂	98.40%	98.60%	99.10%	96.10%	95.30%
Al ₂ O ₃	0.32	0.21	0.08	1.02	1.03
Fe ₂ O ₃	0.19	0.19	0.57	0.78	0.51
FeO	0.36	0.32	0.12	0.25	0.54
MgO	0.01	0.11	0.003	0.09	0.33
CaO	0.10	0.24	0.11	0.14	0.67
Na ₂ O	0.02	0.02	0.007	0.54	0.05
K ₂ O	0.11	0.04	n.d.	n.d.	0.11
H ₂ O	0.11	0.13	0.00	0.35	0.57
CO ₂	0.22	0.19	0.04	0.65	0.79
TiO ₂	0.02	0.01	0.00	n.d.	0.05
P ₂ O ₅	0.03	0.03	0.02	0.05	0.005
MnO	0.001	0.008	0.005	0.009	0.004

Table 6c: Analysis of Vein Rocks Containing White Coarse-Grained Quartz

<u>Trace Elements</u>	<u>16-7-16(1)</u>	<u>16-7-16(2)</u>	<u>16-7-24(2)</u>	<u>16-7-36(2)</u>	<u>16-8-210</u>
S	90 PPM	50 PPM	0 PPM	390 PPM	PPM
Ni	3	10	4	11	29
Cu	27	4	7	23	387
Co	10	3	0	8	9
Zn	17	4	0	39	12
Pb	0	0	0	12	303
Zr	0	110	530	160	0
Cr	192	132	217	304	225
V	30	8	0	6	0
Sr	0	7	10	7	57
Rb	0	0	0	0	9
Li	0	0	0	0	
Ba	200	300	0	400	230
Totals	99.96	100.16	100.14	100.08	100.19

Total includes all elements pertinent correction.

Table 6d: Analysis of Vein Rocks Containing White Granular Massive Quartz

<u>Major Elements</u>	<u>16-8-41</u>	<u>16-8-92(3)</u>	<u>16-8-346(2)</u>
SiO ₂	99.30%	99.30%	90.54%
Al ₂ O ₃	0.06	0.03	1.02
Fe ₂ O ₃	0.17	0.18	0.44
FeO	0.04	0.16	1.28
MgO	0.01	0.01	0.83
CaO	0.31	0.14	4.02
Na ₂ O	0.003	0.01	0.02
K ₂ O	0.004	0.00	0.002
H ₂ O	0.01	0.03	0.05
CO ₂	0.03	0.40	2.37
TiO ₂	0.00	0.00	0.00
P ₂ O ₅	0.05	0.03	0.06
MnO	0.00	n.d.	n.d.

Table 6d: Analysis of Vein Rocks Containing White Granular Massive Quartz

<u>Trace Elements</u>	<u>16-8-41</u>	<u>16-8-92(3)</u>	<u>16-8-346(2)</u>
S	100 PPM	0 PPM	80 PPM
Ni	8	4	17
Cu	23	14	23
Co	9	11	8
Zn	13	13	19
Pb	0	15	21
Zr	220	30	100
Cr	140	207	240
V	3	15	38
Sr	0	0	0
Rb	0	0	0
Li	1	1	4
Ba	400	400	500
Totals	99.89	99.99	100.13

Total includes all elements with pertinent correction.

yellowish-brown in color due to weathering effects of sulfides. It was originally a white aphanitic type, and its composition is similar to other aphanitic quartz vein samples.

C. VEIN MATERIAL WITH REDDISH-BROWN QUARTZ

This color of quartz from the vein rocks is similar to traditional rose (pink). The color is not uniform.

The analytical results (Table 7) were expected to contain large amounts of elements typical of major color types such as Fe (violet), Ti (rose) and Mn (violet).

Reddish-brown quartz in the vein rocks contains about equal amounts of trivalent and divalent iron, which may account for the color. However, comparable or larger amounts of iron are present in other color varieties.

Mn and Ti are present in amounts of the order of 0-0.00X%.

DISTRIBUTION AND ASSOCIATION OF ELEMENTS IN VEINS

The results of the vein-rock analyses should only be considered as a guide to more detailed work on specific minerals and in a specific sulfide or silicate phase.

The abundance and distribution of major and minor elements is hereby discussed for individual elements, or groups of elements. Abundance data for elements in average crustal rocks are listed in Table 12, Appendix 3, and element ratios are given for these vein materials and for average crustal rocks in Table 14, Appendix 4.

Table 7: Analysis of Vein Rocks Containing Reddish-Brown Quartz

<u>Major Elements</u>	<u>16-7-26(2)</u>	<u>16-7-27(2)</u>	<u>Trace Elements</u>	<u>16-7-26(2)</u>	<u>16-7-27(2)</u>
SiO ₂	98.95%	97.30%	S	60 PPM	3100 PPM
Al ₂ O ₃	0.06	0.21	Ni	2	5
Fe ₂ O ₃	0.32	0.80	Cu	223	3300
FeO	0.40	0.72	Co	22	0
MgO	0.003	0.01	Zn	11	2
CaO	0.08	0.21	Pb	18	0
Na ₂ O	0.01	0.02	Zr	15	600
K ₂ O	0.00	n.d.	Cr	122	256
H ₂ O	0.04	0.08	V	16	19
CO ₂	0.03	0.27	Sr	0	0
TiO ₂	0.00	n.d.	Rb	0	2
P ₂ O ₅	0.02	0.04	Li	0	2
MnO	0.002	0.001	Ba	100	500
			Totals	99.97	100.31

Total includes all elements with pertinent correction.

A distinctive feature of all of the vein samples is the enrichment of SiO_2 .

The Al_2O_3 contents are variable, depending on the amounts of country rock inclusions, or of chlorite and epidote in the sample.

The ratio $\text{SiO}_2:\text{Al}_2\text{O}_3$ is also variable, reflecting the sporadic Al_2O_3 content. By comparison with data published by Audley-Charles (1965), these veins have a silica-alumina composition similar to cherts.

The most abundant iron mineral observed is pyrite. Small amounts of magnetite and hematite are present, and $\text{Fe}_2\text{O}_3:\text{FeO}$ ratios are variable. The $\text{Fe}_2\text{O}_3:\text{Al}_2\text{O}_3$ ratio approximates that obtained by Audley-Charles (1965) for cherts. The concentration ranges of Fe_2O_3 and FeO are rather erratic, being lower than in average crustal rocks, but similar to cherts (Audley-Charles, 1965).

The concentration ranges of Na, K, and Ca, is similarly erratic, and considerably lower than in average rocks. The ratios discussed and given in Table 14, Appendix 4 are: $\text{CaO}:\text{MgO}$, $\text{Na}_2\text{O} + \text{K}_2\text{O}:\text{CaO} + \text{MgO}$, $\text{Na}_2\text{O}:\text{CaO}$, $\text{Na}_2\text{O} + \text{K}_2\text{O}:\text{Al}$, $\text{K}_2\text{O}:\text{BaO}$, $\text{K}_2\text{O}:\text{Rb}$, $\text{CaO}:\text{Sr}$ and $\text{CaO}:\text{BaO}$. The variation of these ratios reflects the wide range of concentration, which in turn is dependent on the number of country rock mineral inclusions in the sample.

The value for water is the total for water of crystallization, water of constitution and adsorbed water. Carbon dioxide analyses represent elemental carbon and reduced

carbonates. In the veins, graphite and carbonates of calcium and copper are irregularly distributed.

The only trace elements in which all the vein rock samples are enriched compared with average rocks are Cr and Co, the former occurring as the chrome mica-fuchsite. However, in some veins, the following elements are also enriched: Cu (in veins from rhyolites and granites), Pb (in veins from sedimentary and basaltic-gabbroic rocks), V and Ba (in veins from sedimentary rocks) and S (in veins from basaltic-gabbroic rocks). The enrichment of Co is consistent with studies on cherts by Audley-Charles.

Average values for Ni, V, Zr, Zn, Sr, Rb, Li, P (in part), Mn (in part) are found to be lower than crustal-rock averages.

The elements whose concentration is about the same as in average crustal rocks are Ba, Zr, Pb, Ti, P, Mn, and Cu.

The Ni:Co ratio ranges from 0.35 to 3.33, with an average of 2.0. This average value is comparable to that of average crustal rocks. The Ni:Cr ratios, like those of cherts (Audley-Charles, 1965), do not vary greatly.

The concentration of Pb, Zn, Li, P and S are likewise variable, being dependent on mineral inclusions from the country rock.

VEIN ROCKS FROM VARIOUS TYPES OF CRUSTAL ROCKS

Tables 8 to 11 are lists of the chemical compositions of quartz vein rocks, grouped according to the types of country rock in which they occur. These compositions are compared with average values for crustal rocks (Table 12, Appendix 3), and the comparison is summarized in Table 13.

In the veins from the gabbro-basalt family (Table 8) and from the sedimentary rocks (Table 9), there are relatively larger amounts of Ca, Mg, Al, Sr, and CO_2 than in other veins from the more acid rocks. These families have been referred to as the "calcic" rocks by Davies (1963), and in these "calcic" rocks are located most of the productive mines and exploration shafts. Compared to their wall-rocks, these vein rocks have much higher SiO_2 values. The values for Alumina, total iron, Magnesia, Lime, Soda, and Potash are variable, depending on amounts of chlorite, clinozoisite, and epidote inclusions.

In comparison with the average composition of sedimentary rocks (Table 12, Appendix 3), the vein rocks from sedimentary rocks (Table 9) contain more SiO_2 . However they are similar to siliceous sedimentary rocks, as reported by Audley-Charles (1965). Total iron has values equivalent to average sandstones and average sedimentary rocks.

The veins from the Granite-Granodiorite-Quartz diorite family (Table 10), and those veins within the Rhyolite-Dacite family, (Table 11), contain a greater

Table 8: Veins from Gabbroic - Basaltic Rocks

<u>Major Elements</u>	<u>16-7-3(1)</u>	<u>16-7-7</u>	<u>16-7-18(1)</u>	<u>16-7-19(1)</u>
SiO ₂	98.45%	80.55	97.50%	97.25%
Al ₂ O ₃	0.36	6.30	0.59	0.19
Fe ₂ O ₃	0.12	2.76	0.67	0.61
FeO	0.44	0.40	0.28	0.48
MgO	0.02	0.74	0.04	0.05
CaO	0.13	4.60	0.40	0.20
Na ₂ O	0.03	0.24	0.03	0.02
K ₂ O	0.01	0.02	0.06	0.002
H ₂ O	0.11	0.58	0.10	0.09
CO ₂	0.06	3.44	0.116	0.64
TiO ₂	0.00	0.13	0.03	0.00
P ₂ O ₅	0.01	0.06	0.03	0.02
MnO	0.03	0.04	0.00	0.004

Table 8: Veins from Gabbroic - Basaltic Rocks

<u>Trace Elements</u>	<u>16-7-3(1)</u>	<u>16-7-7</u>	<u>16-7-8(1)</u>	<u>16-7-19(1)</u>
S	2060 PPM	1350 PPM	90 PPM	7600 PPM
Ni	12	17	10	8
Cu	950	34	26	2850
Co	4	22	0	28
Zn	900	33	1	43
Pb	32	68	16	28
Zr	0	160	110	60
Cr	192	188	236	238
V	10	58	8	6
Sr	0	80	7	0
Rb	0	0	0	0
Li	0	1	1	0
Ba	200	400	100	400
Totals	100.07	100.03	100.19	99.55

Total includes all elements with pertinent correction.

Table 8 (Cont.): Veins from Gabbroic - Basaltic Rocks

<u>Major Elements</u>	<u>16-7-31(1)</u>	<u>16-7-31(2)</u>	<u>16-7-34(1)</u>	<u>16-7-35(2)</u>
SiO ₂	97.60%	76.60%	86.80%	70.65%
Al ₂ O ₃	0.34	2.66	0.40	3.72
Fe ₂ O ₃	0.77	3.55	0.62	11.72
FeO	0.00	1.76	1.60	3.60
MgO	0.15	1.98	1.19	0.28
CaO	0.40	4.93	3.16	0.59
Na ₂ O	0.05	0.87	0.03	0.59
K ₂ O	n.d.	0.10	0.01	0.83
H ₂ O	0.16	0.90	0.00	0.32
CO ₂	0.35	4.17	4.71	0.86
TiO ₂	0.01	0.08	n.d.	0.74
P ₂ O ₅	0.03	0.07	0.09	0.18
MnO	0.01	0.05	0.03	

Table 8 (Cont.): Veins from Gabbroic - Basaltic Rocks

<u>Trace Elements</u>	<u>16-7-31(1)</u>	<u>16-7-31(2)</u>	<u>16-7-34(1)</u>	<u>16-7-35(2)</u>
S	0 PPM	29600 PPM	2030 PPM	110500 PPM
Ni	6	39	14	36
Cu	7	35	21	72
Co	0	17	9	98
Zn	1	46	30	14
Pb	0	30	0	0
Zr	1560	0	0	0
Cr	326	255	98	218
V	27	0	0	94
Sr	0	27	53	10
Rb	0	0	0	30
Li	1	3	0	0
Ba	500	200	0	400
Totals	100.10	99.22	98.76	99.72

Total includes all elements with pertinent correction.

Table 8(Cont.): Veins from Gabbroic - Basaltic Rocks

<u>Major Elements</u>	<u>16-7-36(2)</u>	<u>16-8-46</u>	<u>16-8-346</u>	<u>16-8-210</u>
SiO ₂	96.10%	97.70%	90.45%	95.30%
Al ₂ O ₃	1.02	0.26	1.02	1.03
Fe ₂ O ₃	0.78	0.97	0.44	0.51
FeO	0.25	0.02	1.28	0.54
MgO	0.09	0.05	0.83	0.33
CaO	0.14	0.22	3.02	0.67
Na ₂ O	0.54	0.11	0.02	0.05
K ₂ O	n.d.	0.00	0.002	0.11
H ₂ O	0.35	0.08	0.53	0.57
CO ₂	0.65	0.44	2.38	0.79
TiO ₂	n.d.	0.00	0.00	0.05
P ₂ O ₅	0.05	0.04	0.06	0.01
MnO	0.01	0.002	n.d.	0.004

Table 8 (Cont): Veins from Gabbroic - Basaltic Rocks

<u>Trace Elements</u>	<u>16-7-36(2)</u>	<u>16-8-46</u>	<u>16-8-346</u>	<u>16-8-210</u>
S	390 PPM	194 PPM	80 PPM	2050 PPM
Ni	11	6	17	29
Cu	23	1400	23	387
Co	8	9	8	9
Zn	39	35	19	12
Pb	12	22	21	303
Zr	160	160	100	0
Cr	304	232	240	225
V	6	14	38	0
Sr	7	0	0	57
Rb	0	0	0	9
Li	0	2	4	2
Ba	400	232	500	230
Totals	100.08	100.18	100.13	100.19

Total includes all elements with pertinent corrections.

Table 9: Veins from Sedimentary Rocks

<u>Major Elements</u>	<u>16-7-14(2)</u>	<u>16-7-22(2)</u>	<u>16-8-210</u>
SiO ₂	92.60%	93.55%	95.30%
Al ₂ O ₃	2.63	1.28	1.03
Fe ₂ O ₃	0.91	0.87	0.51
FeO	0.44	0.52	0.54
MgO	0.19	0.26	0.33
CaO	1.02	2.02	0.67
Na ₂ O	0.63	0.15	0.05
K ₂ O	0.34	0.002	0.11
CO ₂	0.59	0.17	0.79
H ₂ O	0.36	0.17	0.57
TiO ₂	0.10	0.12	0.05
P ₂ O ₅	0.03	0.68	0.005
MnO	0.008	n.d.	0.004

Table 9: Veins from Sedimentary Rocks

<u>Trace Elements</u>	<u>16-7-14(2)</u>	<u>16-7-22(2)</u>	<u>16-8-210</u>
S	1000 PPM	50 PPM	2050 PPM
Ni	12	17	29
Cu	39	7	387
Co	4	8	9
Zn	8	4	12
Pb	38	22	303
Zr	120	50	0
Cr	210	210	225
V	23	38	0
Sr	17	37	57
Rb	0	0	9
Li	3	1	2
Ba	200	0	230
Totals	99.97	99.83	100.19

Total includes all elements with pertinent corrections.

Table 10: Veins from Granitic - Plutonic Rocks

<u>Major Elements</u>	<u>16-7-16(1)</u>	<u>16-7-16(2)</u>	<u>16-7-26(2)</u>	<u>16-7-27(2)</u>
SiO ₂	98.40%	98.60%	98.95%	97.30%
Al ₂ O ₃	0.32	0.21	0.06	0.21
Fe ₂ O ₃	0.19	0.19	0.32	0.80
FeO	0.36	0.32	0.40	0.72
MgO	0.02	0.11	0.003	0.01
CaO	0.10	0.24	0.08	0.21
Na ₂ O	0.022	0.017	0.008	0.02
K ₂ O	0.11	0.046	0.00	n.d.
H ₂ O	0.11	0.13	0.04	0.08
CO ₂	0.22	0.19	0.03	0.27
TiO ₂	0.02	0.01	0.00	n.d.
P ₂ O ₅	0.03	0.03	0.02	0.04
MnO	0.001	0.01	0.002	0.01

Table 10: Veins from Granitic - Plutonic Rocks

<u>Trace Elements</u>	<u>16-7-16(1)</u>	<u>16-7-16(2)</u>	<u>16-7-26(2)</u>	<u>16-7-27(2)</u>
S	90 PPM	50 PPM	60 PPM	3100 PPM
Ni	3	10	2	5
Cu	27	4	223	3300
Co	10	3	22	0
Zn	17	4	11	2
Pb	0	0	18	0
Zr	0	110	15	600
Cr	192	132	122	256
V	30	8	16	19
Sr	0	7	0	0
Rb	0	0	0	0
Li	0	0	0	2
Ba	200	300	100	800
Totals	99.96	100.16	99.97	100.31

Total includes all elements with pertinent corrections.

Table 10: Veins From Granitic - Plutonic Rocks

<u>Major Elements</u>	<u>16-8-41</u>	<u>16-8-44</u>	<u>Elements</u>	<u>16-8-41</u>	<u>16-8-44</u>
SiO ₂	99.30%	97.80%	S	100 PPM	1890 PPM
Al ₂ O ₃	0.06	0.25	Ni	8	17
Fe ₂ O ₃	0.17	0.47	Cu	23	1450
FeO	0.04	0.20	Co	9	10
MgO	0.01	0.09	Zn	13	6
CaO	0.13	0.18	Pb	0	16
Na ₂ O	0.003	0.03	Zr	220	110
K ₂ O	0.004	0.00	Cr	140	160
H ₂ O	0.01	0.12	V	3	6
CO ₂	0.03	0.25	Sr	0	0
TiO ₂	0.00	0.004	Rb	0	0
P ₂ O ₅	0.05	0.04	Li	1	2
MnO	0.00	0.00	Ba	400	600
			Totals	99.89	100.77

Total includes all elements with pertinent corrections.

Table 11: Veins from Rhyo-Dacitic Rocks

<u>Major Elements</u>	<u>16-7-23(2)</u>	<u>16-7-24(2)</u>	<u>16-7-25(1)</u>	<u>16-7-30(1)</u>
SiO ₂	98.80%	99.10%	92.45%	96.05%
Al ₂ O ₃	2.26	0.08	1.01	0.35
Fe ₂ O ₃	0.99	0.57	2.59	0.84
FeO	0.48	0.12	0.56	1.16
MgO	0.21	0.004	0.02	0.09
CaO	0.48	0.11	0.20	0.10
Na ₂ O	0.23	0.007	0.02	0.02
K ₂ O	0.45	n.d.	0.29	0.00
H ₂ O	0.59	0.00	0.19	0.15
CO ₂	0.37	0.04	0.59	0.51
TiO ₂	0.04	0.00	0.00	0.02
P ₂ O ₅	0.05	0.02	0.03	0.06
MnO	n.d.	0.005	0.003	0.005

Table 11: Veins from Rhyo-Dacitic Rocks

<u>Trace Elements</u>	<u>16-7-23(2)</u>	<u>16-7-24(2)</u>	<u>16-7-25(1)</u>	<u>16-7-30(1)</u>
S	550 PPM	0 PPM	17700 PPM	5900 PPM
Ni	5	4	10	5
Cu	46	7	240	4100
Co	5	0	152	0
Zn	9	0	1	48
Pb	17	0	18	18
Zr	140	530	510	150
Cr	167	217	288	170
V	20	0	30	8
Sr	23	10	7	0
Rb	0	0	0	0
Li	2	0	1	0
Ba	300	0	300	700
Totals	100.06	100.14	99.01	100.18

Total includes all elements with pertinent corrections.

Table 11: Veins from Rhyo-Dacitic Rocks

<u>Major Elements</u>	<u>16-8-42</u>	<u>16-8-43</u>	<u>16-8-45(1)</u>	<u>16-8-45(2)</u>
SiO ₂	91.90%	72.10%	98.55%	98.70%
Al ₂ O ₃	1.62	1.04	0.00	0.03
Fe ₂ O ₃	0.47	2.05	0.76	0.39
FeO	0.48	0.76	0.12	0.24
MgO	0.32	3.94	0.01	0.01
CaO	2.01	8.21	0.16	0.15
Na ₂ O	0.39	0.13		0.01
K ₂ O	0.20	0.06	0.00	0.00
H ₂ O	0.25	0.25	0.00	0.04
CO ₂	1.98	11.37	0.41	0.36
TiO ₂	0.004	0.002	0.000	0.000
P ₂ O ₅	0.05	0.11	0.04	0.05
MnO	0.02	0.14	0.00	0.00

Table 11: Veins from Rhyo-Dacitic Rocks

<u>Trace Elements</u>	<u>16-8-42</u>	<u>16-8-43</u>	<u>16-8-45(1)</u>	<u>16-8-45(2)</u>
S	1790 PPM	190 PPM	4240 PPM	2930 PPM
Ni	19	30	24	21
Cu	1245	15	14	12
Co	14	13	11	9
Zn	9	21	6	5
Pb	21	33	14	19
Zr	0	0	0	0
Cr	223	140	91	118
V	12	12	0	0
Sr	37	62	0	0
Rb	1	0	0	0
Li	2	3	4	1
Ba	500	300	400	300
Totals	100.01	100.24	100.08	100.02

Total includes all elements with pertinent corrections.

Table 13: Comparison of Trace Element Concentration in Veins to that of Crustal Rocks

	ENRICHED (in veins)	IMPOVERISHED (in veins)	ABOUT SAME (in veins & in crust)
SEDIMENTARY ROCKS:			
Shales:	Pb, Cr	Ti, Zr, Zn, S, Ni, V, P, Mn, Cu, Co, Sr, Rb, Li, Ba	
Sandstones:	P, Pb, Sr, S, Ni, Cu, Co, Cr, Li, Ba	Rb, Zn, Zr	Mn, V, Ti
GABBRO/BASALT:	Pb, S, Cr	Cu, Co, Zn, Ni, Sr, Rb, Li, Mn, Ti, P, V, Zr	Ba
GRANITES:	Co, Cr, Cu	Zn, Zr, S, Ni, Sr, Rb, Li, Mn, Ti, P, V, Pb, Ba	
RHYOLITES:	Cr, Cu,	Zn, Ni, Sr, Rb, Li, Ba, V	

abundance of Potassium than those veins from gabbroic-basaltic and sedimentary rocks. In comparison to granite, granodiorite and quartz diorite (Table 12, Appendix 3), SiO_2 contents are higher, exceeding 97% in all vein-rock samples. The values for oxides of Al, Fe^{3+} , Fe^{2+} , Mg, Ca, Na and K are lower in the vein rocks than those acid plutonic and crustal rocks cited.

The analyses of vein rocks from extrusive acidic rocks (Table 11) show irregular variations, but are generally similar to veins from granitic terrains. A comparison of these analyses with the analyses of "average low Ca granite" (Table 12a, Appendix 3), and "average granite" (Table 12b, Appendix 3) reveals the following: SiO_2 contents are higher in the vein rocks, while the values for the oxides of Al, Fe^{3+} , Fe^{2+} , Mg, Ca, Na, and K are lower in the veins. The distribution of the minor elements in veins from acid extrusive rocks is similar to that in veins from the acid intrusive rocks.

THE ALTERATION ZONES AND COUNTRY ROCKS

The alteration zones are described in Chapter III. The material in them represents various degrees of metamorphism of the country rocks. The distribution and variable amount of metasomatism^{is} related to the development of the vein.

Detailed sampling across shear zones was conducted in the Eldorado (16-8-100-116) and Packsack (16-8-205-209)

mines. At the Eldorado mine, the country rock is a quartz diorite (Rice Lake Batholith). The main shear zone strikes in the direction of 320° azimuth, and sampling was done at 10-foot intervals from the shear, in a NE-SW profile at right angles to the shear. Analytical data is given in table 15a (Appendix 4). At the Packsack mine, the country rock is an intermediate to acid volcanic rock with numerous cross-cutting quartz-feldspar-porphyry dikes. The major shear strikes at an azimuth of 140° , and sampling was done at 0.5', 2', 3' and 5' away from the center of the shear, along a NE-SW line at right angles to it. The analytical data is given in Table 15b (Appendix 4). Ratios calculated across the shear are given in Table 15c (Appendix 4). The behaviour of elements with distance towards the vein derived from the analyses and trend diagrams in Figure 10-19 is used to classify the elements into groups as summarized in Table 16.

The elements showing strong trends decreasing towards the vein on the east side of the Eldorado vein are: Ca (except 40'E), S (except 40'E), and Cr. There are no strong trends showing an increase towards the veins sampled probably due to inadequate sampling techniques.

From the east side of the Eldorado vein, those elements showing weak trends of a decrease towards the vein (except 40'E) are Si, Al, Total Fe, Sr, and Zr. Only Na_2O shows a weak trend decreasing towards the vein on the west side of the Eldorado vein. Those elements with a weak trend that

Figure 10a: Trends of Silica and Alumina (in wt.%) - Eldorado Mine

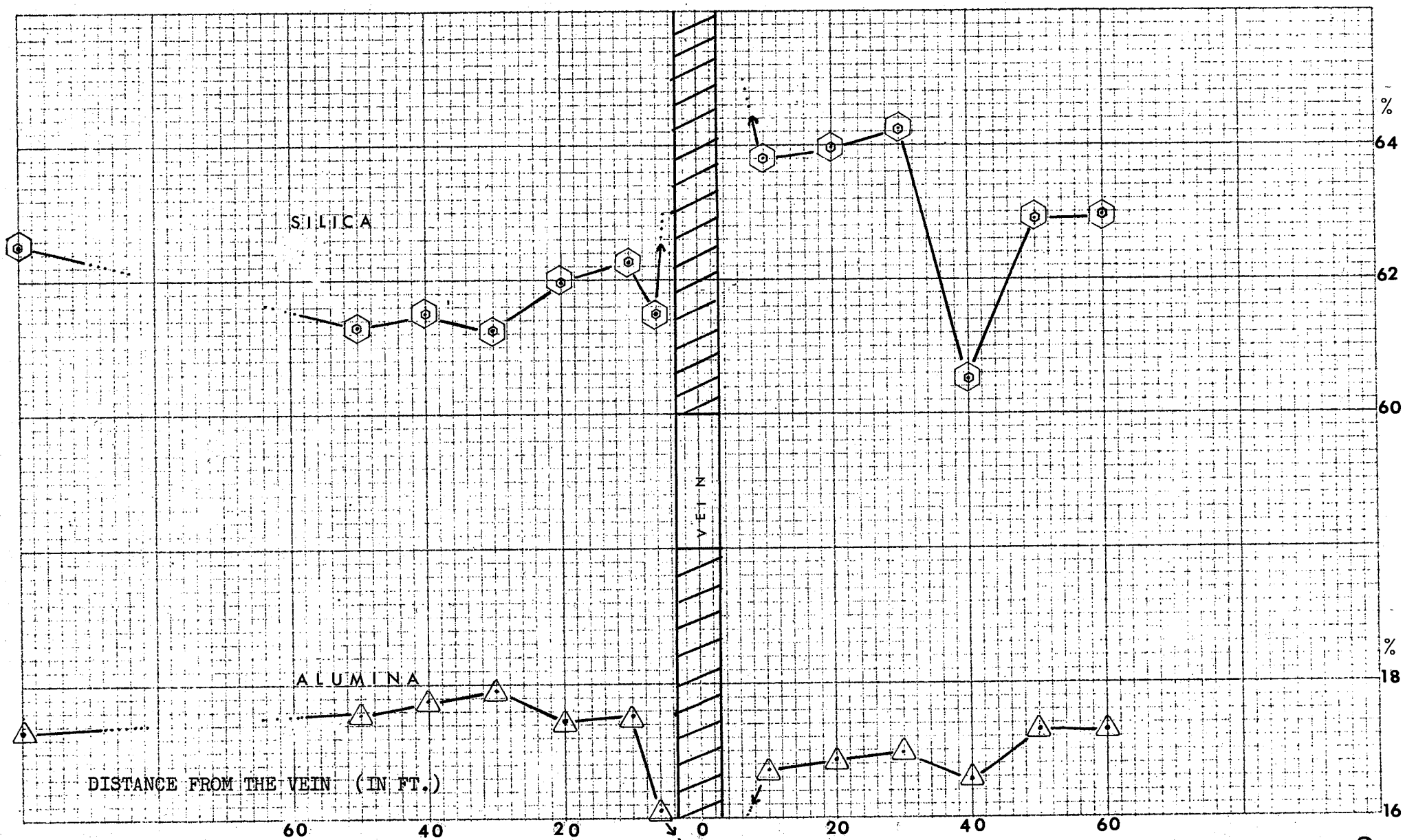


Figure 10b: Trends of Silica and Alumina (in wt.%) - Packsack Mine

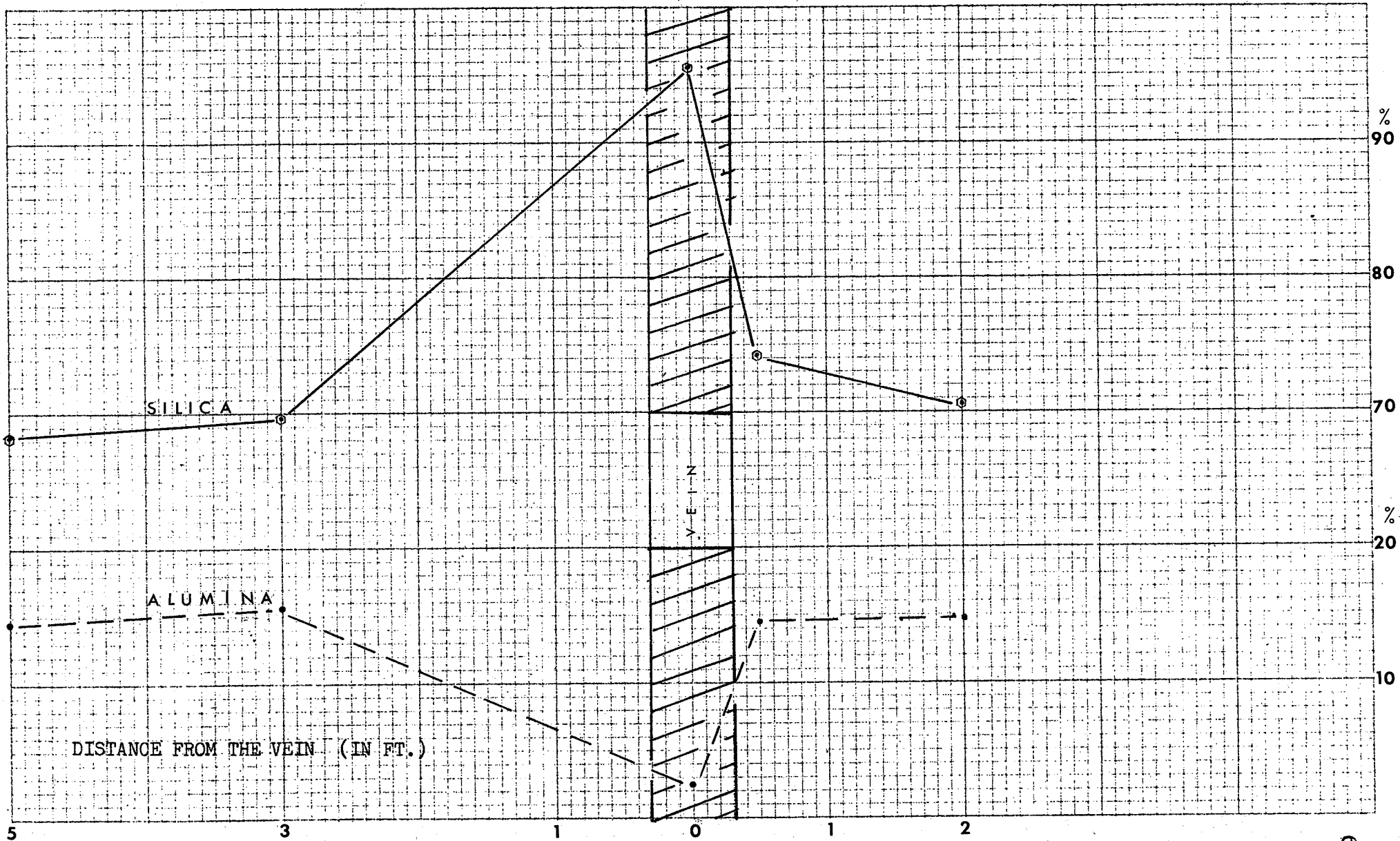


Figure 11a: Trends in Ferric, Ferrous and Total Iron (in wt.%) - Eldorado Mine

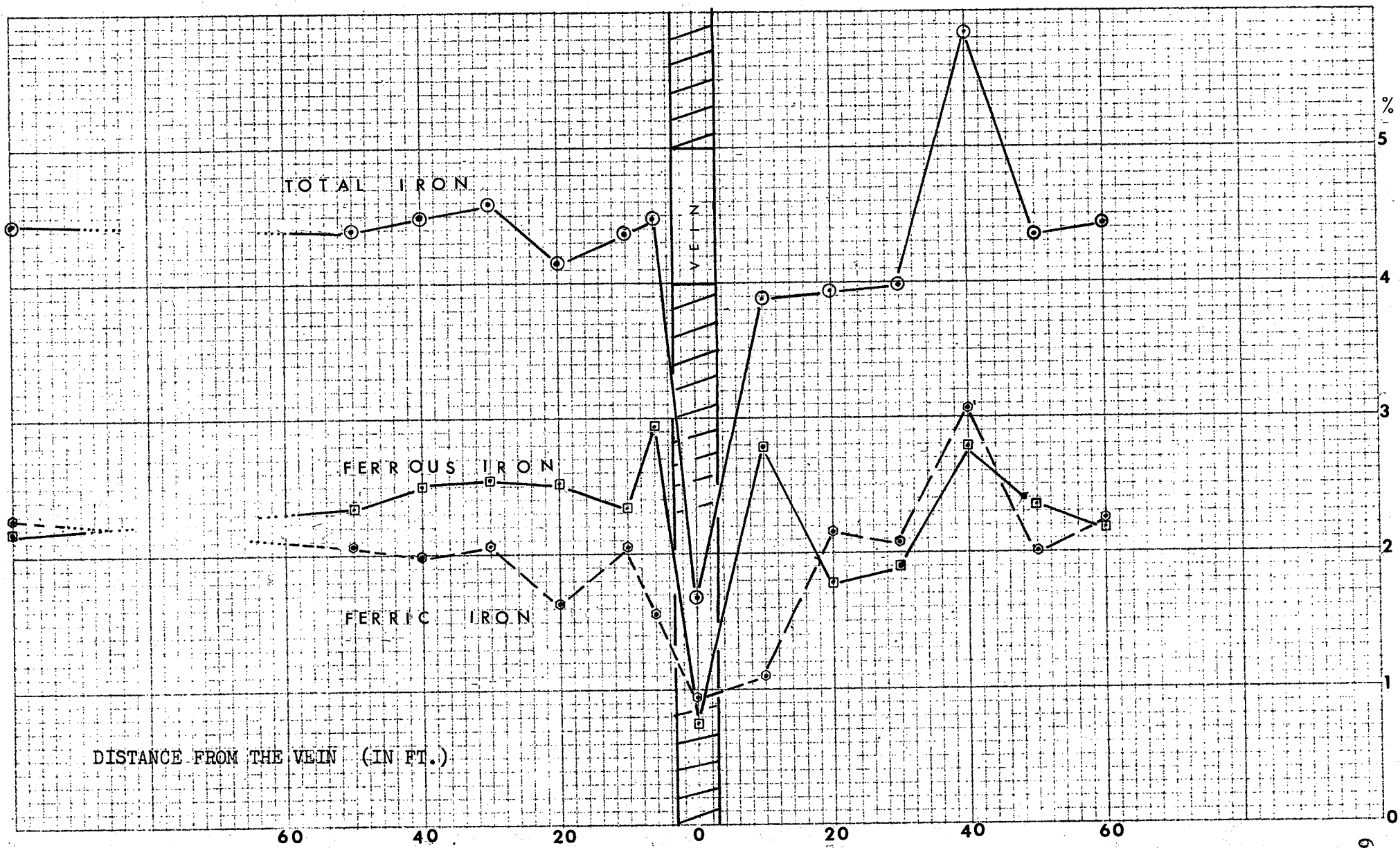


Figure 11b: Trends in Ferric, Ferrous and Total Iron (in wt.%) - Packsack Mine

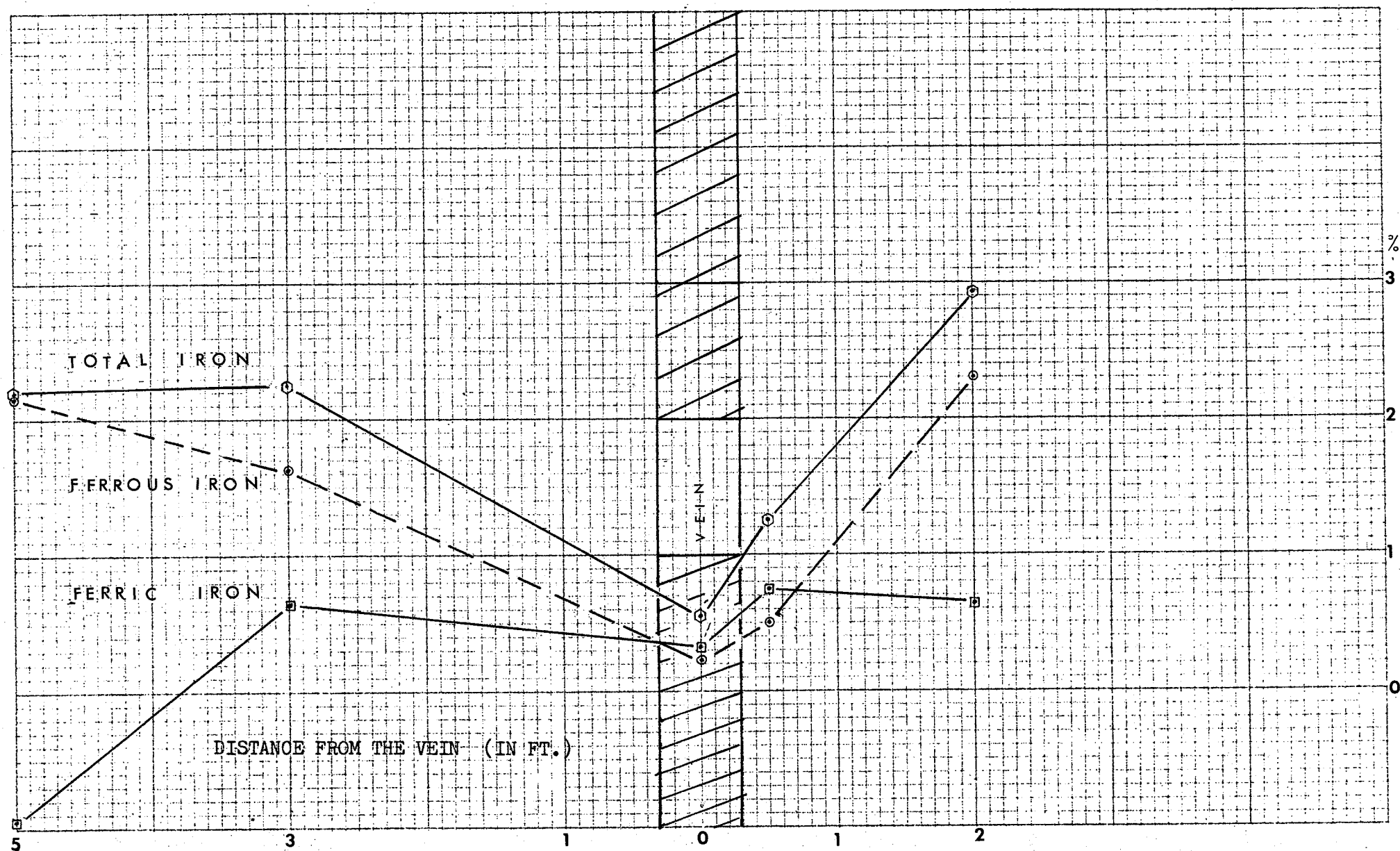


Figure 12a: Trends in Magnesia , Lime, Soda and Potash (in wt.%) - Eldorado Mine

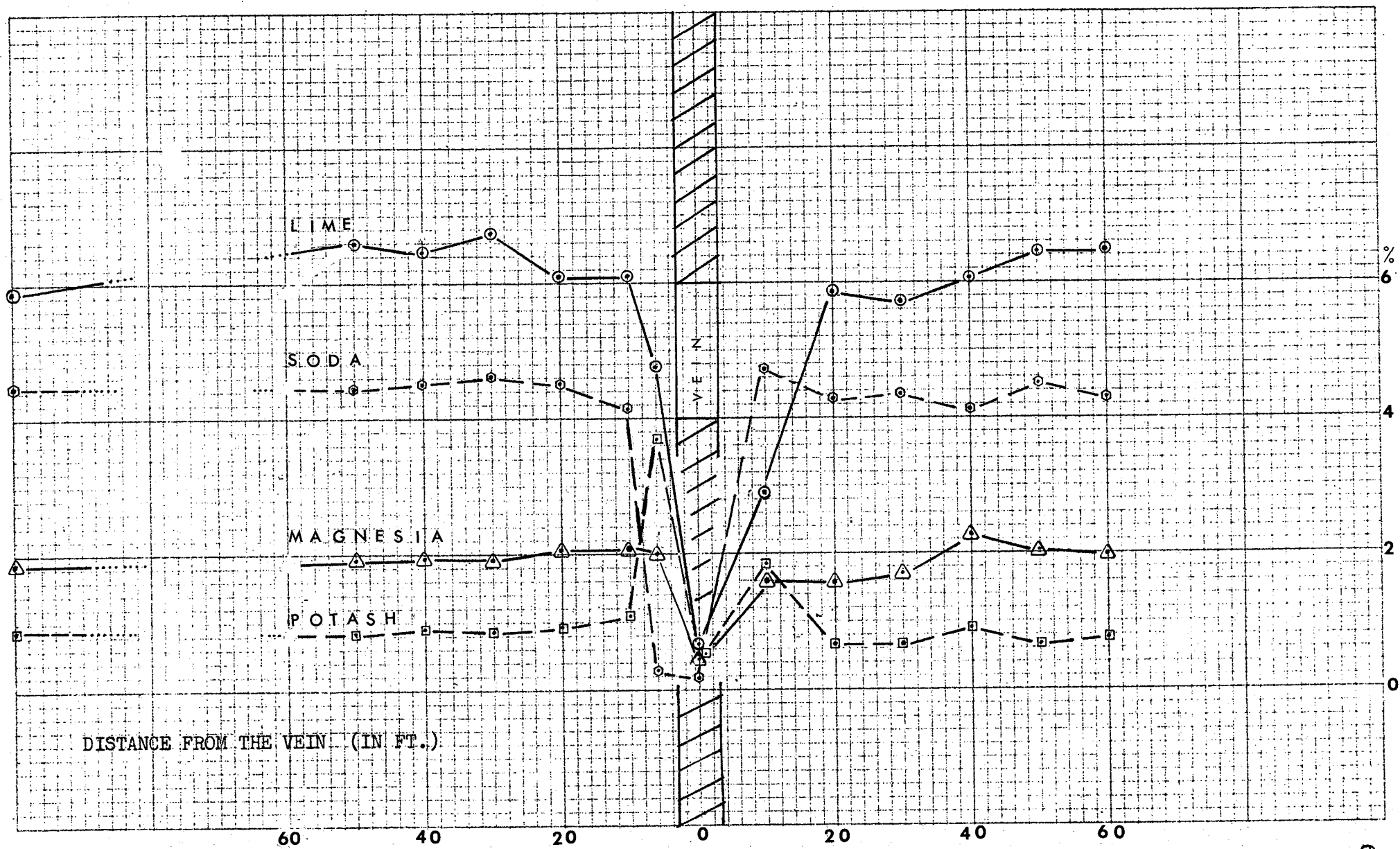


Figure 12b: Trends in Magnesia, Lime, Soda and Potash - Packsack Mine

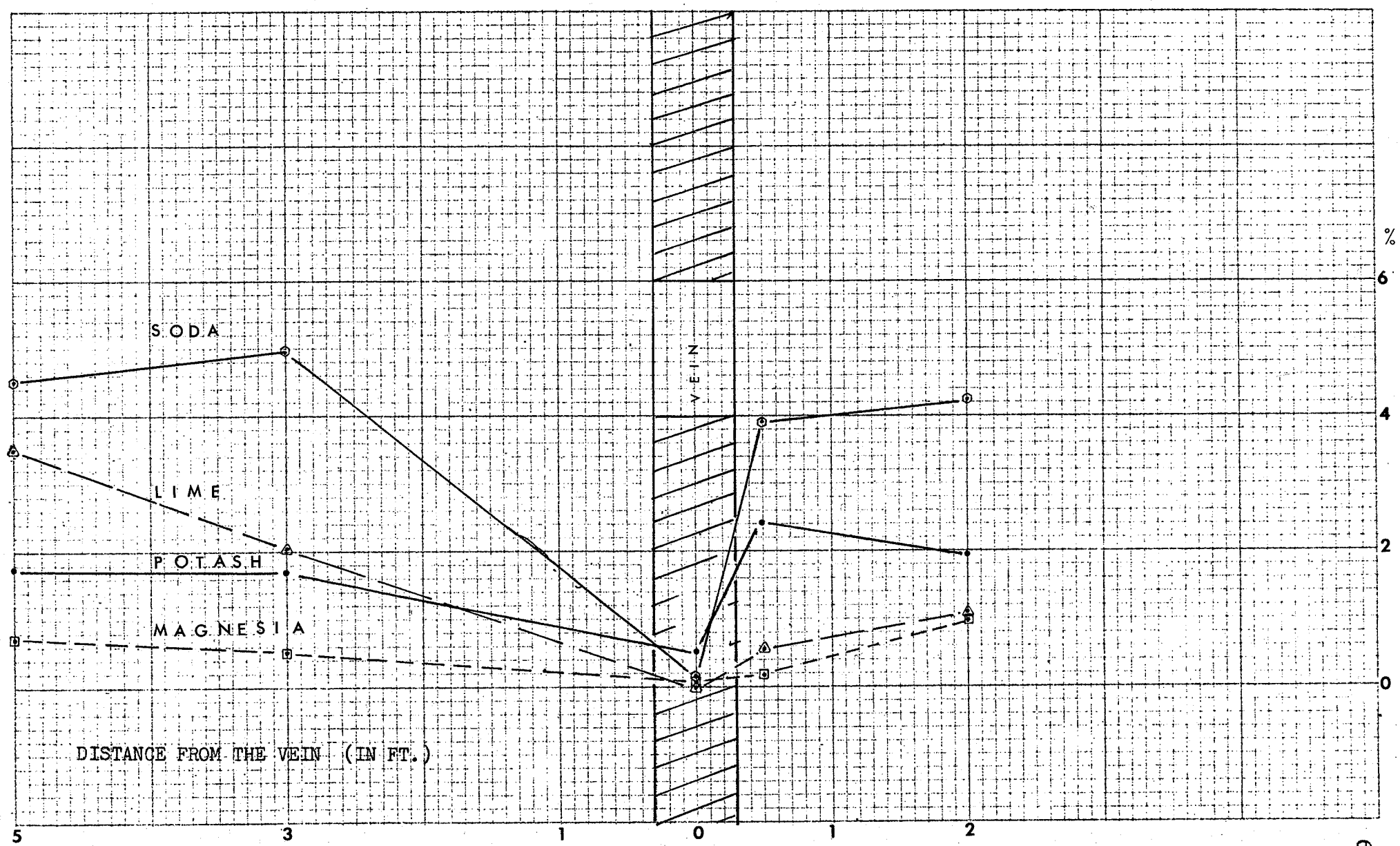


Figure 13a: Trends in Carbon Dioxide and Water (in wt.%) - Eldorado Mine

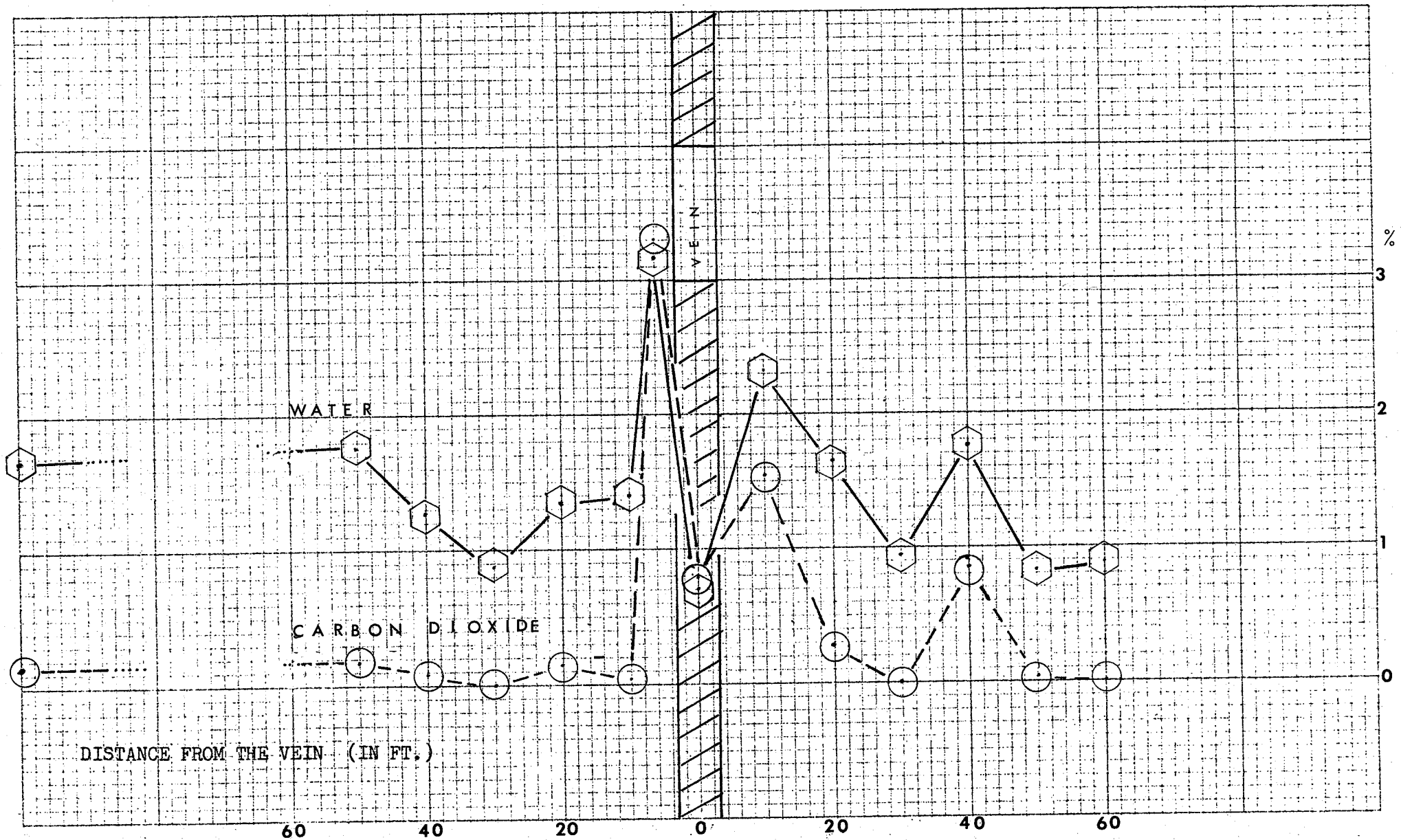


Figure 13b: Trends in Carbon Dioxide and Water (in wt.%) - Packsack Mine

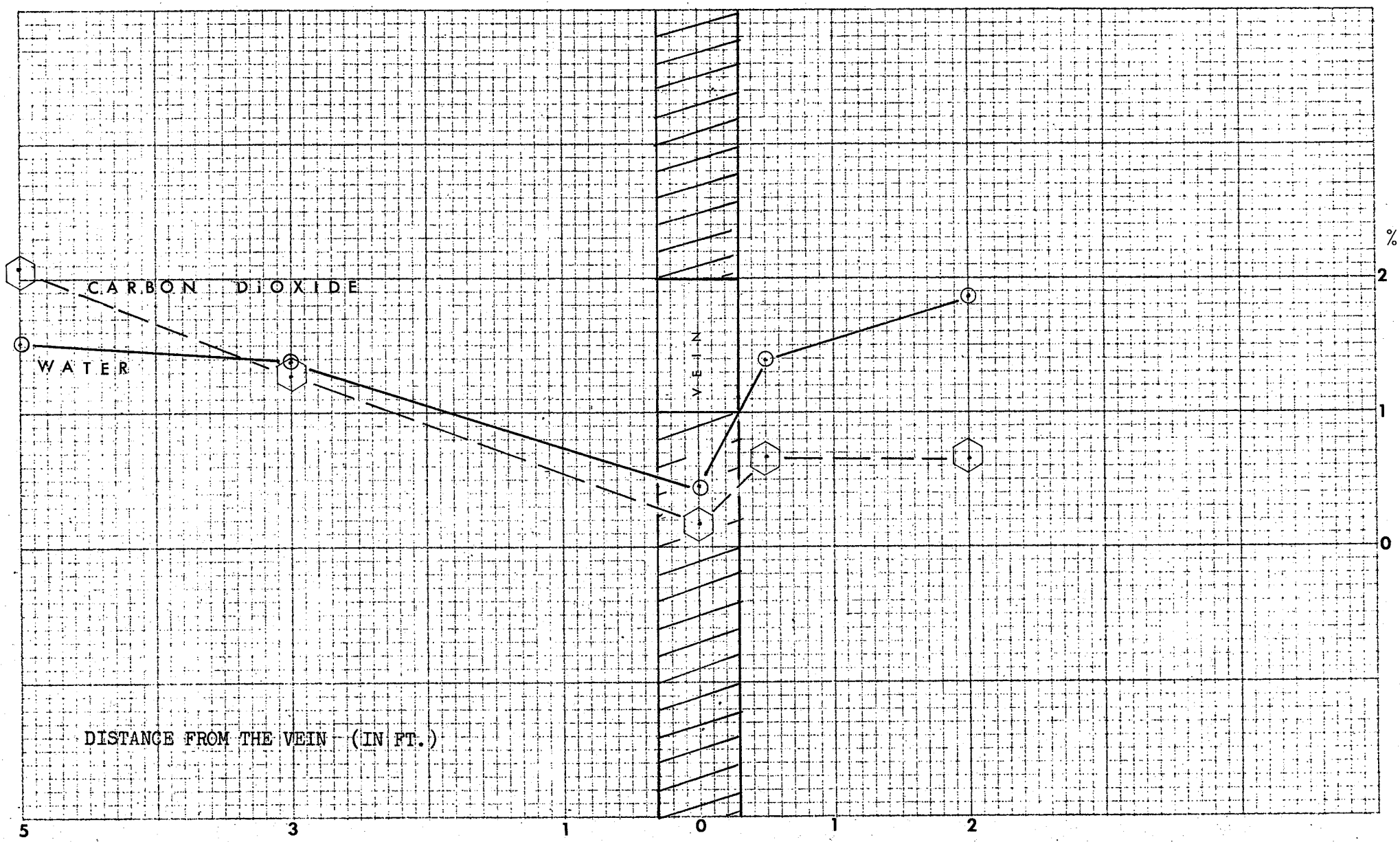


Figure 14a: Trends in Phosphorus and Titanium (in wt.%) - Eldorado Mine

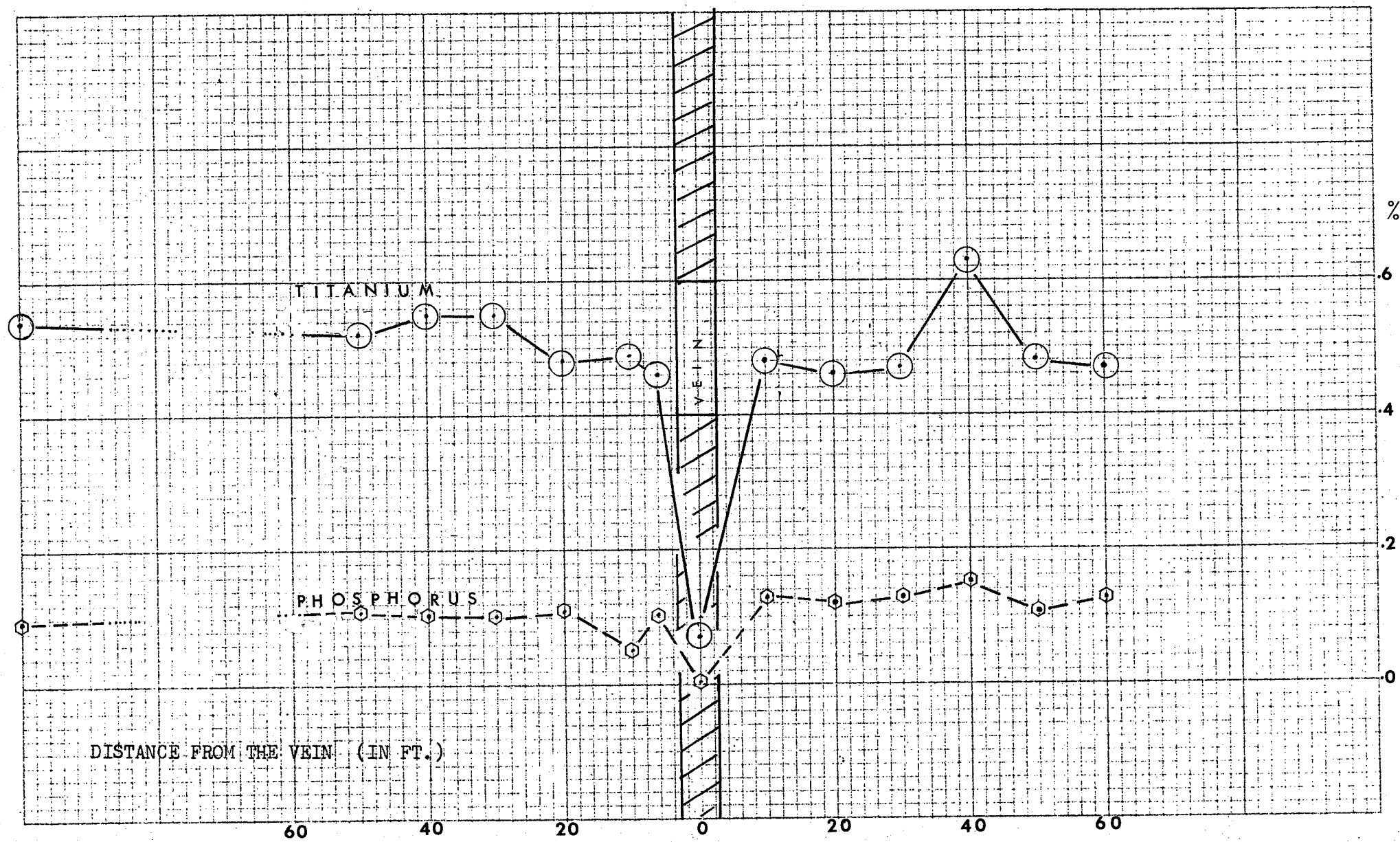


Figure 14b: Trends in Phosphorus and Titanium (in wt.%) - Packsack Mine

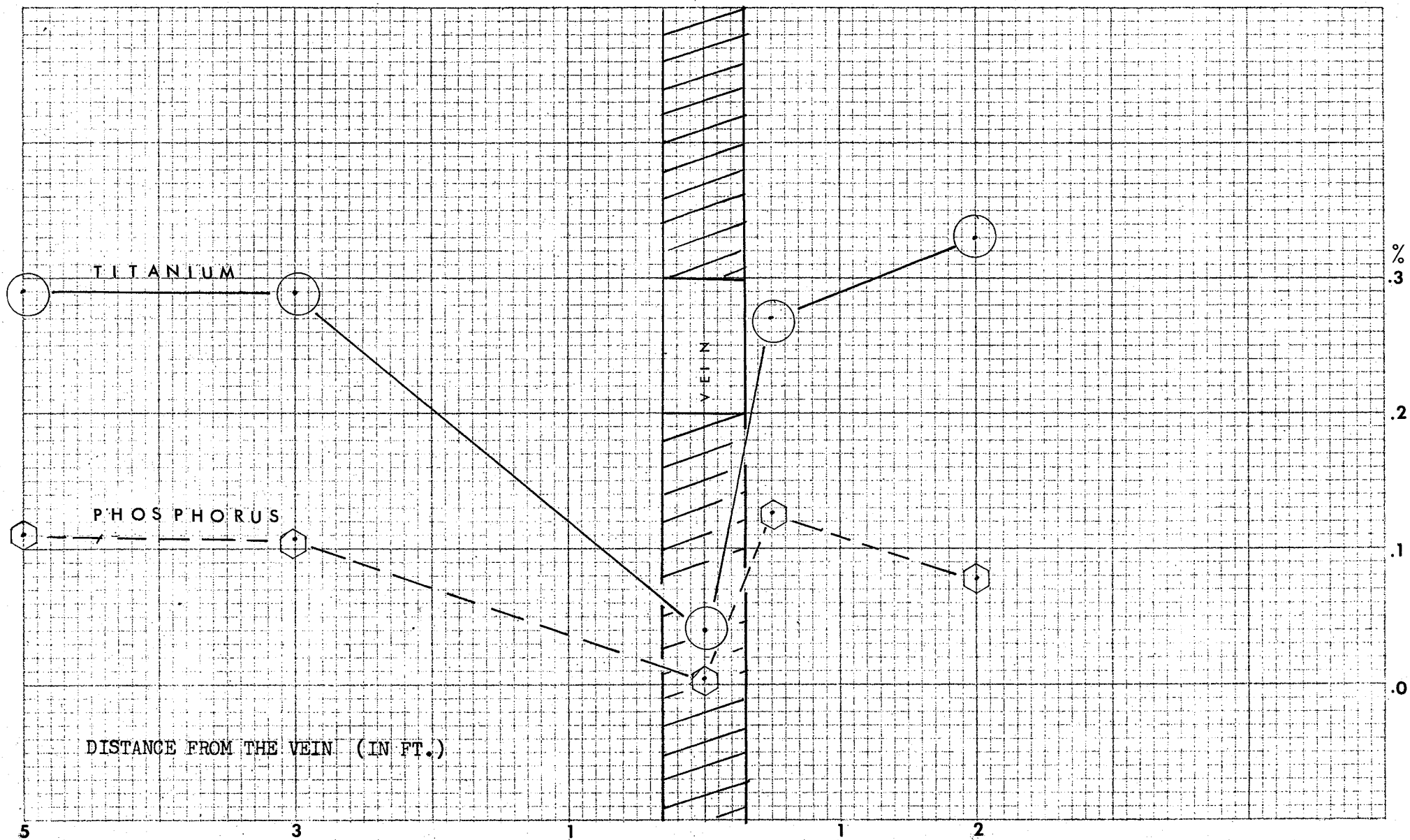


Figure 15a: Trends in Manganese and Barium (in wt.%) - Eldorado Mine

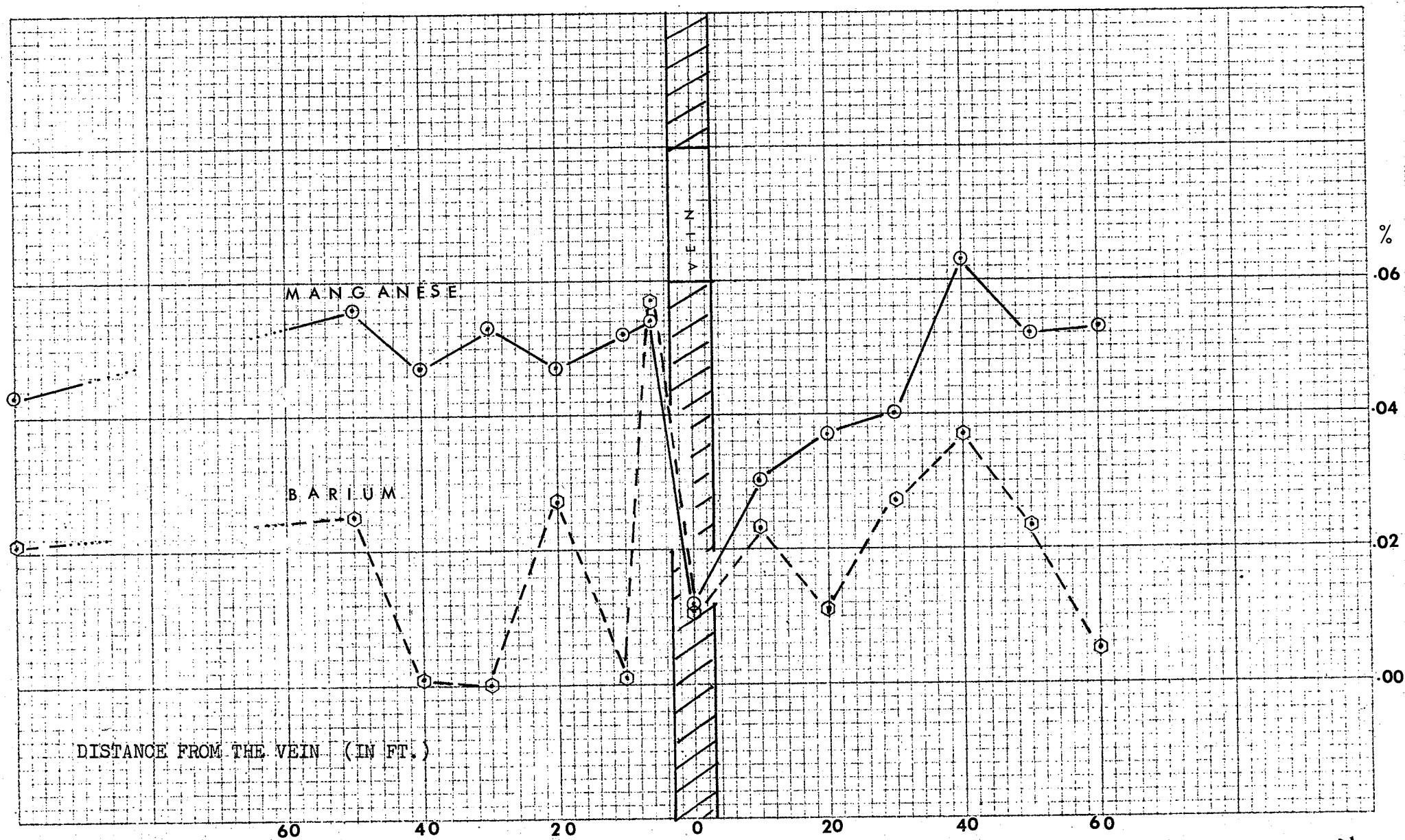


Figure 15b: Trends in Manganese and Barium (in wt.%) - Packsack Mine

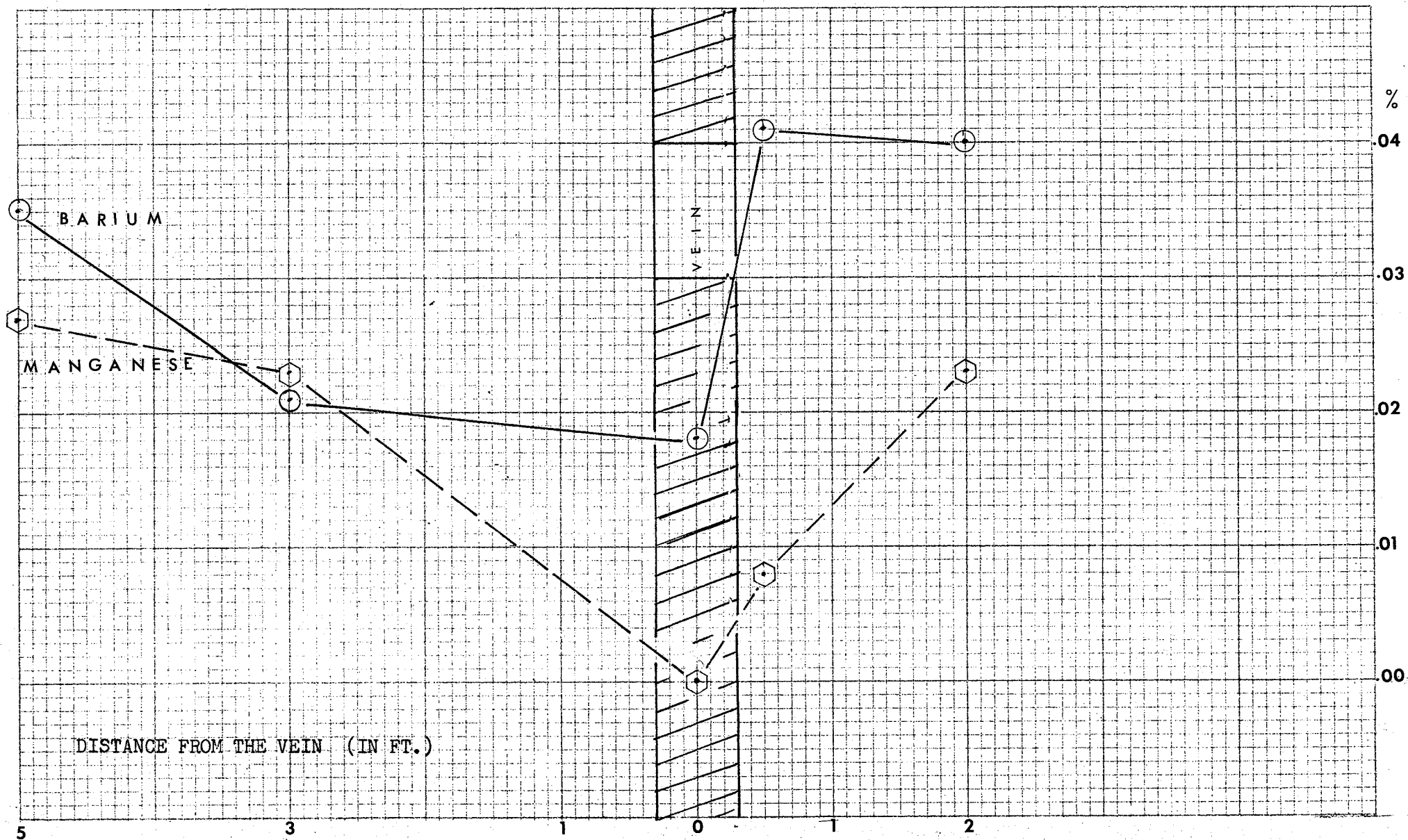


Figure 16a: Trends in Nickel, Lithium, Copper and Cobalt (in wt.%) - Eldorado Mine

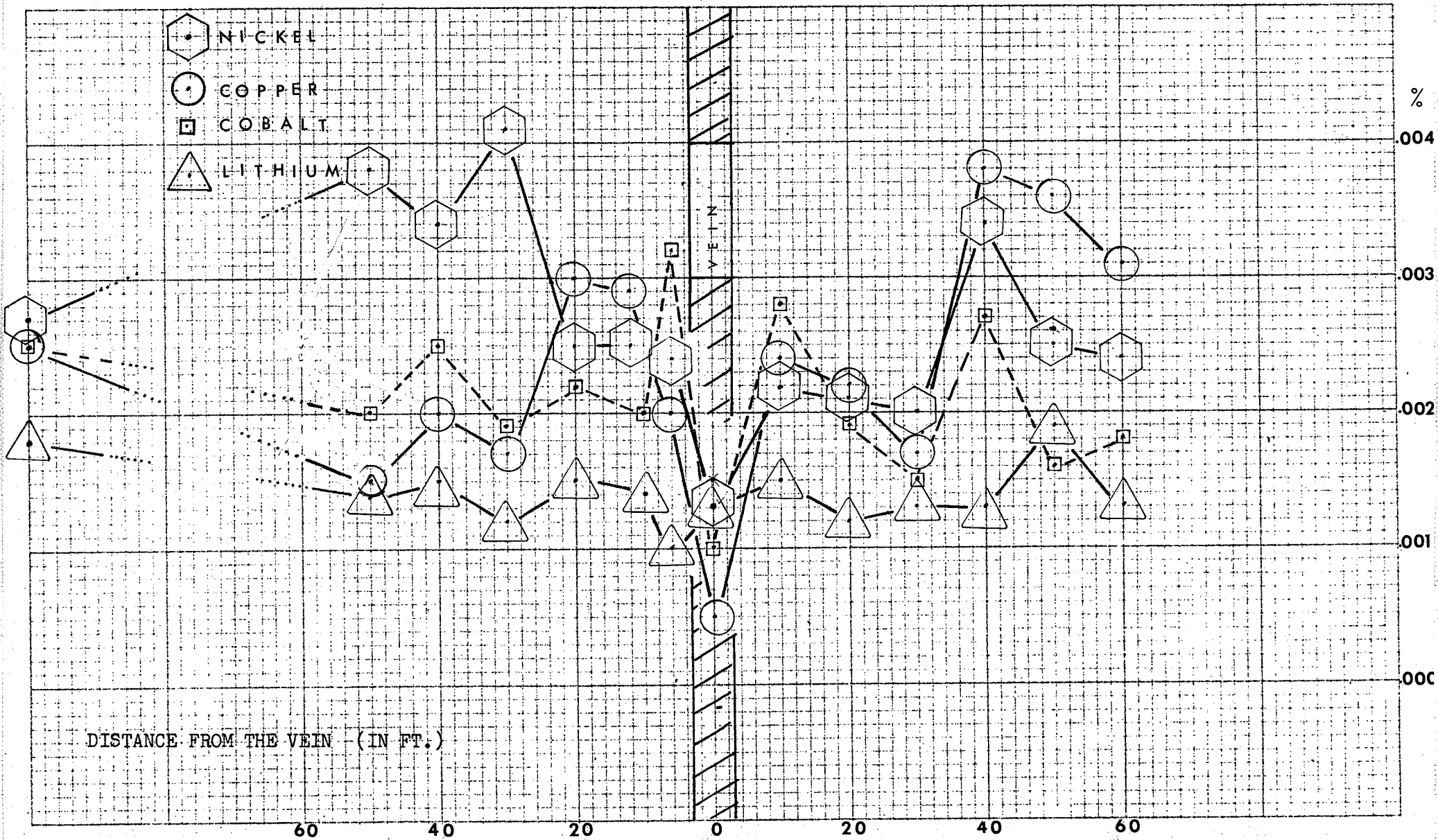


Figure 16b: Trends in Nickel, Lithium, Copper and Cobalt (in wt.%) - Packsack Mine

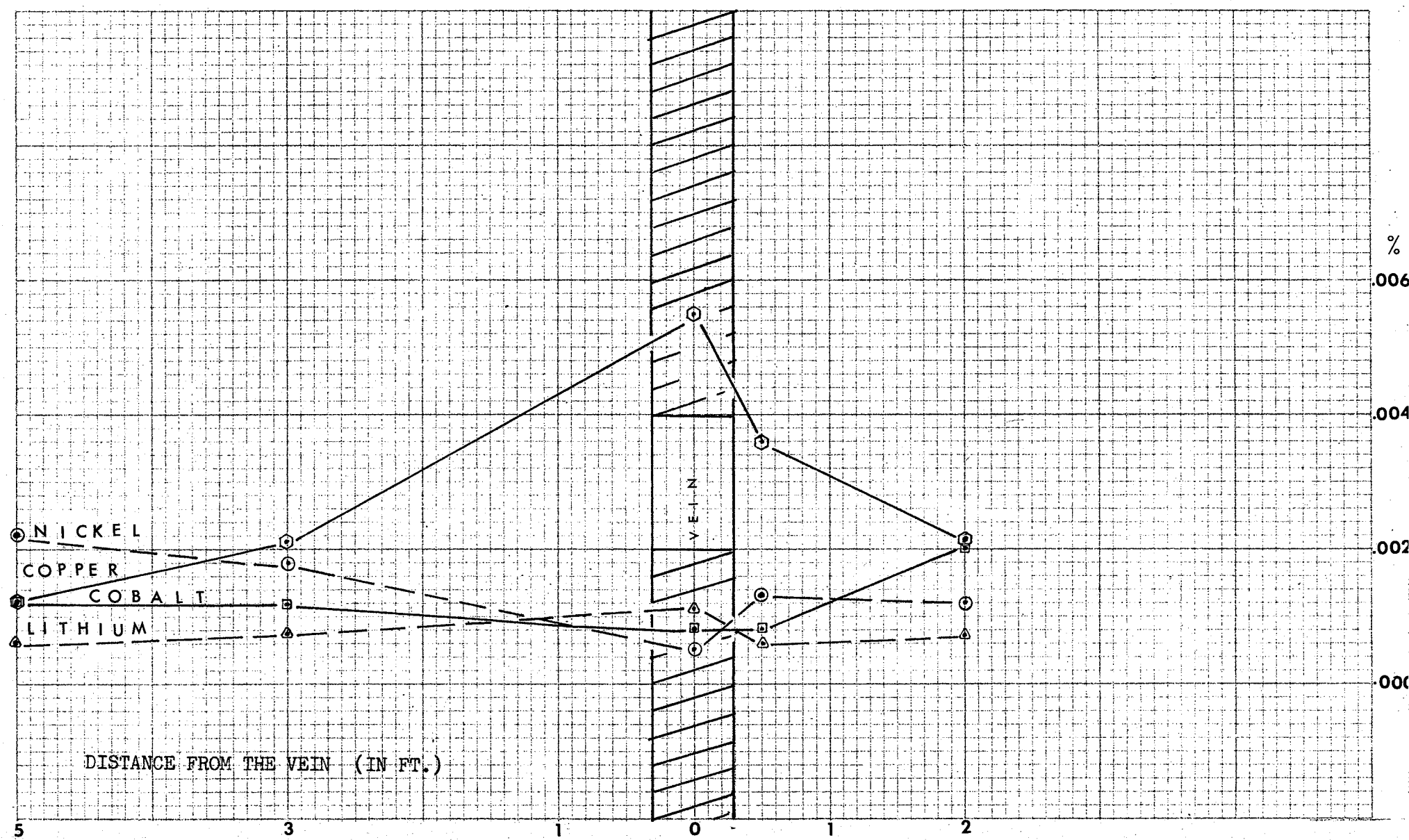


Figure 17a: Trends in Zinc, Sulfur and Lead (in wt.%) - Eldorado Mine

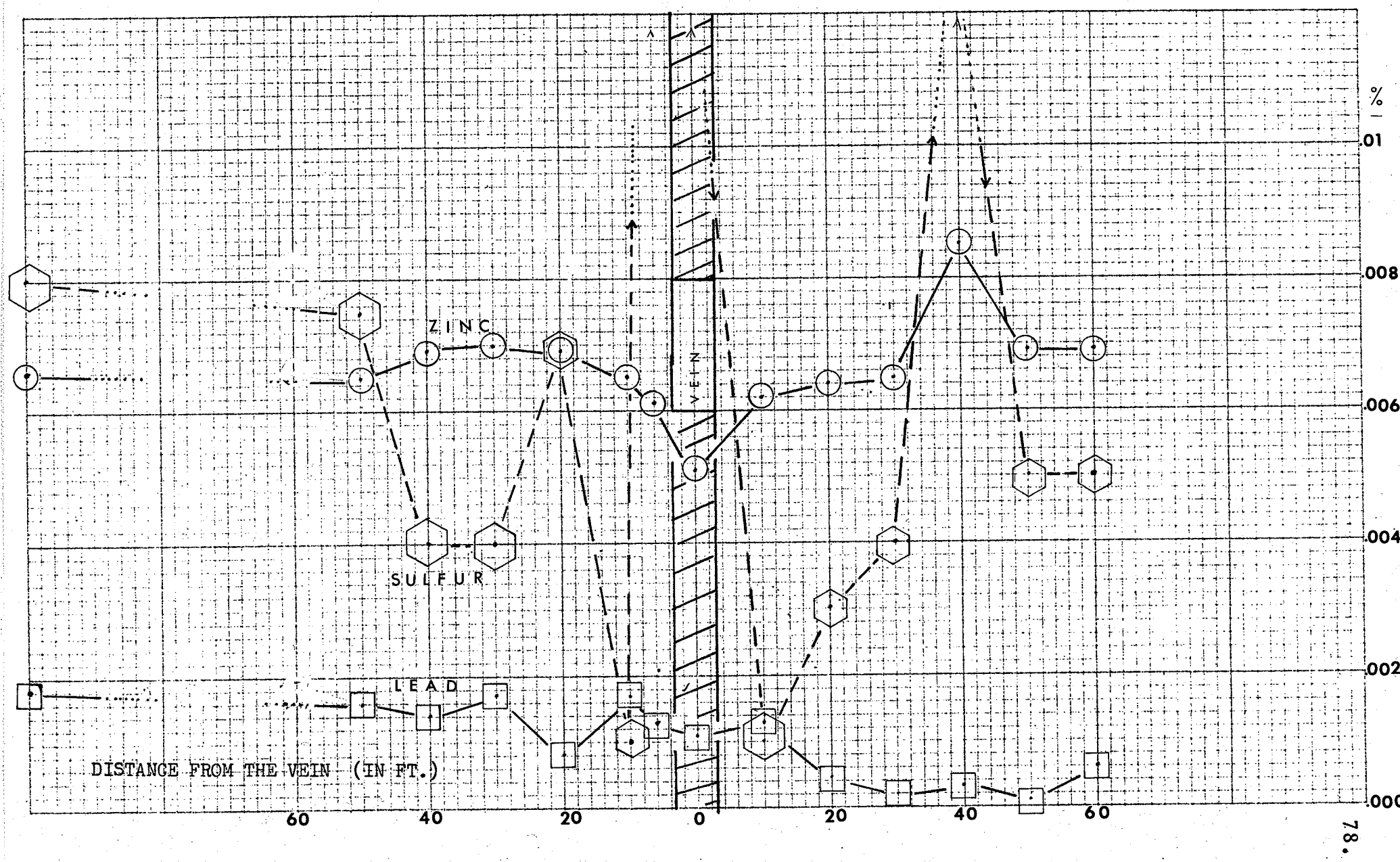


Figure 17b: Trends in zinc, Sulfur and Lead (in wt.%) - Packsack Mine

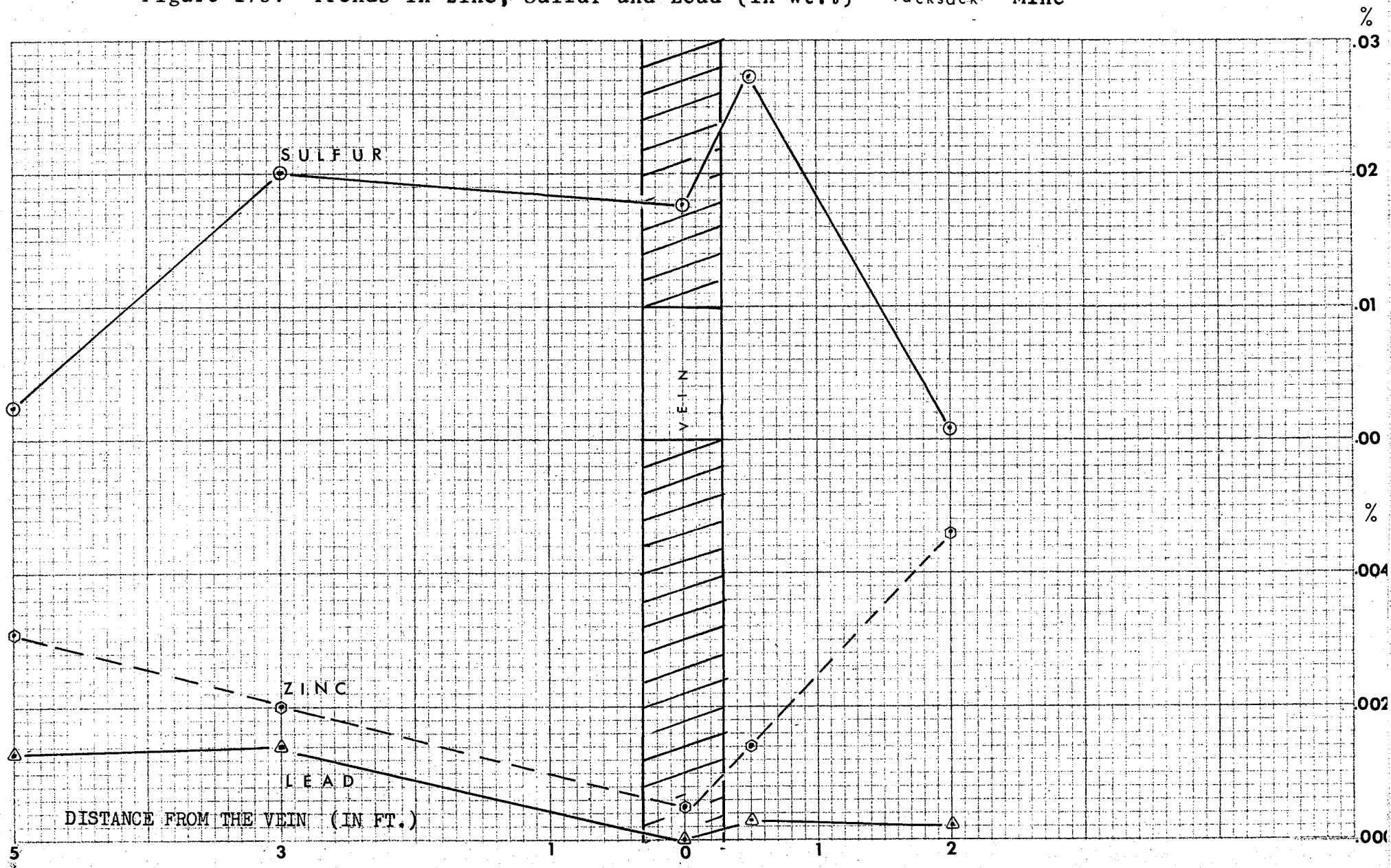


Figure 18a: Trends in Strontium, Chromium and Rubidium (in wt.%) - Eldorado Mine

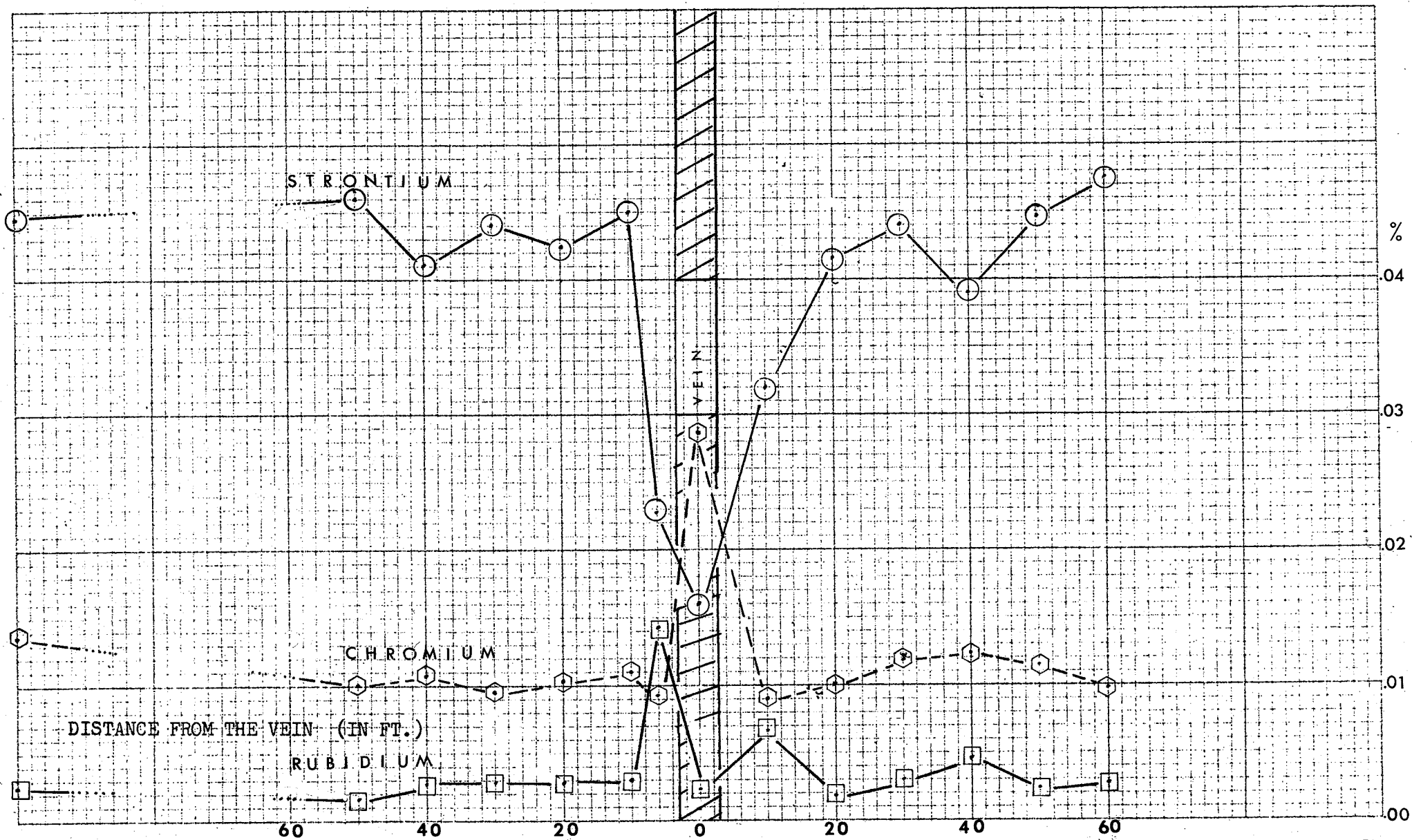


Figure 18b: Trends in Strontium, Chromium and Rubidium (in wt.%) - Packsack Mine

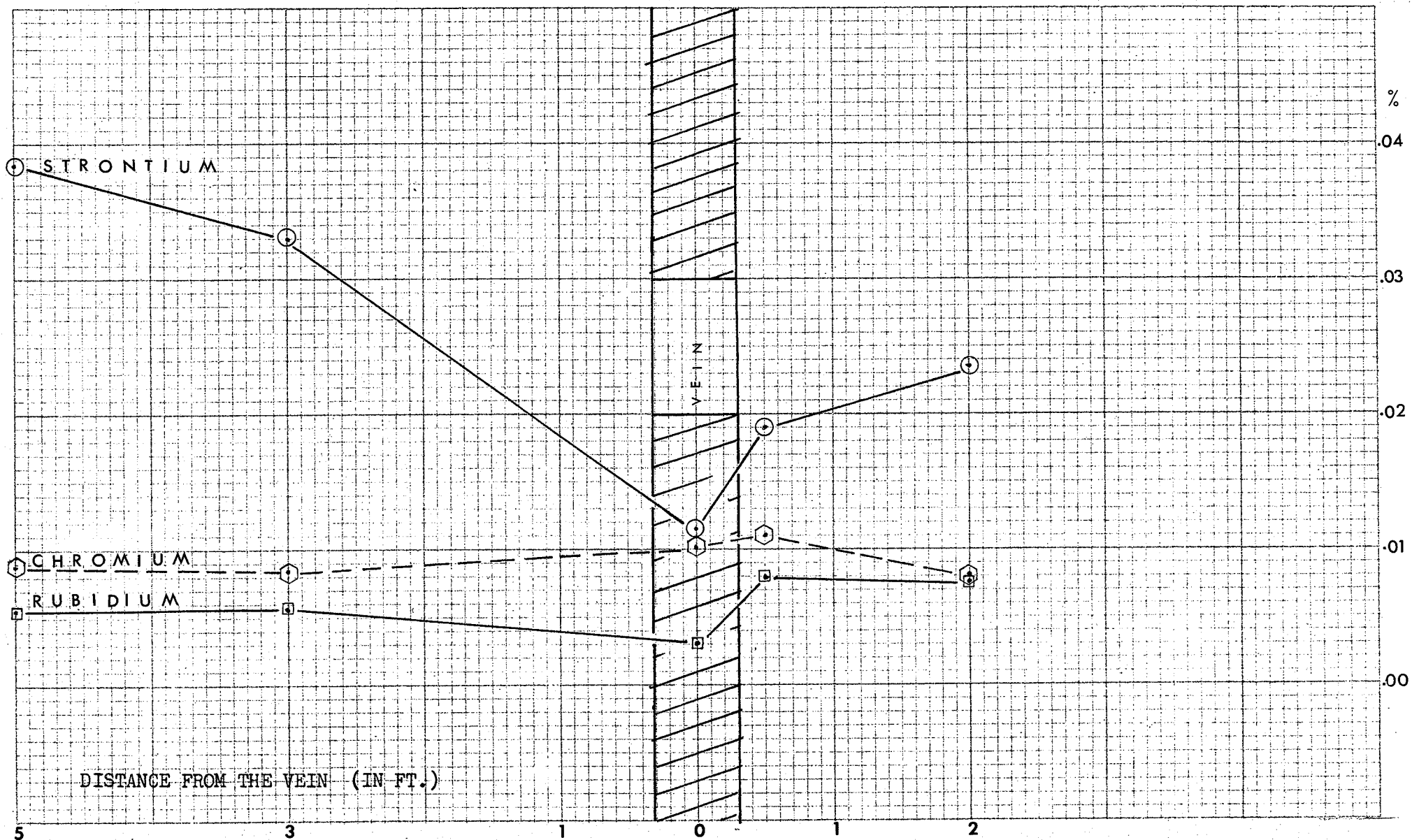


Figure 19a: Trends in Vanadium and Zirconium (in wt.%) - Eldorado Mine

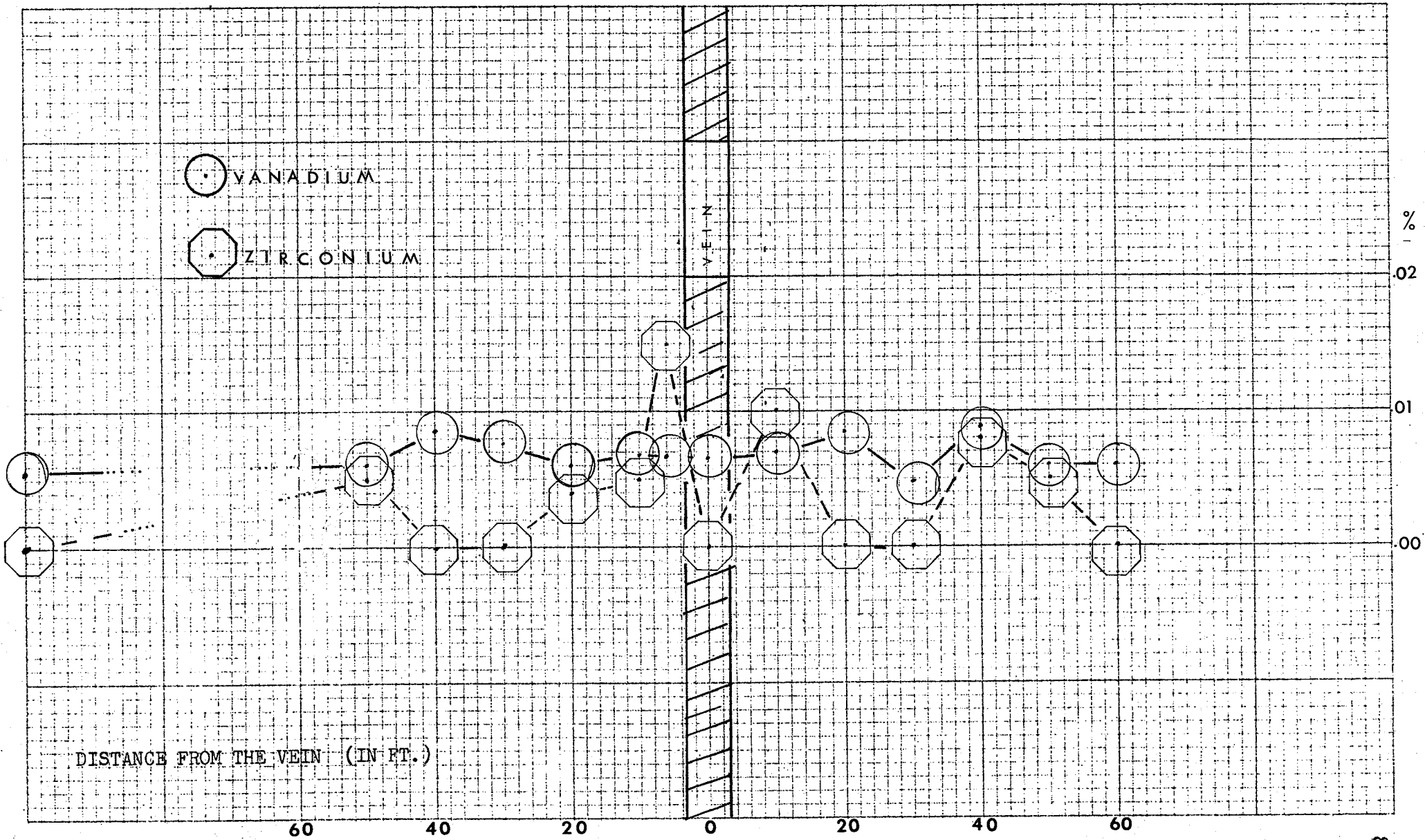


Figure 19b: Trends in Vanadium and Zirconium (in wt.%) - Packsack Mine

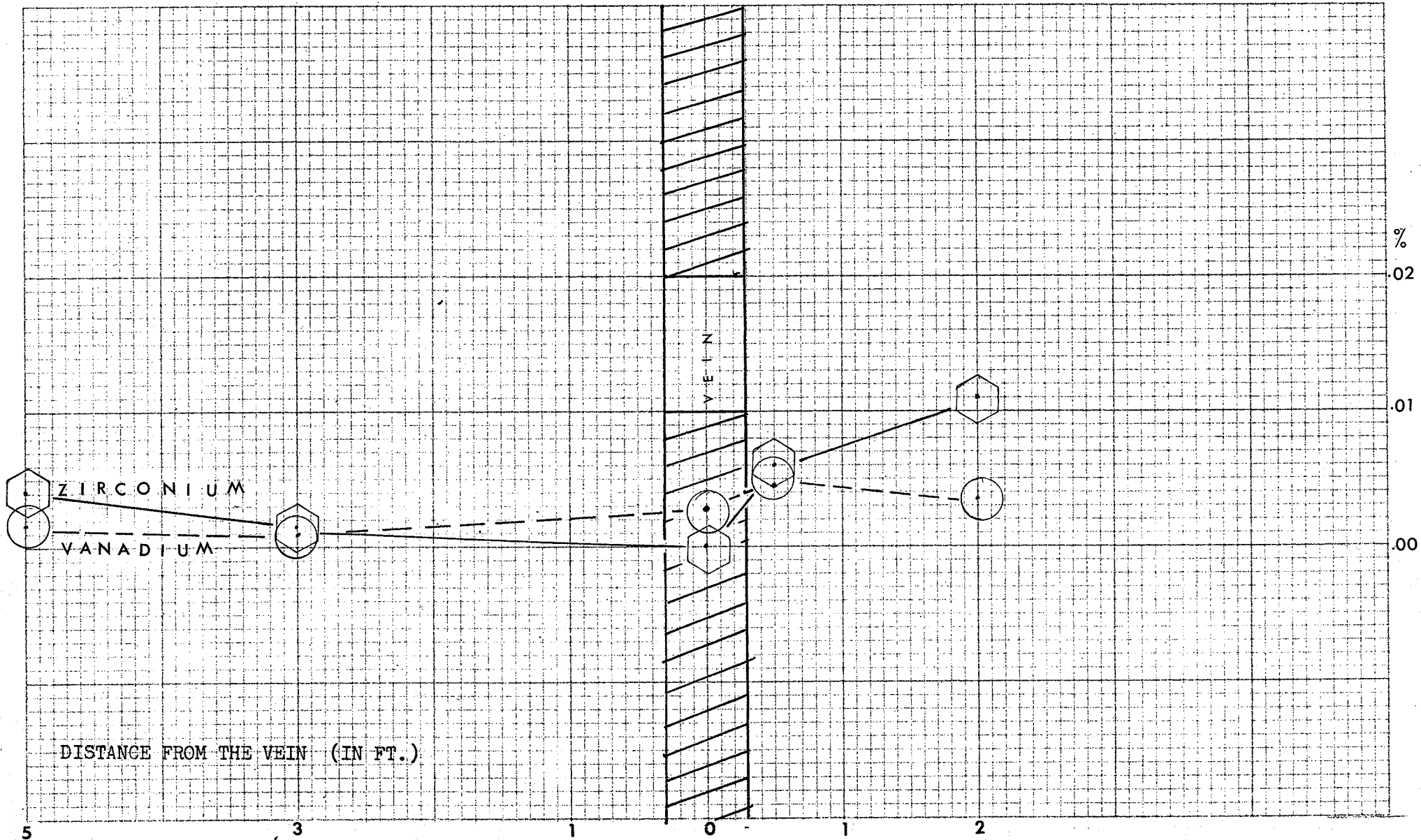


Table 16: Summary of Trends from Figures 10-19

- I. Concentration increase towards vein:
 - A. Well-defined trend - none
 - B. Poorly - defined trend - Mg, K, Rb

- II. Concentration decrease towards veins:
 - A. Well-defined trend - Ca, S, Cr
 - B. Poorly-defined trend - Si, Al, Fe, Na, Sr, Zr

- III. No Trend:
 - A. Uniform distribution - Ba, Mn, P
 - B. Irregular distribution - Al, Li, Ti, Ni, Co,
Pb, Cu, V, H₂O, CO₂

indicates an increase towards the Eldorado vein on the west side are: MgO, K₂O, and Rb. There are no elements showing an increase on the east side of this vein.

The elements with no trends are sub-divided into two groups. First, those which are uniformly distributed are: P₂O₅ (east and west side of Eldorado vein, except 40'E, LOW) BaO and MnO; second those which are irregularly distributed and include: Al on the west side of the Eldorado vein; Fe²⁺, Fe³⁺, H₂O, CO₂, TiO₂, Ni, Li, Co, Pb, Cu, and V, on the east and west side of the Eldorado vein. The behaviour of both Si and Al (Figure 10) is irregular, but on the east side of the Eldorado vein, the Si:Al ratio steadily increases towards the vein.

From the analyses and trend diagrams in Figures 10-19 it is suggested that most of the lithophile elements, especially the alkali metals (K, Rb) generally increase towards the vein. The alkaline earths (Ca, Al, Fe, and Sr) on the other hand decrease towards the vein.

The increase of Mg near the vein (Figure 12) corresponds to the intensity of development of chlorite.

The loss of Na and an increase of K close to the vein, is thought to correspond to the alteration of feldspars to mica (sericitization). K is also lost during chloritization of biotite.

Calcium decreases towards the vein, probably because Ca is gained during saussitization, and this alteration increases away from the vein.

Water, which is added during uralitization, sericitization, and chloritization, increases towards the vein, but is low in the vein itself (Figure 13).

CHAPTER V

SUMMARY AND INTERPRETATIONS

The rocks of the Bissett area greenstone belt contain at least four generations of quartz injections that are located in steeply dipping fractures, shears and faults. Gold-bearing veins are concentrated in basic plutonic and volcanic rocks at the noses and in the areas of anticlinal axial planes of the Beresford and Rice Lake folds. They carry recoverable amounts of gold and have been subject to repeated investigation since 1911.

The most abundant mineral of the vein rocks is quartz. This mineral exhibits a wide range of colors, textures and fracture patterns.

The black color of quartz may be caused by graphite, chlorite, tourmaline, rutile, or sulfide inclusions or by irradiation.

The yellowish-brown and reddish-brown (pink) colors are pigmentations of black or white quartz.

Other minerals present in vein rocks include carbonates, tourmaline, rutile and also numerous inclusions of other quartzo-feldspathic, ferro-magnesian minerals of the country rocks. The most abundant sulfides and oxides are: pyrite, arsenopyrite, chalcopyrite, pyrrhotite, magnetite, hematite, sphalerite and galena.

In these veins gold occurs as a native element in the form of small plates and segregations within the country rocks, within the carbonates (mostly calcite and ankerite), and with the quartz. The largest amounts of gold occur as particles and nuggets in the clear microcrystalline quartz. Some gold is disseminated within the pyrite and arsenopyrite in a finely divided state as a replacement product.

Most of the quartz in the veins was probably deposited by silica-rich solutions that flowed along fracture zones, shear zones and fault zones. However, the late granular white quartz within joints, which may crosscut the foliation, may have been derived from the enclosing outer alteration-zone rocks by alteration and diffusion. This is speculated because there are no visible channels for solutions, and their lack of gold.

The mylonites and augen gneisses of the alteration zones are believed to be shears and fault zones, and probably developed under conditions unfavorable for recrystallization. The other vein rocks within the alteration zones are products of dynamic, regional and retrograde (hydrothermal) metamorphism.

The behaviour of some major and some trace elements in the alteration zones surrounding the veins, corresponds to metamorphic alteration of: feldspars to mica (sericitization), feldspars to clinozoisite (saussuritization), and biotite to chlorite (chloritization).

The contents of major and trace elements in the veins,

compared to average composition of the rock types in which they occur, indicate a relative enrichment of Co, Cr, Ba and Pb in veins from sedimentary rocks; of Pb, S and Cr in veins from gabbroic-basaltic rocks; of Co, Cr, and Cu in veins from granites; and of Cr and Cu in veins from rhyo-dacitic rocks. Those elements which are impoverished in veins are: Zr, Zn, S, Ni, Sr, Rb, and Li (from sediments); Cu, Co, Zr, Zn, Ni, Sr, Rb, Li, Mn, Ti and P (from gabbros); Zr, Zn, S, Ni, Sr, Rb, Li, Mn, Ti and P (from granites); and Zn, Ni, Sr, Rb, Li, Ba, and V (from rhyolites). The concentration of Ti, V and Mn (from sediments), and Ba (from gabbros), is similar to that of average crustal rocks.

This behaviour is interpreted as reflecting on the relative mobility of elements or their geochemical affinities.

The element ratios given for vein rocks (except for Ni:Co) are not similar to those obtained from data on average crustal rocks. Furthermore, the ratios are highly variable because they are affected by inclusions of country rock minerals.

No analyses were made of separated silica-sulfide phases, but most of the elements, especially those which concentrate in the sulfide form (chalcophile) are assumed to be associated with the sulfide rather than the silica phase. There were also many inclusions of quartzo-feldspathic ferromagnesian minerals, probably derived from the country rocks. Those inclusions are variable

in amount in the vein, and account for erratic concentrations of elements.

The similarity of concentration and element ratios of the vein to that in cherts and radiolarites, as reported by Audley-Charles, is thought to depend on the relatively similar silica saturation environment, and consequently on a similar geochemical behavior (mobility, migration, enrichment, depletion (impoverishment)).

It has been suggested by numerous authors that gold in the quartz veins could have been derived from the country rocks themselves. The origin of gold and the vein material is subject to a number of possible interpretations.

The author favors the following sequence of events to explain the gold mineralization. The mineralization history probably started with injection of relatively barren fine-grained black quartz into shear planes. This was followed by a period of deformation and near contemporaneous injection of relatively barren coarse-grained white and black quartz. A second period of deformation may have affected these coarse-grained younger varieties of quartz and induced or initiated migration of relatively small amounts of gold and other highly mobile elements, especially from the surrounding basic country rocks, into dilation zones. A later period of quartz intrusion that carried the mineralizing

solutions was followed by more less severe deformation and deposition of more quartz. The youngest quartz, which is granular and contains no gold, was probably the last stage of deposition, and comes from the joint surfaces.

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APPENDIX I

SUMMARY OF GENERAL GEOLOGY AND LOCATION OF THE AREA OF STUDY
LOCATION , SIZE AND ACCESS

"Project Pioneer" area(Figure 1) is located in the Rice Lake Mining District, about 120 miles to the northeast of the city of Winnipeg, Manitoba. It covers an area of 27 Townships, approximately 750 square miles, and is accessible by boat, road and air. Generally, accessibility within the area itself is good. Where it is poor, sampling was done by helicopter.

PREVIOUS WORK

The rocks of the area have been repeatedly investigated since the first discovery of gold in 1911. A good summary of the previous work in the area is given by Davies (1963, p.1). Briefly, early geological studies of reconnaissance type were done by E. S. Moore (1912), J. S. Delury (1921, 1927) and H. C. Cook (1921). More extensive geological works of J. F. Wright (1923, 1925, 1927, 1932), C. H. Stockwell (1938, 1945) and C. S. Lord (1938) followed.

The most recent studies on the area were done by Russell (1948, 1952), and by Davies (1949, 1950, 1953, 1963). Unpublished theses by Troop (1949), Bell (1968), Paulus (1968), Freund (1968) and Zwanzig (1969) have been

written on specific problems within the area.

Currently under preparation is a final report of "Project Pioneer" investigators and more theses on specific aspects by J. Arthur, A. Bailes, F. Campbell, J. Marr and J. Stephenson all for the University of Manitoba.

GENERAL GEOLOGY

The consolidated rocks of the Rice Lake greenstone belt are Precambrian. A table of formations, after Stockwell (1938, 1945), with revisions by "Project Pioneer" investigators, is presented in Table 1.

The gold-bearing quartz veins are intrusive into the rocks of the Rice Lake Group and the Rice Lake batholith, and therefore are younger in age.

Rocks of the Rice Lake Group make up the oldest known rocks within the area. They form a belt which trends northwest-southeast (see Figure 1). This group consists of interlayered metamorphosed volcanic flows and fragmental rocks (pyroclastic breccias and tuffs) upon which clastic and tuffaceous metasedimentary rocks rest conformably (Stockwell, 1938).

The Rice Lake Group has been divided into lithologic units by Stockwell (1938), Davies (1949, 1953, 1963) and Zwanzig (1969). A simplified classification has been derived from these sources and is here employed.

The basic volcanic rocks have been metamorphosed to chlorite-amphibole-schists (greenstone), with steeply

TABLE 1: FORMATIONS

ACID INTRUSIVE ROCKS

Granite, granodiorite, quartzdiorite, quartz monzonite.

ENGLISH RIVER GNEISSIC ROCKS

Granite, Gneisses, Pegmatites.

SAN ANTONIO FORMATION

Arkosic quartzite, Conglomerate.

RICE LAKE BATHOLITH

Quartz diorite, Quartz-feldspar porphyry.

BASIC INTRUSIVE ROCKS

Serpentine, Peridotite and other ultrabasics.

Quartz diorite

Meta-Gabbro, Meta-Diorite, Meta-Diabase.

RICE LAKE GROUP

Pyroclastic breccias and tuffs (Fragmental rocks).

Clastic and tuffaceous sediments (Sedimentary rocks).

Basic lava, acid lava and derived schists (Volcanic
rocks).

dipping foliation and complex folds.

The intermediate to acid lavas comprise the bulk of the Rice Lake Group in some areas (Davies, 1963). They consist of rhyolite, dacite and trachyte which have been metamorphosed by shearing.

The sedimentary rocks of the Rice Lake Group are predominantly thin beds of arkosic greywacke, interfingered with tuff, shale (slate), chert and iron formation, quartzite, conglomerate and minor limestone. They have been metamorphosed to schists and meta-sandstones.

The fragmental rocks of the Rice Lake Group were not described by Stockwell. They form the Long Lake Formation of Zwanzig (1969). He (Zwanzig) stated that in his area of study

the Long Lake Formation consists of layered and clastic volcanic rocks....The formation is light green on weathered surfaces....It consists of predominantly pyroclastic rocks which can be divided into volcanic breccia, tuff breccia and sand-size crystal tuff. There are subordinate amounts of epiclastic rocks which consist of tuffaceous sandstone and shale.

These rocks are interfingered with the volcanic sedimentary rocks.

The rocks of the Rice Lake Group have been intruded by sills and dykes of meta-gabbro, meta-diabase, meta-diorite and quartz diorite, Stockwell (1938). The Rice Lake Batholith is an oval intrusion 8 by 11 miles of uniform quartz diorite (Paulus, 1968).

Overlying the intrusions with an apparent unconformity

(Davies, 1963). They are predominantly arkosic quartzite which is interbedded with narrow bands of conglomerate. The formation outcrops in the area immediately to the west of Rice Lake, with large-scale folding shown in the outcrop pattern.

The English River gneissic rocks outcrop on the southwest of the Rice Lake Group, south of the large fault that is the southern boundary of the greenstone belt. They consist of quartzo-feldspathic gneisses and granites (Freund 1968). Turck (1968) has determined a minimum age of 2630 m.y. for these rocks.

North of the fault boundary at the northern side of the greenstone belt, there are two or three plutons of granitic rocks. The rocks in these plutons range in composition from quartz diorite to granite.

STRUCTURAL GEOLOGY

The complex structural history of the area includes at least three separate periods of deformation (Zwanzig, 1969).

The distribution and concentration of the elements of study in the area (see Figure 2), are dependant upon the following structural features:

A. Shears, Fractures and Faults

Shearing, fracturing and faulting of the area was studied in considerable detail by Stockwell (1938), Davies (1963) and Russell (1953). These workers observed that cataclastic deformation is widespread except in the San

Antonio formation. They further noted that the principal directions of faulting, fracturing and shearing trend northwest-southeast, northeast-southwest and north-south; and that many of them dip steeply, Figure 4.

The northwest-southeast set usually strike at low angles to the foliation of the country rock, where as those of the northeast-southwest set commonly strike at high angles to it and the north-south set strikes almost at right angles to it.

Two large faults, roughly making the courses of the Wanipigow and Manigotagan Rivers, are continuous throughout the entire map area (McRitchie, W. D., 1968, personal communications). They will be referred to as the Wanipigow-Siderock and Manigotagan faults respectively. The vein rocks and dykes of the area confined within a belt bounded by these two faults.

B. Folds

A major anticline, hereby called the Beresford fold (near Beresford Lake) and an anticlinal-synclinal pair, to be called the Rice Lake fold (near Rice Lake) were recognised by Stockwell (1938) and Davies (1963). The Rice Lake batholith separates these two folds (see Figure 1 and 2) and the veins are concentrated within them.

Elsewhere in the area, the veins fill fractures and shears, and are associated mainly with anticlinal noses where there is evidence for intense deformation (Davies, 1963) and (McRitchie, W.D., 1968, personal communication).

C. Joints

Joint planes occur in all rock types, but are best developed in the Rice Lake Group and rocks intrusive into it. The orientation of these planes is genetically related to the major shear directions (McRitchie, W.D., 1968, personal communications, and Zwanzig, 1969). Some of the joint sets are filled with vein material.

ECONOMIC GEOLOGY

All the known gold-bearing quartz veins in the area occur within shear zones in greenstone of the Rice Lake Group and rocks intruded into it. The production of gold has come from San Antonio, Central Manitoba and Gunnar mines, plus smaller amounts from Gold Pan, Poundmaker, Jeep Diana and Eldorado mines.

Sulfides occur in most veins. Pyrite is the most common sulfide; chalcopyrite, sphalerite, galena and arsenopyrite are uncommonly present.

APPENDIX II

SUMMARY OF METHODS USED IN THE ANALYTICAL LABORATORY
DEPARTMENT OF EARTH SCIENCE, UNIVERSITY OF MANITOBA

<u>ELEMENT</u>	<u>METHOD</u>
Si, Al, Fe (total)	<p><u>X-ray Fluorescence Spectrometry.</u> Method described by Wilson, Andrews, Moxham and Ramlal (1965). In this method, 0.5000 gm. of sample (-200mesh), plus 0.5000gm. of lanthanum oxide (La_2O_3), and 1.000gm. lithium tetraborate ($\text{Li}_2\text{B}_4\text{O}_7$), are thoroughly mixed in a platinum crucible using a platinum spatula. The mixture is then heated in a graphite crucible at about 1050°C for 30 minutes. To the resulting glass bead is added enough boric acid (H_3BO_3) to make a total weight of 2.1000 gm.</p> <p>The bead and boric acid are ground to -200 mesh in a Bleuler rotary grinder for about 1 minute, then compressed to 50,000 p.s.i., using boric acid as a backing material. The resulting pellets are used for analyzing the elements simultaneously on a multi-channel ARL x-ray Spectrometer.</p>
Mg, Ca, K,	
Ti, Mn, Zr	
Na_2O	<p><u>Atomic Absorption Spectrophotometry.</u> In this method, 1.0000gm. of the rock is dissolved with hydrofluoric acid (HF), sulphuric acid (H_2SO_4), and nitric acid (HNO_3) in a platinum crucible. The resulting solution is diluted to a volume of 100 mls. Each element is then separately analyzed using a Perkin Elmer 303 Atomic Absorption Spectrophotometer.</p>
Cu, Ni, Co,	
Cr, Pb, Zn,	
and other	
trace metals	

<u>ELEMENT</u>	<u>METHOD</u>
P ₂ O ₅	<p><u>Colorimetry.</u> 1.0000gm. of the sample is dissolved with the acids as for elements for Atomic Absorption. The absorption at ⁴³⁰mμ of the molybdivanadophosphoric acid complex, used to determine the concentration of P₂O₅ using a Coleman Spectrophotometer.</p>
FeO	<p>The method consists of decomposing 0.5000gm. of the rock with hydrofluoric acid (HF) and 1:4 sulphuric acid (H₂SO₄). The solution is titrated with potassium dichromate (K₂Cr₂O₇), using barium diphenylamine sulfonate as an indicator.</p>
H ₂ O (Total)	<p>1.000gm. of the rock powder is heated in a stream of dry oxygen in an induction furnace at about 1200°C. H₂O is collected on a magnesium perchlorate and weighed.</p>
CO ₂	<p>Any traces of SO₂ are removed by manganese dioxide (MnO₂) (activated), and then carbon dioxide (CO₂) is collected on Ascarite and weighed. This gives total C as CO₂.</p>
<p>CO₂ In sulphide and graphite containing samples.</p>	<p>For sulphide and graphite containing samples, 1.000gm. of the sample is decomposed by hydrochloric acid (HCL) and heat. The carbon dioxide gas thus evolved is passed through a drying train, and is then collected on Ascarite.</p>
S	<p>Sulphur is determined by heating 1.0000gm. of the sample in an Leco induction furnace, with oxygen flowing through the combustion chamber. The resulting sulphur dioxide (SO₂) gas evolved is then titrated using an automatic Titrator.</p>

Table 3: Precision and Accuracy of Major Elements

<u>Constituent</u>	<u>Concentration</u> <u>%</u>	<u>Instrument</u> <u>Precision</u>	<u>Accuracy of</u> <u>Replicates</u>
			Std. Dev.
SiO ₂	60.0	.12	.20
Al ₂ O ₃	9.0	.05	.13
Fe ₂ O ₃ (Total)	10.0	.017	.03
MgO	4.0	.04	.10
CaO	10.0	.02	.07
K ₂ O	2.6	.01	.01
MnO	.41	.01	.01
TiO ₂	.48	.02	.02
Na ₂ O	4.20	.01	.05
H ₂ O (Total)	1.60	.03	.06
CO ₂	1.15	.05	.12
P ₂ O ₅	0.20	.01	.01

Table 4: Precision and Accuracy of Minor Elements

<u>Constituent</u>	<u>Concentration</u>	<u>Instrument Precision</u>	<u>Std. Dev.</u>	<u>Accuracy of Replicates</u>
FeO	10.9%			0.04
S	.185%	0.003		0.005
Zr	.027%	0.003		0.005
V	380 ppm	10		15
Ba	790 ppm	10		20
Sr	260 ppm	5		8
Ni	77 ppm	1		3
Cu	40 ppm	1		2
Co	53 ppm	1		2
Zn	108 ppm	1		2
Pb	34 ppm	2		1
Rb	228 ppm	.5		1
Li	10 ppm	.04		.05

Table 12a: Average Values, After Turekian and Wedepohl (1965)

<u>Major Elements</u>	<u>Ultrabasics</u>	<u>Gabbros</u>	<u>High Ca⁺⁺ Granodiorites</u>	<u>Low Ca⁺⁺ Granites</u>	<u>Shales</u>	<u>Sandstones</u>
SiO ₂	20.50%	23.00%	31.40%	34.70%	7.30%	36.80%
Al ₂ O ₃	2.00	7.80	8.20	7.20	8.00	2.50
Fe ₂ O ₃	9.43	8.65	2.96	1.42	4.72	0.98
FeO						
MgO	20.40	4.60	0.94	0.16	1.50	2.50
CaO	2.50	7.60	2.53	0.51	2.21	3.91
Na ₂ O	0.42	1.80	2.84	2.58	0.96	0.33
K ₂ O	0.0040	0.83	2.52	4.20	2.66	1.07
TiO ₂	0.03	1.38	0.34	0.12	0.46	0.15
P ₂ O ₅	0.02	0.11	0.092	0.06	0.07	0.017
MnO	0.162	0.15	0.054	0.039	0.085	0.00X0

Table 12a: Average Values, after Turekian and Wedepohl (1965)

<u>Trace Elements</u>	<u>Ultrabasics</u>	<u>Gabbros</u>	<u>High Ca⁺⁺ Granodiorites</u>	<u>Low Ca⁺⁺ Granites</u>	<u>Shales</u>	<u>Sandstones</u>
S	300 PPM	300 PPM	300 PPM	300 PPM	2400 PPM	240 PPM
Ni	2000	130	15	4.5	68	2
Cu	10	87	30	10	45	x
Co	150	48	7	10	19	0.3
Zn	50	105	60	39	95	16
Pb	1	6	15	19	20	7
Zr	45	140	140	175	160	220
Cr	1600	170	22	4.1	130	20
V	40	250	88	44	130	35
Sr	1.0	465	440	100	300	20
Rb	0.2	30	110	170	140	60
Li	2	17	24	40	66	0.X
Ba	0.4	330	420	840	580	XO
As	1	2	19	1.5	13	1

APPENDIX III

**AVERAGE CRUSTAL ABUNDANCE
OF VARIOUS ROCKS CITED**

Table 12b: Average Values, after Taylor (1965)

<u>Trace Elements</u>	<u>Crustal</u>	<u>Basalt</u>	<u>Granodiorite</u>	<u>Granite</u>	<u>Greywacke</u>	<u>Quartzite</u>
Ni	75 PPM	150 PPM	20 PPM	0.5 PPM	50 PPM	2 PPM
Cu	55	100	30	10	40	
Co	25	50	10	1	20	1
Zn	70	100	60	40	50	10
Pb	12.5	5	15	20	15	2
Zr	165	150	140	180	140	250
Cr	100	200	20	4	140	50
V	135	250	100	20	70	20
Sr	375	465	450	285	450	
Rb	90	30	120	150	120	30
Li	20	10	25	30	30	5
Ba	425	250	500	600	500	
As	1.8	2	2	1.5	2	1

Table 12c: Average Values, after Heier and Adams (1963)

<u>Major Elements</u>	<u>Na₂O</u>	<u>K₂O</u>
Part I - Plutonic Rocks		
All Gabbro	1.89	0.74
Diorite	2.52	1.76
Quartz Diorite	2.50	1.74
Granodiorite	2.75	2.28
Granite	2.58	3.41
Syenite	2.95	3.73
Part II - Volcanic Rocks		
All Basalt	2.31	1.26
Andesite	2.66	1.69
Dacite	2.95	2.22
Trachyte	3.29	4.76
Rhyolite	2.48	3.80
Part III - Sediments		
Sandstone	--	2.89
Quartzite	--	--
Shale	0.97	3.80

Table 12c: Average Values, after Heier and Adams (1963)

<u>Trace Elements</u>	<u>Rb</u>	<u>Li</u>
Part I - Plutonic Rocks		
All Gabbro	28	10
Diorite	77	20
Quartz Diorite	76	20
Granodiorite	99	20
Granite	170	30
Syenite	124	10
Part II - Volcanic Rocks		
All Basalt	47	7
Andesite	73	12
Dacite	97	25
Trachyte	238	35
Rhyolite	217	50
Part III - Sediments		
Sandstone	63	16
Quartzite	273	--
Shale	146	70

Table 12: Chemical Compositions of Cherts and Radiolarities - After Audley-Charles (1965).

12 (e)

Chemical composition of radiolarites

Sample no.	%							PPM												CO ₂ + H ₂ O	Total %
	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MnO	CaO	MgO	TiO ₂	Cu	Ni	Co	Cr	V	Sr	Rb	Ba	Y	Zr	Zn			
7802	85.8	5.18	1.02	0.02	0.81	1.12	0.39	80	35	.	45	220	370	50	520	.	50	.	5.5	99.84	
7803	92.8	2.58	0.31	0.01	0.67	0.49	0.03	40	10	5	25	90	200	.	300	.	40	.	3.6	100.49	
7804	66.7	11.66	6.26	0.19	2.52	1.65	0.91	40	10	5	30	360	830	.	1100	100	120	.	9.7	99.59	
7811	90.7	2.68	2.09	0.05	0.44	0.73	0.14	35	30	20	.	90	120	.	—	80	60	.	3.8	100.63	
7818	69.5	10.43	6.02	0.04	1.17	1.87	0.69	380	40	.	60	330	900	100	400	.	60	100	10.7	100.42	
7819	77.9	8.02	2.38	0.04	1.13	1.38	0.43	250	30	.	50	260	600	40	300	50	50	50	9.1	100.38	
7824	87.2	3.88	1.74	0.40	1.10	1.45	0.03	110	40	10	35	50	270	40	1150	80	45	.	4.7	100.50	
7875	92.0	3.10	0.44	0.01	0.54	0.56	0.10	90	.	.	30	110	200	40	—	.	45	.	3.8	100.55	
7876	87.7	2.97	1.69	0.21	0.57	1.26	0.26	120	60	30	30	110	110	.	210	.	40	.	5.6	100.26	
7877	90.5	2.55	0.97	0.81	0.41	0.50	0.06	50	35	.	15	20	85	.	530	.	70	.	4.3	100.10	
7878	91.3	2.77	0.85	0.03	0.70	0.75	0.09	60	.	.	25	20	85	.	80	.	40	.	4.1	100.59	
7879	75.7	7.87	4.08	0.87	0.81	1.09	0.36	280	100	50	50	285	430	100	400	.	50	100	9.3	100.08	
7880	89.2	1.41	5.01	0.11	0.54	0.37	0.04	150	45	40	30	200	50	.	75	.	.	.	4.2	100.88	
7882	89.3	3.17	1.40	0.11	0.90	0.81	0.31	60	20	.	30	105	180	.	560	.	50	50	4.4	100.40	
7883	89.0	2.41	1.41	0.62	1.10	0.81	0.20	110	50	40	20	70	80	.	420	.	.	.	4.5	100.05	
7884	83.8	4.23	2.38	0.93	0.54	2.27	0.19	280	115	70	30	220	90	70	230	.	90	50	6.2	100.54	
7885	86.9	3.85	2.04	0.18	0.53	1.31	0.10	120	65	30	30	100	50	40	70	.	50	200	5.7	100.61	
7886	91.1	3.47	0.56	0.02	0.29	0.70	0.15	80	10	5	25	170	120	40	240	.	.	200	4.2	100.49	
S								5	5	2	10	10	40	40	50	50	30	50			

12 (d)

Chemical composition of cherts

Sample No.	%							PPM										CO ₂ + H ₂ O	Total %
	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	CaO	MgO	TiO ₂	MnO	Cu	Ni	Co	B	Sr	Rb	Ba	V	Cr	Zr		
7812	95.3	0.53	0.72	0.07	0.12	0.01	0.44	30	25	90	70	80	50	900	.	.	.	2.0	99.20
7813	95.8	0.12	0.37	0.81	0.06	0.01	0.18	5	25	50	35	.	.	160	.	.	.	2.0	99.48
7852	96.3	0.08	0.18	0.31	0.02	0.01	0.07	5	10	40	35	.	.	.	.	.	.	2.1	99.06
7856	96.1	0.03	0.33	1.34	0.03	0.01	0.03	5	.	110	50	.	.	.	.	.	.	1.9	99.77
7857	95.0	0.13	0.61	1.50	0.01	0.02	0.03	10	.	110	60	.	.	90	.	.	.	2.4	99.69
7858	95.5	0.29	0.82	0.14	0.08	0.04	0.12	10	15	80	75	.	.	80	.	.	.	2.3	99.31
7859	98.0	0.09	0.39	0.67	0.16	0.01	0.03	5	10	130	60	.	.	.	.	.	.	1.3	100.65
7851	95.9	1.93	0.12	0.04	0.01	0.00	0.003	5	10	50	35	.	.	.	.	.	.	1.4	99.44
7854	96.2	2.54	0.01	.	0.01	0.01	0.003	20	.	90	40	.	.	.	.	.	.	0.6	99.34
7855	95.4	1.80	0.41	0.10	0.05	0.02	0.06	10	10	90	40	.	.	.	.	.	.	1.7	99.53
7853	85.4	0.16	0.43	7.69	0.07	0.18	0.02	10	.	70	35	230	50	1900	.	.	.	5.5	99.62
S								2	5	5	20	40	40	50	20	20	50		

APPENDIX IV

ELEMENT RATIOS FROM VEIN ROCKS,
AND AVERAGE CRUSTAL ROCKS CONTAINING THEM.

Table: 14a: Some Element Ratios from Vein Rocks
 (Ratios calculated using wt.% of oxides from Tables 5-7)

No.	Rk. Type	Si/Al	Si/Mg	Fe ³⁺ /Al	Fe ³⁺ /Fe ²⁺	Fe/Mg	Fe/Ti	Fe/Mn
3	Gabbro	274	6563	0.33	0.27	37	--	187
7	Gabbro	13	109	0.44	6.90	4	24	79
14-2	Sed	35	489	0.35	2.07	7	14	169
16-1	Granite	308	6150	0.59	0.53	34	55	550
16-2	Granite	470	888	0.90	0.59	5	26	64
18-1	Gabbro	165	2566	1.14	2.39	25	32	--
19-1	Gabbro	511	1945	3.21	1.27	22	--	273
22-2	Sed	73	360	0.68	1.67	5	12	--
23-2	Rhyolite	44	470	0.44	2.06	7	36	--
24-2	Rhyolite	1239	28314	7.12	4.75	197	--	138
25-1	Rhyolite	92	3934	2.56	4.62	134	--	1050
26-2	Granite	1649	32983	5.33	0.80	240	--	360
27-2	Granite	463	14309	3.81	1.11	224	--	169

Table 14a: Some Element Ratios from Vein Rocks.
 (Ratios calculated using wt.% of oxides from Tables 5-7)

No.	Rk. Type	Si/Al	Si/Mg	Fe ³⁺ /Al	Fe ³⁺ /Fe ²⁺	Fe/Mg	Fe/Ti	Fe/Mn
30-1	Rhyolite	274	1000	2.40	0.72	1	100	400
31-1	Gabbro	287	651	2.26	--	5	96	86
31-2	Gabbro	29	40	1.33	2.02	3	66	111
34-1	Gabbro	217	73	1.68	0.39	2	--	74
35-2	Gabbro	19	249	3.15	3.26	54	21	3064
36-2	Gabbro	94	1092	0.76	3.25	12	--	113
41	Granite	1655	9930	2.83	4.25	21	--	--
42	Rhyolite	57	287	0.29	0.98	3	238	50
43	Rhyolite	69	18	1.97	2.70	1	1405	21
44	Granite	391	1099	1.88	2.35	8	168	--
45	Rhyolite	3277	14455	1.00	0.08	135	--	--
46	Gabbro	376	1994	3.73	48.50	20	--	495
92-3	Granite	3310	21128	6.00	1.12	72	--	--
346-2	Gabbro	89	1090	0.43	0.34	2	--	--

Table 14:^a Some Element Ratios from Vein Rocks.
 (Ratios calculated using wt.% of oxides from Tables 5-7)

No.	Fe/Ni	Mg/Ni	Li /Mg	Ca/Mg	Na+K/Ca+Mg	Na/Ca	K/Ca	Na+K/Al
3	467	13	0	8.67	1.10	0.23	0.08	0.44
7	1859	435	1	621.62	0.05	0.05	0.00	0.04
14-2	1125	158	16	5.37	0.80	0.62	0.33	0.37
16-1	1833	53	0	6.25	0.32	0.22	1.10	0.38
16-2	510	111	--	2.16	0.18	0.07	0.19	0.30
18-1	950	38	26	10.53	0.22	0.08	0.16	0.16
19-1	1363	63	0	4.00	0.41	0.09	0.00	1.15
22-2	818	153	4	7.77	0.07	0.07	0.94	0.12
23-2	2940	420	10	2.29	0.99	0.05	--	0.30
24-2	1725	9	0	--	0.06	0.06	1.45	0.08
25-1	3150	24	43	8.51	1.40	0.12	--	0.31
26-2	3600	15	0	--	0.10	0.10	--	0.13
27-2	3040	14	294	--	0.07	0.07	--	0.07

Table 14:^a Some Element Ratios from Vein Rocks.
 (Ratios calculated using wt.% of oxides from Tables 5-7)

No.	Fe/Ni	Mg/Ni	Li /Mg	Ca/Mg	Na+k/Ca+Mg	Na/Ca	K/Ca	Na+K/Al
30-1	4000	19	0	--	0.10	0.20	--	0.06
31-1	1283	250	7	--	0.09	0.12	--	0.15
31-2	1362	495	2	2.55	0.14	0.18	0.02	0.37
34-1	1586	85	0	2.66	0.01	0.01	0.00	0.09
35-2	4256	79	0	2.08	1.63	1.00	1.41	0.38
36-2	927	80	0	--	2.37	3.86	--	0.53
41	263	13	100	13.00	0.05	0.02	0.03	0.12
42	500	168	6	6.28	0.26	0.20	0.10	0.37
43	937	1313	1	2.08	0.02	0.15	0.08	0.18
44	394	52	23	--	0.10	0.16	--	0.11
45	259	2	405	--	0.05	0.05	--	0.26
46	1650	82	122	--	0.43	0.52	--	0.44
92-3	850	11	213	--	0.05	0.05	--	0.04
346-2	1012	519	5	3.64	0.01	0.01	0.00	0.05

Table 14a: Some Element Ratios from Vein Rocks.
 (Ratios calculated using wt.% of oxides from Tables 5-7)

No.	K/Ba	K/Rb	Ca/Sr	Ni/Co	Ba/Ti	Ba/Sr	Ca/Ba	Ni/Cr	Rb/Sr
3	0.50	--	--	3	--	--	7	0.06	--
7	0.40	--	575	1	0.31	5	115	0.09	--
14-2	17.00	0.23	600	3	0.20	12	51	0.06	0.88
16-1	5.50	--	143	1	2.00	29	5	0.02	--
16-2	15.33	--	--	3	1.50	--	8	0.08	--
18-1	6.40	--	571	-	0.33	14	40	0.04	--
19-1	0.05	--	--	1	--	--	5	0.03	--
22-2	--	--	546	2	--	--	--	0.08	--
23-2	15.00	--	209	1	0.75	13	16	0.03	--
24-2	--	--	--	-	--	--	--	0.02	--
25-1	9.67	--	286	1	--	43	7	0.03	--
26-2	--	--	--	1	--	--	--	0.02	--
27-2	--	--	--	-	--	--	--	0.02	--

Table 14a: Some Element Ratios from Vein Rocks.
 (Ratios calculated using wt.% of oxides from Tables 5-7)

No.	K/Ba	K/Rb	Ca/Sr	Ni/Co	Ba/Ti	Ba/Sr	Ca/Ba	Ni/Cr	Rb/Sr
30-1	--	--	--	-	3.50	-	--	0.03	--
31-1	--	--	--	-	6.65	-	--	0.02	--
31-2	5.00	--	1826	2	0.25	7	246	0.15	--
34-1	--	--	596	2	--	-	--	0.14	--
35-2	20.75	0.03	590	1	0.05	40	15	0.16	3.00
36-2	--	--	--	1	--	57	--	0.04	--
41	0.10	--	--	1	--	-	3	0.06	--
42	4.00	0.20	543	1	12.50	14	40	0.08	0.03
43	21.33	--	1324	2	15.00	5	274	0.21	--
44	--	--	--	2	15.00	-	--	0.11	--
45	--	--	--	2	--	-	--	0.22	--
46	--	--	--	1	--	-	--	0.03	--
92-3	--	--	--	1	--	-	--	0.02	--
346-2	--	--	--	2	--	-	60	0.07	--

Table 14a: Some Element Ratios from Vein Rocks.
 (Ratios calculated using wt.% of oxides from Tables 5-7)

No.	Mn/Ni	Cu/Mn	Ti/Al	Ti/Zr	Cr/Fex10 ³	Cr/Mg	V/Mg
3	0.25	32	--	--	34	1.28	0.07
7	23.53	0	0.43	8.13	5	0.03	0.01
14-2	6.67	1	0.04	8.33	2	0.11	0.01
16-1	3.33	3	0.03	--	35	1.20	0.19
16-2	8.00	0	0.09	1.82	3	0.12	0.01
18-1	--	-	0.05	2.73	2	0.62	0.02
19-1	5.00	71	--	--	20	0.48	0.01
22-2	--	-	0.09	24.00	15	0.08	0.02
23-2	--	-	0.02	2.86	11	0.08	0.01
24-2	12.50	0	--	--	31	6.20	--
25-1	3.00	8	--	--	9	1.23	0.01
26-2	10.00	12	--	--	17	4.07	0.53
27-2	18.00	37	--	--	17	3.77	0.28

Table 14a: Some Element Ratios from Vein Rocks
 (Ratios calculated using wt.% of oxides from Tables 5-7)

No.	Mn/Ni	Cu/Mn	Ti/Al	Ti/Zr	Cr/FeX10 ³	Cr/Mg	V/Mg
30-1	10.00	82	0.06	1.33	9	0.02	0.01
31-1	15.00	0	0.02	0.05	42	0.22	0.02
31-2	12.31	0	0.03	--	5	0.00	--
34-1	21.43	0	--	--	4	0.01	--
35-2	1.39	1	0.02	--	14	0.08	0.03
36-2	8.18	0	--	--	30	0.35	0.01
41	--	-	--	--	61	1.40	0.03
42	10.00	7	0.04	--	20	0.07	0.01
43	45.67	0	0.02	--	50	0.00	0.00
44	--	-	0.02	0.36	24	0.18	0.01
45	--	-	--	--	14	1.98	--
46	3.33	70	--	--	23	0.47	--
92-3	--	-	--	--	81	4.40	0.32
346-2	--	-	--	--	14	0.03	0.01

Table 14b:

Some element ratios of the ferromanganiferous sediments from Timor

Sample no.	Fe/Mn	Mn/100Ni	Mn/100Cu	Mn/100Ba	Mn/100Mo	Fe/100Co	Fe/100Ni	Fe/Ti	Ni/Co	Ba/Cu	Ti/Zr	Al ₂ O ₃ /TiO ₂
<i>A</i>												
7809	35	0.1	3.8	—	3	77	4.3	200	18	—	—	25
7807	20	1.1	8.0	—	4	120	23	300	5.1	—	—	34
7808	5.1	5.5	31.3	—	19	240	29	350	8.5	—	—	55
7806	0.2	14.1	22.3	—	130	4.3	3.2	6	1.3	—	95	10
<i>B</i>												
7888	0.44	5.5	18	—	89	7.1	2.4	11	2.9	—	—	12
7887	0.04	17.5	16	—	160	2.5	0.5	2	5.3	—	—	11
7820	0.014	12.6	14	—	98	1.7	0.2	7	8.9	—	11	60
<i>C</i>												
7821	0.002	10.1	4.5	4.9	18	0.6	0.03	4.5	24	9.3	2.2	200
<i>D</i>												
7827	0.001	18.6	1.2	9.5	19	0.1	0.04	3.3	33	1.2	2.3	155
<i>E</i>												
7823	2.4	17.0	34	3.3	135	72	45	700	1.6	100	—	123
<i>F</i>												
7889	0.89	0.57	0.5	8.8	2.6	0.9	0.51	13.4	1.7	0.58	35	10
7890	1.21	0.79	0.5	7.0	2.8	1.8	0.95	12.8	1.9	0.75	23	9
7891	1.06	0.85	0.5	6.7	5.5	1.1	0.89	11.7	1.3	0.77	52	5.4
7892	1.21	0.78	0.7	7.2	4.6	1.7	0.94	12.3	1.8	1.00	71	4.3
7893	0.97	0.89	0.6	8.5	2.3	1.3	0.86	12.0	1.5	0.65	87	7.8
<i>G</i>												
7817	0.05	16.5	2.2	50	66	1.0	0.80	5.4	1.2	0.45	—	14
7816	0.07	5.7	1.7	10	45	—	0.41	2.2	—	1.7	24	11
7815	14.8	—	0.9	—	3.4	—	—	20	—	—	85	3.5
7814	7.7	—	1.3	—	3.3	—	—	12	—	—	44	3.9

After Audley-Charles (1965)

Table 14c:

Some element ratios of the radiolarites										
Sample No.	Mn/Ni	Fe/Ni	Ni/Co	Ni/Cr	BaO/TiO ₂	Ba/Sr	Ca/Ba	Ca/Mg	Ca/Sr	Ti/Zr
7802	5	200	-	0.8	0.15	1.4	11	1.8	16	46
7803	8	220	2	0.4	1.1	1.5	16	3.4	24	5
7804	140	4400	2	0.3	0.13	1.4	16	3.8	22	45
7811	13	490	1.5	-	-	-	-	1.5	25	13
7818	8	1050	-	0.6	0.06	0.44	21	1.6	9	68
7819	10	550	-	0.6	0.08	0.51	27	2.0	13	52
7824	75	300	4	1.1	4.3	4.3	7	1.9	29	4
7875	-	-	-	-	-	-	-	2.4	20	13
7876	27	200	2	2	0.09	1.9	2	1.1	37	40
7877	180	190	-	2.3	1.0	6.2	5	2.1	34	5
7878	-	-	-	-	0.1	0.94	60	2.2	59	12
7879	67	290	2	2	0.12	0.93	14	1.9	13	44
7880	19	780	1	1.5	21.0	1.5	50	3.5	78	-
7882	42	490	-	0.7	0.2	3.2	11	2.8	36	38
7883	95	200	1	2.5	0.23	5.3	19	3.4	100	-
7884	63	140	1.5	3.8	0.13	2.5	17	0.6	43	12
7885	21	220	2	2.1	0.008	1.4	55	1.0	76	12
7886	15	400	2	0.4	0.18	2.0	9	1.0	17	-

After Audley-Charles (1965)

APPENDIX V

**ANALYSES AND ELEMENT RATIOS
OF THE ALTERATION ZONES**

Table 15a: Rocks From Eldorado Mine (Feet away from Vein Indicated)

<u>Major Elements</u>	<u>10E</u>	<u>20E</u>	<u>30E</u>	<u>40E</u>	<u>50E</u>	<u>60E</u>
SiO ₂	63.80%	63.95%	64.25%	60.50%	62.90%	62.95%
Al ₂ O ₃	16.70	16.84	16.97	16.58	17.32	17.30
Fe ₂ O ₃	1.10	2.16	2.08	3.07	2.01	2.21
FeO	2.78	1.78	1.90	2.78	2.34	2.18
MgO	1.61	1.58	1.68	2.23	2.03	1.96
CaO	2.86	5.84	5.73	6.05	6.45	6.45
Na ₂ O	4.70	4.25	4.37	4.17	4.54	4.32
K ₂ O	1.83	0.63	0.63	0.89	0.66	0.79
H ₂ O	2.32	1.64	0.95	1.76	0.82	0.88
CO ₂	1.53	0.26	0.00	0.84	0.02	0.00
TiO ₂	0.48	0.46	0.47	0.63	0.48	0.47
P ₂ O ₅	0.125	0.120	0.127	0.511	0.105	0.126
MnO	0.030	0.037	0.040	0.063	0.052	0.053

Table 15a: Rocks from Eldorado Mine (Feet away from Vein Indicated)

<u>Trace Elements</u>	<u>10E</u>	<u>20E</u>	<u>30E</u>	<u>40E</u>	<u>50E</u>	<u>60E</u>
S	10 PPM	30 PPM	40 PPM	700 PPM	50 PPM	50 PPM
Ni	24	22	17	38	36	31
Cu	22	21	20	34	25	24
Co	15	12	13	13	19	13
Zn	62	64	65	85	69	69
Pb	13	45	2	3	1	6
Zr	10000	0	0	0	8000	5000
Cr	90	102	118	121	114	97
V	70	85	48	88	60	60
Sr	320	415	440	390	447	475
Rb	66	19	30	46	23	26
Li	28	19	15	27	16	18
Ba	23000	11000	27000	37000	23000	5000
Totals	98.97	99.64	99.30	99.88	99.84	99.82

Table 15a: Rocks from Eldorado Mine (Feet Away from Vein Indicated)

<u>Major Elements</u>	<u>10W</u>	<u>20W</u>	<u>30W</u>	<u>40W</u>	<u>50W</u>	<u>100⁺W</u>
SiO ₂	62.25%	61.95%	61.25%	61.55%	61.30%	62.50%
Al ₂ O ₃	17.58	17.44	17.88	17.78	17.56	17.39
Fe ₂ O ₃	2.03	1.63	2.06	1.99	2.06	2.26
FeO	2.34	2.52	2.54	2.50	2.34	2.18
MgO	2.03	2.03	1.92	1.97	1.87	1.86
CaO	6.10	6.12	6.74	6.45	6.60	5.87
Na ₂ O	4.15	4.50	4.62	4.48	4.42	4.42
K ₂ O	1.08	0.97	0.84	0.87	0.84	0.81
H ₂ O	1.40	1.33	0.87	1.28	1.77	1.67
CO ₂	0.03	0.14	0.00	0.08	0.18	0.14
TiO ₂	0.49	0.48	0.55	0.55	0.52	0.54
P ₂ O ₅	0.048	0.113	0.105	0.105	0.107	0.092
MnO	0.052	0.047	0.053	0.047	0.056	0.043

Table 15a: Rocks from Eldorado Mine (Feet Away from Vein Indicated)

<u>Trace Elements</u>	<u>10W</u>	<u>20W</u>	<u>30W</u>	<u>40W</u>	<u>50W</u>	<u>100⁺W</u>
S	10 PPM	70 PPM	40 PPM	40 PPM	75 PPM	80 PPM
Ni	29	30	17	20	15	25
Cu	25	25	41	34	38	27
Co	14	15	12	15	14	18
Zn	65	69	70	69	65	66
Pb	17	8	17	14	16	18
Zr	5000	4000	0	0	5000	0
Cr	110	103	96	106	100	134
V	67	60	76	84	60	56
Sr	450	425	440	410	460	448
Rb	30	29	29	28	17	26
Li	20	22	19	25	20	25
Ba	1000	27000	0	1000	25000	21000
Totals	99.67	99.38	99.51	99.74	99.74	99.89

Table 15b: Rocks from Packsack Mine (Feet Away from Vein Indicated)

<u>Major Elements</u>	<u>00</u>	<u>00.5 S</u>	<u>02.0 N</u>	<u>03.0 S</u>	<u>05.0 N</u>
SiO ₂	95.60%	74.10%	70.60%	69.80%	68.20%
Al ₂ O ₃	2.44	14.76	14.77	15.51	14.59
Fe ₂ O ₃	0.32	0.74	0.63	0.62	0.05
FeO	0.22	0.50	2.30	1.62	2.14
MgO	0.05	0.19	0.99	0.56	0.75
CaO	0.00	0.59	1.06	2.02	3.49
Na ₂ O	0.16	3.94	4.21	4.94	4.50
K ₂ O	0.57	2.43	1.94	1.71	1.77
H ₂ O	0.45	1.39	1.86	1.39	1.51
CO ₂	0.17	0.67	0.65	1.29	2.09
TiO ₂	0.04	0.27	0.33	0.29	0.29
P ₂ O ₅	0.002	0.126	0.077	0.107	0.110
MnO	0.000	0.008	0.023	0.023	0.027

Table 15b: Rocks from Packsack Mine (Feet Away from Vein Indicated)

<u>Trace Elements</u>	<u>00</u>	<u>00.5 S</u>	<u>02.0 N</u>	<u>03.0 S</u>	<u>05.0 N</u>
S	1780 PPM	2730 PPM	90 PPM	2000 PPM	250 PPM
Ni	5	13	12	18	22
Cu	55	36	21	21	12
Co	11	6	7	7	6
Zn	5	14	46	20	31
Pb	0	3	2	14	13
Zr	0	6000	11000	15000	4000
Cr	104	110	80	83	88
V	27	45	35	10	17
Sr	115	190	235	330	385
Rb	30	80	75	56	56
Li	8	8	20	12	12
Ba	18000	41000	40000	21000	35000
Totals	100.16	99.94	99.95	100.06	99.64

Table 15c: Some Element Ratios from Alteration Zones

Eldorado Mine

Quartz Diorite - Distance from the vein and direction indicated.

<u>Dist.</u>	<u>Si/Al</u>	<u>Si/Mg</u>	<u>Fe³⁺/Al</u>	<u>Fe³⁺/Fe²⁺</u>	<u>Fe²⁺/Mg</u>	<u>Fe/Ti</u>	<u>Mg/Ni</u>	<u>Li^{X10⁴}/Mg</u>
10E	3.82	39.63	0.66	0.40	1.73	7.87	671	17
20E	3.80	40.47	0.13	1.21	1.13	8.56	718	12
30E	3.79	38.24	0.12	1.09	1.13	8.47	988	9
40E	3.65	27.13	0.19	1.10	1.25	9.28	587	12
50E	3.63	30.98	0.12	0.86	1.15	9.06	564	8
60E	3.63	32.12	0.13	1.03	1.11	9.43	632	9
00	50.12	216.74	0.51	1.27	1.72	24.00	860	23
06W	3.83	30.75	0.10	0.53	1.47	9.76	1000	16
10W	3.54	30.66	0.12	0.87	1.15	8.92	700	10
20W	3.55	30.52	0.09	0.65	1.24	8.65	677	11
30W	3.43	31.90	0.12	0.81	1.32	8.36	1129	10
40W	4.46	31.24	0.25	0.80	1.27	8.16	985	13
50W	3.49	32.78	0.12	0.88	1.25	8.46	1247	11
100W	3.59	34.53	0.13	1.04	1.17	8.22	744	13

Table 15c: Some Element Ratios from Alteration Zones

Packsack Mine

Acid Volcanic - Distance from the vein and direction indicated.

<u>Dist.</u>	<u>Si/Al</u>	<u>Si/Mg</u>	<u>Fe³⁺/Al</u>	<u>Fe³⁺/Fe²⁺</u>	<u>Fe²⁺/Mg</u>	<u>Fe/Ti</u>	<u>Mg/Ni</u>	<u>Li^{X10⁴}/Mg</u>
00	39.18	1912.00	0.05	1.45	4.40	13.50	100	160
0½N	5.02	71.31	0.13	1.48	2.63	4.60	146	42
02N	4.78	390.00	0.04	0.27	2.32	8.88	825	20
03S	4.50	124.64	0.04	0.38	2.89	7.72	311	21
05S	4.67	90.93	0.00	0.23	2.85	7.55	341	16

Table 15C: Some Element Ratios from Alteration Zones

Eldorado Mine

Quartz Diorite - Distance from the vein and direction indicated.

<u>Dist.</u>	<u>Ca/Mg</u>	<u>Na+K/Ca+Mg</u>	<u>Na/Ca</u>	<u>K/Ca</u>	<u>Na+K/Al</u>	<u>K/Ba</u>	<u>K/Rb</u>
10E	1.77	1.42	1.64	0.64	0.38	80	277
20E	3.69	0.60	0.73	0.11	0.29	57	332
30E	3.41	0.67	0.76	0.11	0.29	23	210
40E	2.71	0.61	0.69	0.15	0.31	24	194
50E	3.17	0.61	0.70	0.10	0.30	29	287
60E	3.29	0.61	0.67	0.12	0.30	158	304
00	1.51	0.67	0.28	0.83	0.39	49	245
06W	2.39	0.58	0.05	0.77	0.25	65	260
10W	3.00	0.64	0.68	0.18	0.30	1080	360
20W	3.01	0.67	0.73	0.16	0.31	36	335
30W	3.51	0.81	0.68	0.12	0.31	00	290
40W	3.27	0.64	0.69	0.13	0.30	870	310
50W	3.53	0.62	0.67	0.13	0.30	34	494
100W	3.16	0.68	0.75	0.14	0.30	39	312

Table 15c: Some Element Ratios from Alteration Zones

Packsack Mine

Acid Volcanic - Distance from the vein and direction indicated.

<u>Dist.</u>	<u>Ca/Mg</u>	<u>Na+K/Ca+Mg</u>	<u>Na/Ca</u>	<u>K/Ca</u>	<u>Na+K/Al</u>	<u>K/Ba</u>	<u>K/Rb</u>
00	-	14.60	-	-	0.30	32	190
0½N	3.10	8.17	6.67	4.12	0.43	59	303
02N	1.07	3.00	3.97	1.83	0.42	48	259
03S	3.60	2.58	2.44	0.84	0.43	81	305
05S	4.65	1.48	1.29	0.51	0.43	51	316

Table 15c: Some Element Ratios from Alteration Zones

Eldorado Mine

Quartz Diorite - Distance from the vein and direction indicated.

<u>Dist.</u>	<u>Ca/Sr</u>	<u>Rb/Sr</u>	<u>Ba/Sr</u>	<u>Ni/Co</u>	<u>Ni/Cr</u>	<u>Fe/Mn</u>	<u>Fe/Ni</u>	<u>Mn/Ni</u>
10E	894	0.20	0.72	1.60	0.27	126	1575	12.5
20E	141	0.05	0.26	1.80	0.22	107	1790	16.8
30E	130	0.07	0.61	1.30	0.14	100	2341	23.5
40E	155	0.12	0.95	2.90	0.31	93	1540	16.6
50E	144	0.05	0.51	1.90	0.31	84	1208	14.4
60E	136	0.05	0.01	2.40	0.32	84	1429	17.1
00	41	0.14	0.69	0.40	0.02	140	3360	24.0
06W	210	0.62	2.50	2.00	0.22	83	2245	27.0
10W	136	0.07	0.02	2.00	0.26	84	1507	17.9
20W	144	0.07	0.63	2.00	0.29	88	1383	15.7
30W	153	0.07	-	1.40	0.18	87	2706	31.2
40W	157	0.07	0.00	1.30	0.19	96	2245	23.5
50W	144	0.04	0.54	1.00	0.15	79	2933	37.3
100W	131	0.06	0.47	1.40	0.19	103	1776	17.2

Table 15c: Some Element Ratios from Alteration Zones

Packsack Mine

Acid Volcanic - Distance from the vein and direction indicated.

<u>Dist.</u>	<u>Ca/Sr</u>	<u>Rb/Sr</u>	<u>Ba/Sr</u>	<u>Ni/Co</u>	<u>Ni/Cr</u>	<u>Fe/Mn</u>	<u>Fe/Ni</u>	<u>Mn/Ni</u>
00	0	0.26	1.57	0.50	0.05	0	1080	-
o $\frac{1}{2}$ N	31	0.42	2.16	2.20	0.12	155	9539	6.1
02N	45	0.32	1.70	1.70	0.15	127	2442	19.2
03S	61	0.17	0.64	2.60	0.22	97	1244	12.8
05S	91	0.14	0.91	3.70	0.25	81	9955	12.3

Table 15c: Some Element Ratios from Alteration Zones

Eldorado Mine

Quartz Diorite - Distance from the vein and direction indicated.

<u>Dist.</u>	<u>Cu/Mn</u>	<u>Ba/Ti</u>	<u>Ca/Ba</u>	<u>Cr/Ni</u>	<u>Ti/Al</u>	<u>Ti/Zr</u>	<u>Cr/Fe</u>
10E	0.07	0.05	124	3.75	0.03	48	0.002
20E	0.06	0.02	531	4.63	0.03	-	0.003
30E	0.05	0.06	212	6.94	0.03	-	0.003
40E	0.05	0.06	163	3.18	0.04	79	0.002
50E	0.05	0.05	280	3.17	0.03	96	0.003
60E	0.05	0.01	1290	3.13	0.03	-	0.002
00	0.10	0.16	591	57.40	0.04	-	0.017
06W	0.04	0.12	839	4.55	0.03	307	0.002
10W	0.05	0.02	6100	3.80	0.03	98	0.003
20W	0.05	0.06	227	3.43	0.03	120	0.003
30W	0.08	0.00	-	5.65	0.03	-	0.002
40W	0.07	0.02	6450	5.30	0.03	-	0.002
50W	0.07	0.04	264	6.67	0.03	104	0.002
100W	0.06	0.04	280	5.36	0.03	-	0.003

Table 15c: Some Element Ratios from Alteration Zones

Packsack Mine

Acid Volcanic - Distance from the vein and direction indicated.

<u>Dist.</u>	<u>Cu/Mn</u>	<u>Ba/Ti</u>	<u>Ca/Ba</u>	<u>Cr/Ni</u>	<u>Ti/Al</u>	<u>Ti/Zr</u>	<u>Cr/Fe</u>
00	-	0.45	-	20.80	0.02	-	0.019
0½N	0.45	0.16	14	8.46	0.02	45	0.009
02N	0.09	0.12	27	6.67	0.02	30	0.003
03S	0.09	0.07	96	4.61	0.02	193	0.004
05S	0.04	0.12	100	4.00	0.02	72	0.004