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GEOLOGIC LOG AND CHEMICAL DATA, DIAMOND DRILL HOLE 1, SAMRAH, KINGDOM OF SAUDI ARABIA

TECHNICAL LETTER

86

by

Paul K. Theobald, Jr., Charles E. Thompson, and
Henry D. Horn

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JIDDAH, SAUDI ARABIA

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Technical Letter
Saudi Arabian Mineral
Exploration - 86
November 10. 1966

Dr. Fadil K. Kabbani
Deputy Minister for Mineral Resources
Directorate General for Mineral Resources
Ministry of Petroleum and Mineral Resources
Jiddah, Saudi Arabia

Dear Dr. Kabbani:

Transmitted herewith are 10 copies of:

TECHNICAL LETTER NUMBER 86
GEOLOGIC LOG AND CHEMICAL DATA,
DIAMOND DRILL HOLE 1, SAMRAH,
KINGDOM OF SAUDI ARABIA

by

Paul K. Theobald, Jr.,* Charles E. Thompson,* and
Henry D. Horn**

Sincerely,

Glen F. Brown
Glen F. Brown, Chief
Saudi Arabian Mineral Exploration Project

* U. S. Geological Survey, Denver, Colorado

** U. S. Geological Survey, Jiddah, Saudi Arabia

GEOLOGIC LOG AND CHEMICAL DATA, DIAMOND DRILL HOLE 1, SAMRAH, KINGDOM OF SAUDI ARABIA

by

Paul K. Theobald, Jr., Charles E. Thompson, and Henry D. Horn

U. S. Geological Survey

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Diamond drill hole number 1 at the Samrah ancient mine, Kingdom of Saudi Arabia penetrated a series of mineralized fractures. Lead, zinc, and silver are the principal ore metals and galena and sphalerite are the ore minerals identified to date. Throughout the core there is a somewhat better correlation of silver with zinc than with lead.

The richest interval of core is in the main vein, 51-1/2 feet of core from 430 to 482 feet, and averages nearly 20 ounces of silver to the ton. Within this interval, 15 feet of core from 444 to 459 feet averages 60 ounces of silver to the ton. The richest single sample represents the five-foot interval from 454 to 459 feet and is reported to contain nearly 140 ounces of silver to the ton. All of these intervals contain recoverable quantities of lead and zinc and some contain a small amount of gold.

Introduction

Diamond drill hole number 1 at Samrah ancient mine, Kingdom of Saudi Arabia (Theobald, 1966) was spotted to coincide with hole number 7 of H. A. Quinn's recommendations (fig. 1) (Quinn, 1964). It was rotated from his recommendation to cut the major part of the andesite dike swarm and to pass through the main vein zone with its subsidiary veins beneath the glory hole at the western end of the principal group of ancient mines. Inclination of the hole was 45 degrees. The hole was collared with BX core and continued to 32 feet at this diameter. The hole was completed with AX core. Core recovery was excellent; the average interval returned 95 percent.

The site was located by Theobald with the approval of H. A. Quinn. Horn supervised the drilling and provided the preliminary log. The final log and sampling is that of Theobald with the assistance of Louis Gonzalez. Thompson performed the spectrographic analyses. Assays for gold and silver were performed by Sayyad Matouq Bahijri, and assays for copper, lead and zinc by Jamal Sumbul.

Geology

Description of the rocks are given in the accompanying log and have been presented previously (Theobald, 1966) with the interpretation of surface relations among the various intrusive rocks. Practically all of the rocks seen at the surface were cut in this single drill hole, the possible exception being gabbro, which is probably present in relict form in many of the intervals listed as amphibolite. In the core, more detailed identification of some units has been possible, but these changes do not effect the surface picture. In fact, units have been regrouped into more general units for presentation in the detailed surface map, figure 1,the cross section, figure 2, and the graphic log, figure 3.

Supergene weathering effects can be seen to a depth of about 75 feet in the unfractured rocks and extend to a greater depth in open fracture systems.

The sequence of rocks established on the surface by cross-cutting relations is confirmed and extended by the relations that may be seen in the core. The surface relations given by Theobald (1966) provide the following general sequence, from oldest to youngest: 1) amphibolite, 2) granodiorite, 3) granite, 4) lamprophyre, 5) aplite and pegmatite, 6) andesite, and 7) quartz and carbonate veins. The amphibolite has been interpreted to be a secondary feature, resulting from alteration of a prexisting gabbro. This relation is emphasized by the appearance of what seems to be relict pyroxene at a depth of about 110 feet and by the grain-size and compositional relations in the interval from 125 to 129 feet.

The most difficult of the relationships among the various rock types at the surface is that between the amphibolite and the foliated granodiorite. In the core, granodiorite at 60 feet contains large inclusions of hornblende, evidently derived from the amphibolite. Several of the granodiorite masses found in the core are, however, of questionable origin. Particularly in the interval from 65 to 69 feet it would appear that the hornblende-biotite-quartz diorite is a transitional rock reflecting further metasomatismof the amphibolite along compositional changes that could lead to granodiorite.

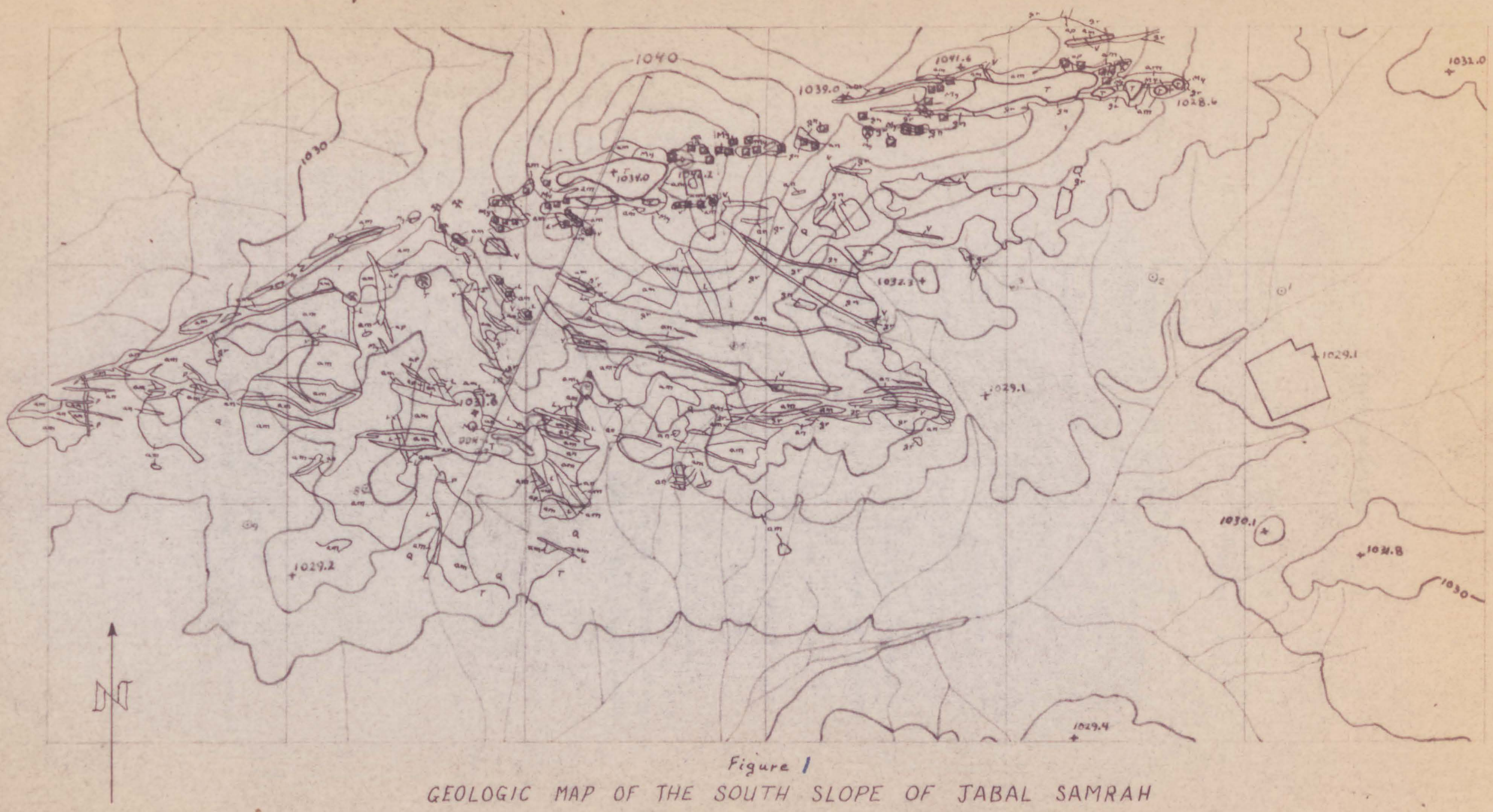

Figure 1

GEOLOGIC MAP OF THE SOUTH SLOPE OF JABAL SAMRAH

Scale approximately 1:2500

0 50 100 150 200 meters

Contour interval 2 meters

Base from KLM, sheet 27, Samrah, B-19

EXPLANATION

T — Tailings	Prospect pit
Q — Alluvium	Shaft or open stope
V — Vein	Glory hole or Trench
my — Mylonite	
an — Andesite	Drill hole collar from work of Quinn
p — Pegmatite	Projected drill hole U.S.G.S.
ap — Aplite	DDH-1 Line of section along U.S.G.S. DDH-1, Samrah
L — Lamprophyre	
gr — Granite	
gn — Ganodiorite	
am — Amphibolite	

To accompany figure 1

Geologic map of the south slope of Jabal Samrah

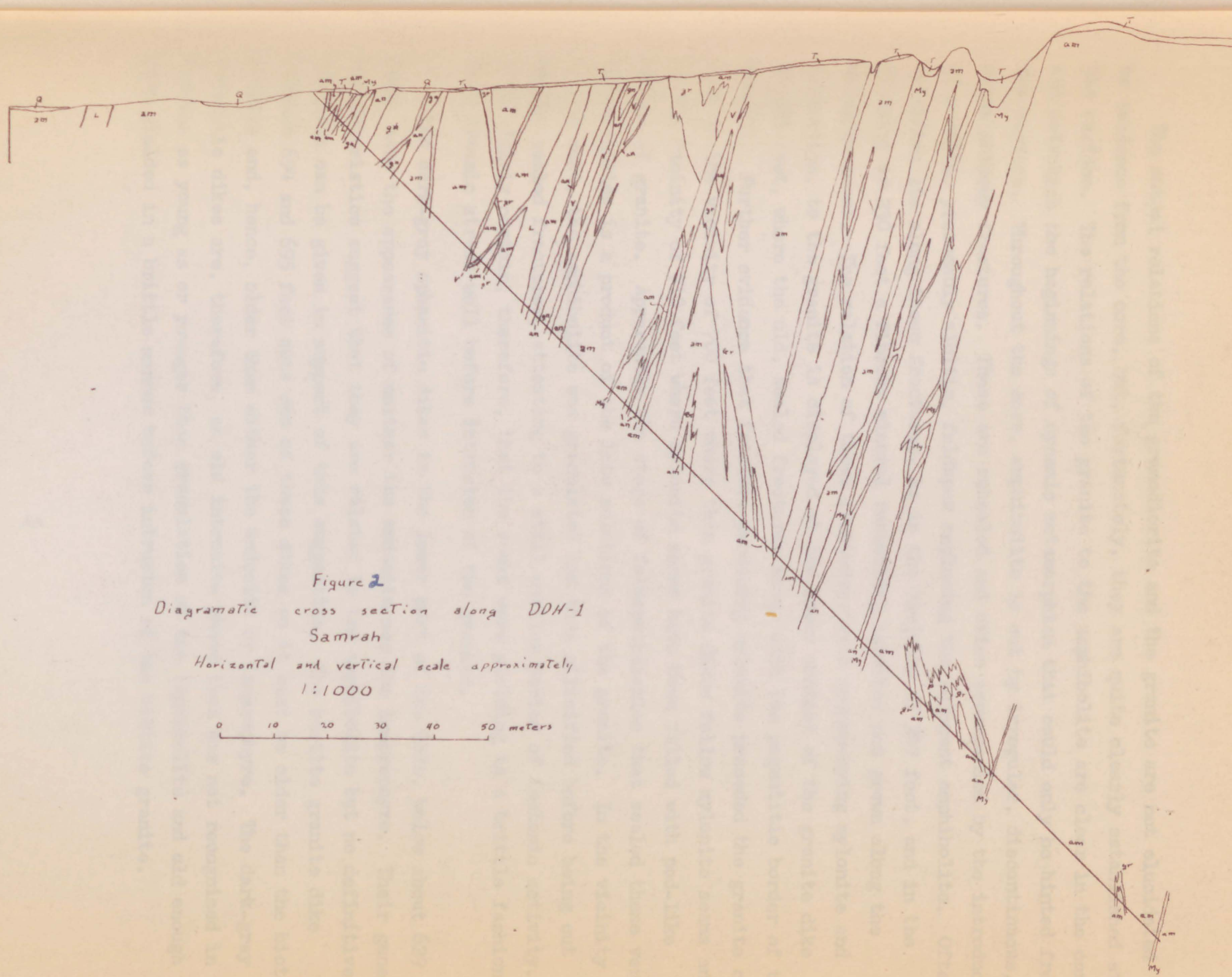

Figure 2

Diagramatic cross section along DDH-1

Samrah

Horizontal and vertical scale approximately 1:1000

0 10 20 30 40 50 meters

The mutual relations of the granodiorite and the granite are not elucidated by evidence from the core, but, fortunately, they are quite clearly established at the surface. The relations of the granite to the amphibolite are clear in the core and establish the beginnings of dynamic metamorphism that could only be hinted from the surface. Throughout the core, amphibolite is cut by irregular, discontinuous, often shadowy fractures. These are rehealed and often accompanied by the introduction of a white, presumably albitic, feldspar replacing the adjacent amphibolite. Often mylonites lie along these fractures, as in the vicinity of 247 feet, and in the vicinity of 230 feet a fibrous mineral resembling asbestos has grown along the mylonite seams. The relation of these fractures, with accompanying mylonite and alteration, to the granite is displayed at the lower contact of the granite dike at 575 feet, where the old, sealed fractures merge with the pegmatitic border of the granite. Further evidence that fracture producing mylonite preceded the granite can be seen in the vicinity of 700 feet where thin granite dikes follow mylonite seams and in the vicinity of 710 feet where mylonite seams have been filled with pod-like masses of granite. Apparently the stage of feldspathization that sealed these very old mylonites is a product of the late solutions of the granite. In the vicinity of 356 feet, the amphibolite was granulated and then silicified before being cut by the sealed fractures, attesting to a still earlier period of tectonic activity. It is fairly certain, therefore, that the rocks were yielding in a brittle fashion to a dynamic stress well before intrusion of the granite.

The dark-gray aphanitic dikes in the lower part of the hole, below about 629 feet, have the appearance of neither the andesite nor the lamprophyre. Their general characteristics suggest that they are related to the amphibolite but no definitive criteria can be given in support of this suggestion. The biotite granite dike between 694 and 695 feet cuts one of these dikes so it must be older than the biotite granite and, hence, older than either the andesite or lamprophyre. The dark-gray aphanitic dikes are, therefore, an old intrusive phase that was not recognized in the surface as young as or younger than granulation of the amphibolite and old enough to have yielded in a brittle manner before intrusion of the biotite granite.

The age relations of the granite and lamprophyre are established by cross-cutting relations at the surface. In the core, lamprophyre intrudes, and in the dike at 145 feet it includes fragments of amphibolite, but relations to the granodiorite and granite are not elucidated. Both the dikes at 145 feet and the large dike between 162 and 183 feet provide evidence of the dynamic, brittle fracture that accompanied intrusion. Both the amphibolite and, to a lesser extent, the lamprophyre were brecciated during intrusion. Rehealing of the breccia within the lamprophyre and gradual diminution of the brecciation toward the core of the lamprophyre dikes indicate that the brecciation was contemporaneous with intrusion. These features establish the presence of a second phase of brittle fracture.

The distinctively pink, K-feldspar-rich granites with minor biotite, aplites, and pegmatites of the core correlate with the aplite and pegmatite dikes and pegmatite of the surface. As suggested in Technical Letter 42, these rocks are complexly interwoven with a period of stress release. The aplitic-pegmatitic sequence is younger than the lamprophyre, which appears as inclusions in the granite and pegmatite at the lower contact of the lamprophyre dike at 182 feet. Inclusions of mylonite in the pegmatite and granite dike at 150 feet suggest a period of mylonite production between the intrusion of the lamprophyre and the intrusion of the pink granite, because the earlier, pre-biotite-granite mylonites are nowhere of sufficient size to produce the inclusions, and the inclusions do not have associated feldspathized amphibolite as would be expected for the older mylonites. A period of mylonite production after intrusion of the lamprophyres, but following the zones established before intrusion of the biotite granite, is further suggested by the mylonite seam that cuts the lower contact of the lamprophyre dike at 145 feet. This seam is associated with the typical, older feldspathization of the amphibolite but continues into the lamprophyre without attendant feldspathization.

Veins containing quartz and pink feldspar, sometimes with carbonate, appear to be related to the aplite-pegmatite sequence. These veins commonly cut rocks older than the aplites, including the lamprophyre at 180 feet, and they frequently cut older mylonite seams both of the pre- and post-lamprophyre types, as at 160, 202, and 350 feet. At 713 feet, a pink K-feldspar replacing cataclastic amphibolite is granulated adjacent to an aplitic granite, and at 532 feet the pegmatites cut amphibolite partially replaced by K-feldspar and serpentine suggesting at least partial emplacement of the aplite-pegmatite suite later than quartz-feldspar vein emplacement. None of the quartz-feldspar veins are found cutting later rocks or veins.

The maximum alteration is associated with the quartz-feldspar veins. Vein walls in all rock types are extensively serpentinized, and there appears to be an increase in the amount of secondary biotite, chlorite and hematite in the amphibolite near quartz-feldspar veins, as at 160 feet. The relation of serpentine to the quartz-feldspar veins is particularly well shown at 202 feet where the vein walls are serpentinized mylonite and where serpentine is included in the vein. Hematite in minute fracture coatings apparently imparts the characteristic pink color to the feldspar of both the aplite-pegmatite sequence and the veins. Hematite is also a conspicuous associate of serpentine both in the alteration halos around the quartz-feldspar veins, as noted above, and in the serpentine and hematite coated fractures. These latter, however, appear to be a later phenomenon. The alteration sequence is well defined at 310 feet where amphibolite is altered first to poikilitic biotite, replacing hornblende, which gives way to hematite-coated sericite, and finally to serpentine.

The andesite melt invaded all available open fractures some time after emplacement of the aplite-pegmatite sequence. In general dikes were emplaced along older fractures but locally sills were emplaced along foliation planes of the granodiorite, occasionally in a lit-par-lit-injection producing migmatitic mixtures, as at 195 feet. The andesite dike following the main fault zone at 435 feet is younger than most of the mylonite and serpentine, which it cuts. The andesite dikes are, however, cut by mylonite seams, and some of these are filled by a hematite-serpentine mixture, notably at 214 feet where the lower contact of the andesite dike is a fault with serpentine and hematite and hematite with pyrite occurs in the quartz and carbonate filled fractures in the andesite.

The principal open mesh of interlocking mylonite seams that produced the most common of the breccias occurred after emplacement of the andesite. Most of this shattering took place in the previously broken wall rocks rather than in the andesite. Pre-existing mylonites were particularly susceptible to breakage. These fractures were filled by the ubiquitous, quartz-carbonate seams and the attendant third maxima of alteration. Alteration at this time took the form of pink K-feldspar replacing wall rocks. All preceding rocks were effected and occur as fragments in the breccias, as is well illustrated in the carbonate-sealed breccia at 30 feet. All rocks were replaced to some extent by the pink K-feldspar up to and including the andesite. Some epidote was produced at this time, for example at 95 and 145 feet, but in general K-feldspar predominates, leading to the contradiction of K-feldspar veins accompanied by serpentine while the quartz-carbonate veins are also accompanied by K-feldspar. The time sequence, with intervening andesite, is sufficiently good to establish the associations, and at 160 feet the relations are particularly clear. In this interval the quartz-feldspar veins, with minor alteration of wall rocks to biotite, chlorite, and hematite, are cut by quartz-carbonate veins with attendant replacement of wall rocks by K-feldspar. A small amount of serpentine apparently accompanied the quartz-carbonate-vein filling, and in the main vein zone at 450 feet veinlets of a distinctive, pale-colored serpentine cut the quartz and carbonate.

The main period of sulfide introduction began passively, following the quartz-carbonate veins. Sphalerite, and to a lesser extent pyrite, replaces the breccias in large, zoned crystals. These were shattered in another wave of tectonism accompanied by the introduction of cross-cutting veins of galena. The galena was, in turn, granulated in what appears to have been the final dynamic episode, and it is cut by the late, undeformed veins of comb quartz.

A generalized summary of these data are presented in figure 4, which constitutes a graphical geologic history of Samrah. Practically all of the visible mineralization is in the main fault zone, extending from 430 to 481 feet. It is later than the quartz-carbonate vein filling, which it replaces, and is earlier than the comb quartz veins, which cut the sulfides.

Trace element geochemistry

Spectrographic determination of 27 elements in each of the 234 samples gives a continuous chemical log of all parts of the drill hole providing core. The general character of the distributions for each of the elements is summarized in the histograms of figure 5. The elements group on a basis of distribution into: 1) elements having no significant, detectable variation, germanium, niobium, tungsten, and gallium; 2) the ore metals, silver, lead, and zinc; 3) elements introduced with the ore metals and having no other significant variation, antimony, boron, bismuth, cadmium, and tin; 4) elements introduced with the ore that also vary with the lithology of the country rocks, beryllium, copper, manganese, molybdenum, and possibly zirconium; 5) elements removed from rocks associated with the ore deposit that also varied with the lithology of the country rocks, barium, chromium, scandium, strontium, and titanium; 6) elements exhibiting only a variation with the lithology of the country rocks, cobalt, lanthanum, nickel, vanadium, and yttrium.

Only three of the elements sought were consistantly below the limit of sensitivity; germanium less than 20 parts per million (ppm), niobium less than 50 ppm, and tungsten less than 50 ppm. The narrow range and symmetrical distribution of gallium allows only a statement of the modal value, 10 ppm, and the range, less than 10 to 20 ppm. All other elements have a significant variance that requires further explanation.

The three ore metals are shown on figure 5 and provide a base against which the other elements may be compared. These three distributions are strongly skewed toward higher values. At the low end they are truncated at the limit of sensitivity and each of the modes is below the limit of sensitivity. Plotted against the generalized geologic log of the drill hole, figure 3, it is clear that the dominant controls for the distribution of these elements are the structural discontinuities. The ore metals were introduced along the main fault zones, and lateral penetration of wall rocks, even as shattered as these are, has been slight. Only the main fault zone, 429 through 482 feet, has economic interest along this intercept, but virtually all of the fault zones are mineralized.

The distributions for boron, bismuth, cadmium, and tin are remarkably similar to those for the ore metals and apparently result from introduction of metal along the fault zones with a modal value for the country rocks near or below the limit of sensitivity. The similarity of the molybdenum distribution to these is misleading as its overall distribution is more complex. The single detectable antimony is in sample 29171, one of the richest in silver, lead, and zinc; hence, antimony is included in this group. The enrichment of boron, bismuth, cadmium, and tin in the fault and vein material can be seen in figure 6 where the comparison of these materials with the country rocks is presented. A chi-square median test indicates a probability of less than 1 in 1000 that the fault zones do not contain more boron, bismuth, and tin than the country rocks. The single value of 1000 ppm cadmium reported for sample 29178, from a brecciated andesite dike, hinders a statistical analysis for this element. I suspect this is a typographical error and the high cadmium should be in the zinc-rich vein sampled as 29180. There is about 1 chance in 10 that the fault zones are not richer in cadmium even with the probable error.

Cross correlations of these four elements with each other and with the ore metals in samples of vein and fault material (fig. 7) define the dependence of the minor elements on the major phase precipitating, particularly on the presence of galena. The only exception to the latter association is that between silver and zinc which is the highest correlation recorded despite the apparent association of the richest silver zones with the zones richest in galena and despite the higher silver content of galena in comparison with sphalerite. The reservation applied to cadmium is more evident in the cross correlations, and the strong association of this element with lead is supplemented by the more common association with zinc if the presumed error is corrected.

Beryllium, copper, manganese, molybdenum, and probably zirconium are richer in the vein and fault materials than in the country rocks, and the concentration of these elements varies with the lithology of the country rocks. Manganese, which provides the clearest example of this grouping, has a median concentration in the felsic rocks of 200 ppm, in the mafic and intermediate rocks of 500 ppm,

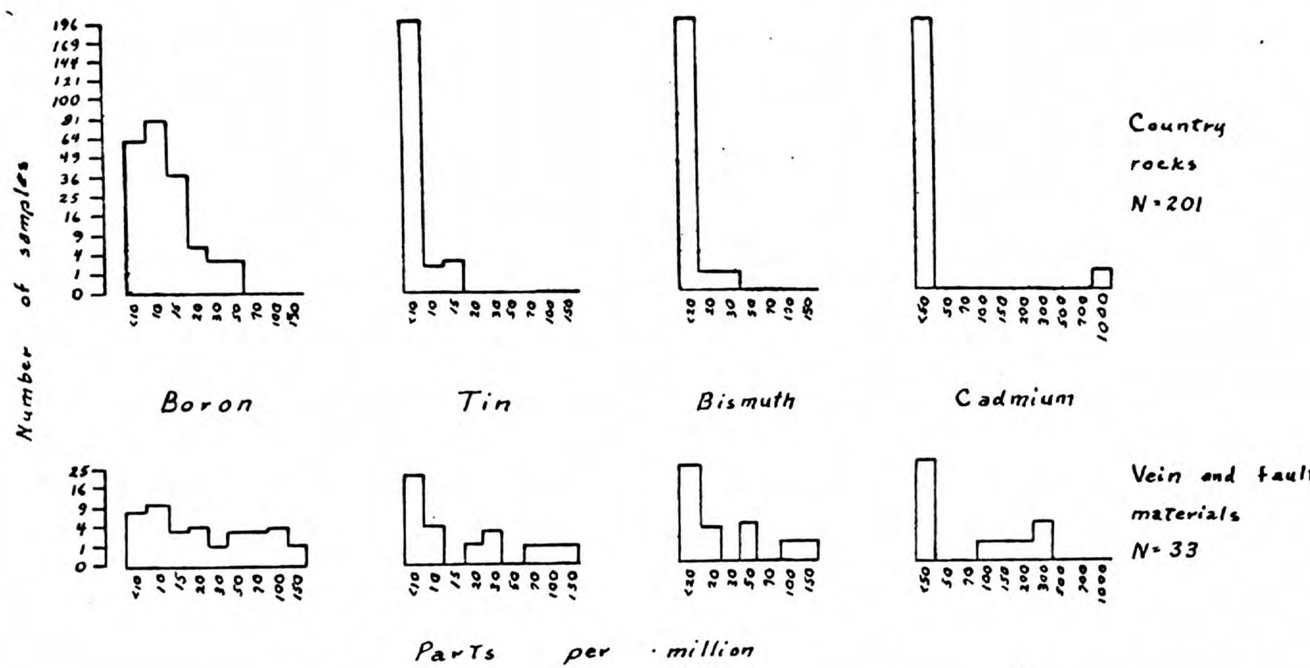

Figure 6

Distribution of boron, tin, bismuth, and cadmium among selected lithologic groups

DDH-1, Samrah

	Zn	Ag	Sn	Cd	Bi	B
Pb	0.67	0.68	0.55	0.35	0.37	0.30
Zn		0.77	0.54	0.30	0.30	0.25
Ag			0.55	0.32	0.34	0.18
Sn				0.32	0.20	0.07
Cd					0.20	-0.05
Bi						0.02

Significant at $\alpha = 0.01$

Significant at $\alpha = 0.05$

Not significant

Figure 7

Cross correlations, Kendalls τ (Stuart), among selected elements concentrated in vein and fault materials DDH-1, Samrah and in the vein and fault materials of 3000 ppm (fig. 8). There is a very low probability that these medians do not differ. Correlations of manganese with the ore metals in samples of vein and fault materials are all strong and positive: Kendalls T (Stuart) ranges from 0.50 for the association with lead to 0.64 for the association with silver.

The copper distribution is similar to but more complex than that of manganese. Felsic rocks contain significantly less copper than the intermediate and mafic rocks (fig. 9). The five samples with 300 ppm or more of copper all have more than 1 percent zinc, a half to more than 1 percent lead, and 150 to 3000 ppm silver. Although copper was evidently introduced in the richest veins, it is less abundant than silver. The spread of the copper values in both the amphibolite and the vein and fault materials is greater than would normally be expected. The medians for these two lithologic subdivisions are the same and coincide with the median for the other mafic and intermediate rocks. The distribution of copper in amphibolite is markedly bimodal. Variation with lithology and introduction along the faults is too simple a model to completely explain the copper distribution. On figure 10 the copper content of amphibolite is plotted with respect to position along the core, and this may be compared with the distribution of the major fault zones. The horizontal line in the diagram of copper content separates the two modes. Bars extending below this line indicate a copper content in the lower mode and are most common in the vicinity of the major faults. Bars extending above the line indicate a copper content in the higher mode and are most common in areas remote from the major faults. The data are suggestive that copper was removed from the fault zones and adjacent amphibolite during one of the stages of tectonic development preceding introduction of the ore metals. If this suggestion is correct, much more copper was removed from the system than was added with the ore metals.

The molybdenum distribution is truncated at the limit of spectrographic sensitivity, but the 22 samples in which molybdenum was detected are sufficiently distinctive to establish a lithologic variation as well as enrichment along the

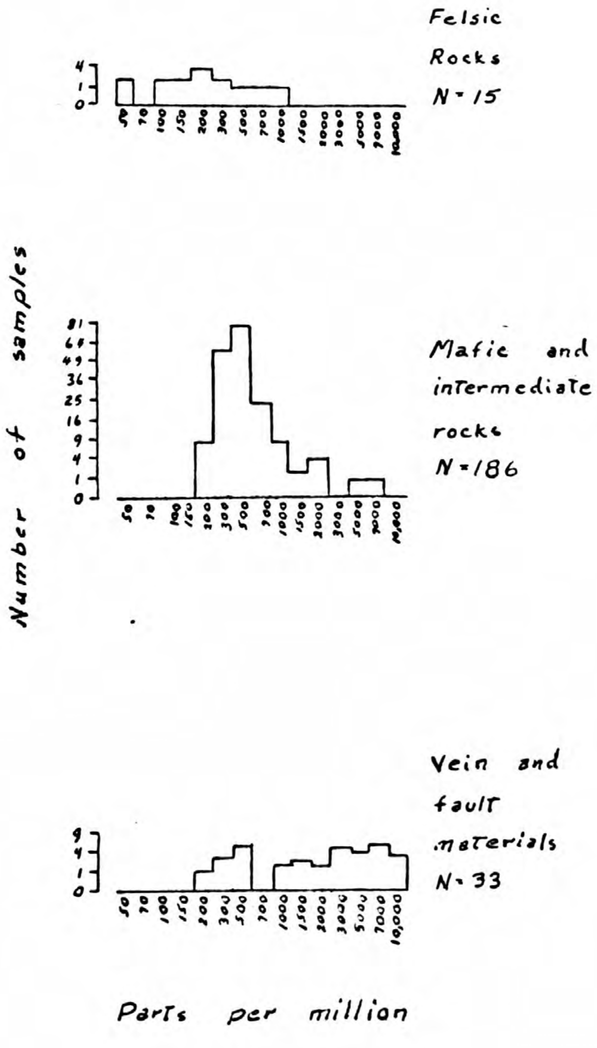

Figure 8
Distribution of manganese among selected lithologic groups
DDH-1, Samrah

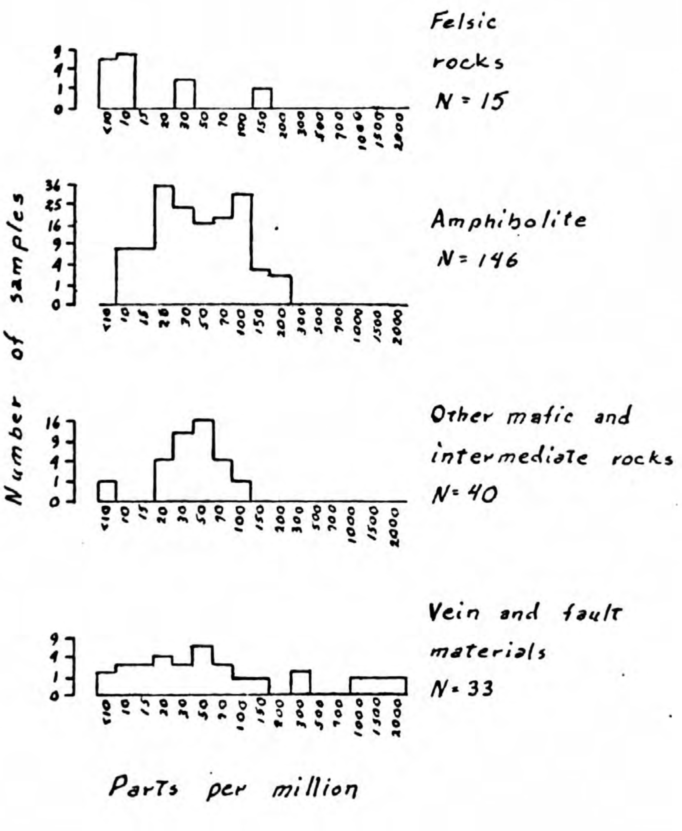

Figure 9.
Distribution of copper among selected lithologic groups
DDH-1, Samrah

fault systems. Five of the seven samples of country rock with detectable molybdenum are from andesite dikes, a highly significant relative enrichment. The proportion of samples with detectable molybdenum is about the same for andesite as for vein and fault materials, but the latter samples have somewhat greater amounts of molybdenum. Within the vein and fault materials there is a highly significant correlation of molybdenum with each of the ore metals, particularly with silver. Since molybdenum is usually concentrated in early, high-temperature phases of ore formation, since the andesites and the fault zones are rich in molybdenum, and since there is a time and space association of the andesite dikes with the fault-vein systems, there would appear to be genetic association of the andesite and the ore-forming solution. This postulate is strengthened by the fact that andesite is normally not a molybdenum accumulator in comparison with granite, aplite, or pegmatite. The latter rocks, represented in 15 samples from this core, do not contain detectable molybdenum.

The beryllium distribution is more severely truncated than the molybdenum distribution, but the 10 samples with detectable beryllium establish a highly significant difference in concentration among the lithologic entities. Four samples with detectable beryllium are from the felsic rocks, granite, aplite, or pegmatite. The remaining six are from vein and fault materials. A genetic connection between the felsic rocks and some of the early veins has been postulated on geologic evidence, and the chemical data supports this postulate.

The distribution of zirconium exhibits variation with lithology and relative enrichment in vein and fault materials in samples derived from this core (fig. 11). The lamprophyre and andesite dikes contain significantly more zirconium than the other rocks. The vein and fault materials contain somewhat more zirconium than the parent rocks, though the chance that this difference is not significant, 1 in 10, is considerably higher than for the differences discussed previously. Furthermore, it should be emphasized that (1) the amount of zirconium in all these rocks is abnormally low, and (2) the highest zirconium is in the dark-colored, fine-grained, dike rocks rather than in the felsic rocks. These relations suggest that the overall process throughout the interval represented by this core may be removal of zirconium. With such removal the relative enrichment of zirconium in the andesite reflects

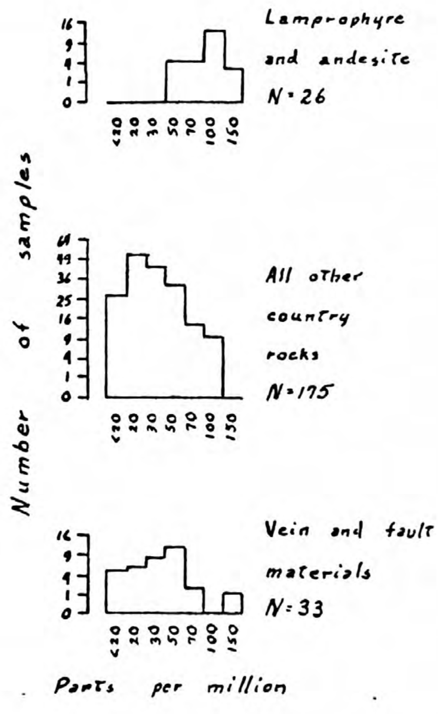

Figure 11
Distribution of zirconium among selected lithologic groups
DDH-1, Samrah

shielding in the dense, impermeable dike rocks, and the slight relative enrichment of zirconium in the vein and fault materials reflects lag concentration along the channel-ways for removal. This interpretation is more harmonious with the wider distribution seen in samples from the surface than the alternative suggestion of primary enrichment in andesite and introduction along the fault zones.

Barium, chromium, scandium, strontium, and titanium are relatively impoverished in vein and fault materials and exhibit a variation with lithology of the country rocks (figs. 12, 13, and 14). The effect of removal is most pronounced for barium and strontium where a test for significance of the difference between the distributions of the elements in vein and fault materials compared with the distributions in the country rocks (for practical purposes amphibolite) leads to values for chi square of 50 for barium and 37 for strontium. With chi square equal to 11 there is much less than 1 chance in 1000 that the distributions are not different. For strontium the effect of removal largely masks the variation due to lithology of the country rocks, though there appears to have been a slight increase in original strontium content in the order from aplite and pegmatite to granite and andesite to amphibolite, granodiorite, and lamprophyre. Barium exhibits its characteristic distribution, least abundant in the amphibolite, including the closely associated quartz diorite and aphanitic dark gray dikes, most abundant in the intermediate to felsic rocks, including the granodiorite, granite, lamprophyre, and andesite, and again less abundant in the extreme felsic derivatives aplite and pegmatite.

Chromium, scandium, and titanium are less abundant in the vein and fault materials than in the mafic and intermediate rocks that provide the vast bulk of the parent material in the fault zones so have apparently been removed from the system during alteration. As would be expected, the mafic and intermediate rocks are richer than the felsic rocks. Chromium and titanium are further enriched in the andesites and titanium is further enriched in the lamprophyres also.

The remaining elements exhibit significant variation with lithology and have usual concentrations in the fault systems. Lanthanum was detected in only four samples, but two of these samples are granite dikes. Cobalt, nickel, and vanadium

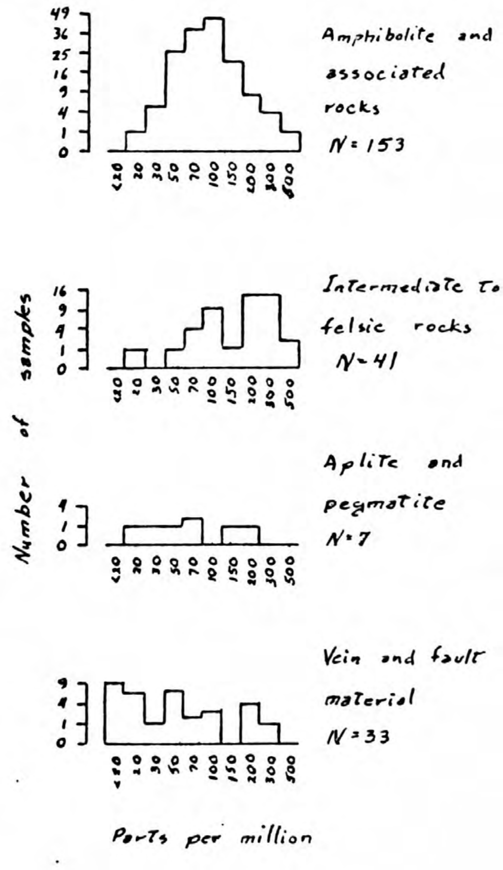

Figure 12
Distribution of barium among selected lithologic groups
DDH-1, Samrah

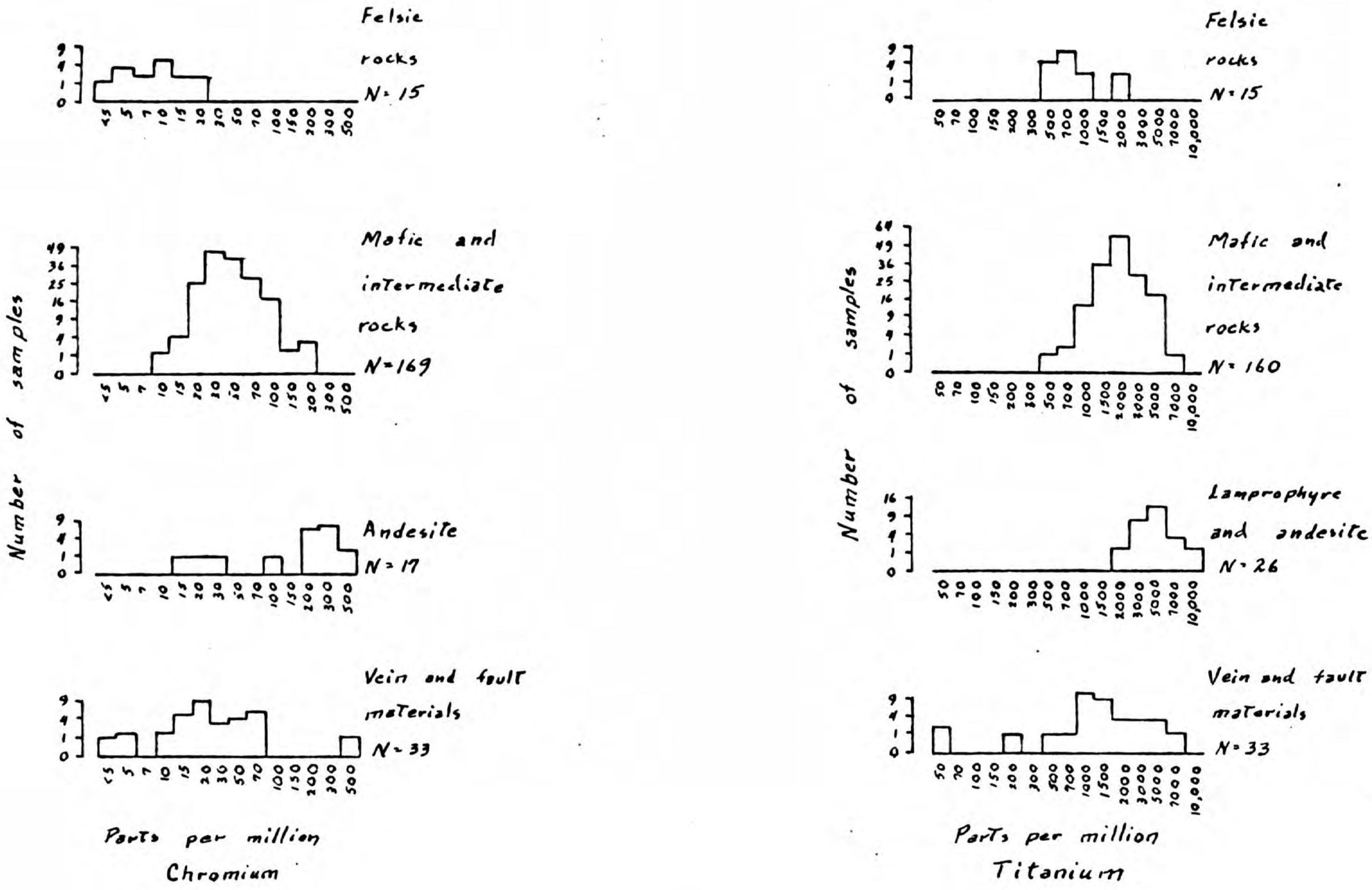

Figure 13

Distribution of chromium and titanium among selected lithologic groups DDH-1, Samrah

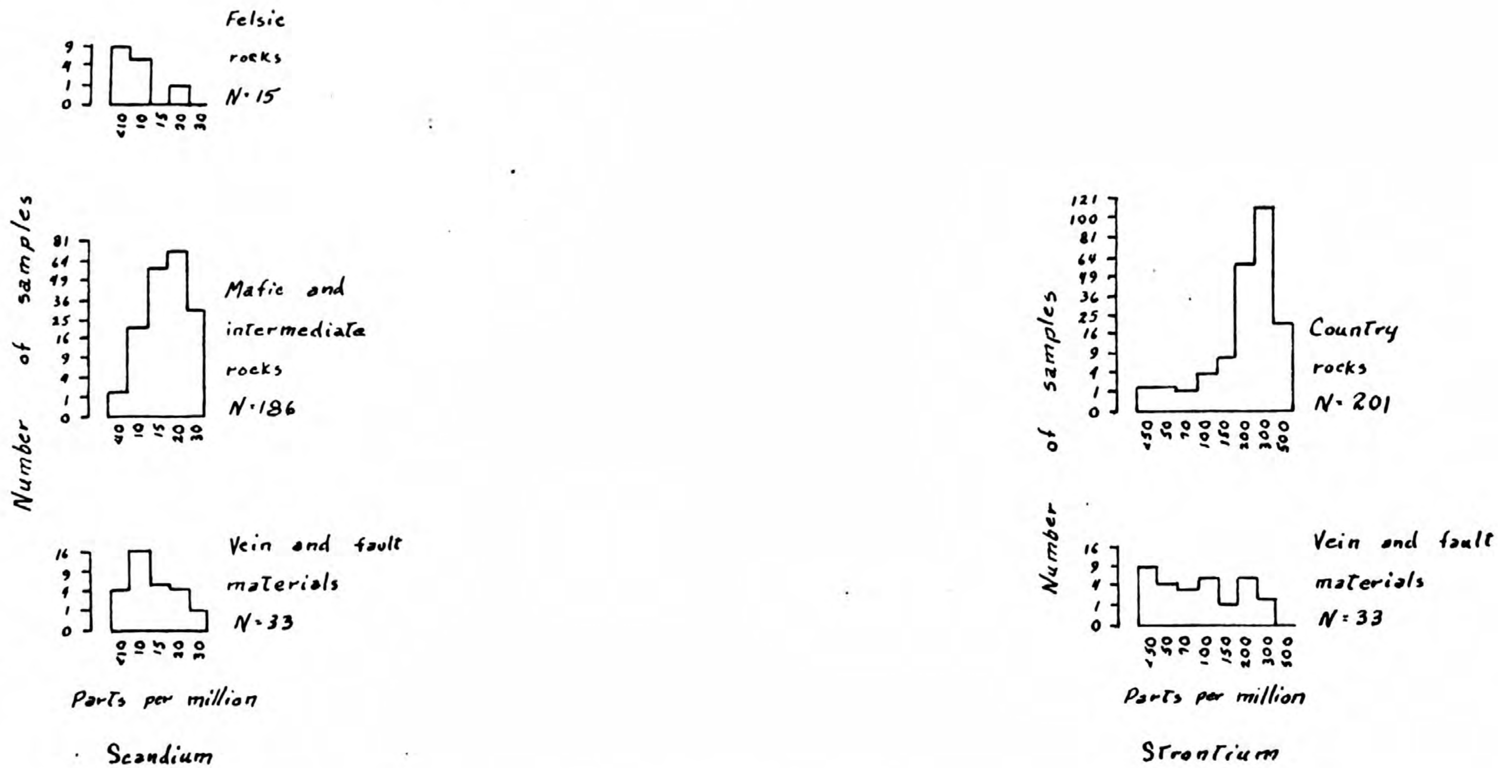

Figure 14

Distribution of scandium and strontium among selected lithologic groups

DDH-1, Samrah

are more abundant in the mafic and intermediate rocks than in the felsic rocks (fig. 15). Yttrium is more abundant in the lamprophyre and andesite dikes than in the other rocks.

Variations with lithology for the whole suite of elements exhibiting significant differences may be summarized as follows:

Concentration highest in:	Elements
felsic rocks	Be
intermediate rocks	Ba
lamprophyre and/or andesite	Cr, Mo, Ti, Y, Zr
mafic rocks	Co, Cu, Mn, Ni, Sc, V

The andesite and less commonly the lamprophyre, the two dark colored, late, dike rocks, are anomalous in this otherwise natural grouping. Their relative enrichment in mafic- and felsic-associated elements belies their apparent intermediate composition. Either they are odd rocks, or, as has been suggested, they are more resistant to alteration and removal of these elements.

Trace elements in selected minerals

Analyses of six handpicked mineral separates are presented in table 1. Because of the pronounced changes in matrix inherent in analyses of pure minerals, these figures are probably not as reliable as those presented elsewhere in this text, but they serve to verify associations of elements in the ore minerals.

Silver was detected in all of the mineral separates. The amounts, particularly in the galena, exceed the solubility of silver in the minerals, so evidently reflect intergrowth of a silver mineral with the primary mineral phase. The reasonably uniform distribution of copper through the minerals of the main vein probably also reflects intergrowth of chalcopyrite in minute particles. The galena is rich in antimony and the sphalerite is rich in cadmium and tin.

The two sphalerite samples from 477 feet are dark and light colored bands of a single, large, zoned crystal. The light colored band is richer in cadmium, copper, and lead than the dark band.

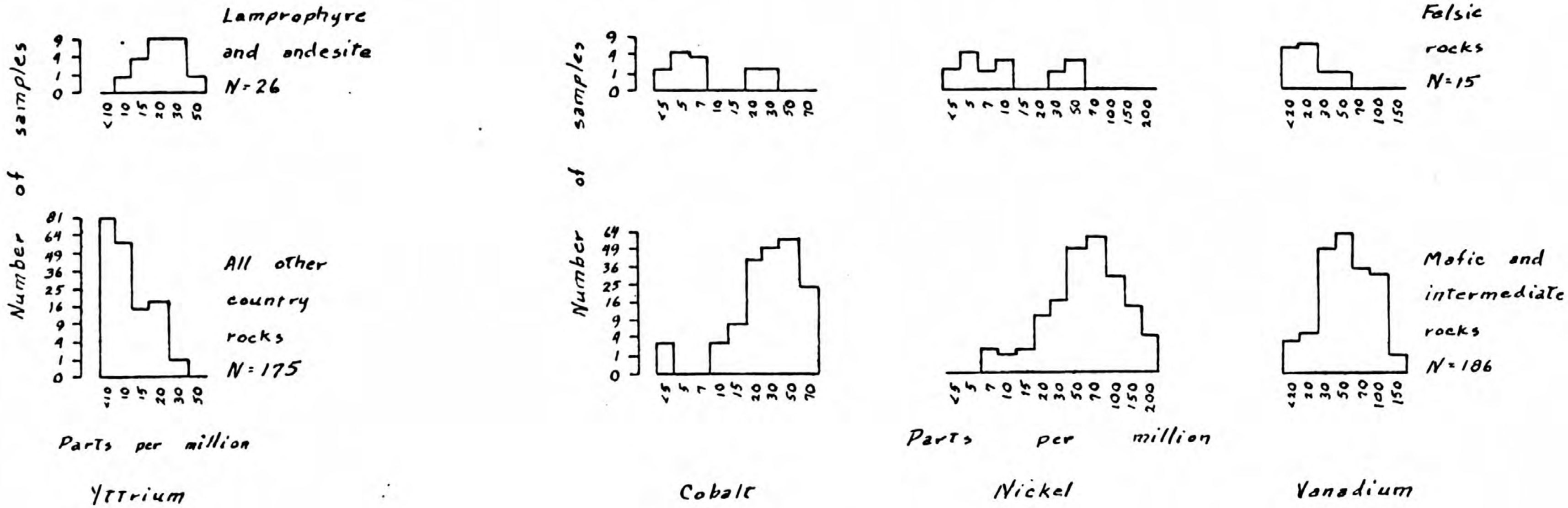

Figure 15

Distribution of yttrium, cobalt, nickel, and vanadium among selected lithologic groups DDH-1, Samrah

The hematite at 725 feet contains no detectable silver or lead and remarkably little copper or zinc. It is evidently not a product of the ore fluid. More likely it was produced during one of the earlier periods of dynamic metamorphism. The small amount of molybdenum is suggestive of an association with the pegmatite.

Table 1. Spectrographic analyses of selected, handpicked minerals from DDH-1, Samrah. Only those elements detected are shown; all values in parts per million (Analyst: C. E. Thompson)

Mineral	Galena	Sphalerite	Sphalerite Dark	Sphalerite Pale	Pyrite	Hematite
Feet below collar of hole	450	450	477	477	450	725
Ag	5,000	50	150	150	500	-
Cd	-	1,500	5,000	10,000	-	-
Co	-	-	-	-	-	100
Cr	-	-	-	-	-	15
Cu	100	500	70	150	200	10
Mn	-	-	-	-	-	1,500
Mo	-	-	-	-	-	3
Ni	-	-	-	-	-	200
Pb	>10,000	1,000	30	200	3,000	-
Sb	3,000	-	-	-	-	-
Sn	-	50	70	70	-	-
Ti	-	-	-	-	-	2,000
V	-	-	-	-	-	30
Zn	-	>10,000	>10,000	>10,000	-	100
Zr	-	-	-	-	-	30

Assay data for the main vein

The entire interval of the main vein, from 430 to 482 feet in the drill hole, has been assayed for gold, silver, copper, lead, and zinc in the laboratories of the Ministry of Petroleum and Mineral Resources in Jiddah. The results are presented in table 2 along with selected assays for manganese. Averages, weighted for the length of core sampled, are presented for the richest segment of the core, for the 15-foot interval from 444 to 459 feet, and for the entire vein. The results of these assays show that this is clearly a silver-lead-zinc deposit of considerable potential.

Splits of the three richest intervals have been assayed by Crismon and Nichols of Salt Lake City, Utah, to verify sampling and analytical precision. As would be expected, there is an inter-laboratory bias, particularly evident for gold, lead, and copper (table 3). The differences for silver undoubtedly reflect sampling error. Despite these differences, the agreement is generally excellent. The original assays may be accepted with a high degree of confidence. The single gross difference, the zinc assays for sample 29111, probably reflect a typographical error. As will be shown, the lower value of 3.45 percent zinc fits the general association of silver and zinc defined earlier somewhat better than the higher value does.

The assay data offer an opportunity to test the association of silver with zinc and lead by a more rigorous statistical method. The product moment correlation coefficient for the two associations has been computed for three groupings of the samples, as presented in table 4. Using all 16 samples as presented in table 2, the association of silver with lead is stronger than that with zinc; both are highly significant associations. Eliminating sample 29113, which is so rich that it overshadows all the other samples combined, the correlation of silver with zinc remains essentially unchanged while the correlation of silver with lead is no longer significant. The relatively low correlation of silver and zinc results largely from the reversal of highs between samples 29111 and 29113. As noted, the only questionable figure in the tabulation is the zinc value for 29111. Replacing

Table 2. Assay data for the main vein in DDH-1, Samrah

(Gold and silver assays by Sayyad Matoug Bahijri; copper, lead, and zinc by Jamal Sumbul; and manganese by Mohammed A. Fourati)

Sample No.	Interval represented (ft.)	Au (oz. per ton)	Ag	Pb (percent)	Zn	Cu	Mn
29169	1.2	0.04	1.12	0.05	1.95	Tr	0.51
170	4.2	nil	0.52	0.10	1.80	0.05	0.77
171	1.8	nil	13.72	4.00	3.00	0.10	0.62
172	2.0	nil	1.12	0.15	1.65	0.05	1.05
173	1.1	nil	1.24	0.10	1.60	Tr	1.17
174	3.4	nil	2.20	0.20	1.85	0.10	1.78
111	5.3	0.1	37.69	5.1	9.6	0.2	n.d.
112	4.9	Tr	4.00	2.85	2.9	Tr	n.d.
113	5.0	0.5	139.49	38.4	8.25	0.4	n.d.
175	4.8	Tr	0.72	0.05	1.30	Tr	0.62
176	3.9	nil	0.92	0.15	1.70	Tr	0.42
177	3.3	nil	0.84	0.10	1.00	0.10	1.77
178	3.8	nil	0.84	0.10	1.30	0.10	0.77
179	1.7	nil	1.12	0.10	1.15	0.10	0.97
180	0.9	0.2	42.62	0.20	3.50	0.30	0.64
181	4.3	nil	1.20	0.10	0.40	0.05	1.19
Weighted averages							
A) 15 feet near middle		0.2*	60.31	15.32	6.15	0.20*	-
B) Entire vein, 51-1/2 ft		Tr	19.66	4.73	2.87	0.10*	-

* Minimum figure, trace taken as zero.

Nil - Sought but none detected.

Tr - Detected but quantity insufficient to measure.

n.d. - Not determined.

Table 3. Interlaboratory comparison of assays for three samples from Samrah DDH-1

Element	Sample No.	Min.	C and N
Gold oz/ton	29111	0.1	0.04
	29112	Tr	Tr
	29113	0.5	0.34
Silver oz/ton	29111	37.69	42.75
	29112	4.00	2.80
	29113	139.49	120.05
Lead percent	29111	5.1	7.55
	29112	2.85	4.05
	29113	38.4	51.35
Zinc percent	29111	9.6	3.45
	29112	2.9	2.95
	29113	8.25	8.35
Copper percent	29111	0.2	0.40
	29112	Tr	0.10
	29113	0.4	1.00

Min. - Ministry of Petroleum and Mineral Resources Laboratory, Jiddah.

C and N. - Crismon and Nichols, assayers and chemists, Salt Lake City, Utah.

the zinc value of 9.6 percent with the referee value of 3.45 percent produces a correlation coefficient of zinc and silver equal to the best obtainable for silver and lead. From this we conclude that the probability is high that all three metals were travelling in a single solution and that the conditions of deposition of silver were generally more similar to those of zinc than to those of lead.

Table 4. Product moment correlation coefficient, r, for the association of silver with lead and zinc in the main vein in DDH-1, Samrah

	Ag vs Pb	Ag vs Zn
All 16 samples	0.91	0.74
Excluding sample 29113	0.50	0.73
All 16 samples, correcting 29111	-	0.92
Significant at $\alpha = 0.05$ with $r \geq 0.51$		
at $\alpha = 0.01$ with $r \geq 0.64$		

Recommendation

Samrah has now been shown to have high grade ore. The problems now are to determine quantity and economics. To this end, the recommendations of Bogue (1954) and Quinn (1964) should be followed. Drilling all of Quinn's holes in their original bearing, perpendicular to the main fault zone, will provide a measure of the frequency of high grade and intermediate grade ore. If this frequency is promising, then continued drilling and clearing of the ancient workings would be designed to block out ore zones.

References cited

Bogue, R. G., 1954, Reconnaissance of mineral deposits in a part of western Saudi Arabia: U. S. Geol. Survey, unpubl. rept. for Saudi Arabia Ministry of Finance and Natl. Economy, 50 p.

Quinn, H. A., 1964, Geology, silver mines, and pegmatites of Ad Dawadami and Halaban areas: Kingdom of Saudi Arabia, Ministry of Petroleum and Mineral Resources, Directorate General of Mineral Resources, Jiddah, unpubl. rept., 70 p.

Theobald, P. K., Jr., 1966, Geology of Samrah and vicinity, Kingdom of Saudi Arabia: U. S. Geol. Survey Saudi Arabian Mineral Exploration Tech. Letter 42, pp. 24.

Table 5. Geologic log of Samrah Diamond Drill Hole Number 1, Kingdom of Saudi Arabia. (Log by P. K. Theobald, Jr.)

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)			SAMPLE
11-6 to 12-0	83	--	Amphibolite and equigranular granite, oxidized	29033
12-0 to 14-5	70	--	Andesite, weathered, brown, generally aphanitic with a a few recognizable feldspar laths	29034
14-5 to 15-9	70	--	Amphibolite, granulated, generally fine grained. A few coarser pods are weathered. Interval includes irregular seams of andesite and a seam of biotite granite 1 cm thick.	29035
15-9 to 16-8	70	--	Biotite granite, pink, fine-grained	29036
16-8 to 17-6	70	--	Andesite, weathered, brown	29037
20-0 to 21-8	60	--	Andesite, weathered, brown	29038
21-8 to 22-6	60	--	Amphibolite, granulated, gray, weathered on fractures.	29039
22-6 to 25-2	67	--	Amphibolite, granulated with fine-grained rosettes of feldspar. Weathering slight.	29040
25-2 to 26-0	67	--	"Lamprophyre", gray, porphyritic. Dark gray aphanitic groundmass with poikilitic feldspar phenocrysts up to 1 cm diameter.	29041
26-0 to 26-11	61	--	"Lamprophyre", gray, somewhat weathered	29042

Table 5. cont'd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)			SAMPLE
26-11 to 30-4	61	--	Carbonate-sealed breccia. Fragments in upper part are "lamprophyre", in middle part mostly andesite, and in lower part fine-grained, mafic-rich granite(?). Some fragments of coarse-grained gneissic granite. Carbonate is coarsely crystalline. Some dark purplish brown single crystals, probably siderirte, merge with calcite	29043
30-4 to 32-0	61	--	Granodiorite, fine-grained with pegmatoid pockets, gray, weathered and altered. Alteration of feldspar to clay and biotite to chlorite and iron oxides.	29044
32-0 to 39-0	55	--	Granodiorite, gray, fine-grained, biotite-rich, altered as in interval above, cut by carbonate veinlets up to 5 mm thick	29045
39-0 to 44-8	112	--	Andesite, weathered to brown, aphanitic, locally with a few feldspar laths as phenocrysts up to 3 mm long. Fractured and laced by carbonate seams up to 5 mm thick.	29046
44-8 to 47-6	38	--	Andesite, weathered to brown, cut by 2 cm, vuggy, quartz-carbonate vein at 46 feet	29047
47-6 to 53-1	38	--	Granodiorite, biotite-rich fine-grained, altered and weathered.	29048
53-1 to 53-8	100	--	Granodiorite and granite. Pink fine-grained biotite granite with 2 inches of gray biotite-rich granodiorite above and below.	29049

Table 5. cont'd

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)		SAMPLE
53-8 to 60-1	58	-- Granodiorite, biotite-rich with some hornblende, fine-grained, gray. A few large inclusions of hornblende. Alteration slight in upper part, intense below 59 feet, mafic minerals to iron oxide. Black, lustrous, slickensided fractures near end of interval.	29050
60-1 to 62-0	78	-- Andesite, weathered to brown, three inch vein of brecciated granodiorite interleaved with carbonate at beginning of interval.	29051
62-0 to 65-0	78	-- Biotite granodiorite, some hornblende and some of biotite replaces hornblende, fine-grained, gray, altered. Carbonate veinlets up to 1 cm thick, some with secondary K-feldspar replacing wall rock.	29052
65-0 to 69-4	83	-- Hornblende-biotite-quartz diorite, relatively fresh. Biotite poikilitic and secondary after hornblende. Preceding granodiorite apparently produced by alteration from this rock.	29053
69-4 to 74-6	76	-- Composite of andesite dikes cutting quartz diorite, 69-4 to 69-8, and hornblende diorite, 71-8 to 72-9. Biotite present in diorites and joints smeared with manganese oxide and pyrite. Andesite dikes, 69-8 to 71-8 and 72-9 to 74-6, are dark gray, aphanitic, and weathered brown along open fractures.	29054

Table 5. cont'd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)			SAMPLE
74-6 to 75-11	98	--	Andesite, black, aphanitic	29055
75-11 to 78-5	98	--	Amphibolite, medium grained with abundant secondary biotite. Quartz vein at 77-4 is 3 cm thick, has feldspathized walls.	29056
78-5 to 82-5	97	--	Amphibolite, rich in feldspar and biotite. Quartz-feldspar vein at 81-3 is 2 cm thick.	29057
82-5 to 85-3	97	--	Andesite, aphanitic, dark gray, with occasional blobs of calcite and pyrite	29058
85-3 to 89-6	97	--	Amphibolite, biotite-rich, with occasional pods of pyrite 2-3 mm diameter	29059
89-6 to 94-5	100	--	Amphibolite, biotite-rich,with grains or small pockets of pyrite. Occasional slickensided fractures.	29060
94-5 to 98-5	94	--	Amphibolite, biotite-rich, with scattered, disseminated grains of pyrite. Occasional splays of epidote adjacent to a quartz-carbonate vein 2 cm thick at 95-8.	29061
98-5 to 102-4	100	--	Amphibolite, medium to coarse grained, with scattered grains of pyrite and clots of poikilitic biotite.	29062
102-4 to 106-3	100	--	Amphibolite, medium to coarse grained, with scattered grains of pyrite and clots of poikilitic biotite	29063

Table 5. cont'd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)		SAMPLE
106-3 to 109-10	107	-- Amphibolite, medium-grained, biotite abundant, with scattered grains of pyrite. Rock is unusually dark colored and probably contains some relict pyroxene. Cut by a few mylonite seams with associated secondary K-feldspar.	29064
109-10 to 113-11	96	-- Amphibolite, medium grained, biotite-rich, with scattered grains and halos of pyrite. Cut by a few mylonite seams and quartz veinlets with associated secondary K-feldspar.	29065
113-11 to 117-11	98	-- Amphibolite, medium-to fine-grained, biotite-rich with scattered grains of pyrite. Cut at 116-11 by a quartz seam 1 cm thick	29066
117-11 to 121-9	100	-- Amphibolite, medium- to coarse-grained with irregular fine-grained bands. Grains of pyrite fairly common. Feldspathic pods, some vuggy, are common, fine-grained bands are much less feldspathic. Cut by mylonite seams and quartz veinlets up to 5 mm thick.	29067
121-9 to 125-9	98	-- Amphibolite, fine- to coarse-grained, with disseminated fine grains of pyrite. Cut by mylonite seams, some vuggy or with a filling of quartz and carbonate a few mm thick. Coarse pyrite near mylonite, particularly where vuggy	29068

Table 5. contd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)		SAMPLE
125-9 to 129-6	91	-- Amphibolite, fine-to coarse-grained. Grain size reflects extent of alteration from fine-grained pyroxene-amphibole - labradorite rock toward an amphibole-biotite-sodici-plagioclase rock. Biotite and pyrite largely confined to coarser units. Cut by minor mylonite seams with associated secondary white feldspar.	29069
129-6 to 133-6	100	-- Amphibolite, fine-grained with a few irregular, coarse-grained seams rich in biotite. Pyrite largely confined to coarser pods. Sparse mylonite seams cut core at 60°.	29070
133-6 to 137-3	96	-- Amphibolite, fine- to coarse-grained. Textures are thoroughly intermixed with biotite and sparse pyrite in the coarser-grained rocks.	29071
137-3 to 137-8	100	-- Quartz vein system in amphibolite. A 2 and a 3 cm vein with numerous, smaller, interconnecting veinlets cut the core at 45 to 60 degrees. Chlorite or serpentine with mylonite lines vein walls, and abundant secondary K-feldspar replaces amphibolite.	29072
137-8 to 139-5	95	-- Amphibolite, medium-grained, with scarce very-fine-grained pyrite. Cut by numerous mylonite seams, some with quartz lining, up to 5 mm thick.	29073

Table 5 cont'd.

INTERVAL (Feet & Inches	CORE RECOVERY (Percent)		SAMPLE
139-5 to 143-5	100 --	Amphibolite merges into breccia at end of interval. Amphibolite is medium to coarse grained with scattered, fine grains of pyrite. Serpentine replaces plagioclase below 143 feet. Breccia, about 15 mm thick, is composed of 1 to 10 mm mineral grains. A few minor mylonite seams cut the amphibolite and quartz-lined mylonite seams cut the breccia.	29074
143-5 to 145-9	107 --	"Lamprophyre", generally aphanitic with rectangular phenocrysts of feldspar up to 5 mm on a side most common near the top of the interval. Upper contact is a fine grained breccia with parallel quartz seams that cut both the breccia and the dike. Lower contact, at end of interval, marked by inclusions of amphibolite in the dike. Thin mylonite seam crossing lower contact has attendant feldspathization only in the amphibolite. A zone of fine-grained breccia at 145-1 is in part parallel by a thin quartz seam. Epidote and carbonate along minor fractures.	29075
145-9 to 149-4	98 --	Amphibolite, medium- to coarse-grained, biotite-rich with sparse to locally abundant pyrite. Mafic is partially replaced by chlorite, and locally feldspathic near pockets of serpentine resembling irregular, filled vesicles. Core cut in the middle of the interval at 30 to 45 degrees by a few quartz-carbonate filled fractures up to 8 mm thick	29076

Table 5. cont'd.

INTERVAL	CORE RECOVERY (Percent)		SAMPLE
149-4 to 150-7	100 --	Pegmatite and granite, pink, biotite is mafic in granite. Local accumulations of pyrite and inclusions of mylonite(?) are common. Apparently a composite dike with a 2 cm vein of milky, vuggy, comb quartz at its core. Cut by numerous quartz-carbonate filled fractures up to 1 cm thick.	29077
150-7 to 153-5	97 --	Amphibolite, fine- to coarse-grained, biotite-rich, with sparse pyrite and some chloritization. At 152-1 a fine-grained, gray, granite dike 3 cm thick has fuzzy contacts with amphibolite. Quartz-carbonate seams up to 5 mm thick cut the core at 45 to 60 degrees.	29078
153-5 to 157-3	100 --	Amphibolite, medium-coarse-grained, biotite-rich, with sparse to locally abundant pyrite. Feldspathized along seams of shearing that cut core at 60 to 80 degrees and are filled by up to 2 mm of quartz and carbonate.	29079
157-3 to 161-3	96 --	Amphibolite, medium-to coarse-grained, with sparse pyrite, Cut, in order from oldest to youngest, by mylonite and mylonite breccia zones up to 2 cm thick, by quartz-feldspar veins, and by quartz-carbonate-filled fractures up to 5 mm thick, all at 45 to 60 degrees to the core. Biotite occurs within, and is particularly abundant adjacent to quartz-feldspar veins. Secondary K-feldspar is common adjacent to quartz-carbonate veins. Amphibole is commonly altered to chlorite, sometimes further altered to hematite.	29080

Table 5. cont'd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)		SAMPLE
161-3 to 162-3	100 --	Amphibolite, medium- to coarse grained, feldspar-rich. Amphibole is altered to biotite and chlorite. Core cut at 45 to 60 degrees by quartz seams up to 1 cm thick	29081
162-3 to 165-2	100 --	Porphyritic "lamprophyre" with nearly equidimensional feldspar phenocrysts up to 1 cm square in an aphanitic, black groundmass. Upper contact, at the beginning of the interval, is marked by two zones of granulated amphibolite, each about 1 cm thick and separated by 1 cm of "lamprophyre". Fine-grained breccia zones, fairly common in the dike rock, have irregular boundaries that do not give age relative to the dike. Secondary, pink K-feldspar is adjacent to quartz-carbonate-filled fractures up to 5 mm thick cutting both the dike and breccia zones.	29082
165-2 to 169-0	102 --	Porphyritic "lamprophyre". Breccia zones, noted in interval above, merge in upper part of interval to a general, faint breccia-like texture in the groundmass of the rock. The groundmass is coarser grained and phenocrysts are sparse in the lower part of the interval. Fractures cutting core at 45 to 75 degrees are marked by strongly slickensided mylonite seams and a filling up to 1 cm thick of quartz and carbonate.	29083

Table 5. cont'd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)		SAMPLE
169-0 to 172-10	102 --	"Lamprophyre", fine-grained. The few large grains of feldspar appear to be inclusions. One inclusion is amphibolite. Several fine-grained, granitic-textured, dark-colored dikes may be more felsic varieties of the "lamprophyre" because they merge with it. Core cut by some quartz-carbonate lined fractures.	29084
172-10 to 176-10	98 --	"Lamprophyre", generally fine-grained with a faint, coarse, breccia-like structure imparted by irregular, interlocking, feldspathic masses. Below a few fine-grained breccia masses near the middle of the interval, the groundmass is aphanitic with sparse, fine-grained feldspar phenocrysts. Secondary, pink, K-feldspar adjacent to a few epidote-lined and quartz-carbonate-filled fractures.	29085
176-10 to 180-9	100 --	"Lamprophyre" with a faint breccia-like structure imparted by interlocking masses of more feldspathic "lamprophyre" or fine-grained breccia. Numerous fractures up to 1 cm thick filled by quartz and pink K-feldspar are cut by quartz-carbonate veins. Most fractures cut core at about 60 degrees. K-feldspar replaces "lamprophyre" adjacent to some fractures.	29086

Table 5. cont'd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)		SAMPLE
180-9 to 182-8	100 --	"Lamprophyre", aphanitic groundmass with strongly oriented mafic and feldspar phenocrysts up to 5 mm long. Lower contact, at end of interval, marked by zone 8 cm thick of pink granular granite and pegmatite that includes angular fragments of "lamprophyre". Numerous fractures and quartz-carbonate filled seams cut all rock types.	29087
182-8 to 185-11	90 --	Amphibolite, medium- to coarse-grained, biotite-rich with sparse pyrite. A few slickensided fractures are filled by quartz and feldspar or quartz and carbonate	29088
185-11 to 189-11	92 --	Chaotic mixture of mylonite veins, andesite, and amphibolite. Breccia-mylonite-quartz carbonate vein system rich in pink K-feldspar extends to 186-5. Fine-grained, tabular feldspar phenocrysts, commonly with a strong flow orientation, in an aphanitic, dark gray groundmass constitute a rock presumed to be andesite which alternates with granulated amphibolite from 186-5 to 189-6. From 189-6 to 189-11 this mixture is serpentinized. Numerous fractures, commonly slickensided and with quartz-carbonate or quartzpink-K-feldspar filling cut the core at 30 to 45 degrees. Iron oxides coat one fracture near the end of the interval.	29089

Table 5. cont'd.

INTERVAL (Feet & Inches	CORE RECOVERY (Percent)		SAMPLE
189-11 to 191-2	67 --	Composite vein system. Mylonite and breccia partially replaced by pyrite with some sphalerite forms vein walls, 2 cm at top and 8 cm at lower contact. The core is later, apparently barren, quartz with scattered inclusions of mylonite.	29090
191-2 to 195-5	100 --	Andesite with strong flow banding and admixed, granulated, pink granodiorite. Interlayering of andesite and granodiorite approaches a migmatitic structure. Beginning of interval is mylonitized, and end of interval is marked by the pegmatized lower contact zone of the dike containing sparse pyrite. Numerous quartz-carbonate filled fractures, some with iron-oxide coatings, cut the core at 45 to 60 degrees.	29091
195-5 to 201-1	97 --	Granodiorite, gneissic, pink near fractures, otherwise gray. Coarse-grained granitic texture with biotite, minor hornblende and abundant chlorite (after hornblende?). Where least altered, plagioclase is dark colored resembling labradorite, and quartz is sparse or absent. This may be a potassium-enriched amphibolite. Core cut at 45 to 90 degrees by quartz-carbonate and quartz-feldspar veins up to 1 cm thick and by numerous, minor, slickensided mylonite seams. Abundant serpentine at end of interval.	29092

Table 5. cont'd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)		SAMPLE
201-1 to 202-0	100 --	Complex vein zone. Serpentine for 5 cm at beginning of interval and serpentinized mylonite for 8 cm at end of interval separated by quartz-K-feldspar vein cutting core at about 30 degrees that includes fragments of serpentinized fine-grained breccia of mylonite. Quartz-feldspar vein is composite and younger than serpentine. Some pyrite replaces mylonite	29093
202-0 to 203-6	100 --	Granodiorite, coarse-grained, partially serpentinized. Cut by minor quartz-carbonate sealed fractures. Sparse pyrite and sphalerite(?)	29094
203-6 to 205-1	100 --	Complex vein zone. In sequence, serpentinized granodiorite merges into mylonite, brecciated mylonite, quartz-carbonate sealed breccia, brecciated mylonite, and into andesite at end of interval. Pyrite abundant replacing lower brecciated mylonite.	29095
205-1 to 209-5	83 --	Andesite with admixed, granulated granodiorite. Blocky mixture at beginning of interval takes on a migmatitic appearance near the middle of the interval where the andesite has a strong flow structure defined by alignment of mafic phenocrysts. Pyrite is locally abundant. Several brecciated zones cut both andesite and granodiorite. Numerous fractures, usually lined by quartz and carbonate, culminate in a 3 cm vein that cuts core at 45 degrees.	29096

Table 5. cont'd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)		SAMPLE
209-5 to 214-5	100 --	Andesite, fine-grained, with a few interleaved masses of granulated, pink granite. Numerous fractures, many with quartz-carbonate filling up to 1 cm thick and some with pyrite and hematite, cut core at 30 to 45 degrees.	29097
214-5 to 218-5	77 --	Amphibolite, contorted and altered between andesite dikes with sparse pyrite in least altered phases. Andesite contact at beginning of interval and in last 8 cm of interval. Serpentine and a 5 mm hematite veinlet at contact with upper andesite. Mylonite and quartz-carbonate veins with considerable pyrite mark contact with lower andesite. Serpentinization 216 to 217 feet is adjacent to quartz-carbonate veins up to 1 cm thick cutting core at 20 degrees.	29098
218-5 to 221-11	98 --	Amphibolite, somewhat altered, with sparse pyrite, cut by numerous mylonite zones. Composite quartz-carbonate vein at 20 degrees to core near end of interval is 2 cm thick and flanked by serpentine.	29099
221-11 to 225-11	98 --	Amphibolite, with sparse pyrite, mildly altered, feldspathized adjacent to numerous quartz-carbonate veinlets up to 1.5 cm thick.	29100
225-11 to 229-9	102 --	Amphibolite, coarse-grained, biotite-rich, feldspathic, with sparse pyrite remote from veins. A few composite mylonite-quartz-carbonate veins, up to 1 cm thick cut core at about 20 degrees.	29101

Table 5. cont'd.

INTERVAL (Feet & Inches	CORE RECOVERY (Percent)		SAMPLE
229-9 to 233-9	94 --	Amphibolite, biotite-rich with sparse pyrite. Discontinuous, healed fractures marked by coarser-grained, more feldspathic, somewhat serpentinized amphibolite. Some mylonite seams contain a fibrous amphibole(?), possibly asbestos.	29102
233-9 to 237-9	100 --	Amphibolite, biotite-rich, with sparse pyrite. Some of biotite is bleached. Quartz-carbonate veinlets up to 5 mm thick, at 45 to 60 degrees to the core, apparently follow earlier feldspathized fractures.	29103
237-9 to 241-7	100 --	Amphibolite, medium-to coarse-grained, with sparse pyrite. Scattered feldspathic zones apparently follow old healed fractures.	29104
241-7 to 245-7	98 --	Amphibolite, medium- to coarse-grained. Rock is more feldspathic adjacent to healed fractures and adjacent to a quartz-carbonate veinlet 5 mm thick at 242-9.	29105
245-7 to 249-4	100 --	Amphibolite, medium-grained. Sealed fractures are accompanied by feldspathization and some are coated by mylonite.	29106
249-4 to 253-4	98 --	Amphibolite, medium-to coarse-grained, biotite-rich locally feldspathic. Rehealed fractures are common.	29107

Table 5. cont'd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)		SAMPLE
253-4 to 257-4	98 --	Amphibolite, fine- to coarse-grained, biotite-rich, feldspathic, with sparse pyrite. Gradational contact at 256-8 into fine-grained, apparently granulated amphibolite. Last 2 cm of interval is gneissic biotite granodiorite. Sparse mylonite seams up to 1 cm thick.	29108
257-4 to 257-9	100 --	Mylonite with a few later fractures and irregular, discontinuous quartz-carbonate seams	29109
257-9 to 261-4	93 --	Amphibolite, fine- to coarse-grained, biotite-rich, with sparse pyrite. Fine-grained apparently granulated amphibolite to 158-10 is nearly a mylonite. Coarse-grained, recrystallized amphibolite is adjacent to a seam of quartz and carbonate 5 mm thick. Local feldspathization follows sealed fractures.	29110
261-4 to 265-3	100 --	Amphibolite, feldspathic, with sparse pyrite. Texture and composition varies systematically. Feldspathic amphibolite grades into a zone of pink K-feldspar at 262-8 on a contact with medium- to fine-grained amphibolite containing abundant inclusions of fine-grained gabbro and coarse-grained amphibolite. With depth the grain size increases again to coarse-grained, feldspathic amphibolite at end of interval. Scattered quartz-carbonate veinlets up to 15 mm thick, at 45 to 60 degrees to the core, follow mildly altered, older shear zones. Some fractures are coated by pyrite grains 1 to 3 mm in diameter.	29114

Table 5. cont'd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)		SAMPLE
265-3 to 269-2	100 --	Amphibolite, medium- to fine-grained, with abundant coarse-grained pockets, mafic clots, and sparse pyrite. Faulted and apparently brecciated zone at 269-1 marks contact with andesite. Frequent mylonitic seams filled by up to 2 cm of quartz and carbonate and bordered by up to 5 cm of K-feldspathization producing a pink hornblende granite.	29115
269-2 to 270-10	95 --	Amphibolite, fine-grained, granulated, with relict coarse-grained pods and sparse pyrite. Quartz-carbonate veinlet 1 cm thick, at 30 degrees to the core at 270-8 is bordered by pink hornblende granite of secondary origin and marks the contact with andesite.	29116
270-10 to 273-10	103 --	Andesite with sparse pyrite, aphanitic at beginning of interval, coarser grained below 272-5 with trachytic texture imparted by 1 to 3 mm feldspar phenocrysts. Mild shearing at beginning of interval increases in intensity below 272-5 to mild brecciation at end of interval. Older mylonite seams offset by shearing.	29117
273-10 to 274-11	100 --	Vein of brecciated andesite filled by quartz and carbonate. Rock is about 50 percent breccia fragments. Major fracture pattern is at 45 degrees to the core.	29118
374-11 to 277-6	84 --	Andesite, brecciated, porphyritic, with sparse blobs of pyrite. Lower part of interval finer-grained, sheared, aphanitic andesite cut by quartz-carbonate seams.	29119

Table 5. cont'd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)		SAMPLE
277-6 to 282-1	91	-- Amphibolite, generally medium- to coarse-grained but granulated and fine grained at beginning of interval. Local feldspathization follows sealed fractures. Some K-feldspar occurs at end of interval.	29120
282-1 to 282-9	100	-- Vein system. A series of quartz veins occupies about 8 cm in the middle of the interval in silicified and serpentinized amphibolite with abundant pink K-feldspar. A soft greenish mineral is presumably fluorite.	29121
282-9 to 285-9	100	-- Amphibolite. A few quartz carbonate veinlets at 45 to 90 degrees to the core in the early part of the interval are accompanied by secondary K-feldspar. Local feldspathization along older sealed fractures.	29122
285-9 to 289-8	100	-- Amphibolite, medium- to coarse-grained, feldspathized along old healed fractures.	29123
289-8 to 293-8	98	-- Amphibolite, medium- to coarse-grained, biotite-rich, commonly feldspathized and mildly serpentinized. Common quartz- and carbonate-filled fractures up to 2 cm thick cut the core at 45 to 80 degrees. Some pink K-feldspar occurs between larger veins.	29124
293-8 to 298-2	83	-- Amphibolite, medium- to coarse-grained, sheared, feldspathized, with specks of hematite. Grades into graulated amphibolite at 295-10. Shears are accompanied by feldspathization in coarse-grained amphibolite.	29125

Table 5. cont'd.

INTERVAL (Feet & Inches)	CORE RECOVERY (percent)		SAMPLE
298-2 to 301-10	98 --	Amphibolite, fine- to coarse-grained, feldspathized. Most of the secondary feldspar is along sealed fractures. Cut by a few quartz-carbonate veinlets up to 5 mm thick.	29126
301-10 to 305-10	98 --	Amphibolite, medium- to coarse grained, with large labradorite crystals up to 3 cm long and sparse pyrite. Numerous mylonitic zones up to 3 mm thick cut the core at 30 degrees. White feldspar is along sealed fractures.	29127
305-10 to 309-6	100 --	Amphibolite, fine- to coarse-grained, commonly granulated. Granulation increases with depth. Mylonite seams are common, some with quartz-carbonate filling up to 5 mm thick that cuts core at 30 to 75 degrees. Feldspathization is common adjacent to quartz-carbonate seams or along old sealed fractures.	29128
309-6 to 311-0	100 --	Amphibolite, fine- to coarse-grained, with alteration increasing in intensity with depth. Large, poikilitic biotite flakes replacing hornblende give way to hematite-coated sericite and to serpentine at end of interval. Mylonite seams up to 5 mm thick may have quartz-carbonate filling up to 1 cm thick.	29129
311-0 to 313-8	88 --	Breccia composed of large, pink K-feldspar grains with interstititaial mylonite cut by a second generation of mylonite with quartz-carbonate veins up to 2 cm thick at 10 to 30 degrees to the core.	29130

Table 5. cont'd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)		SAMPLE
313-8 to 317-10	92	-- Amphibolite, granulated, mildly serpentinized, cut by prominent, feldspathized mylonite seams at 313-8 to 314-0 and 315-8 to 316-11. Younger mylonite seams with up to 1 cm filling of quartz and carbonate cut core at 30 to 70 degrees.	29131
317-10 to 321-11	96	-- Breccia of granulated and feldspathized amphibolite re-broken to a chaotic mesh of mylonite seams with miscellaneous mineral and rock fragments.	29132
321-11 to 324-9	82	-- Breccia, as in interval above.	29133
324-9 to 330-0	102	-- Amphibolite, granulated, feldspathized, silicified with sparse 2 to 4 mm grains of pyrite.	29134
330-0 to 334-0	100	-- Amphibolite, fine-grained, granulated, locally feldspathized, partially serpentinized, and cut by minor quartz-carbonate seams.	29135
334-0 to 338-1	94	-- Amphibolite, granulated, feldspathized, cut by a few mylonite seams with filling of quartz and carbonate up to 1 cm thick.	29136
338-1 to 342-1	96	-- Amphibolite, granulated in lower part of interval, mildly serpentinized, with sparse pyrite. Mylonite seams, some with filling of quartz and carbonate, are up to 2 cm thick and cut core at 45 to 80 degrees. Secondary feldspar is adjacent to quartz-carbonate veinlets and older, sealed, irregular fractures.	29137

Table 5. cont'd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)		SAMPLE
342-1 to 346-1	98 --	Amphibolite, granulated serpentinized below quartz-carbonate veinlet 1 cm thick at 345-8. Secondary feldspar is not abundant, has pink hue at end of interval. Core is cut by thin mylonite seams.	29138
346-1 to 350-0	100 --	Amphibolite, granulated, mildly serpentinized, with sparse pyrite. Core laced by old mylonite seams cut by quartz-feldspar veins up to 3 cm thick which are cut by granular, quartz-carbonate veins up to 2 cm thick. Veins cut core at 30 to 80 degrees. Pink K-feldspar is common adjacent to larger or zones of more numerous fractures.	29139
350-0 to 351-9	95 --	Amphibolite, partially granulated. Core is cut at 60 to 80 degrees by mylonite seams some with quartz-carbonate filling up to 3 cm thick. Minor, local, secondary feldspar is pink adjacent to complex mylonite zones.	29140
351-9 to 355-1	100 --	Reconstituted amphibolite. Composition ranges from granulated amphibolite with numerous mylonite seams to a feldspathized or silicified relic of amphibolite. At beginning of interval, irregular pods of carbonate fill interstices of brecciated amphibolite. Quartz-carbonate and quartz-feldspar veins up to 2 cm thick cut core at 45 to 80 degrees. Pink K-feldspar adjacent to veins locally converts rock to hornblende granite.	29141

Table 5. cont'd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)		SAMPLE
355-1 to 357-10	100	-- Amphibolite, granulated then silicified, then feldspathized. Most of feldspathization is along irregular sealed fractures. Core is cut by a few mylonite seams, some with minor quartz-carbonate filling.	29142
357-10 to 361-8	98	-- Amphibolite, granulated, silicified, feldspathized, with sparse pyrite. Most feldspathization is along old sealed fractures. Core is cut by a few slickensided fractures and a few quartz-carbonate seams.	29143
361-8 to 365-7	100	-- Amphibolite, granulated, silicified, locally feldspathized, mildly serpentinized, with sparse pyrite, and a few irregular, segmented mylonite seams.	29144
365-7 to 369-6	100	-- Amphibolite, granulated, locally feldspathized, mildly serpentinized, with sparse pyrite and a few quartz-carbonate seams.	29145
369-6 to 372-3	100	-- Amphibolite, granulated, locally feldspathized, mildly serpentinized, cut by a few quartz-carbonate seams. Pyrite occurs in irregular masses up to 5 mm diameter.	29146
372-3 to 372-7	100	-- Biotite-granite dike, fine-grained, white, nearly perpendicular to core.	29147
372-7 to 373-6	100	-- Amphibolite, feldspathic, biotite-rich, medium-grained, mildly serpentinized, with smears of pyrite on minor fractures.	29148

Table 5. Cont'd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)		SAMPLE
373-6 to 377-6	98 --	Amphibolite with sparse pyrite grades downward from medium-grained and biotite-rich to granulated, feldspathized, and locally silicified. Core cut at 374-8 by a dike of fine-grained, biotite granite 2 to 3 cm thick and by a few quartz-carbonate seams.	29149
377-6 to 381-5	98 --	Amphibolite, granulated, locally feldspathized. Core is cut by a 2 cm, fine-grained, biotite-granite dike at 380-5 and by some quartz-carbonate seams.	29150
381-5 to 383-3	100 --	Biotite aplite, pink, fine-grained, with 5 to 10 cm of pegmatite on the upper contact and 10 cm of tourmaline-rich quartz on the lower contact. Dike cuts the core at 60 degrees and is cut by a few hematite-and serpentine-coated fractures.	29151
383-3 to 385-5	100 --	Amphibolite, granulated, feldspathized, mildly serpentinized. Core is cut at 20 degrees by a red, serpentine-rich, K-feldspar seam 1 cm thick and by sparse quartz-carbonate seams.	29152
385-5 to 389-5	100 --	Amphibolite, granulated and feldspathized with sparse pyrite, locally merges into masses 5 cm thick of coarse-grained, biotite-hornblende granodiorite. Core is cut by a few quartz-carbonate or pink quartz-feldspar seams up to 5 mm thick.	29153

Table 5. cont'd.

INTERVAL (Feet & Inches	CORE RECOVERY (Percent)		SAMPLE
389-5 to 393-2	100 --	Biotite-muscovite granite, pink fine-grained, aplitic. The upper contact is marked by 15 cm of pegmatite. Color is due to hematite on fractures.	29154
393-2 to 396-3	97 --	Biotite-muscovite granite, pink, aplitic. The lower contact is 15 cm of pegmatite. Sparse serpentine occurs near quartz-carbonate seams.	29155
396-3 to 399-2	92 --	Amphibolite, granulated, locally feldspathized, cut by minor quartz-carbonate seams. The feldspar is pink.	29156
399-2 to 401-0	68 --	Mylonite, serpentinized, with sparse pyrite. Quartz-carbonate seams up to 1 cm thick cut the core at 45 degrees.	29157
401-0 to 401-9	100 --	Biotite-hornblende granodiorite, serpentinized, coarse grained, with locally abundant pyrite. Core is cut by discontinuous mylonite seams, some with a thin quartz-carbonate filling.	29158
401-9 to 404-1	100 --	Cataclasite, serpentinized, grades downward into pink K-feldspar pegmatite by 402-9. Numerous quartz and quartz-carbonate veinlets up to 1 cm thick cut the core at 45 to 75 degrees.	29159
404-1 to 408-3	72 --	Mylonite, serpentinized, and partially replaced by pink K-feldspar. Numerous quartz-carbonate seams up to 1 cm thick cut core at 60 degrees.	29160
408-3 to 410-11	106 --	Mylonite, serpentinized with sparse pyrite. Numerous quartz and quartz-carbonate veins up to 2 cm thick cut the core at 45 to 90 degrees.	29161

Table 5. contd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)		SAMPLE
410-11 to 414-10	100 --	Altered amphibolite, serpentinized, locally K-feldspathized with relict labradorite laths. Quartz-feldspar and quartz-carbonate seams cut core at 10 to 60 degrees.	29162
414-10 to 418-8	100 --	Amphibolite grades into mylonite at 418-0. Amphibolite is serpentinized granulated, and partially K-feldspathized with sparse pyrite. Quartz-carbonate seams cut core at 45 to 60 degrees.	29163
418-8 to 420-1	94 --	Mylonite replaced by serpentine and K-feldspar. Fracture cleavage is at 45 degrees to core. Quartz-carbonate seams cut core at 30 to 75 degrees.	29164
420-1 to 422-7	100 --	Amphibolite, granulated, partially serpentinized, locally replaced by pink K-feldspar, with sparse pyrite, and numerous minor mylonite and quartz-carbonate lined seams.	29165
422-7 to 426-5	98 --	Amphibolite, granulated, partially serpentinized, locally replaced by pink K-feldspar, with sparse pyrite. Quartz-carbonate veins up to 1 cm thick cut core at 30 to 45 degrees.	29166
426-5 to 429-5	95 --	Amphibolite, granulated, partially serpentinized, partially replaced by K-feldspar, with sparse pyrite. Alteration increases with depth. Mylonite and quartz-carbonate seams cut core at 60 to 90 degrees, increase in number with depth.	29167

Table 5. cont'd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)		SAMPLE
429-5 to 430-5	100 --	Cataclasite grades into mylonite at 429-11. Both rock types are serpentinized. Numerous quartz-carbonate stringers up to 15 mm thick cut core at 60 to 90 degrees	29168
430-5 to 431-7	100 --	Mylonite, partially serpentinized, laced by later mylonite and quartz-carbonate seams cutting core at 30 to 60 degrees.	29169
431-7 to 435-9	82 --	Andesite, brownish-gray, aphanitic. A few mylonite or quartz-carbonate seams cut core at about 45 degrees.	29170
435-9 to 437-6	100 --	Breccia of quartz, andesite, and mylonite fragments in a matrix of mylonite, quartz and carbonate, and sulfides. Fine-grained aggregates of galena and sphalerite form veins up to 3 cm thick cutting core at about 60 degrees at 436-11 and 437-6. Pyrite abundant replacing mylonite in footwall of vein at 436-11.	29171
437-6 to 439-6	96 --	Mylonite, serpentinized, cut by numerous quartz-carbonate seams and a few seams of sphalerite or pyrite. A light-tan colored mineral, probably sphalerite, partially replaces mylonite.	29172
439-6 to 440-7	93 --	Mylonite, serpentinized, cut by two quartz veins. Quartz, in zoned crystals up to 3 cm diameter, appears barren but includes mylonite fragments partially replaced by sphalerite(?) and pyrite.	29173

Table 5. cont'd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)		SAMPLE
440-7 to 444-0	88	-- Mylonite partially replaced by sphalerite in pale-cream-colored masses up to 2 cm diameter and dark-colored pockets. Seams of quartz and carbonate, pyrite, and galena cut core at about 45 degrees.	29174
444-0 to 449-4	85	-- Breccia, serpentinized, extensively mineralized. Most fragments are mylonite in a cement of irregular quartz-carbonate veins. Sphaerite in large zoned and partially crushed crystals is particularly abundant at 444-7 to 445-1, 446-5 to 446-10, and 447-0. Galena in aggregates of large, curved, platy crystals form veins at 444-5 to 444-6, 445-0 to 445-2, and 449-2 to 449-4 that are nearly perpendicular to the core and cut sphalerite. Quartz veins at 447-10 to 448-1 and 449-0 to 449-1, composed of large zoned crystals apparently free from mineralization, are later than sulfides.	29111
449-4 to 454-3	90	-- Breccia, serpentinized, extensively mineralized. Most fragments are mylonite cemented by irregular veinlets of quartz and carbonate or by veinlets of pale-colored serpentine younger than the quartz and carbonate. Some pale-colored sphalerite replaces breccia and fills the core of a quartz vein. Dark colored sphalerite replaces the breccia fragments at the end of the interval. One mass of light-colored, coarse-grained sphalerite at 451-0 to 451-4 is nearly perpendicular to the core. Galena is not abundant exept for a vein of granular, platy crystals at 449-4 to 449-5.	29112

Table 5. cont'd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)		SAMPLE
454-3 to 459-3	95	-- Breccia, serpentinized and largely replaced by coarse-grained galena with subordinate sphalerite and pyrite. Quartz vein 456-4 to 456-7 is relatively free of mineralization, apparently cuts sulfides. Most of pyrite is marginal to the quartz vein. Sphalerite is generally dark-colored, zoned, large crystals in the upper part of the interval is disrupted by galena. Galena is in curved, platy grains up to 2 cm across in the upper part of the interval, and is granulated with a 2 mm average grain size below the quartz vein.	29113
459-3 to 464-0	58	-- Mixture of serpentinized and K-feldspathized rocks including mylonite, granulated amphibolite, and andesite. Sparse pyrite. Core is cut at 45 to 90 degrees by numerous mylonite and quartz-carbonate seams.	29175
464-0 to 467-11	94	-- Serpentine and pink K-feldspar, medium- to coarse-grained, with sparse pyrite, and of uncertain parentage. Core is cut at 30 to 70 degrees by numerous quartz-carbonate seams up to 1 cm thick.	29176
467-11 to 471-2	93	-- Mylonite, partially to completely serpentinized, with local replacement by light-colored sphalerite(?). Core cut at 0 to 60 degrees by numerous quartz-carbonate seams.	29177
471-2 to 474-11	100	-- Andesite dike, brecciated, with abundant pyrite. Core cut at an average of 30 to 60 degrees by an interlacing mesh of mylonite and quartz-carbonate seams up to 3 cm thick.	29178

Table 5. cont'd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)		SAMPLE
474-11 to 476-7	95 --	Breccia, silicified, with local pockets of pyrite, galena, or sphalerite up to 1 cm diameter. Core is cut by irregular seams of mylonite, quartz, and carbonate up to 1 cm thick.	29179
476-7 to 477-6	100 --	Breccia largely replaced by pyrite and zoned crystals of sphalerite up to 2 cm diameter. Rock is re-brecciated and laced by quartz-carbonate seams in the lower half of the interval.	29180
477-6 to 481-10	96 --	Breccia, fragments mostly mylonite, silicified and serpentinized with partial replacement of lower 15 cm of the interval by K-feldspar, with local blobs of pyrite up to 1 cm diameter and sparse sphalerite and galena. Core cut by quartz-carbonate seams, some of which are pinched and distorted.	29181
481-10 to 484-4	100 --	Amphibolite, granulated, partially silicified and serpentinized. Core cut by numerous, minor, quartz-carbonate seams, some with pink K-feldspar on borders.	29182
484-4 to 488-3	100 --	Amphibolite, mildly serpentinized, locally feldspathized along old healed fractures, with sparse pyrite.	29183
488-3 to 492-1	98 --	Amphibolite, mildly chloritized, locally feldspathic adjacent to sealed fractures. Pyrite is common in grains up to 5 mm diameter.	29184

Table 5. cont'd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)		SAMPLE
492-1 to 496-1	98 --	Amphibolite, mildly chloritized, locally feldspathized along sealed fractures, with pyrite in grains up to 15 mm diameter most common in granulated seams. Quartz vein 2 cm thick cutting core at 30 degrees near 494-3 has feldspathized margins with sparse sphalerite.	29185
496-1 to 500-0	100 --	Amphibolite, mildly chloritized, locally feldspathized along sealed fractures. An irregular, fine-grained dike of biotite-aplite 1 to 2 cm thick cuts the core at 30 degrees near 497-7	29186
500-0 to 504-0	98 --	Amphibolite, granulated, locally feldspathized, cut by sparse quartz-feldspar seams. Quartz vein 2 cm thick cuts core at 45 degrees near 501-1. Dike of gneissic biotite granodiorite 3 cm thick cuts core at 30 degrees near 501-4.	29187
504-0 to 507-11	98 --	Amphibolite, granulated, locally feldspathized along sealed fractures, with sparse pyrite. Core cut by a few mylonite seams.	29188
507-11 to 511-10	100 --	Amphibolite, granulated, with mild chloritization, local mild serpentinization, local feldspathization along sealed fractures, and sparse pyrite. Last 10 cm of interval is feldspathic. Core cut by a few mylonite seams.	29189
511-10 to 515-10	98 --	Amphibolite, granulated, partially feldspathized, with locally abundant pyrite. Irregular, healed fractures are common. A few through-going mylonite seams have a filling of quartz and carbonate.	29190

Table 5. cont'd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)		SAMPLE
515-10 to 518-4	100	-- Amphibolite, granulated, with sparse pyrite, cut by a few mylonite and quartz-carbonate seams.	29191
518-4 to 520-5	100	-- Biotite granite dike, fine-grained, cutting core at 80 degrees. Each border is marked by about 10 cm of biotite peg-matite.	29192
520-5 to 523-8	100	-- Amphibolite, locally feldspathized along sealed fractures, with sparse very-fine-grained pyrite.	29193
523-8 to 527-7	100	-- Amphibolite, locally feldspa-thized along sealed fractures, with sparse pyrite. Core is cut at 30 to 45 degrees by mylonite seams with lining of quartz and carbonate.	29194
527-7 to 528-10	100	-- Amphibolite, granulated, felds-pathized, with sparse pyrite and sparse quartz-carbonate-lined mylonite seams.	29195
528-10 to 531-0	96	-- Amphibolite(?), fine-grained, gray, granulated with a few 1 to 3 cm aggregates or single crystals of feldspar. Core cut at 30 to 45 degrees by mylonite seams usually with a coating of quartz and carbonate.	29196
531-0 to 531-10	100	-- Amphibolite, partially granulated feldspathized. Core cut by a quartz-carbonate sealed mylonite seam at the end of the interval.	29197

Table 5. cont'd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)			SAMPLE
531-10 to 532-10	92	--	Pegmatites, one 5 and one 8 cm thick, cutting K-feldspathized and serpentinized amphibolite. Pegmatites and later quartz-carbonate-sealed mylonite seams cut core at 60 to 80 degrees.	29198
532-10 to 535-10	100	--	Amphibolite, partially chloritized, locally feldspathized, with sparse pyrite. Core is cut at 45 to 75 degrees by quartz-carbonate-sealed mylonite seams.	29199
535-5 to 538-6	100	--	Amphibolite, partially chloritized, feldspathized with locally abundant pyrite. A few, irregular, discontinuous, sealed fractures occur throughout the interval, and a few quartz-carbonate-sealed mylonite seams occur in the upper part of the interval.	29200
538-6 to 542-5	100	--	Amphibolite, granulated, with sparse pyrite. Core is cut by sparse quartz-carbonate seams and, at 538-10, by a mylonite seam 3 cm thick.	29201
542-5 to 546-4	100	--	Amphibolite with sparse pyrite and minor, local feldspathization along discontinuous sealed fractures, cut by a few quartz-carbonate seams.	29202
546-4 to 550-2	100	--	Amphibolite, locally feldspathized along sealed fractures, with sparse pyrite. Core cut at 30 to 60 degrees by mylonite seams, most with a quartz-carbonate lining.	29203

Table 5. cont'd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)		SAMPLE
550-2 to 554-1	100	-- Amphibolite with sparse pyrite, cut by a few mylonite seams with local quartz-carbonate lining and feldspathization of adjacent walls.	29204
554-1 to 558-8	100	-- Amphibolite, granulated in last half of interval, with sparse pyrite, cut by mylonite seams with local quartz-carbonate lining and feldspathization of adjacent walls	29205
558-8 to 559-1	100	-- Granite dike, fine-grained, aplitic-textured cuts core at about 60 degrees.	29206
559-1 to 562-7	100	-- Amphibolite, granulated in upper part of interval, with sparse pyrite, cut by a few mylonite seams	29207
562-7 to 566-6	100	-- Amphibolite, locally feldspathized, with sparse pyrite, cut by a few mylonite seams locally with quartz-carbonate lining.	29208
566-6 to 570-5	98	-- Amphibolite, locally feldspathized, with sparse pyrite, cut by mylonite seams. Quartz-carbonate up to 1 cm thick fills a seam nearly perpendicular to the core.	29209
570-5 to 573-9	98	-- Amphibolite with sparse pyrite and a few poorly developed feldspathized zones along old fractures	29210
573-9 to 575-0	74	-- Andesite dike with sparse pyrite "eyes"	29211
575-0 to 575-9	100	-- Biotite-granite dike, fine-grained, aplitic with pegmatitic borders, cut core at 60 degrees.	29212

Table 5. cont'd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)		SAMPLE
575-9 to 578-3	97	-- Amphibolite with locally abundant pyrite, locally feldspathized along old sealed fractures that merge into the border zone of the granite dike above.	29213
578-3 to 582-2	100	-- Amphibolite, partially granulated, with sparse pyrite, cut by a few quartz-feldspar-sealed fractures up to 5 mm thick.	29214
582-2 to 585-5	98	-- Amphibolite, partially granulated, locally feldspathized, with sparse pyrite. Core is cut at 45 degrees by mylonite seams, some with a lining of quartz and carbonate.	29215
585-5 to 586-1	88	-- Amphibolite, fine-grained, granulated. Granular quartz-feldspar veinlets, nearly parallel to the core are cut and offset by quartz-carbonate-lined-mylonite seams that are nearly perpendicular to the core.	29216
586-1 to 587-8	100	-- Amphibolite, fine-grained, granulated. Core is cut by mylonite seams, some with quartz-carbonate lining, and one with greenish-colored ultra mylonite 2 cm thick.	29217
587-8 to 589-0	100	-- Pegmatite, pink, with pockets of fine-grained yellow muscovite, some pyrite, and partially serpentinized inclusions of granulated amphibolite, cut by mylonite seams filled with up to 2 cm of dense cherty ultra-mylonite.	29218

Table 5. cont'd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)			SAMPLE
589-0 to 593-11	92	--	Mylonite, partially serpentinized to 589-11. Amphibolite, granulated, locally feldspathized, with some pyrite coated fractures, cut by quartz-carbonate-coated-mylonite seams 589-11 to 593-11.	29219
593-11 to 597-11	100	--	Amphibolite, partially granulated, feldspathized adjacent to fractures. Core is cut at 5 to 60 degrees by mylonite seams, some coated by quartz and carbonate, and at nearly 90 degrees by a myrmekite and quartz dike 3 to 5 cm thick at 594-5	29220
597-11 to 601-9	98	--	Amphibolite, granulated, generally fine-grained, with sparse pyrite. A few relict, coarser-grained blocks are usually feldspathized. Core is cut by mylonite seams, some with quartz-carbonate coating, and at 60 degrees by a quartz-feldspar vein 1 cm thick at 598-2	29221
601-9 to 605-9	100	--	Amphibolite, granulated, fine-grained, with a few relict coarser-grained pods and sparse mylonite seams.	29222
605-9 to 609-8	100	--	Amphibolite, granulated, fine-grained, coarser-grained with depth, with a few quartz-carbonate-lined seams and mylonite seams and sparse pyrite.	29224
609-8 to 613-7	100	--	Amphibolite, partially chloritized, locally serpentinized, local feldspathization along old sealed fractures, with sparse mylonititic zones and sparse pyrite. The texture is erratic ranging from coarse to fine grained.	29225

Table 5. cont'd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)		SAMPLE
613-7 to 617-7	98	-- Amphibolite, granulated, generally fine grained, with sparse mylonite seams, af few feldspathized zones along healed fractures, and sparse pyrite.	29226
617-7 to 621-5	96	-- Amphibolite, granulated, feldspathized along old sealed fractures, cut by mylonite seams, with sparse pyrite.	29227
621-5 to 625-3	100	-- Amphibolite, partially granulated, feldspathized along old sealed fractures, cut by mylonite seams.	29228
625-3 to 629-2	98	-- Amphibolite, partially granulated, locally feldspathized along sealed fractures or mylonite seams some of which are coated by quartz and carbonate.	29229
629-2 to 630-9	95	-- Amphibolite, partially granulated, biotite-rich cut by mylonite seams in lower part of interval.	29230
630-9 to 633-0	96	-- Dike rock, aphanitic, dark-gray, cut by a few mylonite seams.	29231
633-0 to 636-11	100	-- Amphibolite, partially granulated, feldspathized, locally chloritized, cut by mylonite seams locally with a filling of quartz and carbonate.	29232
636-11 to 639-2	100	-- Amphibolite, partially granulated, feldspathized, with sparse pyrite, cut by mylonite seams.	29233
639-2 to 643-0	100	-- Amphibolite, partially granulated, with sparse pyrite. Rock is locally feldspathized, particularly so near a pair of mylonite-quartz-carbonate veinlets at 642-0.	29234

Table 5. cont'd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)		SAMPLE
643-0 to 646-11	98	-- Amphibolite, granulated, locally feldspathized, cut by mylonite seams locally with quartz-carbonate linings.	29235
646-11 to 650-9	100	-- Amphibolite, granulated, feldspathized, cut by mylonite seams locally with quartz-carbonate linings.	29236
650-9 to 654-9	98	-- Amphibolite, granulated, feldspathized, with sparse pyrite, cut by mylonite seams.	29237
654-9 to 658-8	100	-- Amphibolite, partially granulated, feldspathized, with sparse pyrite, cut by mylonite seams locally with quartz-carbonate linings.	29238
658-8 to 662-7	100	-- Amphibolite, granulated, feldspathized. An opaque, soft mineral is mixed with biotite along sealed fractures.	29240
662-7 to 666-6	100	-- Amphibolite, locally feldspathized, biotite-rich, somewhat granulated, cut by a few mylonite seams.	29241
666-6 to 668-10	97	-- Amphibolite, partially feldspathized, locally granulated, cut by a few mylonite seams.	29242
668-10 to 670-6	100	-- Dike rock, aphanitic, dark gray, cuts core at 30 degrees.	29243
670-6 to 674-2	100	-- Amphibolite, partially granulated, feldspathized, locally biotite-rich with locally abundant pyrite. An aphanitic, dark gray dike 1 cm thick cuts the core at 671-9.	29244

Table 5. cont'd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)		SAMPLE
674-2 to 678-1	98	-- Amphibolite, feldspathized, partially granulated, with sparse pyrite, cut by mylonite seams locally with quartz-carbonate lining. At 675-2 the walls of a quartz-carbonate vein are mildly serpentinized.	29245
678-1 to 681-11	100	-- Amphibolite, partially granulated, feldspathized, cut by mylonite seams locally with quartz-feldspar or quartz-carbonate filling.	29246
681-11 to 685-10	100	-- Amphibolite, locally granulated, feldspathized, with sparse pyrite. Quartz-feldspar and quartz-carbonate veinlets along mylonite seams are accompanied by minor serpentinization. Aphanitic dikes 1 to 5 cm thick cut core 683-7 to 684-10.	29247
685-10 to 689-9	100	-- Amphibolite, partially granulated, feldspathized locally mildly serpentinized, with sparse pyrite, cut by mylonite seams and by an aphanitic dike 1 cm thick at 688-0.	29248
689-9 to 693-9	98	-- Amphibolite, partially granulated, feldspathized, local mild serpentinization, with sparse pyrite, cut by mylonite seams.	29249
693-9 to 694-4	86	-- Amphibolite, partially serpentinized, K-feldspathized, at beginning of interval is cut at 30 degrees to the core by a dark-gray, aphanitic dike in last half of the interval.	29250

Table 5. cont'd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)		SAMPLE
694-4 to 694-10	100	-- Biotite-granite dike, aplitic, fine-grained, cuts the core at 45 degrees, and has pegmatites 1 to 2 cm thick on its margins composed of quartz and feldspar with comb structure.	29251
694-10 to 695-4	100	-- Dike rock, dark-gray aphanitic, with a smear of amphibolite at the lower contact.	29252
695-4 to 696-8	88	-- Amphibolite, partially feldspathized, with locally abundant pyrite	29253
696-8 to 696-11	100	-- Amphibolite, sheared, partially serpentinized pink from K-feldspathization. Core is cut at about 60 degrees by mylonite seams with up to 1 cm of quartz and K-carbonate.	29254
696-11 to 699-5	97	-- Amphibolite, fine-grained, granulated, cut by mylonite, quartz-carbonate, and quartz-K-feldspar seams.	29255
699-5 to 699-9	75	-- Biotite-granite dike, fine-grained, aplitic. Lower contact is a seam 1 cm thick of mylonite, quartz, and carbonate at 60 degrees to the core. Sparse pyrite occurs adjacent to the mylonite seam.	29256
699-9 to 703-3	98	-- Amphibolite, granulated fine grained, cut by mylonite seams. Biotite-granite dikes up to 3 cm thick follow some of the mylonite seams.	29257
703-3 to 706-11	100	-- Amphibolite, granulated, fine-grained. Core is cut at 10 to 45 degrees by mylonite seams with quartz-carbonate filling up to 15 mm thick.	29258

Table 5. cont'd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)		SAMPLE
706-11 to 710-5	100 --	Amphibolite, granulated, fine-grained. Core is cut at 5 to 45 degrees by numerous mylonite seams some with a lining of quartz and carbonate, others filled by pod-like masses of aplitic biotite granite up to 3 cm diameter.	29259
710-5 to 712-1	100 --	Amphibolite(?), an aphanitic, dark-gray rock laced by mylonite seams with a quartz-carbonate lining up to 5 mm thick.	29260
712-1 to 714-2	100 --	Amphibolite, cataclastic, pink from partial replacement by K-feldspar which is also granulated adjacent to an aplitic-granite dike. All of these rocks are cut by mylonite seams with a filling of quartz and carbonate up to 5 mm thick.	29261
714-2 to 717-10	98 --	Amphibolite(?), an aphanitic, gray rock that is partially K-feldspathized in segments, patches and vein-like masses. Core is cut by numerous mylonite seams with a filling of quartz and feldspar or quartz and carbonate up to 1 cm thick.	29262
717-10 to 721-5	98 --	Amphibolite, granulated, aphanitic, gray, with minor serpentine toward end of interval. Core is cut at 30 to 60 degrees by veins of quartz or quartz and carbonate up to 5 cm thick that may compose 5 percent of the interval. Sparse pyrite occurs in veins or as veinlets.	29263

Table 5. cont'd.

INTERVAL (Feet & Inches)	CORE RECOVERY (Percent)		SAMPLE
721-5 to 723-4	100	-- Amphibolite, very-fine grained, granulated, locally feldspathized, with minor serpentinization increasing in intensity with depth. Core is cut by a few pink K-feldspar-rich granitic dikes and is laced by mylonite seams with a filling of quartz and carbonate up to 1 cm thick. Sparse pyrite occurs along veins.	29264
723-4 to 724-9	94	-- Amphibolite, granulated, merges into mylonite and brecciated, serpentinized amphibolite. Quartz and carbonate fill breccia. Sparse pyrite is in seams that cut the quartz and carbonate. Pink K-feldspar occurs as seams and replacing amphibolite where it is not serpentinized.	29265
724-9 to 728-11	98	-- Amphibolite, medium- to coarse-grained, locally granulated, feldspathized, with irregular patches of hematite(?) up to 1 cm long. Core is cut by mylonite seams with quartz-K-feldspar or quartz-carbonate filling.	29266
728-11 to 732-8	98	-- Amphibolite, medium- to coarse-grained, feldspathized, locally granulated, locally biotite-rich, with irregular patches of hematite(?) in upper part of interval and sparse pyrite in lower part of interval. Core is cut by numerous mylonite seams, some with a filling of quartz and carbonate.	29267
732-8 to 733-11	100	-- Amphibolite, granulated grades through strongly banded material into an aphanitic gray rock at end of interval. All are probably granulated amphibolite. Core is cut by a few mylonite seams with a lining of quartz and carbonate.	29268
	Bottom of Hole		

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