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Preliminary Report on The Distribution of Copper and Platinum Group Metals in Mafic Igneous Rocks of the Sierra Madre, Wyoming

By

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Prepared in cooperation with the Geology Department, University of Wyoming, and the Geological Survey of Wyoming

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This report is preliminary and has not been edited or reviewed for conformity with U.S. Geological Survey standards and nomenclature.

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Introduction

This study was undertaken to assess the platinum group metal content of some mafic igneous rocks of the Sierra Madre and compare the platinum group metal content of these mafic igneous rocks with that of mineralized rocks of the area. Portions of the central Medicine Bow Mountains have been shown to have mafic igneous rocks and mineralized areas with platinum group metals in greater than crustal abundances (Theobald and Thompson, 1968), and preliminary results suggested that parts of the Sierra Madre might also have anomalous amounts of these metals.

In addition to the study of platinum group metals, analyses were made for copper and other trace metals in the mafic igneous rocks to make a preliminary evaluation of Arnold C. Spencer's (1904, p. 56) hypothesis that these mafic igneous rocks were the source of copper in mineral deposits of the Sierra Madre. Chemical analyses of major elements in the mafic igneous rocks were made to see if there was a relationship between bulk chemistry and trace metal content.

Inasmuch as no summation of the general geology of the Sierra Madre has been made since Spencer's report of 1904, a brief review based on work at the University of Wyoming since 1955 is included in this report.

Regional setting

The Sierra Madre is one of three major mountain areas of southeastern Wyoming. These are the Laramie Mountains to the east, the Medicine Bow Mountains in the center, and the Sierra Madre on the west (fig. 1). These mountain areas resemble three hooked fingers extending in a northerly direction from the main Rocky Mountains of Colorado, but curved to the west as they enter and continue into Wyoming. The Laramie and Medicine Bow Mountains are northward extensions of the Colorado Front Range that, in effect, splits into two mountain ranges near the Wyoming-Colorado border. The Sierra Madre is a northward extension of the Park Range of Colorado (fig. 1).

Figure 1.--NEAR HERE

All of these mountain areas are uplifts that developed during the Rocky Mountain or Laramide orogeny, and they are cored by rocks of Precambrian age that are more resistant to erosion than Paleozoic, Mesozoic, and Tertiary rocks that are exposed on the flanks of the mountains and in intervening basins.

Both the Medicine Bow and Laramie Mountains are bordered on the east by west-dipping thrusts and these two mountains are separated from each other by the synclinal Laramie basin that is underlain by Paleozoic, Mesozoic, and Tertiary rocks. The Laramie basin is approximately 40 miles (64 km) wide (east to west) and is a syncline plunging north (fig. 1).

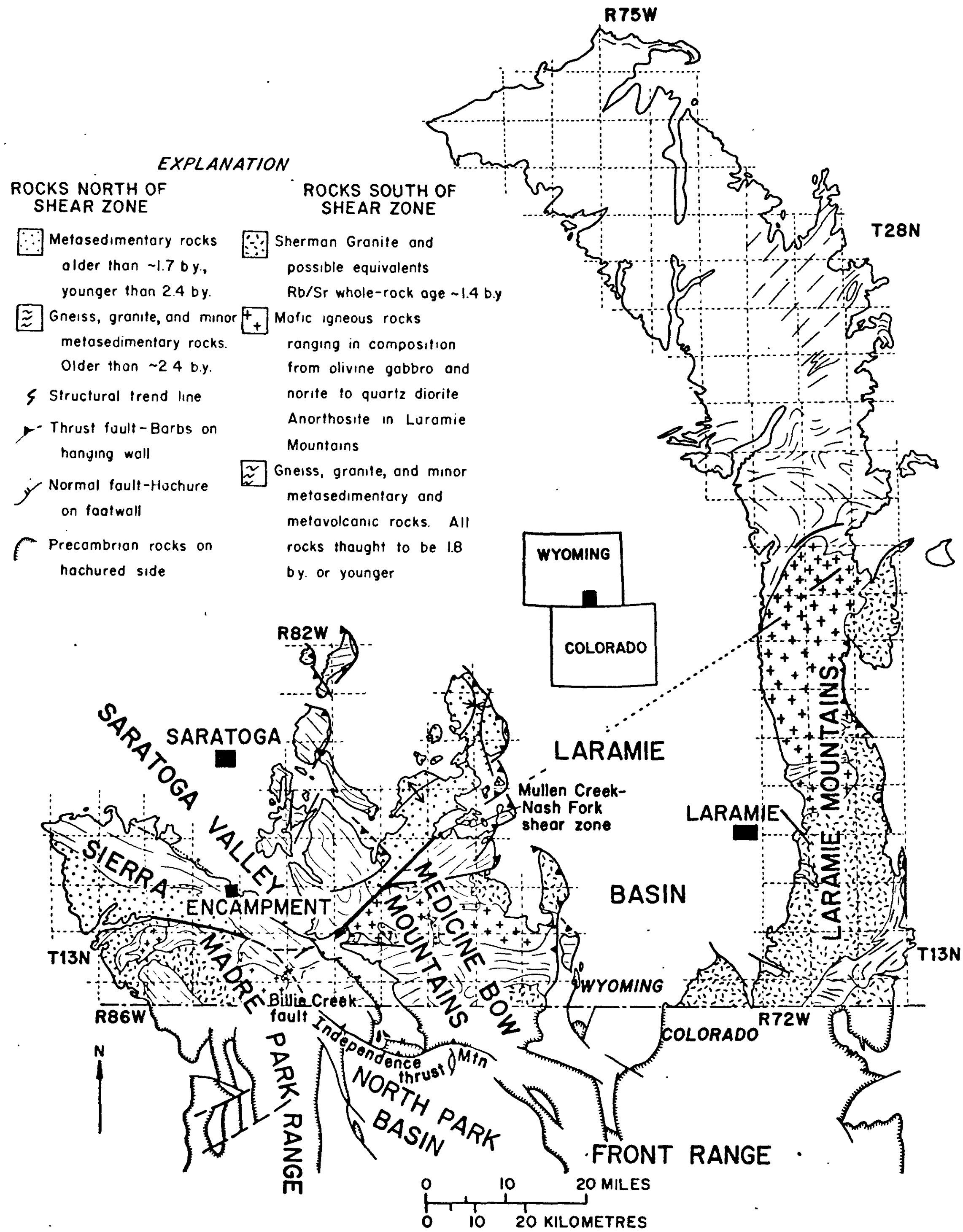

FIGURE 1.--Generalized geologic map of the Laramie and Medicine Bow Mountains and the Sierra Madre.

The Sierra Madre is separated from the Medicine Bow Mountains by a valley, the Saratoga Valley, that is much narrower than the Laramie basin. In fact, southeast of the town of Encampment the Precambrian rocks of the Medicine Bow Mountains and Sierra Madre are nearly joined (fig. 1). It is possible that these two mountain areas were once one large uplifted block and are separated only because normal faults of Tertiary age developed on the east side of the Sierra Madre and sediments were deposited during Tertiary time in the down-dropped block that is the present Saratoga Valley. In other words, there is no intervening synclinal valley containing rocks of Paleozoic and Mesozoic age, and the rocks of Precambrian age in the Saratoga Valley are covered by a relatively thin succession of sedimentary rocks of Tertiary age.

Regional geology of rocks of Precambrian age

In this study rocks of interest are all Precambrian in age. To understand the Precambrian geology of the Sierra Madre it is desirable to review the rocks of Precambrian age in the three major mountain areas mentioned above.

The Precambrian rocks of southeastern Wyoming are in a transition zone between the ancient rocks (generally older than 2.5 b.y.) of the Wyoming province (Engel, 1963) and the much younger rocks ($\leq$ 1.8 b.y.) of the Colorado Front Range. In the Medicine Bow Mountains this transition is abrupt and is marked by a northeast-striking shear zone (Houston and McCallum, 1961; Houston and others, 1968). On the northwest side of this shear zone an older gneissic basement (Rb/Sr whole rock on gneiss $\sim$2.4 b.y.; Hills and others, 1968, p. 1763) is overlain by two sequences of metasediments; an older poorly exposed sequence of metavolcanic rocks, tilloid, and quartzite; and a younger sequence of well-exposed quartzite, slates, tillites(?), and metadolomite. The metasedimentary rocks are probably Middle Precambrian in age in that they are older than $\sim$1.7 b.y. and younger than $\sim$2.4 b.y. (Hills and others, 1968)

All of the units north of the fault are cut by both mafic and felsic igneous rocks. The felsic igneous rocks are much more abundant in the basement gneiss where a well-foliated granite has been dated as ∿2.5 b.y. (Hills and others, 1968, p. 1763).

On the southeast side of the shear zone an entirely different group of rocks is exposed and no rocks can be positively equated to those found northwest of the shear zone. South of the shear zone probable metasedimentary rocks include impure quartzite, hornblende gneiss, calc-schist, marble, and rare layers of conglomerate and metavolcanic(?) rocks. These probable metasedimentary rocks and metavolcanic rocks have numerous interlayers of quartzo-feldspathic gneiss that are of uncertain origin. The above rocks south of the fault have been dated as older than 1.7 b.y. and a massive post-tectonic granite, Sherman Granite, has been well dated as ∿1.35 b.y. (Hills and others, 1968, p. 1770).

If we follow the Medicine Bow shear zone to the northeast (fig. 1) it goes beneath the Laramie basin cover and where it should reappear in the Precambrian rocks of the Laramie Mountains a major unit of anorthosite is emplaced. If the fault is present here it has been invaded by anorthosite, but north of the anorthosite only older gneisses and igneous rocks of the Wyoming province are exposed and south of the anorthosite the most abundant rock type is the Sherman Granite of Late Precambrian age (Hills and Armstrong, 1971, p. 599-600). Thus it appears that the transition zone from older to younger Precambrian is present in both mountain uplifts, but there is no proof of a shear zone at the transition in the Laramie mountains.

Recent mapping (Huang, 1970; Ridgley, 1971) in the Sierra Madre has shown that the northeast-striking shear zone of the Medicine Bow Mountains extends at least 4 miles (6.5 km) into the southeastern Sierra Madre (fig. 1), and either changes strike to a westerly direction or is offset by a northwest striking fault system.

Precambrian geology of the Sierra Madre

Mapping in the Sierra Madre has been done at different times and on different scales. Early regional mapping (1:96,000) by A. C. Spencer (1904) was completed in 1902 and covered about two-thirds of the Sierra Madre excluding the northern (north of latitude 41°15') and eastern (east of longitude 106°45') part. More recent mapping (1:24,000) has been done by graduate students of the University of Wyoming and includes mapping by Ben L. Short (1958), Otto J. Wied (1960), Ray D. Merry (1963), Clinton S. Ferris, Jr. (1964), Larry L. Lackey (1965), Kenneth J. DeNault (1967), Chi-I Huang (1970), Ballard Ebbett (1970), Mark A. Hughes (1973), Neill H. Ridgley (1971), William R. Miller (1971), and Robert Michael (personal commun., 1971). Published reports on the more recent work are by Ferris (1966) on the gneissic basement near Encampment and by Ebbett (1970) on the metasedimentary rocks. Geologic maps of the various areas are available through the Geological Survey of Wyoming, Laramie. No age determinations are available for the Sierra Madre, but extensive collections have been made by F. Allan Hills and R. S. Houston and are currently being studied by Hills at the State University of New York at Buffalo.

The following review of the Precambrian geology of the Sierra Madre is based on the work of individuals listed above and on observations of Houston made over the last 15 years while working with graduate students at the University of Wyoming. Plate 1 is a generalized geologic map prepared by Houston to illustrate the major features of the geology and to aid in the discussion of mafic igneous rocks that will follow.

Plate 1.--IN POCKET

It is not possible at this time to unequivocally subdivide the Sierra Madre into two provinces as has been done for the Medicine Bow and Laramie Mountains because of lack of information on the age of rocks. However, our best information suggests that the fault or transition zone continues into the eastern Sierra Madre for about 4 miles (6.5 km) and is either offset by a northwest-striking right-lateral fault or the fault system simply changes to a more westerly strike. By either assumption the rocks of the younger province are further north in the Sierra Madre than in the Medicine Bow Mountains (pl. 1). If we are correct in this, a reasonable subdivision for the Sierra Madre rocks is to divide them into three major groups: older basement gneisses equivalent to those of the Medicine Bow Mountains that are exposed in the northern and northeastern Sierra Madre; metasedimentary rocks that crop out in a v-shaped body with apex to the east and that are located in the north-central Sierra Madre; and mixed gneisses, metasedimentary, and volcanic rocks exposed in the southern and western Sierra Madre (fig. 2).

Fig. 2.--NEAR HERE

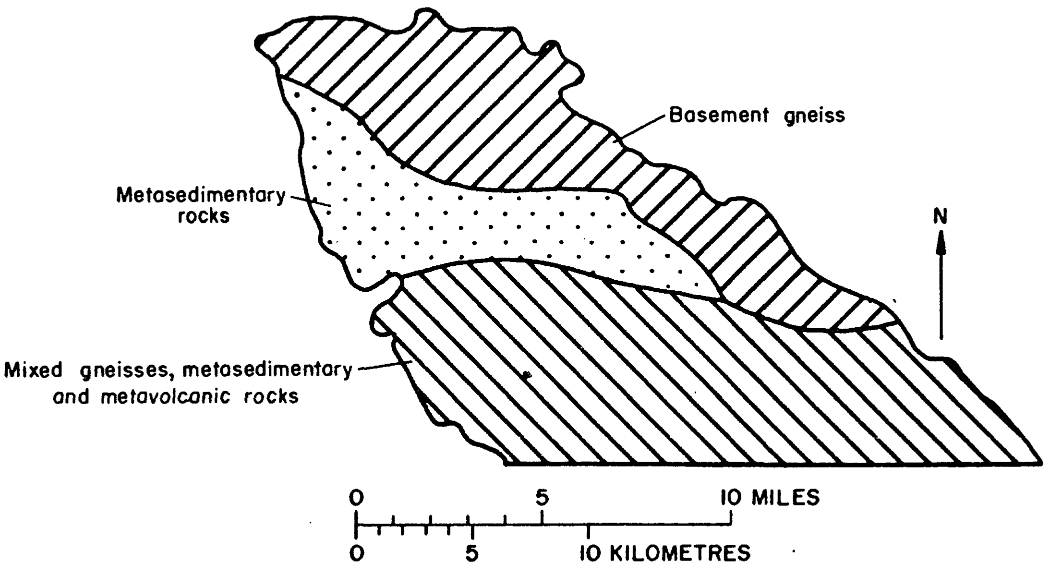

FIGURE 2.--Geologic subdivision of the Sierra Madre.

These various units are cut by a complex group of mafic and felsic igneous rocks that will be reviewed below, but major rock types are basaltic and gabbroic rocks that are common in the older gneiss and metasedimentary rocks and quartz monzonite and granite that are more common in the southern and central part of the Sierra Madre.

Older gneiss

This unit is exposed in the north and the northeastern Sierra Madre and may be said to extend from the north side of Little Beaver Creek (T. 13 N., R. 82 W.) northwesterly to the limit of Precambrian outcrop (pl.1). It is probably equivalent in age and is similar in lithology to older gneisses that crop out in the northwestern part of the Medicine Bow Mountains (Houston and others, 1968, p. 11-14). In fact, the older gneisses of the Medicine Bow Mountains are separated from those of the Sierra Madre by less than one mile (0.6 km) in the vicinity of the Summit Reservoir (T. 13 N., R. 82 W.).

These older gneisses are largely quartzo-feldspathic gneisses but contain interlayers of hornblende gneiss, amphibolitic, and quartzite. In the Medicine Bow Mountains the quartzo-feldspathic gneiss was subdivided into a layered biotite-rich type and a poorly foliated biotite-poor type, and field and petrographic evidence suggests that the biotite-poor type was derived from the biotite-rich type through metasomatism and metamorphism accompanied by recrystallization (Houston and others, 1968, p. 11-14). In the Sierra Madre these same gneisses have been recognized (Ferris, 1964, p. 4-13) and, in addition, a pink quartzo-feldspathic gneiss can be distinguished in the field.

Ferris (1964, p. 6) cites evidence that shows the biotite-poor gneiss of the Sierra Madre was derived from the biotite-rich type as in the Medicine Bow Mountains, but, in addition, demonstrates that the transformation took place during deformation. The pink quartzo-feldspathic gneiss of the Sierra Madre intrudes the biotite gneiss and forms dikes and irregular-shaped bodies with indistinct borders, but is foliated and conforms in structure to that of older gneisses. Augen gneiss, that is clearly later than the above gneisses but still strongly foliated, is present northwest of Encampment. This augen gneiss along with foliated granite, quartz monzonite, and quartz diorite recognized in the Medicine Bow Mountains is probably igneous or, at least, had a mobile history in that it shows cross-cutting relationships to the gneissic rocks. These rocks are nonetheless generally conformable in gross shape and in internal structure (foliation) to the regional foliation of the older gneisses.

Perhaps the most interesting rock types in the older gneiss unit from the viewpoint of geologic history are the bodies of amphibolite and mafic igneous rocks. A few outcrops have been noted in the Medicine Bow Mountains where dikes of amphibolite cut older gneiss but are, in turn, cut by foliated granite. Most bodies of amphibolite and mafic igneous rocks cut all units including foliated granite and are considered the last rocks formed, but even these rocks are deformed and metamorphosed. These younger mafic bodies include fine-grained sills and dikes of amphibolite that locally retain a diabasic texture but rarely have original minerals preserved and large sill-like but locally cross-cutting bodies of norite and gabbro that are also largely converted to amphibolite but may have local areas near their centers that retain original mineralogy. Many of these mafic igneous bodies have well-developed foliation and even gneissic structure especially near borders, and, in some cases, throughout the rock unit.

It is clear from this review that the older gneissic terrain has undergone a complex geologic history. This has been reviewed in some detail for the Medicine Bow Mountains (Houston and others, 1968, p. 101-118) and will not be repeated here, but it should be noted that there were probably several periods of emplacement of mafic magma at different levels in the crust and that even the most recent igneous bodies formed by crystallization of mafic magma have been deformed and recrystallized.

Medasedimentary rocks

Metasedimentary rocks crop out in a wedge-shaped area with the apex in the east-central part of the Sierra Madre (Sec. 1, T. 13 N., R. 84 W.). The metasedimentary rocks are in a west-northwest striking belt that extends to the western border of the Sierra Madre and that has a width perpendicular to strike of over 6 miles (10 km) at that point. The metasedimentary rocks are in fault contact with metamorphic and igneous rocks along their southern border, and on the northern border the older gneiss terrain is in fault contact in places but in other places the contact is either covered or the gneiss is separated from metasedimentary rock by sills of metamorphosed mafic igneous rock. In some areas (northern border) where the contact between gneiss and metasedimentary rocks is covered the strike and dip of foliation in the gneiss conforms to the strike and dip of layering (bedding and foliation) in the metasedimentary rocks.

The wedge-shape plan of outcrop of the metasedimentary rocks permits the interpretation that they constitute a syncline plunging west-northwest. This interpretation is not supported by the dip of bedding in the metasediments which with few exceptions is to the south, but Spencer (1904, p. 17-18) stated that the rocks were in a synclinorium with beds overturned to the north. Spencer based his interpretation, in part, on repetition of a bed of conglomerate that he believed was the same repeated by folding.

Spencer recognized two successions of metasedimentary rocks; an older sequence primarily of volcanic origin and a younger sequence, cratonal in aspect, that was mostly quartzite, slate or phyllite, and conglomerate. The metavolcanic rocks were thought to be the most ancient rocks of the region and were found along the northwest border of the synclinorium in an area northwest of Spring Lake and widely distributed south of the synclinorium where they were thought to be largely converted to hornblende gneiss, hornblende schist, and amphibolite. These metavolcanic rocks were thought to have been invaded by felsic to intermediate magmas that ultimately crystallized as quartz diorite and granite. This group of metavolcanic rocks and igneous rocks was thought to be the basement upon which the "cratonal" rocks were deposited. Following deposition of the "cratonal" rocks the entire area was deformed and the metasedimentary rocks were downfolded into a synclinorium that was bordered by the basement rocks on the north, east, and south. This period of deformation was followed by the introduction of mafic magma in faults that cut all rocks; magma that eventually crystallized as dikes and sills of basalt and gabbro. Spencer (1904, p. 19) states: "The structural relations between the sediments and the outside formations (metavolcanic rocks and felsic intrusive rocks) suggest that the former are all younger than any of the latter except the intrusive gabbros. It is believed, therefore, that the hornblende-schist (metavolcanic rocks), with its intrusive rocks, originally formed a basement upon which the sediments were laid down. All the basement rocks must then have taken part in the downfolding by which the synclinorium was produced. Folding was, however, greatly complicated by faulting, and probably all the contacts now observed between the sediments and the older rocks are fault contacts along which the invading gabbro found easy lines of intrusion."

This concept of geologic history proposed by Spencer is an appealing one and is remarkably accurate in view of the fact that Spencer devoted only one short field season to study of this area from July 12 to October 1, 1902. The writer's concept of the relationship between the major rock units differs primarily because of geochronological information gained from studies of the Medicine Bow Mountains and because the use of top and bottom criteria in the study of the metasedimentary rocks allows us to make a different structural interpretation. This new information makes possible several changes in the interpretation of the relationship of the "cratonal" metasedimentary rocks to other geologic units. These are as follows:

1. The basement rocks, described above as older gneiss, are confined to the area northwest of the cratonal metasedimentary rocks and north of the Mullen Creek-Nash Fork shear zone as extended into the Sierra Madre (pl. 1).
2. The metavolcanic rocks northwest of Spring Lake are considered to be part of the "cratonal" metasedimentary succession and not related to hornblende gneiss, hornblende schist, and amphibolite found south of the shear zone.

3. All rocks south of the fault system (shear zone) are part of a different geologic province.

4. The metasedimentary succession (including metavolcanic rocks north of Spring Lake) are not in a synclinorium but are part of a monoclinal sequence with top to the south that is cut by the shear zone at its southern limit.

To reinforce our case for considering the "older gneiss" as basement the evidence is listed below.

1. Contacts between the older gneiss and the metasedimentary rocks are fault contacts.

2. Where primary sedimentation features have been observed in the metasedimentary rocks, they indicate top to the south and since the beds dip south, the gneiss underlies the metasedimentary rocks.

3. The geologic history of the older gneiss is far more complex than that of the metasedimentary rocks and includes more than one period of gneiss formation and tectonism that is in no way shown by the metasedimentary rocks.

4. If our assumption of equivalence between older gneiss of the Sierra Madre and gneiss of the Medicine Bow Mountains is correct, the gneiss belongs to the lower Precambrian whereas the metasedimentary rocks of the Sierra Madre resemble lower middle Precambrian sedimentary rocks of the Medicine Bow Mountains.

Ebbett's (1970) detailed map shows thirty-one areas from throughout the succession of metavolcanic and metasedimentary rocks where he has observed either crossbedding, graded bedding, or channeling that can be used to determine top of the succession. Twenty-nine of these areas indicate top to the south. Thus the metasedimentary rocks are a monoclinal succession dipping south instead of a synclinorium as suggested by Spencer.

It would appear a simple matter to establish a stratigraphic column for a succession of metasedimentary rocks with a consistent dip in one direction, but several aspects of the metasediments and their structure have made this a complex problem. There is no distinctive lithology in the metasedimentary rock sequence that can be traced throughout the outcrop area, and it has been difficult to establish mappable units that might be designated as formations. The various lithologies within the metasedimentary rocks appear to show facies changes along strike over relatively short distances and faults, generally parallel to the strike of bedding, bound the metasedimentary rocks on both the northeast and south and are probably common within the succession. Therefore, some apparent facies changes, pinch outs, or repetition of lithologies may result from faults that are difficult to recognize because of uneven distribution of outcrop and lack of distinctive marker beds.

Despite problems cited above general groupings of rock types can be made and an interpretation of structure is possible using a generalized stratigraphic succession as illustrated by figure 3.

Fig. 3.--NEAR HERE

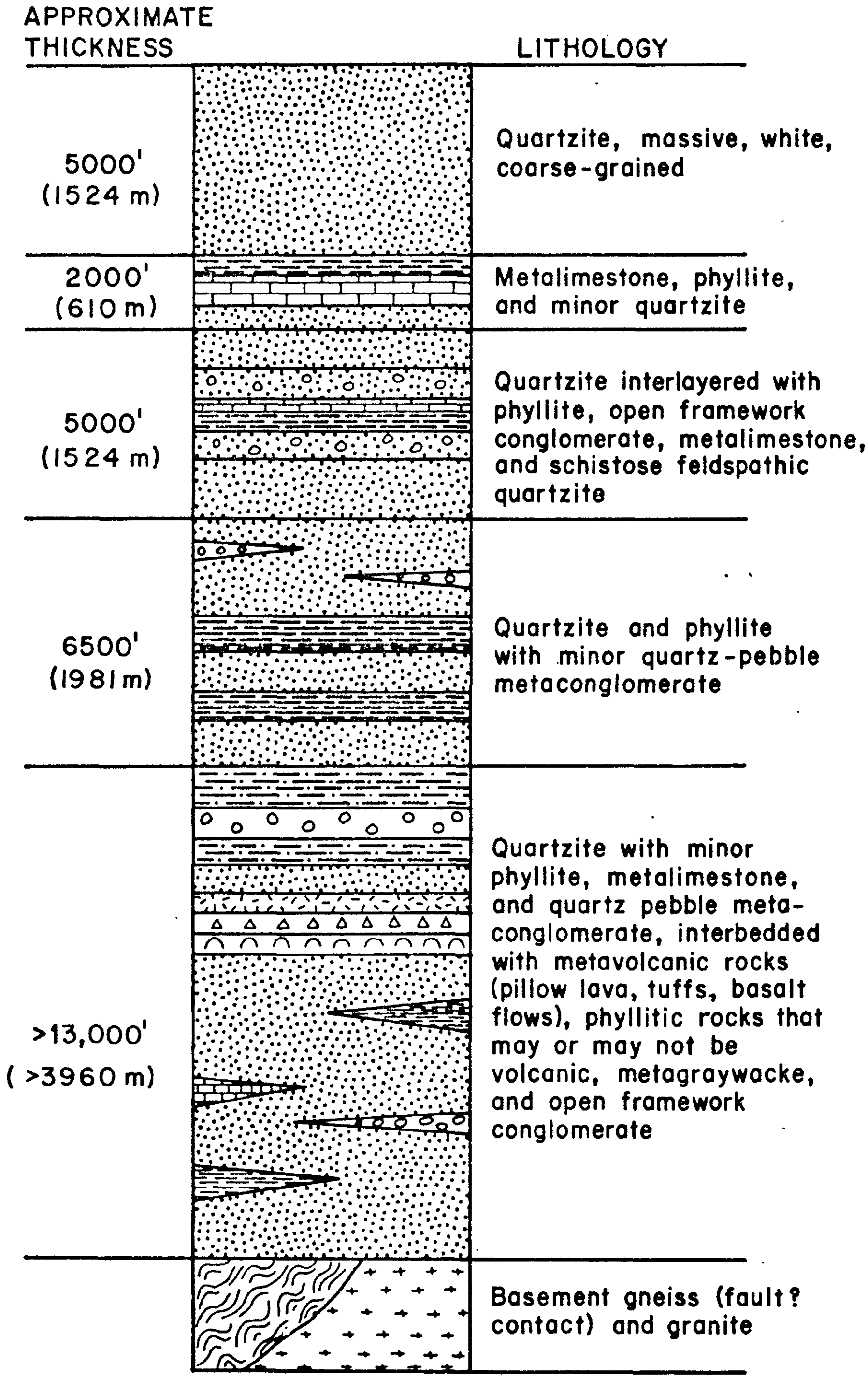

Figure 3. Generalized stratigraphic section of the central Sierra Madre

A brief review of the metasedimentary rocks follows so that the reader may better understand the rest of the report. The basal rock subdivision is a quartzite-metavolcanic rock-conglomerate unit. Inasmuch as the contact between the metasedimentary rocks and older gneiss is a fault or obscured by cover or mafic igneous rocks we do not know if the observed base is the true base of the succession. The lowermost exposed rock unit is quartzite which is generally more highly deformed than other rocks of the succession because of penetrative movement associated with faults. No basal conglomerate has been observed. The quartzite is gray, fine to medium grained and shows a good planar structure (in most cases parallel to bedding) that gives the rock a slabby appearance; it has a few interlayers of phyllite, fine-grained light-colored metalimestone, and coarse-grained quartzite and quartz pebble metaconglomerate. Locally the quartzite shows crossbedding and ripple marks. The metavolcanic rock group includes pillow metabasalt, metatuffs, schistose metarhyolite(?), and a group of interlayered phyllitic rocks that may or may not be volcanic. The rocks interlayered with metavolcanic rocks are dark-gray garnet-amphibole schist, dark-gray garnet-amphibole-feldspar schist, schistose pebbly biotite-muscovite quartzite, green chlorite-quartz schist, green metagraywacke, and metaconglomerate. The metaconglomerate has an open framework and has clasts of rounded red granite, gray granite, amphibole schist, and quartzite. The matrix of the conglomerate is quartzite, yellow phyllite, or amphibolitic schist.

The quartzite-phyllite unit that overlies the quartzite-metavolcanic rock-conglomerate unit is similar to quartzite and phyllite described above except that phyllite is more abundant and is in thicker and more continuous units. Interbeds of coarse-grained quartzite and quartz-pebble metaconglomerate are common. The overlying tilloid-quartzite unit has interlayers of quartzite, metaconglomerate, phyllite, metalimestone, and a schistose feldspathic quartzite. The metaconglomerate contains angular to rounded clasts (up to 2 feet or 0.6 m in diameter) of red granite, gray granite, quartzite, and green phyllite in a matrix of green or tan phyllite and medium- to coarse-grained pale-green schistose feldspathic quartzite. This conglomerate is a tilloid in the sense of Pettijohn (1957, p. 265) and there is evidence that suggests a glaciomarine origin (Ebbett, oral commun., 1970).

The tilloid-quartzite unit is overlain by a metalimestone unit that consists of interbedded fine-grained yellow, red, and green metalimestone, fine-grained chlorite-calcite schist, and dark-gray phyllite or metalimestone that is locally graphitic.

The top of the sequence of metasedimentary rocks may be a massive white quartzite best exposed in the southwest corner of the area underlain by metasedimentary rocks. This unit is in fault contact with rock types both to the north and south so its exact stratigraphic position is unknown.

The structure of the metasedimentary rocks is a simple monoclinal succession dipping south, but is complicated by strike faults within and bordering the metasedimentary rocks. The increase in width of outcrop from east to west in the metasedimentary succession is the result of four factors: (1) the major east-striking fault at the southern border cuts out successively older rocks to the east, (2) an uplift on the east side of a northeast-striking transverse fault has resulted in removal of a portion of the eastern one-third of the metasedimentary rocks, (3) a series of faults on the northeastern border has cut out a portion of the lower part of the metasedimentary successions, and (4) there is an increase in dip of the metasedimentary rocks to the east resulting in a decrease in width of outcrop.

The metasedimentary rocks are cut by mafic igneous rocks ranging in composition from pyroxenite to diorite. The fine-grained rocks are amphibolized metabasalt that occurs as dikes and sills and the coarse grained rocks are chiefly amphibolized metagabbro and metanorite that occur as large elongate to irregular-shaped bodies. These rocks cut both the older gneiss and the metasedimentary rocks and some cut the faults that separate gneiss from metasedimentary rocks. Some of these mafic bodies are the last igneous rocks formed in the Sierra Madre and are clearly later than the development of the major fault systems.

In the discussion of older gneiss it was noted that there were probably several generations of dikes (one group that pre-dates granite and one that post-dates granite). In the metasedimentary rocks there is no evidence of two ages of dikes so these rocks may be cut by a younger set of mafic igneous rocks only. Regardless of age all mafic bodies are metamorphosed--most to the extent that metamorphic foliation is developed and all to the extent that they are converted to amphibolite with only remnants of the original minerals and textures remaining.

The metamorphism and alteration of dikes, sills, and larger mafic bodies is of two types. The most typical and prevalent type of alteration is a conversion of pyroxene to amphibole and plagioclase to epidote, a new plagioclase, and quartz. This type of alteration may show various transitions from rocks with texture preserved to those that show a complete recrystallization and development of layering. A second type of alteration involves the development of chlorite and serpentine in sheared rocks and appears to be later than the first type in that amphibolized mafic rock may be sheared and altered to chlorite and serpentine.

Mixed gneisses and metasedimentary and metavolcanic rocks exposed in the southern and western part of the Sierra Madre

There are two groups of layered rocks in the southern and western part of the Sierra Madre--metasedimentary and metavolcanic rocks found chiefly along the northern border of the area, where these rocks are in fault contact with the metasedimentary rocks described above, and layered gneiss, amphibolite, and quartz-plagioclase gneiss found chiefly in the western part of the area.

Metavolcanic and metasedimentary rocks are in a belt about three miles wide that extends from Willow Park in the east (sec. 8, T. 13 N., R. 84 W.) probably to the western limit of Precambrian outcrop (pl. 1). The rocks are highly deformed and metamorphosed to the extent that the origin of the bulk of them is indeterminate, but some rocks show structures such as altered and stretched amygdules, relict phenocrysts, and abundant angular fragments of "igneous" rock that suggests that these rocks are volcanic. Some of the rocks are conglomerates of sedimentary parentage. Many fine-grained rocks that may be amphibole rich on the one hand or quartz rich on the other may be of either volcanic or sedimentary origin. Although they make up less than one percent of the volume of rocks in this group, the most distinctive and certainly most easily identified rocks are the conglomerates. These are in discontinuous lenses from 2 to 6 inches (5-15 cm) wide and several feet long to bodies twenty to thirty feet (6-9 m) wide and two-thirds of a mile (1 km) long. Clasts range in size from 1/2 inch to 6 inches (1.3-15 cm) in diameter and are granite, amphibolite, and fine-grained altered rocks of uncertain origin. The conglomerates are open framework or paraconglomerates; their origin is unknown.

Layered gneiss, amphibolite, and quartz-plagioclase gneiss are most abundant in the area west of Hog Park where a northwest-striking body that averages 4 miles (6.5 km) in width extends from the Colorado-Wyoming border to the West Branch of the Little Snake River--a distance of 7 miles (11 km). The layered gneiss has alternate layers (1-5 cm thick) rich in dark-colored minerals (biotite, amphibole, epidote) and light-colored minerals (quartz, feldspar, kyanite). These layers show minor folds in places. Some of the quartz-platioclase gneiss looks like quartzite in the field. A calculation of SiO_2 content of the gneiss from modal analyses shows it has 81 percent SiO_2--a silica content near that of mature quartzite.

The amphibolite is much more abundant than the layered gneiss and quartz-plagioclase gneiss, and makes up 80 to 90 percent of the exposed volume of these rock types. Where it is undeformed it is a very fine-grained dark rock composed chiefly of plagioclase and amphibole. Contacts between the amphibolite and gneissic rocks are sharp, but no evidence of amphibolite cross-cutting, or sending stringers or dikes into gneiss has been noted. In a regional sense the gneissic rocks appear to be inclusions within a much larger body of amphibolite suggesting that the amphibolite was an intrusive body containing remnants of metamorphic rocks, but a metavolcanic or metasedimentary origin cannot be ruled out.

The gneiss and amphibolite are cut by several different igneous rocks that constitute about two-thirds of the exposures in this area. The oldest of these units is a rock exposed west of Huston Park in the south central Sierra Madre that is largely quartz diorite gneiss but ranges in composition from diorite to granodiorite. This unit is well foliated with foliation developed by alinement of stringers of biotite and a poorly developed alternation of light and dark minerals. Contacts with older gneisses and metavolcanic rocks may be gradational or sharp and usually a zone 15-20 feet wide rich in xenoliths of older rock is present near the contact. These xenoliths may be oriented or disoriented with respect to the strike of the contact.

All of the above units are cut by gneisses of quartz monzonite and granite composition that have gradational contacts with respect to each other and are gray, pink, or red in color. These gneisses have gradational contacts with a deep red relatively massive granite that is best exposed in the vicinity of Red Mountain (one mile or 0.6 km south of Old Battle townsite) and from Deadhorse Park (sec. 31, T. 14 N., R. 84 W.) southeast to the Encampment River (pl. 1). East of Hog Park a distinctive white quartz monzonite is exposed that is clearly later than the gray and red gneisses, but its relationship to red granite is unknown. This gneiss-granite group of rocks makes up the bulk of the southern and western Sierra Madre and may be a group of related intrusive rocks that was emplaced near the end of a metamorphic event. On plate 1 the red granite is separated from the quartz monzonite gneisses, but no distinction is made between the various gneissic units.

The red granite requires special comment. It is the most massive of the felsic igneous rocks and is later than all contiguous rocks except mafic dikes Unlike other felsic igneous rocks it cuts the southern fault bounding the main sedimentary sequence and, in addition, dikes, sills, and small pods of red granite cut the metasedimentary rocks north of the fault. The granite is strongly sheared in and near the fault. It cuts sheared rocks (indicating it is later than early faulting) and is strongly sheared (indicating movement of the fault continued after granite emplacement).

The youngest igneous rocks emplaced in this southern area are mafic dikes that cut all rocks including red granite. These dikes may retain igneous textures but all studied have been altered to amphibolite and most have been deformed especially where they are in or near faults.

The extreme southeastern part of the Sierra Madre is not well known. Only two areas have been studied--a small area located on the east side of the Sierra Madre south of the extension of the major shear zone of the Medicine Bow Mountains and a small area south of the East Fork of the Encampment River and west of Blackhall Peak (pl. 1).

Hornblende gneiss, quartzo-feldspathic gneiss, garnet gneiss, and calc-schist are the earliest known rocks of this area. Hornblende gneiss, garnet gneiss, and calc-schist are interlayered with one another and show gradational contacts; their relationship to quartzo-feldspathic gneiss is not well shown in this area, but, in general, these units are very similar to older gneissic sequences of the southern Medicine Bow Mountains (Houston and others, 1968, p. 54-66). Irregularly-shaped masses of amphibolite, the largest mass located in the area west of Blackhall Peak, have either sharp conformable contacts with respect to other lithologic units or crosscut these units. Most masses of amphibolite show no evidence of original mineralogy, texture, or structure, but in some larger bodies remnants of original pyroxene have been identified in thin section and in local areas igneous texture have been noted in the field. Perhaps the majority of these larger bodies of amphibolite are of igneous origin, but as mapping continues in this area each unit will have to be evaluated on the basis of field evidence.

All of the above units are cut by pink gneissic granite and pegmatite. Granite and pegmatite are generally not in contact, but where they are, pegmatite is later than granite. Although the granite is clearly intrusive into other rock types and contains numerous inclusions, its foliation is generally parallel to that of host rocks. Zones in the granite are strongly sheared with the development of foliation as a result. The granite was mobile at some stage in its development and has been sheared after solidification.

Discussion

Sierra Madre geology fits into the Medicine Bow framework reasonably well for the central, northern, and eastern Sierra Madre, but not so well for the southwestern Sierra Madre. The older basement gneiss of the northeast Sierra Madre is very similar to that of the northwestern Medicine Bow Mountains and the main metasedimentary sequence of the north central Sierra Madre is much like the older metasedimentary rocks (Deep Lake Formation of Houston and others, 1968 of the Medicine Bow Mountains). The major shear zone (Mullen Creek-Nash Fork) of the Medicine Bow Mountains continues into the Sierra Madre and in the vicinity of Billie Creek it takes a more westerly course and marks the contact between metasedimentary rocks of the Sierra Madre and younger rocks to the south much as it does in the Medicine Bow Mountains (pl. 1). This change in strike of the shear zone takes place in the vicinity of the Billie Creek fault, a northwest-striking fault originally mapped by Montagne (1955) as a late Tertiary normal fault. This fault certainly moved in late Tertiary, but it may have both a Laramide and Precambrian ancestry. It may connect with the Independence Mountain thrust of Laramide age that crops out in T. 11 N., R. 81 W., in the northern Park Range of Colorado (Walters, 1953) and this fault in turn may have a Precambrian ancestry. Perhaps the Mullen Creek-Nash Fork shear zone was offset by a right lateral fault that brought rocks of the southern province into contact with the metasedimentary rocks of the Sierra Madre. By either of these interpretations, rock south of the shear zone are considered part of a different sequence of Precambrian rocks with a closer affinity to the late Precambrian of the Colorado Front Range than the early and early middle Precambrian rocks north of the fault.

This interpretation requires some elaboration and cannot be considered the only option until additional isotope studies are made on the Precambrian rocks of southeastern Wyoming. Several major questions remain unresolved. The cratonal metasedimentary rocks of the Medicine Bow Mountains and probably the Sierra Madre are younger than 2.5 b.y. and older than 1.7 b.y. This time span covers the entire middle Precambrian and by some definitions part of the early late Precambrian. Therefore, it is possible that the cratonal metasedimentary rocks of the Medicine Bow Mountains and Sierra Madre (Deep Lake Formation and Libby Creek Group of Houston and others, 1968) are the same age but different facies of early late Precambrian rocks of Colorado. For example, felsic gneisses and augen gneiss of the Hahns Peak and Farwell Mountain area, located about eight miles south of Hog Park (T. 12 N., R. 84 W.) in the southern Sierra Madre are dated as 1,650-1,700 m.y. by the rubidium-strontium method (Segerstrom and Young, 1972, p. 16-18). Peterman and others (1968) have dated the Boulder Creek Granite of the northeastern Front Range as 1,700-1,800 m.y., a syntectonic granite formed <u>after</u> a period of sedimentation and green schist metamorphism. These dates suggest that sedimentation in the northern Front Range took place prior to 1800 million years and therefore could be equivalent in age to the cratonal metasedimentary rocks of the Medicine Bow Mountains and Sierra Madre.

The writers prefer to consider the cratonal metasedimentary rocks, Deep Lake Formation and Libby Creek Group of Houston and others (1968) of the Medicine Bow Mountains and the metasedimentary rocks of the Sierra Madre as early middle Precambrian in age, that is, ranging in age from 2.5 b.y. to 2.25 b.y. This age is preferred because of the striking resemblance of these rocks to those of the Huronian Supergroup (Young, 1970; Roscoe, 1973) of the Canadian shield. The hazards of lithologic correlations, especially in unfossiliferous rocks of Precambrian age, are many but most geologists who have studied or examined the Medicine Bow section (Blackwelder, 1935; Hills and others, 1968; Houston and others, 1968; Young, 1970; Roscoe, 1973) have considered these rocks a possible equivalent of the Huronian Supergroup and they are clearly closer lithologically to the Huronian Supergroup than they are to younger middle Precambrian cratonal rocks of the shield such as rocks of the Circum-Ungava geosyncline (Fryer, 1972). A final answer to this correlation may come from additional isotope studies or from proof that pyritic conglomerates that seem to characterize early middle Precambrian rocks (Cloud, 1968; Fryer, 1973) are present or absent in this succession. Certainly should this tentative correlation be correct, it is unlikely that Colorado Front Range rocks correlate with cratonal rocks of the Medicine Bow Mountains or Sierra Madre.

Another point that must be resolved is whether or not remnants of early Precambrian basement (older than 2.5 b.y.) or for that matter any rocks of the Wyoming province survive south of the shear zones in southeastern Wyoming or in the Front Range of Colorado. None have been recognized by isotope studies (Hedge and others, 1967; Peterman and Hedge, 1967; Peterman and others, 1968; Hansen and Peterman, 1968; Hedge and others, 1968; Barker, 1969; Barker and others, 1970; Segerstrom and Young, 1972) and the writers are not aware of any rock successions that are similar lithologically to the cratonal metasedimentary rocks of the Medicine Bow Mountains and Sierra Madre.

If a crystalline sialic basement (reworked early Precambrian or early middle Precambrian) is present in the Front Range or southeastern Wyoming, the transition from the Wyoming province would have characteristics like the Grenville mobile zone of southeastern Canada and eastern United States which consist of medium to high-rank reconstituted basement and infolded cover rocks. This reconstituted basement has been recognized by both field (Gastil and Knowles, 1960) and isotope studies (Grant, 1964) in the Grenville mobile zone, but, to date, no basement rocks have been recognized in the Front Range or southeastern Wyoming. Similarities with the Grenville mobile zone do exist, however, in that large bodies of labradorite and andesine anorthosite are present in both areas.

If no basement is present in this area and sedimentation took place in the time span between 2.0 b.y. and 1.75 b.y., are these sediments part of island arcs accreted to a continental margin like that of California?

Mafic igneous rocks as a source of metals

One of the main features of Sierra Madre economic geology has been the association of sulfide mineralization (especially copper sulfide) and mafic igneous rocks. Spencer (1904, p. 53-55) recognized five types of mineral deposits: (1) chalcopyrite and magnetite disseminated in hornblende schists, (2) pyrrhotite and chalcopyrite in recrystallized hornblende schist near a mafic igneous intrusion, (3) sulfide-bearing quartz veins having calcite, siderite, and feldspar as gangue minerals in faults, (4) chalcopyrite in pegmatite, and (5) copper sulfides at the intersection of fractures in quartzite. The most important of these deposits economically were those such as the Ferris-Haggarty and Doane mines where mineralization was in fractured quartzite, but by far the greatest number of occurrences of sulfide minerals are in or near the mafic igneous intrusions. The sulfide minerals associated with mafic igneous rocks are in fractured or sheared mafic igneous rocks, in quartz veins that cut mafic igneous rock, in quartz veins along contacts between mafic igneous rock and country rock, or in veins and shear zones in adjacent country rock. These occurrences are small and the deposits are not minable.

The general association of mafic igneous rocks and sulfide minerals led Spencer to postulate that mafic igneous rocks were the source of some of the copper in Sierra Madre mineral deposits (Spencer, 1904, p. 49-50). Spencer recognized that not all deposits were derived from mafic magma because some probably were formed prior to introduction of the mafic magma. He suggested that sulfides disseminated in hornblende schist formed during metamorphism of the schists, and were earlier than the bulk of the mineral deposits, but he felt the majority of the deposits and certainly the major deposits (Doane type) were hydrothermal with copper coming from the mafic igneous rocks. He was indefinite on the actual mechanism of derivation of copper from the mafic igneous rocks, but presumably believed that the copper-bearing solutions escaped from crystallizing mafic magma (Spencer, 1904, p. 58) in some cases. Spencer thought, however, that in most cases the igneous rock furnished metals to circulating underground waters that leached copper from the rocks and redeposited it in fractures. In many respects Spencer proposed an origin somewhat like modern source bed concepts (Boyle, 1961; Knight, 1957) in which metals are leached from source rocks during metamorphism and redeposited in local areas of lower temperature and pressure.

Inasmuch as the association of certain metallic elements (such as copper, nickel, cobalt, and platinum) with mafic igneous rocks is well known (Rankama and Sahama, 1950, p. 697, 681-683; Crockett, 1969, p. 78E-1--78F-12) Spencer's postulation that the mafic igneous rocks are a source of copper is reasonable, but was not proven by the data presented in 1904.

The geology of the Sierra Madre is such that it is ideally suited to study the distribution of metals in mafic igneous rocks under varying geologic conditions. It is possible, for example, to study mafic igneous rocks ranging from relatively unaltered rock to rocks showing all gradations of metamorphism and hydrothermal alteration and commonly in a single igneous body. Thus systematic sampling of a number of these mafic intrusions has the following objectives:

1. Are metals such as Cu and Pt present in anomalous amounts in mafic rocks of the Sierra Madre?
2. Is there any relationship between the abundance of these elements and the degree of metamorphism or alteration of mafic igneous rocks?
3. Do these metals show any relationship to changes in chemistry or mineralogy of the mafic igneous rocks?
4. Are Sierra Madre copper deposits in any way related to metamorphism? That is, are deposits or simply abundances greater in areas where mafic igneous rocks are most highly metamorphosed or sheared?

In the following chapters an attempt will be made to answer some of these questions.

Techniques of study of mafic igneous rocks

Mapping and sampling

Mafic igneous rocks were selected to give a range of chemical composition and a reasonably broad geographic distribution (pls. 2 and 3). Smaller intrusions were selected for systematic study because of time factors, but these intrusions appeared to be similar in most respects to the larger bodies except, as determined during the study, very few completely or even partially unaltered samples were obtained. Plane table and alidade were used to establish control points on a selected mafic rock body, and a grid was laid out from these points using compass and tape. Samples were collected and the geology mapped using grid points for control. For rock bodies which were too small or poorly exposed for grid sampling, samples were collected at outcrops only, and maps constructed by compass and tape.

Laboratory procedures

The sample preparation procedure for X-ray fluorescence analysis is summarized in figure 4. X-ray machine settings are nearly the same as those used by Copeland (1970, p. 32-33). Etching and staining for feldspar identification was performed using the procedure of Chayes (1952, p. 337-340), except that polished slabs were etched and stained, rather than thin sections.

Figure 4.--NEAR HERE

Table 1 shows the D.C.-arc spectrographic results for two samples of amphibolite derived from gabbro which were analyzed fourteen times each. The standard deviations presented give a fair idea of the precision to be expected for a single rock analysis when the mean for the element in question falls close to the mean in table 1. Table 2 shows the same data for fire assay-spectrographic analyses of platinum-group elements.

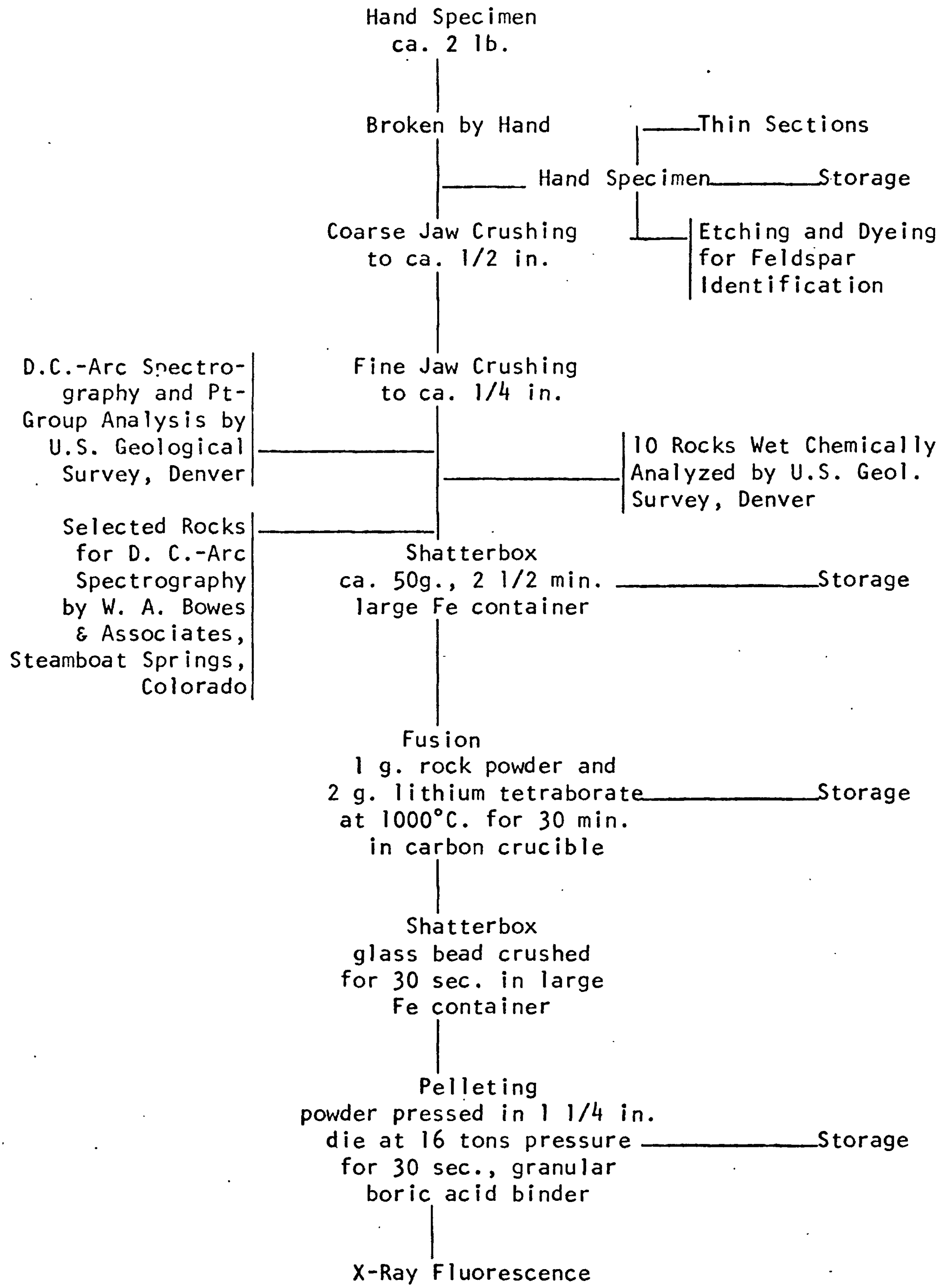

FIGURE 4. SAMPLE PREPARATION FLOW CHART

TABLE 1. PRECISION OF D. C.-ARC SPECTROGRAPHIC RESULTS[1]

SAMPLE NUMBER	MgO^2	B	Ba	Co	Cr	Cu	La	Mn	Mo	Nb	Ni	Pb	Sc	Sr	V	Y	Zr
							ELEMENT IN PARTS PER MILLION										
AHA-010[3]	8.30	L	70	30	70	150	N	700	N	L	70	L	30	500	700	30	70
-074	4.97	N	70	30	50	150	N	700	N	N	70	10	30	200	300	30	70
-085	4.97	N	70	30	30	150	N	700	N	N	50	L	30	300	300	30	100
-120	8.30	L	70	30	70	200	N	500	N	N	100	10	30	300	500	30	70
-147	3.32	N	50	20	30	100	N	500	L	N	30	10	20	200	200	20	50
-160	4.97	N	70	30	50	150	N	700	N	L	70	L	30	300	300	30	50
-168	3.32	N	70	30	50	100	30	500	N	N	70	10	30	300	300	30	50
-185	3.32	N	70	20	30	70	N	500	N	N	50	L	20	300	300	20	100
-204	4.97	N	70	20	30	100	N	500	N	N	30	10	30	200	200	20	50
-250	8.30	L	70	50	70	200	N	1000	3	10	70	N	50	300	500	50	100
-259	8.30	L	70	30	50	150	N	1500	N	N	100	10	50	70	300	50	150
-269	11.60	20	70	30	50	150	N	700	N	10	100	10	30	300	300	30	150
-326	8.30	20	70	30	50	150	N	1000	3	L	70	15	50	200	500	30	100
-337	8.30	L	70	20	30	150	N	700	3	70	70	10	30	100	300	30	100
MEAN	6.52	2.86	68.6	28.6	47.1	141	2.1	729	0.6	6.43	67.9	6.79	32.9	255	357	30.7	86.4
s.d.	2.56	7.26	5.34	7.70	15.4	36.9	8.0	279	1.3	18.6	22.6	5.41	9.94	105	140	9.17	34.1

1. Ag, As, Au, Be, Bi, Cd, Sb, Sn, Te, U, W, and Zn were tested but not detected (N) or present in less than measurable amount (L) in all splits. N and L were assumed zero.
2. MgO is in Wt. %.
3. All samples listed on this page are splits from AHA-010.

TABLE 1 (CONT.). PRECISION ON D. C.-ARC SPECTROGRAPHIC RESULTS[1]

SAMPLE NUMBER	MgO^2	B	Ba	Co	Cr	Cu	Mn	Mo	Nb	Ni	Pb	Sc	Sr	V	Y	Zn	Zr
	ELEMENT IN PARTS PER MILLION																
AHA-040[3]	8.30	L	70	30	70	70	700	N	N	70	10	70	300	500	15	N	30
-078	3.32	N	70	30	30	30	700	N	N	70	N	70	150	300	20	N	50
-094	8.30	N	70	50	30	30	700	N	N	70	L	70	150	300	20	300	70
-134	4.97	N	70	30	50	30	700	N	N	50	N	70	150	200	10	300	30
-157	8.30	N	70	30	50	50	1000	L	L	100	N	70	150	500	20	200	50
-164	4.97	N	70	30	30	50	1000	N	N	70	10	70	150	300	20	300	30
-183	8.30	N	70	30	50	30	500	N	N	70	10	70	200	500	20	200	50
-202	8.30	N	70	30	30	30	700	N	N	70	N	70	150	300	20	300	30
-213	8.30	N	70	30	50	70	500	N	N	100	N	70	150	300	20	300	50
-255	8.30	L	70	30	50	70	1500	5	L	70	10	100	200	300	30	N	50
-260	11.60	L	70	20	50	70	1000	3	L	70	10	100	300	300	20	N	30
-297	8.30	20	100	30	30	70	1000	N	10	100	L	150	200	500	20	300	50
-336	11.60	L	70	30	50	70	1000	5	N	1000	10	100	70	500	20	200	70
-339	8.30	L	70	30	30	50	1000	3	L	50	L	70	70	300	15	200	30
Mean	7.94	1.43	72.1	30.7	42.9	51.4	857	1.1	0.71	140	4.29	82.1	170	364	19.3	186	42.1
s.d.	2.27	5.35	8.02	6.16	12.7	18.3	265	2.0	2.67	248	5.14	23.3	68	108	4.32	129	20.3

1. Ag, As, Au, Be, Bi, Cd, La, Sb, Sn, Te, U, and W were tested but not detected (N) or present in less than measurable amount (L) in all splits. N and L were assumed zero.
2. MgO is in Wt. %.
3. All samples listed on this page are splits from AHA-010.

The single sample AHA-147 (Table 2) is unusually high in platinum and palladium and must result from sample contamination.

Table 3 presents D.C.-arc spectrographic results for ten amphibolites selected at random from the group of rocks analyzed by both E. F. Cooley, U. S. Geological Survey, Denver, and T. Hancock, W. A. Bowes and Associates, Steamboat Springs, Colorado.

Table 4 presents analyses of ten mafic rocks by wet chemical (Blythe E. Engleman, U. S. Geological Survey, Denver, analyst) and X-ray fluorescence (J. Eric Schuster, analyst) methods.

Several standard statistical tests were made to determine precision and accuracy of analyses. The tests are listed below (see next page). As shown in Table 5 replicate determinations by D. C.-arc spectrographic and fire assay techniques for the elements listed in the table are within 25 ± 15% with the exception of lead and zinc.

Table 5--NEAR HERE

The accuracy of D.C.-arc spectrographic analyses between two analysts on the same samples is quite variable as shown in Table 6. Fortunately the results for copper were quite good and this is one of the most critical elements for this study.

Table 6--NEAR HERE

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TABLE 2. PRECISION OF FIRE ASSAY-SPECTROGRAPHIC RESULTS[1]

	ELEMENT IN PARTS PER BILLION						
SAMPLE NUMBER	Pt	Pd	Rh	SAMPLE NUMBER	Pt	Pd	Rh
AHA-010[2]	10	6	N	AHA-040[3]	10	1	N
-074	10	2	N	-078	N	N	N
-085	N	2	N	-094	10	N	N
-120	N	10	N	-134	10	2	40
-147	2000	3000	40	-157	N	2	N
-160	14	2	N	-164	N	N	N
-168	N	N	N	-183	N	N	N
-185	N	N	N	-202	N	N	N
-204	N	N	N	-213	20	N	N
-250	N	N	N	-255	N	N	N
-259	N	N	N	-260	N	N	N
-269	N	N	N	-297	N	N	N
-326	14	10	N	-336	N	15	30
-337	N	N	N	-339	N	N	N
Mean	146	217	2.86	Mean	3.57	1.43	5.00
s.d.	534	801	10.7	s.d.	6.33	3.98	12.9

1. Ir, and Ru were tested but not detected (N) in all splits. N was assumed zero.
2. All samples listed below AHA-010 are splits from AHA-010.
3. All samples listed below AHA-040 are splits from AHA-336.

TABLE 2. (CONT.)

Analytical Method	Test	SiO_2	Al_2O_3	Fe_2O_3	Total FC	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	B	Ba	Co	Cr	Cu	La	Mr	Mo	Nb	Ni
DC-Arc	Precision					x						x	x	x	x	x	x	x	x	x	x
Spectrographic	Accuracy					x						x	x	x	x	x		x		x	x
Fire Assay	Precision																				
X-ray Emission Spectrography	Accuracy	x	x	x	x	x	x	x	x	x	x										

CONTINUED

Analytical Method	Test	Pb	Sc	Sr	V	Y	Zn	Zr	Pt	Pb	Rh	Reference
DC Arc	Precision	x	x	x	x	x	x	x				Table 1
Spectrographic	Accuracy	x	x	x	x	x		x				Table 3
Fire Assay	Precision								x	x	x	Table 2
X-ray Emission Spectrography	Accuracy											Table 4

TABLE 3. ACCURACY OF D. C.-ARC SPECTROGRAPHIC RESULTS[1]

SAMPLE NUMBER	MgO^2	B	Ba	Co	Cr	Cu	Mn	Nb	Ni	Pb	Sc	Sr	V	Y	Zr
						ELEMENT IN PARTS PER MILLION									
AHA-344[3]	8.30	20	50	50	1500	20	1500	10	150	L	30	200	200	20	50
-345	11.60	20	50	50	1500	100	1500	10	150	L	30	200	300	20	70
-361	8.30	10	100	50	1500	100	1500	10	150	L	30	200	200	20	70
-375	8.30	10	50	30	1000	70	1000	10	100	L	50	200	200	10	50
-387	11.60	10	200	50	3000	20	2000	10	300	L	30	100	150	15	50
-389	11.60	10	30	50	2000	10	2000	10	300	L	30	L	100	10	50
-394	16.60	10	50	70	5000	50	2000	10	500	L	50	100	200	10	50
-444	11.60	10	100	50	3000	100	2000	10	500	10	30	150	200	10	50
-475	16.60	10	50	50	3000	20	2000	10	700	L	30	100	100	10	50
-476	16.60	L	30	70	5000	10	1500	10	700	L	30	L	100	10	20
Mean	12.11	11	71.0	52.0	2650	50.0	1700	10	355	1	34	125	175	14	51
SD	3.42	5.67	51.52	11.35	1435	39.15	349.6	0	230.2	3.16	8.43	79.05	63.46	4.74	13.70
AHA-344[4]	6.64	N	20	50	1000	30	1000	10	150	N	30	100	150	10	10
-345	8.30	N	10	70	1500	70	1000	10	200	N	40	100	150	10	10
-361	8.30	N	70	50	1000	100	1000	10	150	N	40	200	200	20	30
-375	8.30	N	20	50	1000	70	1000	10	150	N	40	200	200	L	L
-387	8.30	N	100	70	4000	40	1000	10	700	N	40	L	100	N	L
-389	11.60	N	L	70	5000	20	1000	10	1000	N	30	L	150	N	N
-394	11.60	N	20	70	4000	30	1000	10	700	N	30	L	150	N	N
-444	8.30	N	100	70	3000	70	1000	10	700	N	30	L	150	N	N
-475	11.60	N	N	150	5000	40	1200	10	1500	N	40	L	150	N	L
-476	11.60	N	N	100	5000	15	1000	10	1000	N	40	L	150	N	N
Mean	9.45	N	34.0	75.0	3050	48.5	1020	10	625	N	36	60	155	4	5
SD	1.91	0	40.33	30.27	1771	27.49	63.24	0	462.0	0	5.16	83.85	28.38	6.99	9.71

1. Ag, As, Au, Be, Bi, Cd, La, Mo, Sb, Sn, W, and Zn were tested by both analysts but not detected (N) or present in less than measurable amount (L) in all samples. N and L were assumed zero. 2. MgO is in Wt. %. 3. Analyst, E. F. Cooley. 4. Analyst, T. Hancock.

Table 4 ACCURACY OF X-RAY FLUORESCENCE RESULTS

WET CHEMICAL ANALYSIS, OXIDES IN WT. PER CENT[1]

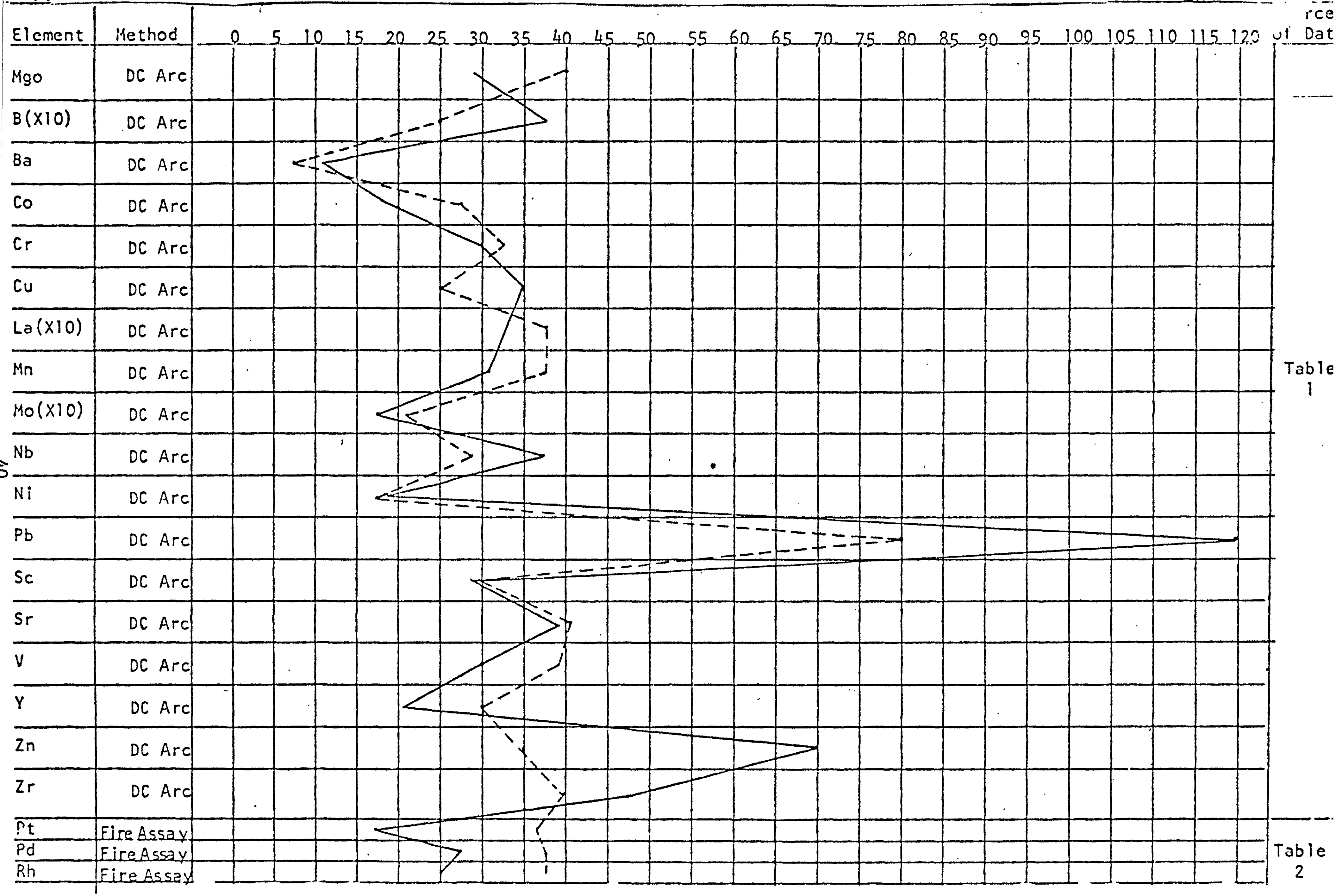
SAMPLE NUMBER	SiO_2	Al_2O_3	Fe_2O_3	FeO	Total Fe as Fe_2O_3	MgO	CaO	Na_2O	K_2O	H_2O+	H_2O-	TiO_2	P_2O_5	MnO	CO_2	Total
AHA-035	51.31	13.49	2.49	9.45	12.98	7.02	10.18	1.79	0.36	1.95	.16	1.29	.09	.20	0.01	99.79
-061	50.30	14.02	2.90	9.65	13.61	5.81	11.72	1.72	0.64	1.64	.15	0.78	.09	.19	0.29	99.90
-114	51.35	12.21	2.07	8.91	11.96	8.77	11.48	1.53	0.28	1.83	.14	0.94	.06	.19	0.00	99.76
-128	50.38	15.04	2.88	6.36	9.94	8.62	10.98	1.35	0.57	2.61	.16	0.54	.05	.17	0.01	99.72
-135	51.40	6.17	1.47	8.80	11.24	21.22	5.42	0.65	0.05	3.77	.18	0.39	.03	.21	0.02	99.78
-167	50.13	12.30	3.09	6.95	10.81	9.57	11.91	1.91	0.49	2.38	.08	0.81	.12	.16	0.02	99.92
-198	50.98	14.36	1.38	8.73	11.07	7.79	11.44	1.71	0.24	2.01	.04	0.72	.06	.19	0.01	99.66
-221	51.44	14.80	8.07	4.66	13.24	4.44	7.24	4.08	0.19	2.41	.21	1.68	.12	.14	0.28	99.76
-300	59.76	13.61	4.98	5.49	11.07	6.84	0.18	2.33	1.19	4.08	.17	0.79	.05	.06	0.04	99.57
-325	50.70	13.59	1.95	9.81	12.84	6.12	7.02	4.83	0.48	2.09	.09	1.35	.13	.31	1.17	99.64
Mean	51.78	12.96	3.13	7.88	11.88	8.62	8.76	2.19	0.45	2.48	.14	0.93	.08	.18	0.18	99.76
SD	2.84	2.56			1.22	4.68	3.80	1.28	0.32			0.40		0.06		

X-RAY FLUORESCENCE ANALYSIS, OXIDES IN WT. PER CENT[2]

SAMPLE NUMBER	SiO_2	Al_2O_3	Total Fe as Fe_2O_3	MgO[3]	CaO	Na_2O	K_2O	TiO_3	MnO	Total
AHA-035	51.01	13.10	13.18	8.30	10.49	1.98	0.39	1.31	.21	99.97
-061	50.51	13.98	13.36	8.30	11.80	2.17	0.69	0.85	.19	101.85
-114	51.66	11.97	11.73	4.97	11.85	1.40	0.29	0.96	.20	95.03
-128	50.37	14.72	9.98	4.97	11.28	1.00	0.58	0.59	.18	93.67
-135	50.77	5.27	12.77	16.60	5.67	0.00	0.04	0.45	.28	91.85
-167	50.45	11.99	10.40	8.30	12.22	2.07	0.53	0.83	.17	96.96
-198	50.71	13.98	10.75	8.30	11.78	1.54	0.26	0.77	.19	98.28
-221	50.73	14.38	15.58	3.32	7.33	3.96	0.26	1.78	.15	97.49
-300	58.00	13.32	13.20	4.97	0.08	1.83	1.24	0.97	.07	93.68
-325	50.77	12.83	14.05	8.30	7.14	4.57	0.55	1.44	.36	100.01
Mean	51.50	12.55	12.50	7.63	8.96	2.05	0.48	1.00	.20	96.87
SD	2.31	2.72	1.76	3.68	3.92	1.33	0.33	0.40	.08	

[1] Analyst, Blythe E. Engleman
[2] Analyst, J. Eric Schuster
[3] D. C.-arc spec. analysis.

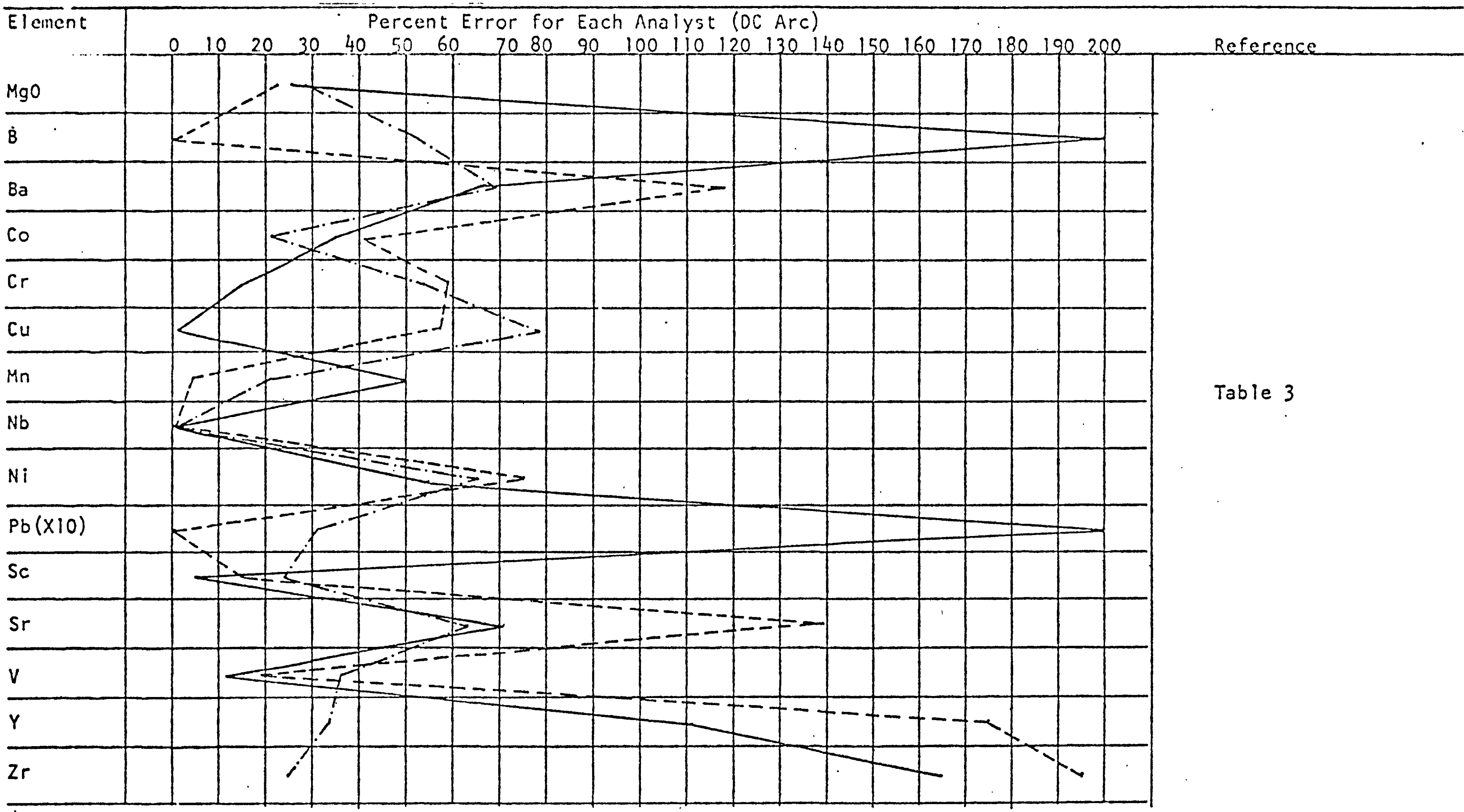
Table 5. Comparison of Precision of D.C. Arc Spectrographic and Fire Assay Methods of Analysis



---- 14 splits from AHA-010 same analyst
—— 14 splits from AHA-336

Measured in percent error in determinations 14 splits (SD/average) from the same sample.

Table 6. Comparison of Accuracy of DC-Arc Spectrographic Determinations



—·— Analyst 1, 10 samples

----- Analyst 2, same 10 samples

——— Percent variation between means of analyst one and two $\frac{(\text{mean 1} - \text{mean 2})}{\text{average mean}}$

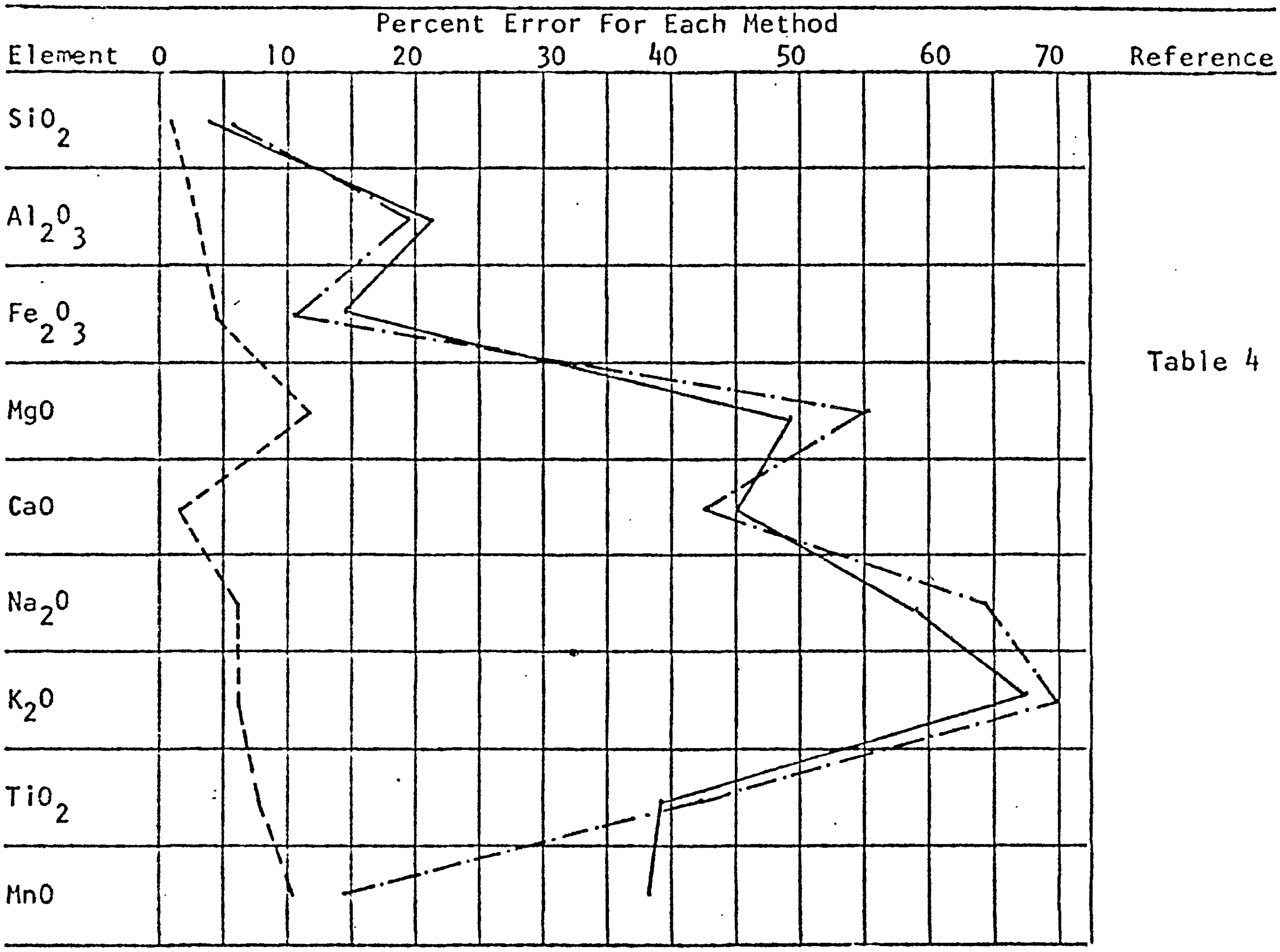
A test is illustrated in table 7 to show the accuracy of X-ray fluorescence methods as compared with wet chemical techniques. The results suggest that the X-ray technique is a useful guide to the comparative chemistry of these mafic rocks, but not useful for quantitative chemical study. If the wet chemical analyses are considered most reliable the X-ray results agree within ten percent or less for SiO_2, CaO, K_2O, TiO_2, and with one exception Al_2O_3. The X-ray results show a higher percentage disagreement for MnO, and major departure for MgO where the results were determined by D.C.-arc spectrographic analysis.

Table 7.--NEAR HERE

Petrography of the mafic rocks

Amphibolized mafic igneous rocks crop out as sill-like bodies that conform to the attitude of the foliation or bedding of the country rocks regionally but are locally cross-cutting. These bodies range in size from sills a few feet wide and several tens of feet long to large irregular-shaped bodies more than a mile (0.6 km) long and a quarter mile (0.15 km) wide. As stated above, only small and intermediate size mafic intrusions were sampled for this study (plate 2; table 18).

Table 7. Percent Error in Analysis of Major Elements Between Wet Chemical and X-ray Fluorescence Methods



—.— Percent error, 10 samples analyzed by wet chemical technique.

——— Percent error, 10 samples analyzed by X-ray fluorescence

----- Percent variation between means of 2 analytical methods $\frac{\text{(X-ray - Wet Chem.)}}{\text{Avg X-ray \& Wet Chem}}$

Fifty samples were examined under the microscope and modal analyses were made for 37 of these samples (table 8). All rocks studied were either partly or wholly converted to amphibolite and only two mafic rock samples were fresh enough to make a positive determination of the original rock type. Sample (AHA-119) is a pyroxenite and sample (AHA-137) is a mela-norite (table 8). Least altered mafic rocks usually show an almost total conversion of pyroxene to a fine-grained fiberous amphibole (tremolite-actinolite, table 8), but plagioclase may or may not be wholly altered. Most of the plagioclase is either partially or wholly altered to fine-grained aggregates of clinozoisite and epidote with or without carbonate. Sphene, opaque minerals, and quartz are usually not altered at this stage and the texture of the rocks is preserved. Amphibolized mafic igneous rocks with texture preserved cannot be accurately classified by petrographic study but a guess can be made as to rock type and some of the smaller mafic units were thought to be diabase and larger mafic bodies included rocks tentatively identified as pyroxenite, norite, gabbro, and leuco-quartz diorite. No peridotites or olivine-rich gabbros or norites were recognized, but altered olivine was positively identified in two rocks and some highly serpentinized masses noted in some thin sections may have been derived from olivine.

A more complete alteration stage of these mafic rocks may be represented by rocks converted to aggregates of fine-grained alteration products with no evidence of a ghost texture but with quartz, opaque grains, and sphene still preserved. Some of the more mafic rocks may have local areas altered to mixtures of serpentine and talc.

Complete conversion to amphibolite appears to be promoted by deformation and accompanying recrystallization. Single thin sections may show this change from a mafic rock with a ghost texture preserved to a foliated amphibolite. The amphibolite consists of oriented amphibole and epidote with scattered stretched pods of quartz and sphene. Amphiboles in the amphibolite are coarser-grained than those of the altered mafic rock and some new amphiboles with blue-green pleochroism are present.

Single thin sections do not show a transition to a layered, recrystallized amphibolite, but these rocks are present within mafic bodies or make up most of some mafic bodies that have local areas of igneous rock with ghost texture. These mphibolites consist of blue-green hornblende, opaque minerals, and sphene (±epidote) interlayered with quartz and plagioclase.

This transition to amphibolite from original mafic igneous rocks is the main kind of alteration, but any of these rocks may also be sheared and subject to additional alteration wherein the most typical alteration is the development of chlorite in the fractures. These chloritized rocks may also be partially silicified and altered to carbonate minerals. This type of alteration may be accompanied by introduction of sulfide minerals.

Table 8 shows the composition of selected altered mafic igneous rocks. Orthopyroxene, clinopyroxene, olivine, sphene, opaque minerals, rutile, and phlogopite are considered primary minerals. Quartz and plagioclase may be wither primary or alteration products of the primary minerals and all other minerals are alteration products of the primary minerals. As can be seen from table 8, all rocks are extensively altered.

Table 8.--NEAR HERE

TABLE 8

MODES FOR AMPHIBOLITES

DERIVED FROM MELA-NORITIC OR PYROXENITIC BODIES

SAMPLE NUMBER	QZ	PL	OPX	CPX	HO	T-A	EP	CL	OP	OL	SE	TA	RU	SP	PH	CA	COMMENTS
	MINERALS IN VOLUME PER CENT																
AHA-119[1]	-	5.2	29.8	3.8	-	23.0	-	9.7	0.9	2.6	24.9	-	-	-	-	0.1	
-124	1.0	1.1	0.5	-	-	63.5	5.4	26.3	0.1	-	1.8	-	0.3	-	-	-	
-128	2.4	36.4	0.1	2.1	-	37.8	17.6	1.3	2.2	-	-	-	-	-	-	0.1	PL is An_{67}
-137	-	13.9	37.6	1.4	-	13.5	-	0.1	0.2	0.2	32.4	-	0.7	-	-	-	PL is An_{68}
-396	0.2	-	7.2	-	-	72.2	-	16.8	-	-	-	3.4	0.2	-	-	-	
-399	-	-	3.1	0.3	-	33.8	-	26.1	-	-	-	36.3	-	-	0.4	-	
-415	0.2	4.8	3.5	0.4	-	83.4	4.0	-	0.3	-	-	3.4	-	-	-	-	
-425	-	15.4	8.5	-	-	61.0	2.3	7.2	1.2	-	-	4.4	-	-	-	-	

QZ = quartz, PL = plagioclase, OPX = orthopyroxene, CPX = clinopyroxene, HO = hornblende, T-A = tremolite-actinolite, EP = epidote-clinozoisite, CL = chlorite, OP = opaque minerals, OL = olivine, SE = serpentine, TA = talc, RU = rutile, SP = sphene, PH = phlogopite, CA = carbonate.

[1] Location of samples shown on plates 2 and 3.

Table 8 (Cont.)

Derived from gabbroic bodies

MINERALS IN VOLUME PER CENT

SAMPLE NUMBER	QZ	PL	OPX	CPX	HO	T-A	EP	CL	OP	OL	SE	TA	RU	SP	PH	CA	COMMENTS
AHA-167	1.5	6.9	-	-	58.6	-	31.5	1.4	-	-	-	-	-	0.1	-	-	
-198	12.5	1.7	-	-	67.0	-	14.4	2.3	-	-	-	-	0.1	2.0	-	-	PL is An_{53}
-199	8.3	-	-	-	79.3	-	2.7	9.1	0.6	-	-	-	-	-	-	-	
-208	26.8	-	-	-	-	49.0	20.2	1.3	0.5	-	-	-	0.1	2.1	-	-	Qtzt. inclusion
-218	0.8	20.8	-	-	45.0	-	29.6	0.1	3.3	-	-	-	-	0.4	-	-	PL is An_{33}
-221	7.6	20.2	-	-	14.0	-	39.0	14.0	3.2	-	-	-	-	2.0	-	-	PL is An_{33}
-327	5.4	0.8	-	-	62.7	-	25.0	0.7	0.2	-	-	-	-	2.9	1.9	0.4	
-344	3.1	0.3	-	-	-	73.6	20.2	2.0	-	-	-	-	-	0.8	-	-	
-360	2.9	-	-	-	-	79.0	11.9	2.7	2.3	-	-	-	-	1.2	-	-	
-369	24.9	21.8	-	-	40.7	-	8.3	1.3	-	-	-	-	-	3.0	-	-	
-372	3.6	4.1	-	-	-	48.4	41.2	1.2	0.5	-	-	-	-	0.6	-	0.4	PL is An_{30}
-378	1.4	0.5	-	-	-	72.3	24.7	0.3	0.2	-	-	-	-	0.6	-	-	

QZ quartz, PL plagioclase, OPX orthopyroxene, CPX clinopyroxene, HO hornblende,
T-A Tremolite-actinolite, EP epidote-clinozoisite, CL chlorite, OP opaque minerals
OL olivine, SE serpentine, TA talc, RU rutile, SP sphene, PH phlogopite,
CA carbonate

Table 8 (Cont.)

Derived from gabbroic bodies

SAMPLE NUMBER	QZ	PL	OPX	CPX	HO	T-A	EP	CL	OP	OL	SE	TA	RU	SP	PH	CA	COMMENTS
							MINERALS IN VOLUME PER CENT										
AHA-044	6.8	2.8	-	0.3	84.1	-	2.2	2.6	-	-	-	-	-	1.2	-	-	
-045	5.6	27.3	0.1	-	-	39.8	20.9	4.9	1.3	-	-	-	-	0.1	-	-	PL is An_{42}
-046	11.7	14.1	0.3	0.9	66.9	-	1.3	0.6	0.6	-	-	-	-	3.6	-	-	
-047	7.6	24.5	0.5	0.4	61.6	-	3.2	0.2	0.1	-	-	-	-	1.6	0.3	-	PL is An_{28}
-075	7.2	18.8	-	0.3	70.1	-	1.2	0.1	-	-	-	-	-	2.2	0.1	-	
-088	4.5	18.9	-	0.2	69.6	-	3.3	0.9	-	-	-	-	-	0.6	2.0	-	
-091	4.2	12.9	-	-	76.9	-	4.2	0.4	0.2	-	-	-	-	1.0	0.2	-	
-108	2.9	8.2	-	0.4	67.9	-	17.8	1.5	0.1	-	-	-	-	1.2	-	-	
-112	11.8	3.0	-	-	73.6	-	8.3	1.3	0.1	-	-	-	-	1.7	0.2	-	
-113	3.8	13.6	-	-	67.7	-	12.6	1.0	-	-	-	-	-	1.3	-	-	
✓ -114	8.0	10.5	-	0.5	71.0	-	8.0	0.3	0.1	-	-	-	-	1.6	-	-	
-165	6.4	3.4	-	0.5	56.0	-	18.4	9.0	1.6	-	-	-	-	2.7	2.0	-	
-166	4.4	0.9	0.2	-	53.1	-	35.5	4.6	0.4	-	-	-	-	0.9	-	-	

QZ quartz, PL plagioclase, OPX orthopyroxene, CPX clinopyroxene, HO hornblende,
T-A tremolite-actinolite, EP epidote-clinozoisite, CL chlorite, OP opaque minerals
OL olivine, SE serpentine, TA talc, RU rutile, SP sphene, PH phlogopite,
CA carbonate

Individual mafic intrusions

If petrographic study alone is used to classify the various individual mafic bodies (pl. 3) most of the intrusions are either gabbros or diabase. The gabbros and diabases are quartz-bearing in the sense of Williams, Turner. and Gilbert (1954, p. 48) in that they contain primary quartz but less than ten percent. The excess quartz shown in some nodes (table 8) is either secondary quartz produced during amphibolization or quartz in inclusions of quartzite.

Two intrusive bodies, the northernmost intrusions shown in plate 3A and 3G, are more mafic than gabbro. The rocks in these intrusions are highly altered, but they are thought to be chiefly pyroxenites or melanorites. Two of the samples studied from the intrusion in plate 3A are fresh enough to classify; sample 119 (table 8) is a pyroxenite and sample 137 (table 8) a mela-norite.

A highly altered more felsic body is shown in the southeastern part of plate 3E. Two samples (272, 275, table 8) have been studied petrographically and these rocks are highly altered but appear to be diorites.

Chemistry of mafic rocks

Major elements

Wet chemical analyses of 9 amphibolized mafic rocks suggest that these rocks were gabbros, pyroxenites, and diorites. Samples 135, 061, 114, 128, 167, and 198 are close to gabbros chemically, sample 135 - pyroxenite, and samples 221 and 325 - diorite (table 4).

The "gabbros" are chemically like tholeiitic basalts (table 9) suggesting they were derived from a tholeiitic magma. If the main chemical change in conversion to amphibolite was the addition of water these Sierra Madre rocks contain more magnesium and less sodium, potassium and titanium than typical tholeiitic basalt. If this chemical variation is real, it may be related to the age of the rocks. Mueller (1970, p. 632) has correlated the chemical composition of mafic rocks of the Beartooth Mountains of Montana and Wyoming with age (whole rock K-ar ages grouped at 2600, 2000, 1800-1500, 1500-1200, and 700 m.y.). He finds that these rocks are continental tholeiites with low Al_2O_3 content and that TiO_2, K_2O, and Na_2O show a negative correlation with age and MgO shows a positive correlation with age. Although we do not know the age of the amphibolites of the Sierra Madre, geologic evidence and a comparison with dated rocks of the Medicine Bow Mountains suggests they are either early Precambrian or early middle Precambrian, thus the chemical variation from the average may be reasonable for rocks of this age (table 13). In any event there seems to be no point in postulating that the magmas of this area are strikingly different from those of similar age rocks elsewhere

Table 9 NEAR HERE

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TABLE 9

WET CHEMICAL ANALYSES* OF AMPHIBOLITES FROM SIERRA MADRE COMPARED WITH OTHER ROCK TYPES

	Amphibolized quartz bearing gabbro or diabase, Sierra Madre (6 samples)	Average tholeiitic basalt and dolerite of Nockolds	Average gabbro of Nockolds	Amphibolized pyroxenite, Sierra Madre (1 sample)	Average pyroxenite of Nockolds	Amphibolized diorite, Sierra Madre (25 samples)	Average diorite of Nockolds
SiO_2	50.74	50.83	48.36	51.40	50.50	51.07	51.86
Al_2O_3	13.57	14.07	16.84	6.17	4.10	14.19	16.40
Fe_2O_3	2.47	2.88	2.55	1.47	2.44	5.01	2.73
FeO	8.34	9.06	7.92	8.80	7.37	7.24	6.97
MgO	7.93	6.34	8.06	21.22	21.71	5.28	6.12
CaO	11.29	10.42	11.07	5.42	12.00	7.13	8.40
Na_2O	1.67	2.23	2.26	0.65	0.45	4.46	3.36
K_2O	0.43	0.82	0.56	0.05	0.21	0.34	1.33
H_2O+	2.07	0.91	0.64	3.77	0.47	2.25	0.80
TiO_2	0.85	2.03	1.32	0.39	0.53	1.52	1.50
P_2O_5	0.08	0.23	0.24	0.03	0.09	0.13	0.35
MnO	0.18	0.18	0.18	0.21	0.13	0.22	0.18

*Analyst, Blythe E. Engleman

Individual mafic intrusions

Chemical variations in individual mafic intrusions must come from X-ray results and are subject to errors especially in MgO and Na_2O. These results do show, however, that the intrusives are not homogeneous in chemical composition. The two northernmost intrusives shown in plates 3A and 3G were classed as pyroxenite or mela-norite from petrographic study and this is supported by the X-ray results (table 10) inasmuch as these rocks are higher

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Table 10.--NEAR HERE

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in MgO and lower in Al_2O_3 than other mafic bodies. The northernmost intrusion of plate 2A must also contain rocks more felsic in composition because samples 127, 128, and 129 (table 10) are closer to gabbro in composition than pyroxenite. These gabbroic rocks are close to the border of the intrusion but not all border rocks are gabbroic. The northernmost intrusion of plate 3G also contains more felsic rocks, samples 415, 425, and 426 (table 10), near the border of the intrusion but again all border rocks are not more felsic.

The most thoroughly sampled gabbroic bodies are the southernmost intrusion of plate 3A and the single intrusion shown in 3B. The intrusion shown in 3B is fairly homogeneous in composition but the southernmost intrusion of plate 3A is variable in composition (table 10). Most rocks are gabbroic, but eight samples are significantly richer in MgO than the average and ten samples are richer in SiO_2 than average. The silica-rich samples show a higher Na/Ca ratio than gabbroic rocks and the magnesium-rich samples a lower Na/Ca ratio than the gabbroic rocks suggesting a systematic compositional variation, but this variation appears random at this level of exposure of the intrusive body.

TABLE 10

X-RAY FLUORESCENCE ANALYSES

Melanoritic or Pyroxenitic Bodies

SAMPLE NUMBER	OXIDE IN WT. PER CENT[1] SiO_2	Al_2O_3	Fe_2O_3	MgO[2]	CaO	Na_2O	K_2O	TiO_2	MnO	TOTAL
AHA-119[3]	47.20	5.93	13.47	17	6.93	0.29	0.10	0.40	0.26	91.6
-122	52.27	7.38	11.00	8	9.96	0.84	0.10	0.40	0.17	90.1
-124	50.48	8.11	10.96	17	7.79	0.65	0.02	0.45	0.21	95.7
-125	50.58	6.70	11.82	17	6.12	0.35	0.06	0.38	0.24	93.2
-126	52.13	5.93	15.82	8	7.95	0.22	0.11	0.78	0.28	91.2
-127	49.90	12.34	9.05	8	10.57	1.98	0.26	0.37	0.15	92.6
-128	50.37	14.72	9.98	5	11.28	1.00	0.58	0.59	0.18	93.7
-129	49.73	18.77	7.47	5	10.10	3.49	0.34	0.39	0.10	95.4
-130	49.59	5.59	14.35	17	4.70	0.00	0.03	0.33	0.31	91.9
-131	50.87	5.75	12.47	17	6.36	0.00	0.04	0.40	0.26	93.2
-132	50.65	5.53	12.09	17	6.76	0.03	0.04	0.42	0.25	92.8
-133	51.00	5.47	12.86	17	6.34	0.06	0.04	0.40	0.28	93.4
-135	50.77	5.27	12.77	17	5.67	0.00	0.04	0.45	0.28	92.2
-136	51.82	3.00	15.81	17	6.25	0.00	0.09	0.52	0.29	94.8
-137	50.47	9.40	11.52	17	8.74	1.44	0.19	0.54	0.24	99.5
-138	50.93	5.60	12.19	17	6.51	0.61	0.06	0.35	0.26	93.5
-139	50.68	6.06	13.31	17	5.88	0.63	0.06	0.42	0.28	94.3
-140	51.16	5.83	11.72	17	6.48	0.69	0.03	0.41	0.25	93.6
-141	51.07	6.50	10.62	17	7.05	0.69	0.04	0.28	0.23	93.5
-142	51.25	6.64	12.21	17	6.66	0.79	0.05	0.32	0.26	95.2
-382	51.15	6.05	13.18	12	7.54	0.63	0.27	0.29	0.31	91.4
-383	51.05	6.80	11.81	12	7.10	0.57	0.10	0.36	0.24	90.0
-384	48.42	6.32	13.70	12	5.91	0.00	0.23	0.40	0.21	87.2
-385	50.63	5.80	13.20	12	4.87	0.00	0.14	0.47	0.26	87.4
-386	49.96	6.87	12.19	12	6.48	0.36	0.10	0.32	0.27	88.6
-387	51.37	5.92	11.27	12	7.40	0.57	0.62	0.55	0.28	90.0
-388	50.56	6.26	12.61	12	5.78	0.90	0.71	0.34	0.27	89.4
-389	51.54	6.23	12.10	12	6.22	0.61	0.07	0.44	0.27	89.5

[1]Analyst, J. Eric Schuster

[2]MgO analyses are by D. C.-arc spectrography. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E.F. Cooley

[3]Location of samples shown on plates 2 and 3.

TABLE 10 (Cont.)

X-RAY FLUORESCENCE ANALYSES

Gabbroic Bodies

SAMPLE NUMBER	SiO_2	Al_2O_3	Fe_2O_3	MgO[2]	CaO	Na_2O	K_2O	TiO_2	MnO	TOTAL
				OXIDE IN WT. PER CENT[1]						
AHA-004	51.72	9.40	12.43	17	9.14	1.32	0.28	0.60	0.21	102.1
-006	70.90	11.96	1.59	3	2.98	5.59	0.15	0.51	0.06	96.7
-008	52.08	8.77	10.87	17	10.20	1.51	0.35	0.59	0.21	101.6
-010	54.76	15.08	9.29	8	9.08	3.07	0.41	1.54	0.13	101.4
-012	53.78	14.58	11.57	5	9.64	3.29	0.67	0.82	0.18	99.5
-013	53.74	14.00	14.70	5	8.28	2.80	1.11	1.18	0.21	101.0
-016	51.09	15.42	11.80	12	10.01	2.80	0.53	1.07	0.18	104.9
-017	51.72	12.60	13.38	12	11.11	1.90	0.39	1.26	0.20	104.6
-019	54.10	14.35	14.77	5	8.18	2.63	0.79	1.17	0.20	101.2
-020	51.28	14.90	8.95	8	11.28	2.25	0.78	0.69	0.16	98.3
-022	51.33	13.57	15.40	5	9.76	2.36	0.37	1.48	0.21	99.5
-023	53.02	13.62	11.95	5	9.59	2.58	0.38	1.61	0.16	97.9
-024	52.34	13.81	11.04	8	9.42	3.48	0.50	1.03	0.16	99.8
-025	55.57	15.13	13.63	2	6.47	3.24	1.04	1.33	0.17	98.6
-026	52.36	14.51	10.38	5	10.85	2.17	0.59	0.87	0.17	96.9
-027	51.81	15.46	9.62	8	9.44	2.69	1.08	0.68	0.17	99.0
-030	51.50	11.05	11.39	12	10.53	2.00	0.62	0.73	0.20	100.0
-031	53.17	14.10	15.11	5	8.89	2.47	0.78	1.01	0.21	100.7
-032	51.64	15.25	10.38	8	10.33	2.42	0.62	0.86	0.17	99.7
-033	51.26	11.25	13.17	12	9.41	1.40	0.33	1.04	0.22	100.1
-035	51.01	13.10	13.18	8	10.49	1.98	0.39	1.31	0.21	99.7
-036	50.56	13.41	12.58	8	10.05	1.87	0.62	1.19	0.21	98.5
-038	51.67	13.57	11.41	5	9.81	2.22	0.64	1.09	0.17	95.6
-039	51.66	15.00	10.90	5	9.99	2.47	0.89	0.72	0.18	96.8
-041	51.80	10.69	11.51	17	12.15	1.62	0.22	0.94	0.21	106.1
-044	53.27	8.17	12.18	17	11.22	1.20	0.19	0.79	0.20	104.2
-045	52.05	14.90	10.08	17	9.87	2.08	0.98	0.83	0.18	108.0
-046	50.96	13.32	15.55	12	9.54	2.37	0.58	1.66	0.22	106.2
-047	52.19	15.22	9.30	17	10.50	2.90	0.58	0.70	0.15	108.5
-050	50.84	12.31	11.96	17	11.79	1.68	0.38	1.01	0.20	107.2
-051	51.98	14.15	14.86	8	9.07	2.35	0.42	1.76	0.20	102.8
-052	50.65	13.20	13.83	12	10.12	2.39	0.47	1.36	0.20	104.2
-053	51.96	15.15	10.58	8	10.00	2.68	0.79	0.84	0.17	100.2
-054	51.61	10.57	12.29	17	7.31	1.48	0.21	0.73	0.23	101.4

[1] Analyst, J. Eric Schuster

[2] MgO analyses are by D. C.-arc spectrography. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley.

TABLE 10 (Cont.)

X-RAY FLUORESCENCE ANALYSIS

Gabbroic Bodies

SAMPLE NUMBER	OXIDE IN WT. PER CENT[1] SiO_2	Al_2O_3	Fe_2O_3	MgO[2]	CaO	Na_2O	K_2O	TiO_2	MnO	TOTAL
AHA-056	52.55	14.89	13.25	3	8.23	2.48	0.99	1.20	0.19	96.8
-057	51.97	15.04	9.63	5	10.88	2.39	0.51	0.81	0.16	96.4
-059	51.54	14.92	8.54	8	11.77	2.84	0.50	0.66	0.16	97.9
-061	50.51	13.98	13.36	8	11.80	2.17	0.69	0.85	0.19	101.6
-062	51.84	14.36	10.43	12	11.01	2.33	0.65	0.81	0.18	103.6
-065	53.53	14.18	15.04	2	6.56	4.12	0.45	1.97	0.16	98.0
-066	52.91	14.13	12.34	5	9.09	2.66	0.96	1.07	0.18	98.3
-067	51.82	13.91	9.08	5	11.02	2.79	0.65	0.79	0.15	95.2
-069	50.13	11.69	10.80	8	10.61	1.79	0.48	0.61	0.19	94.3
-070	50.72	10.73	9.73	12	11.22	1.82	0.96	0.60	0.18	98.0
-071	50.12	12.21	11.01	8	10.75	2.06	0.33	0.73	0.19	95.4
-072	50.02	9.39	11.18	8	12.36	1.53	0.49	0.79	0.20	94.0
-075	51.81	13.98	12.40	5	9.72	2.19	0.61	1.15	0.19	97.0
-082	51.71	15.59	19.04	5	0.13	2.92	0.20	0.84	0.21	95.6
-086	50.66	12.36	11.67	8	9.34	2.96	0.43	0.61	0.17	96.2
-088	51.00	14.32	11.62	5	10.41	2.05	0.57	0.64	0.19	95.8
-090	50.84	14.63	10.61	5	10.57	2.18	0.49	0.66	0.19	95.2
-091	51.57	13.24	11.33	5	10.53	1.72	0.55	0.78	0.19	94.9
-104	51.67	13.04	11.38	5	11.20	1.49	0.44	0.86	0.19	95.3
-106	50.82	12.53	11.12	8	11.83	1.46	0.51	0.83	0.19	97.3
-108	51.19	12.03	11.05	5	12.37	1.69	0.20	0.79	0.19	94.5
-112	50.84	12.41	11.89	5	11.96	1.53	0.41	0.87	0.20	95.1
-113	50.92	12.39	11.18	5	12.42	1.33	0.23	0.81	0.19	94.5
-114	51.66	11.97	11.73	5	11.85	1.40	0.29	0.96	0.20	95.1
-144	50.12	11.44	11.61	8	11.63	1.94	0.55	0.87	0.19	96.4
-149	50.95	11.76	11.81	8	11.63	1.65	0.38	0.93	0.21	97.3
-150	51.26	10.86	11.21	8	11.92	1.34	0.39	0.72	0.20	95.9
-154	51.09	11.01	11.46	8	10.65	1.13	1.58	0.88	0.21	96.0
-155	50.98	11.79	12.81	8	10.91	1.65	0.66	1.07	0.19	98.1
-159	50.51	11.22	13.58	8	11.25	1.50	0.55	1.12	0.23	98.0
-161	47.05	13.52	12.23	8	9.85	1.60	0.89	1.17	0.19	94.5
-165	50.98	11.28	13.23	5	11.46	1.37	0.53	1.02	0.21	95.1
-166	50.84	11.85	12.01	5	11.64	1.70	0.43	0.92	0.20	94.6
-167	50.45	11.99	10.40	8	12.22	2.07	0.53	0.83	0.17	96.7

[1] Analyst, J. Eric Schuster

[2] MgO analyses are by D.C.-arc spectrography. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley

Table 10 (Cont.)

SAMPLE NUMBER	SiO_2	Al_2O_3	Fe_2O_3	MgO[2]	CaO	Na_2O	K_2O	TiO_2	MnO	TOTAL
	OXIDE IN WT. PER CENT[1]									
AHA-171	50.89	11.24	14.12	8	11.16	1.73	0.33	1.05	0.22	98.7
-173	49.93	11.69	10.90	8	11.59	1.55	0.60	0.81	0.18	95.2
-193	55.25	14.19	9.86	3	9.71	1.97	0.66	0.85	0.17	95.7
-194	56.12	13.78	9.97	3	8.57	2.75	0.63	0.91	0.15	95.9
-196	56.37	14.08	10.15	3	9.37	2.10	0.49	0.87	0.16	96.6
-197	53.46	12.07	9.01	12	10.41	1.54	0.44	0.69	0.19	99.8
-198	50.71	13.98	10.75	8	11.78	1.54	0.26	0.77	0.19	98.0
-199	54.75	8.87	14.76	8	9.06	0.50	0.36	0.75	0.29	95.3
-201	51.12	14.83	11.53	8	11.73	0.64	0.31	0.76	0.21	99.2
-208	60.32	12.14	9.14	3	8.48	1.19	0.39	0.87	0.14	95.7
-212	51.14	8.43	10.97	17	8.77	1.64	0.12	0.62	0.22	98.9
-218	49.76	13.28	13.39	8	9.05	4.17	0.40	1.53	0.12	99.7
-219	50.64	13.46	12.08	8	8.21	4.45	0.38	1.61	0.11	98.9
-220	50.57	14.33	13.90	3	7.90	2.99	0.72	1.52	0.19	95.1
-221	50.73	14.38	15.58	3	7.33	3.96	0.26	1.78	0.15	97.2
-222	50.37	15.54	10.20	3	9.33	4.34	0.28	1.30	0.11	94.5
-227	49.61	15.39	13.93	3	9.59	3.34	0.46	1.71	0.19	97.2
-229	48.68	14.60	15.00	3	9.50	2.33	0.45	1.59	0.22	95.4
-232	50.66	13.24	14.36	8	8.00	4.34	0.69	1.55	0.08	100.9
-234	49.57	13.70	11.43	8	7.25	3.86	0.92	1.00	0.09	95.8
-246	49.67	13.83	11.49	8	10.33	3.20	0.71	1.21	0.18	98.6
-247	49.70	14.09	11.03	12	11.66	1.88	0.45	0.95	0.19	102.0
-248	49.71	14.11	11.68	12	10.54	2.61	0.59	0.97	0.19	102.4
-249	50.10	13.19	12.73	8	10.34	2.23	0.61	1.07	0.21	98.5
-253	50.93	13.47	14.30	12	10.35	1.74	0.89	1.21	0.21	105.1
-254	52.21	15.35	10.56	5	7.41	4.79	1.05	1.89	0.19	98.4
-256	49.88	13.30	14.36	8	8.18	2.54	1.40	1.06	0.24	99.0
-311	51.57	12.79	12.24	5	11.60	1.50	0.39	0.88	0.21	96.2
-325	50.77	12.83	14.05	8	7.14	4.57	0.55	1.44	0.36	99.7
-327	51.12	13.81	14.09	8	9.82	1.97	0.64	1.47	0.23	101.2
-328	49.45	13.39	16.52	8	6.75	3.85	1.35	2.10	0.33	101.7
-329	50.60	11.25	10.64	12	9.36	1.56	0.21	0.59	0.21	96.4
-330	51.71	10.84	10.32	17	10.15	1.69	0.42	0.74	0.19	103.1
-331	49.06	9.39	11.63	17	10.61	1.43	0.27	0.95	0.20	100.5

1. Analyst, J. Eric Schuster
2. MgO analyses are by D. C.-arc spectrography. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley

Table 10 (Cont.)

SAMPLE NUMBER	OXIDE IN WT. PER CENT[1]									
	SiO_2	Al_2O_3	Fe_2O_3	MgO[2]	CaO	Na_2O	K_2O	TiO_2	MnO	TOTAL
AHA-332	50.81	11.71	11.80	12	9.73	1.10	0.47	0.88	0.19	98.7
-340	50.60	12.05	12.41	8	11.77	1.69	0.22	0.98	0.20	97.9
-341	50.55	11.67	11.25	8	12.46	1.65	0.35	0.67	0.22	96.8
-342	52.05	10.15	11.06	8	12.88	1.33	0.24	0.70	0.21	96.6
-343	50.98	11.72	10.66	8	12.69	1.92	0.20	0.72	0.18	97.1
-344	49.91	12.02	12.57	8	12.07	1.49	0.27	0.58	0.21	97.3
-345	51.53	9.92	10.69	12	13.09	1.65	0.21	0.68	0.20	100.0
-346	51.16	11.65	11.39	8	11.62	1.82	0.22	0.72	0.21	96.8
-347	50.57	11.66	11.22	8	12.07	2.05	0.25	0.62	0.21	96.6
-348	51.61	10.27	11.63	8	12.80	1.59	0.18	0.74	0.22	97.0
-349	50.47	12.19	11.48	8	12.53	1.59	0.17	0.65	0.20	97.3
-350	51.58	11.16	11.19	12	12.89	1.33	0.18	0.73	0.21	101.3
-352	51.44	11.23	12.57	12	11.73	1.88	0.31	0.95	0.22	102.3
-354	51.13	11.65	11.64	12	12.24	1.46	0.21	0.88	0.22	101.4
-361	50.94	11.68	11.96	8	11.96	1.69	0.24	0.89	0.21	97.6
-362	48.79	13.17	11.87	12	11.83	2.20	0.32	1.00	0.20	101.4
-367	51.03	12.03	12.36	8	12.23	1.90	0.20	0.94	0.21	98.9
-376	51.96	10.31	10.84	8	12.93	1.20	0.12	0.72	0.21	96.3
-378	51.43	10.46	11.65	8	12.88	1.60	0.15	0.81	0.21	97.2
-381	51.02	10.58	12.15	8	12.44	1.63	0.16	0.84	0.22	97.0
-355	49.37	14.16	13.97	8	5.55	1.56	0.05	0.87	0.16	93.7
-359	51.90	14.58	11.73	8	8.62	1.52	0.12	0.83	0.19	97.5
-360	45.90	14.67	17.59	5	10.31	0.62	0.21	1.60	0.31	96.2
-363	50.73	14.78	12.27	8	10.93	1.75	0.35	0.92	0.22	100.0
-365	50.95	13.35	9.42	8	11.50	1.60	0.48	0.69	0.19	96.2
-366	40.58	15.32	21.18	8	10.67	1.90	0.55	2.03	0.37	100.6
-368	53.76	14.43	10.33	8	9.95	2.35	0.34	0.62	0.17	100.0
-370	51.32	14.44	10.16	8	11.74	1.45	0.30	0.77	0.19	98.4
-372	50.84	14.21	10.86	8	11.28	1.63	0.11	0.83	0.21	98.1
-373	50.24	13.72	13.14	8	14.28	0.84	0.08	0.95	0.23	101.5
-375	51.33	14.37	10.73	8	11.39	1.84	0.22	0.84	0.19	98.9
-377	49.22	15.15	12.37	8	11.76	1.69	0.01	1.13	0.1	99.
-379	50.54	14.63	11.03	8	11.12	1.75	0.13	0.81	0.19	98.2
-380	50.88	13.88	9.49	8	12.19	1.72	0.16	0.63	0.18	97.1

1. Analyst, J. Eric Schuster
2. MgO analyses are by D. C.-arc spectrography. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley

Table 10 (Cont.) Hydrothermally(?) Altered Amphibolite

SAMPLE NUMBER	SiO_2	Al_2O_3	Fe_2O_3	MgO[2]	CaO	Na_2O	K_2O	TiO_2	MnO	TOTAL
	OXIDE IN WT. PER CENT[1]									
AHA-300	58.00	13.32	13.20	5	0.08	1.83	1.24	0.97	0.07	93.7
-302	66.39	10.26	9.45	3	3.83	1.06	2.03	0.64	0.11	96.8

1. Analyst, J. Eric Schuster
2. MgO analyses are by D. C.-arc spectrography. Analyst, B. Wayne Lanthorn

Trace elements

Comparison of copper and platinum group abundances with other mafic rocks

Table 11 shows the abundance of copper and platinum group elements in the rocks studied as compared with abundances for similar rocks. These mafic rocks do not have anomalous amounts of these elements as all fall within the ranges reported by other authors for similar rock types. We must emphasize at the outset, however, that all comparisons with crustal abundances and abundances in various rock types for the platinum metals suffer because of the difficulty analysts have enccuntered in determination of low concentrations of these elements in rock.

Table 11.--NEAR HERE

TABLE 11

COPPER AND PLATINUM GROUP ABUNDANCES COMPARED WITH OTHER ROCKS REPORTED IN THE LITERATURE

Rock Type	Number of Samples	Cu, ppm	Pt, ppb	Pd, ppb	Rh, ppb	Ir, ppb
Sierra Madre						
Amphibolite derived from metanorite or pyroxenite	56	34	22	10	1	N
Amphibolite derived from gabbro	132	89	23	14	1	3
Other Rocks						
Basalts[1]	15		26	41		
Diabases[1]	5		37	16		
Bushveld gabbros[1]	4		21	31		
Other gabbros[1]	4		19	20		
Skaergaard (chilled marginal gabbro)[1]	2		18	18		
Bushveld norites[1]	7		38	15		
Sudbury norites[1]	2		11	6		
Igneous rocks[1]	27		11	17		
Igneous rocks[1]	-		5	20	1	1
Ultrabasic[2]	-	10				
Basaltic rocks[2]	-	87				
Ontario diabase[3]	57	72				
Mafic rocks[4]	-	100	100	19		
Intermediate rocks[4]	-	35				

[1]Wright and Fleischer, 1965, p. A13
[2]Turekian and Wedepohl, 1961, Table 2
[3]Fairbairn, Ahrens, and Gorfinkle, 1953, p. 42
[4]Vinogradov, 1962, p. 647

Theobald and Thompson (1968, p. 14) have suggested that parts of the Medicine Bow Mountains (south of and within the shear zone that separates older from younger rocks) and possibly the Sierra Madre have mafic igneous rocks unusually rich in platinum and associated metals. Table 12 shows the abundance of platinum plus palladium in amphibolite of the Medicine Bow Mountains as compared with the Sierra Madre. Although the number of samples of amphibolite analyzed in the Medicine Bow Mountains is small, platinum plus palladium is four times as abundant as in the Sierra Madre and is indeed an order of magnitude above crustal abundances. Further support for anomalous platinum and palladium in the Medicine Bow Mountains comes from analyses of coarse tailings of the Rambler mine of this area and from mineralized samples from four other mines of this area. The sulfide mineralization in these mines occurs where shear zones cut amphibolitized mafic igneous rocks (McCallum, 1968, p. 8). Nine samples from the Rambler mine averages 1750 ppb platinum plus palladium and 9 samples from four other mines of the area average 180 ppb platinum plus palladium (Theobald and Thompson, 1968, p. 6, Table 2, p. 13, Table 6). In contrast, 20 mineralized samples from various parts of the Sierra Madre average 2.0 (SD=6) ppb platinum plus palladium and not one of these samples exceeds crustal abundances. This certainly suggests that there is a strong contrast in abundance of platinum group metals between the Sierra Madre and Medicine Bow Mountains.

Table 12.--NEAR HERE

TABLE 12

COMPARISON OF PLATINUM PLUS PALLADIUM IN AMPHIBOLITES

FROM SIERRA MADRE AND MEDICINE BOW MOUNTAINS

Locality	Rock Type	Platinum plus Palladium
Medicine Bow Mountains[1]	Phyllonitic dike rock	200 ppb
Medicine Bow Mountains[1]	Phyllonitic dike rock	50
Medicine Bow Mountains[1]	Coarse-grained amphibolite	150
Medicine Bow Mountains[1]	Sheared, chloritized amphibolite	100
Medicine Bow Mountains[1]	Coarse tailings - Rambler Mine (largely metagabbro) average 9 samples	1750
Medicine Bow Mountains[1]	Average	1350
Sierra Madre	Amphibolite from gabbro average 132 samples	37
Sierra Madre	Amphibolite from norite average 56 samples	32
Sierra Madre	Hydrothermally altered amphibolite average two samples	35
Sierra Madre	Maximum	280
Medicine Bow Mountains[1]	Average excluding Rambler Mine	125
Sierra Madre	Average 190 samples	35

[1]Theobald and Thompson, 1968

The copper content of amphiboles from samples collected from mineralized areas seems to show a reverse trend to that of platinum group metals in these two areas. The copper content of amphibolites and mafic rocks of the Sierra Madre averages 73 ppm for 190 samples whereas 4 samples of amphibolite from the Medicine Bow Mountains average 24 ppm. Seventeen mineralized samples from five mines of the Medicine Bow Mountains average 3050 ppm copper whereas 18 samples of mineralized rock from the Sierra Madre average 17,000 ppm copper.

In summary, copper and platinum group elements are not present in anomalous amounts in mafic igneous rocks of the Sierra Madre compared with crustal abundances. Sampling of mafic igneous rocks of the Medicine Bow Mountains is not sufficient for a satisfactory comparison with the Sierra Madre, but if all rock types are considered that part of the Medicine Bow Mountains south of and within the shear zone that separates older and younger rocks does have platinum group metals in amounts higher than crustal abundances, and there is a suggestion that this area contrasts with the Sierra Madre in being high in platinum group metals but low in copper.

Possible significance of the contrast in platinum metal abundance between the Sierra Madre and Medicine Bow Mountains

The coincidence of rocks with greater than crustal abundance platinum with the major faults and shear zones of the Medicine Bow Mountains may be significant. Inasmuch as the Mullen Creek-Nash Fork shear zone seems to mark a boundary between geologic and geochronologic provinces, the shear zone may be a major crustal discontinuity and as such a possible site for emplacement of platinum bearing rocks as indicated below.

In our initial discussion of this shear zone (Hills and others, 1968, p. 1778) we compared it with other large shear zones in orogenic belts such as the Brevard zone, which separates the Blue Ridge and Piedmont provinces of the southern Appalachians. The Mullen Creek-Nash Fork shear zone also has characteristics like parts of the Grenville front of eastern Canada but no older "cannibalized" rocks have been recognized south of the Mullen Creek-Nash Fork shear zone, whereas such rocks are common south of the Grenville front which seem to mark the limit of radiometric updating and reworking of sialic basement (Wynne-Edwards, 1971, p. 759) rather than a zone separating two geologic provinces. The Brevard zone of the Appalachians has been compared with Alpine root zones and the suggestion has been made that it is a site of downward movement of crustal material (Burchfield and Livingston, 1967, p. 241-256). Although the Brevard zone may have had a complex history including major strike-slip movement (Reed, Bryant, and Myers, 1970, p. 262), if Burchfield and Livingston are correct, it may have initially developed as a subduction zone bringing unlike rocks into juxtaposition during a period of plate closure; a concept proposed for the northern Appalachian origin by Bird and Dewey (1970, p. 1031-1060). If the Mullen Creek-Nash Fork shear zone is comparable to the Brevard it follows that it may also be a site of subduction, a concept advocated by Hills and Armstrong (1971, p. 599-600) but not specifically discussed in their abstract.

There is no agreement among geologists as to the extent, if any, of plate movement during the Precambrian. Most students of rocks of Precambrian age have been conservative in this respect perhaps following Engel (1971, p. 556-557) who suggests that the K/Na ratios of igneous and sedimentary rocks and secular features of orogenesis indicates that widespread drift (>2,000 km) of large continental fragments is unique to the post-Permian. Engel proposes subparallel spreading centers of limited extent during the Archean, but suggests that Proterozoic rifts and drifts were subordinate and largely accretive. Spall (1971, p. 273, 280), however, has presented evidence for extensive Precambrian polar wandering during middle and late Precambrian, and, if a constancy of magnetic and geographic poles through time is assumed, the amount of drift during this time interval may have been comparable to that of the post-Permian.

If we assume that the Mullen Creek-Nash Fork shear zone is indeed a subduction zone, the occurrence of platinum bearing rocks in the vicinity of the shear zone may be explained because ultramafic and mafic rocks containing platinum are found adjacent to other preserved subduction zones such as that of the west coast of the United States (Hamilton, 1969, Ernst, 1970) and that of the Ural Mountains of Russia (Hamilton, 1970).

Whether or not the Mullen Creek-Nash Fork shear zone was a subduction zone at one stage in its history, the shear zone does separate a basement (>2.4 b.y.) with a miogeosynclinal sedimentary cover (<2.4>1.7 b.y.) in the north from a eugeosyncline facies (1.8 b.y.) on the south. The platinum bearing rocks of the Medicine Bow Mountains are composite bodies that include ultramafic and mafic phases. They are metamorphosed to amphibolite facies and strongly sheared so that it is difficult to determine if they are remnants of ophiolite suites. They are on the south (eugeosynclinal) side of the main shear zone and may represent ophiolite remnants stacked against the main subduction zone. Certainly this interpretation is tentative and requires greater documentation than can be presented here, but it does offer a possible reason for the contrast in platinum content between mafic rocks of the Medicine Bow Mountains and the Sierra Madre.

Nickel and cobalt in mafic igneous rocks

Expected trends in abundances of nickel and cobalt are shown below:

Nickel in mafic rocks

Norite (56 samples)			Gabbro (136 samples)			Alt. mafic rock		
Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
404.5	185.4	100-1000 ppm	108.7	48.3	30-300 ppm	60.0	14	50-70 ppm

Cobalt in mafic rocks

Norite (56 samples)			Gabbro (136 samples)			Alt. mafic rock		
Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
51.1	11.1	30-70 ppm	35.1	19.2	15-200 ppm	25.0	7.1	20-30 ppm

In general, both elements are more abundant. In the more mafic rock types. For a comparison with average abundance figures, Engel, Engel, and Havens (1965) give figures of 32 ppm for cobalt and 97 ppm for nickel in oceanic tholeiitic basalts, Vinogradov (1962) gives averages of 45 ppm for cobalt and 160 ppm for nickel in basalts, and Prinz (1967) finds an arithmetic mean of 40 ppm for cobalt for 257 analyses and 88-90 ppm nickel for 262 analyses for basalt. These figures approximate those for the gabbro of this area. On the other hand Goldschmidt's (1937) averages of 87 ppm cobalt and 174 ppm nickel in gabbros is nearly an order of magnitude higher for both elements than averages of Sierra Madre.

Copper, nickel, cobalt, platinum, and palladium in metasedimentary and metavolcanic rocks

The analytical results for copper, nickel, cobalt, platinum, and palladium in metasedimentary and metavolcanic rocks show a wide range and a high standard deviation. The results, however, give some measure of the availability of these metals in country rock and they allow us to compare abundances in country rock with abundances in the mafic igneous rocks of the area.

Copper

Copper ranges from a low of 14.6 ppm in phyllite to a high of 121.3 ppm in calcareous schist of the Sierra Madre (table 13). The average copper content of metasedimentary rocks (quartzite, metalimestone, quartz-mica schist, phyllite, and calcareous schist) is 35.5 ppm for 154 samples biased towards quartzite which is the most abundant metasedimentary rock of this area (table 14). This figure compares favorably with an average of 33 ppm for copper reported in metasedimentary rocks of the Canadian Shield in the Red Lake-Lansdowne House area, northwestern Ontario (Ernslie and Holman, 1966), but is lower than the mean value of 57 ppm estimated for clay and shale by Vinogradov (1956) (table 14). In general, sandstone and quartzite excepted, the metasedimentary rock appears to have a lower copper content than its unmetamorphosed equivalent. This is true of averages but seems particularly impressive when we compare the averages for copper content of shales (Clarke, 1924, 45 ppm; Vinogradov, 1956, 57 ppm) with the 14.6 ppm average for phyllite of the Sierra Madre. It seems reasonable to assume that copper is liberated from shales during compaction and metamorphism so this is to be expected.

Tables 13 and 14.--NEAR HERE

Table 13. Metallic Metal Contents of Metasedimentary and Metavolcanic Rocks Expressed as Average, Standard Deviation and Range.

Quartzite (80 samples)														
Copper	Mean	23.62	Nickel	Mean	95.15	Cobalt	Mean	81.67	Platinum	Mean	1.75	Palladium	Mean	.8
ppm	SD	42.28	ppm	SD	566.65	ppm	SD	559.10	ppb	SD	6.32	ppb	SD	3.5
	Range	0-300		Range	0-5000		Range	0-5000		Range	0-40		Range	0-
Granite Schist (33 samples)														
Copper	Mean.	25.54	Nickel	Mean	37.18	Cobalt	Mean	18.51	Platinum	Mean	1.21	Palladium	Mean	1.
ppm	SD	50.98	ppm	SD	29.77	ppm	SD	17.66	ppb	SD	6.96	ppb	SD	6.
	Range	2-300		Range	7-150		Range	0-100		Range	0-40		Range	0-
Limestone (29 samples)														
Copper	Mean	21.00	Nickel	Mean	26.96	Cobalt	Mean	9.58	Platinum	Mean	.344	Palladium	Mean	.
ppm	SD	14.19	ppm	SD	39.68	ppm	SD	8.91	ppb	SD	1.856	ppb	SD	.
	Range	7-70		Range	0-150		Range	0-30		Range	0-20		Range	0
Quartz-mica Schist (20 samples)														
Copper	Mean	50.60	Nickel	Mean	66.25	Cobalt	Mean	26.10	Platinum	Mean	1.0	Palladium	Mean	.
ppm	SD	64.85	ppm	SD	58.10	ppm	SD	19.19	ppb	SD	4.47	ppb	SD	1.
	Range	5-300		Range	10-150		Range	0-50		Range	0-20		Range	0-
Phyllite (10 samples)														
Copper	Mean	14.60	Nickel	Mean	10.20	Cobalt	Mean	9.20	Platinum	Mean	0	Palladium	Mean	0
ppm	SD	14.34	ppm	SD	6.52	ppm	SD	5.02	ppb	SD	0	ppb	SD	0
	Range	1-50		Range	0.20		Range	0-15		Range	0		Range	0
Lime Schist (15 samples)														
Copper	Mean	121.33	Nickel	Mean	88.66	Cobalt	Mean	32.66	Platinum	Mean	25.33	Palladium	Mean	21
ppm	SD	64.68	ppm	SD	60.45	ppm	SD	13.87	ppb	SD	27.48	ppb	SD	34
	Range	70-300		Range	50-300		Range	20-70		Range	0-100		Range	0-
Metavolcanic (26 samples)														
Copper	Mean	97.30	Nickel	Mean	60.38	Cobalt	Mean	52.69	Platinum	Mean	0	Palladium	Mean	.
ppm	SD	133.49	ppm	SD	16.84	ppm	SD	15.37	ppb	SD	0	ppb	SD	.
	Range	20-700		Range	20-100		Range	30-100		Range	0		Range	0-
Pillow Lava (13 samples)														
Copper	Mean	50.76	Nickel	Mean	78.46	Cobalt	Mean	50	Platinum	Mean	1.53	Palladium	Mean	.
ppm	SD	21.77	ppm	SD	27.94	ppm	SD	none	ppb	SD	3.75	ppb	SD	1.
	Range	30-100		Range	50-150		Range	50		Range	0-10		Range	0

TABLE 14

ESTIMATES OF THE ABUNDANCE OF COPPER IN PPM IN

SEDIMENTARY AND METASEDIMENTARY ROCKS

Rock Type	Area	Author	Cu PPM
Sandstone	Average	Middleton (1960)	20.0
Quartzite	Sierra Madre		23.6
Shales	Average	Clarke (1924)	45.0
Clay and Shale	Average	Vinogrodov (1956)	57.0
Metasedimentary Rock	Canadian Shield	Emslie (1966)	33.0
Metasedimentary Rock	Sierra Madre		33.5
Shales	Average	Turekian and Wedepohl (1961)	45.0
Clay	Average	Turekian and Wedepohl (1961)	250.00

Thirty-three samples of granite gneiss of the Sierra Madre average 25.5 ppm copper. This compares with 18 ppm copper in gneiss and migmatite of the Canadian Shield (Ernslie and Holman, 1966). Metavolcanic rocks of the Sierra Madre average 97.3 ppm copper and pillow lavas 50.7 ppm copper, with an overall average for 39 samples of mafic volcanic rock of 81.8 ppm copper. Basic volcanic rocks of the Red Lake-Lansdowne House of the Canadian Shield (Ernslie and Holman, 1966) average 61 ppm copper, basalts of the Copper Mine River, District of MacKenzie of the Canadian Shield (Barager, 1969) average 126 ppm copper, "oceanic" tholeiitic basalts (Engel, Engel, and Havens, 1965) average 77 ppm copper, and Vinodgradov's (1962) average basalt contains 100 ppm copper. With the exception of the basalts of Copper Mine River that are probably somewhat copper-rich, the copper values of mafic metavolcanic rocks of the Sierra Madre agree reasonably well with averages obtained by other workers.

The most interesting aspect of the copper analyses in these rocks is the fact that average copper contents of mafic metavolcanic and mafic meta-igneous rocks of the Sierra Madre do not differ appreciably from averages of unmetamorphosed rocks reported in the literature, whereas the copper content of phyllite and metasedimentary rock, in general, of the Sierra Madre is significantly lower than that of unmetamorphosed sedimentary rocks.

Nickel and cobalt

Nickel and cobalt range from 10.2 ppm and 9.2 ppm respectively in phyllite to 95.1 and 81.7 ppm in quartzite. The average nickel content of metasedimentary rocks of the Sierra Madre (biased towards quartzite) is 72.5 ppm, and the average cobalt content is 51.6 ppm. The average nickel content of shales (Clarke, 1924) is 42 ppm and the average nickel content of sandstones (Middleton, 1960) is 25 ppm. The average cobalt content of shales (Clarke, 1924) is 19 ppm and for sandstones (Middleton, 1960) is 10 ppm. Other analyses for cobalt and nickel reported by Rankama and Sahama (1950, p. 685) suggest much higher values for these elements in sedimentary rocks. The variations in results are, in fact, so great that comparisons between values for rocks of the Sierra Madre and those determined elsewhere will not be attempted.

 (p. 70a follows)

The average nickel and cobalt content for metavolcanic rocks of the Sierra Madre are reported in table 13.

Mean values for nickel of all mafic metavolcanic rocks of the Sierra Madre are 66 ppm and for cobalt 52 ppm. Engel, Engel, and Havens (1965) report 97 ppm nickel and 32 ppm cobalt in "oceanic" theoliitic basalts whereas Vinogradov (1962) suggests that basalt averages for nickel should be 160 ppm and for cobalt 45 ppm. Prinz (1967, p. 306) suggests earlier reported values for nickel in basalts may be high and he gives an average arithmetic mean of 88-90 ppm and a median of 75 ppm for 262 analyses, and for cobalt Prinz gives an arithmetic mean of 40 ppm and a median of 38 ppm for 257 analyses. The results for nickel and cobalt compare favorably with Prinz' means of basalt suggesting that Sierra Madre mafic volcanic rocks have normal or expected amounts of these elements.

Summarizing, analyses of cobalt and nickel in metavolcanic rocks do not appear to vary widely from averages suggested for similar rocks elsewhere, but little can be said about the metasedimentary rocks because previous estimates of average values vary considerably.

(p. 71 follows)

Platinum and palladium

A summation of available information on the abundance of platinum metals in common sedimentary rock types has been made by Crockett (1969, p. K-1-K-3). The analyses are limited and seem to be of unusual sedimentary rock types rather than common ones, so it is impossible to make meaningful comparisons with the rocks of the Sierra Madre.

Most of the metasedimentary rocks of the Sierra Madre contain vanishingly small amounts of platinum and palladium (table 13), less than 1 ppb, but the calcareous schist averages 25 ppm platinum and 21 ppb palladium. This calcareous schist is also enriched in copper but not on the same order of magnitude as the platinum metals when compared with other metasedimentary rocks (table 13).

The platinum content of Sierra Madre metavolcanic rocks (table 13) is much lower than suggested values for basalts and diabases (table 11) that might be the closest equivalents of these rocks.

Trace elements in individual mafic bodies

The two intrusive bodies classed as pyroxenite or mela-norite (northernmost body in plate 3A and 3G) contain slightly more cobalt and distinctly more nickel and chromium than gabbroic intrusions (table 15). Platinum varies

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Table 15.--NEAR HERE

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widely in individual mafic bodies as can be seen from standard deviations and platinum content of the individual bodies cannot be clearly related to rock type or location. Despite a wide variance, copper is more abundant in the gabbroic intrusions than in the more mafic bodies (table 15).

TABLE 15

TRACE ELEMENTS IN INDIVIDUAL BODIES

OF AMPHIBOLITE, SIERRA MADRE

Location	Sample Numbers	Total No. Samples	Pt (ppb)	Cu (ppm)	Co (ppm)	Ni (ppm)	Cr (ppm)
1[1]	119-142	20	$\bar{x}$ = 40. SD = 38.	$\bar{x}$ = 40. SD = 35.	$\bar{x}$ = 45. SD = 11.	$\bar{x}$ = 293. SD = 189.	$\bar{x}$ =1332. SD = 660.
2	382-476	34	$\bar{x}$ - 12. SD = 10.	$\bar{x}$ = 32. SD = 27.	$\bar{x}$ = 55. SD = 10.	$\bar{x}$ = 450. SD = 126	$\bar{x}$ =3677. SD =1173.
3	004-072	45	$\bar{x}$ = 23. SD = 29.	$\bar{x}$ =100. SD = 44.	$\bar{x}$ = 28. SD = 7.	$\bar{x}$ = 99. SD = 52.	$\bar{x}$ = 258. SD = 246.
4	82- 91	5	$\bar{x}$ = 18. SD = 21.	$\bar{x}$ = 80. SD = 47.	$\bar{x}$ = 42. SD = 11.	$\bar{x}$ = 114. SD = 35.	$\bar{x}$ = 134. SD = 112.
5	106-114	5	$\bar{x}$ = 46. SD = 22.	$\bar{x}$ = 82. SD = 39.	$\bar{x}$ = 38. SD = 11.	$\bar{x}$ = 94. SD = 13.	$\bar{x}$ = 380. SD = 110.
6	144-173	12	$\bar{x}$ = 41. SD - 35.	$\bar{x}$ = 78. SD = 25.	$\bar{x}$ = 30. SD = 10.	$\bar{x}$ = 110. SD = 26.	$\bar{x}$ = 417. SD = 103.
7	198-201	3	$\bar{x}$ = 13. SD 23.	$\bar{x}$ =133. SD =144.	$\bar{x}$ = 23. SD = 6.	$\bar{x}$ = 100. SD = 50.	$\bar{x}$ = 183. SD = 104.
8	218-229	7	$\bar{x}$ = 33. SD = 33.	$\bar{x}$ = 93. SD = 55.	$\bar{x}$ = 23. SD = 5.	$\bar{x}$ = 73. SD = 21.	$\bar{x}$ = 67. SD = 29.
9	246-249	4	$\bar{x}$ = 15. SD = 19.	$\bar{x}$ =143. SD = 54.	$\bar{x}$ = 26. SD = 8.	$\bar{x}$ = 60. SD = 20.	$\bar{x}$ = 118. SD = 40.
10	253-256	3	$\bar{x}$ = 0.	$\bar{x}$ = 50. SD = 20.	$\bar{x}$ = 27. SD = 6.	$\bar{x}$ = 57. SD = 12.	$\bar{x}$ = 80. SD = 66.
11	329-332	4	$\bar{x}$ = 33. SD = 19.	$\bar{x}$=2288. SD=2007.	$\bar{x}$ = 40. SD = 12.	$\bar{x}$ = 188. SD = 25.	$\bar{x}$ = 625. SD = 377.
12	340-381	19	$\bar{x}$ = 22. SD = 21.	$\bar{x}$ = 56. SD = 30.	$\bar{x}$ = 50. SD = 0.	$\bar{x}$ = 142. SD = 19.	$\bar{x}$ =1421. SD = 251.
13	355-380	14	$\bar{x}$ = 4. SD = 9.	$\bar{x}$ = 67. SD = 35.	$\bar{x}$ = 44. SD = 13.	$\bar{x}$ = 116. SD = 34.	$\bar{x}$ = 639. SD = 479.

[1] Individual bodies located on plates 2 and 3; as follows: 1(pl. 3A), 2(pl. 3G), 3(pl. 3A), 4(pl. 3A), 5(pl. 3A), 6(pl. 3B), 7(pl. 3D), 8(Pl. 3E), 9(pl. 3E), 10(pl. 3E), 11(pl. 2), 12(pl. 3F), 13(pl. 3F).

Trace elements related to degree of metamorphism

Amphibolized gabbroic mafic igneous rocks that show varying stages of alteration are shown in table 16. These rocks range from amphibolized

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Table 16--NEAR HERE

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gabbros with texture preserved to foliated but non-layered gabbros, to layered amphibolites derived from gabbro, to sheared and hydrothermally altered gabbro. These rocks show little change in cobalt and nickel with alteration. Copper appears to be slightly enriched in the more alterated rocks but the large standard deviation for this element makes this questionable. Platinum and chromium are less in the sheared rocks but again large standard deviation and the small number of samples of the sheared rocks makes this questionable.

If mineralization in other rocks (table 17) is derived, as Spencer suggested, from the mafic rocks, chromium and platinum are indeed less

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Table 17--NEAR HERE

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abundant than in the source rocks as compared with nickel, cobalt, and copper.

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TABLE 16

TRACE ELEMENTS RELATED TO DEGREE

OF METAMORPHISM OF GABBROIC ROCKS

Degree of Metamorphism	No. of Samples	Cu(ppm)	Co(ppm)	Ni(ppm)	Pt(ppb)	Cr(ppm)
Texture recognizable in thin section	7	$\bar{x}$ = 59. SD = 16.	$\bar{x}$ = 30. SD = 10.	$\bar{x}$ = 89. SD = 20.	$\bar{x}$ = 36. SD = 36.	$\bar{x}$ = 304. SD = 327.
Foliated, original texture destroyed	7	$\bar{x}$ =101. SD = 92.	$\bar{x}$ = 33. SD = 13.	$\bar{x}$ = 86. SD = 52.	$\bar{x}$ = 42. SD = 52.	$\bar{x}$ = 467. SD = 486.
Layered	9	$\bar{x}$ = 91. SD = 54.	$\bar{x}$ = 33. SD = 10.	$\bar{x}$ =113. SD = 29.	$\bar{x}$ = 37. SD = 34.	$\bar{x}$ = 278. SD = 206.
Sheared and chloritized	3	$\bar{x}$ = 73. SD = 68.	$\bar{x}$ = 23. SD = 6	$\bar{x}$ = 73. SD = 25.	$\bar{x}$ = 10. SD = 10.	$\bar{x}$ = 133. SD = 29.

TABLE 17

TRACE ELEMENTS IN MINERALIZED ROCKS

OF THE SIERRA MADRE

	Cu(ppm)	Co(ppm)	Ni(ppm)	Cr(ppm)	Pt(ppb)
Mean and Standard Deviation for 20 mineralized samples (Table 18) including 10 mineralized quartzites, 6 mineralized limestones, 2 mineralized metavolcanic rocks and one mineralized quartz vein and one diorite dike.	$\bar{x}$ = 87,700 SD = 38,207	$\bar{x}$ = 314. SD = 1107.	$\bar{x}$ = 340. SD = 1118.	$\bar{x}$ = 59. SD = 43.	$\bar{x}$ = 2. SD = 6.

9.1257

The second approach to this test of metal distribution with alteration is that of systematic sampling of individual bodies to see if metals are distributed in any particular part of the intrusion. In general, the most intense deformation and alteration is in the marginal parts of mafic bodies so a comparison between the central parts of intrusions and marginal parts of intrusions might show significant variation. Plate 3 shows the distribution of copper and platinum group elements in the various mafic bodies studied, and the variation appears random.

Unfortunately neither of the above approaches allows us to determine whether or not metals were redistributed during metamorphism of the mafic igneous rocks. Additional studies will have to be made on individual minerals or on metamorphosed intrusives that were more homogeneous originally if such can be found in the Sierra Madre.

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Evaluation of Spencer's hypothesis

If mineralization is an end result of leaching of elements from mafic igneous rocks the metals in mineralized rock might show some relationship to those in the source rock. Twenty mineralized samples of the Sierra Madre average 87,000 ppm Cu and 2.0 ppb Pt. It is clear that the ratio of Pt/Cu in mineralized rock is entirely different from that of "source" rock. This might be used as evidence against the mafic igneous rock as a source of metals but there is really no reason to believe copper and platinum metals would be dissolved from mafic igneous rocks in amounts equivalent to their abundance nor is there evidence to suggest they would be transported to a site of deposition by a solution in which they were equally soluble.

Of the two hypotheses suggesting that mafic igneous rocks may be a source of copper in the Sierra Madre, the Spencer concept that hydrothermal solution may have leached copper from mafic igneous rocks and redeposited it elsewhere is the most plausible. Unfortunately it is the most difficult to evaluate. The limited analytical data available does not support copper leaching at this level in the crust, but this is a three-dimensional problem and certainly leaching may occur at one level in the crust and deposition at another. Thus Spencer's concept remains a possibility but one not supported by available data. The writers would like to emphasize, however, that despite the fact that we find no good support for derivation of major copper deposits from mafic igneous rocks many of the minor occurrences of copper sulfide in and adjacent to mafic bodies are probably derived from the mafic host rocks. It is distant transport of significant amounts of copper that remains a problem.

Sedimentary rocks as a source of copper

If we cannot accept the mafic bodies as a major source of copper what are alternate sources? A key point made in the discussion of possible migration of copper during amphibolitization of mafic rocks was that the highly metamorphosed mafic rocks contained about the same amount of copper as unmetamorphosed equivalents, but that this was not true for the metasedimentary rocks. It is much easier to remove metals from a succession of sedimentary and volcanic rocks undergoing an initial stage of metamorphism than during subsequent metamorphic episodes after the units have consolidated, recrystallized, and lost most of their permeability and porosity and, perhaps more important, after much of the water and other volatiles have been driven out of the system. The metasedimentary rocks of the Sierra Madre do contain significantly less copper than unmetamorphosed equivalents. Also, so far as is presently known, all major copper deposits are either in or adjacent to the metasedimentary succession. If copper and other metals were expelled from sedimentary and volcanic rocks during compaction and metamorphism, a possible host rock for the metal-bearing solutions would be the interbedded sandstones which would have higher permeability initially or perhaps fracture systems that might develop during metamorphism and extend to higher levels in the crust. The major copper deposits of the Sierra Madre are all in quartzite, but if we propose that these deposits are derived from adjacent shales or volcanic rocks there is a problem in timing of events. The ore is primarily chalcopyrite in quartzite and, although most copper-bearing zones follow bedding of the quartzite, Spencer (1904, p. 61-67) believes the ore-bearing solutions were introduced at the intersection of joints that strike roughly parallel and perpendicular to bedding. According to his concept, the quartzite formed prior to the introduction of ore and since similar joints are found in nearby mafic bodies he believes the mafic magma was also introduced prior to the development of joints and the introduction of ore. It is possible, of course, that the ore-bearing zones were partially mobilized in later metamorphic events and the structures and textures seen by Spencer are metamorphic in origin, but since none of these deposits are accessible, there is no way to evaluate this concept.

In addition to the problem of timing the suggestion that sedimentary and volcanic rocks are a possible source of metals simply because there appears to be a lower metal content in metamorphosed as compared to unmetamorphosed equivalents is an over simplification. For example, Wedepohl (1968) suggests that the range of chemical fractionation between shales, graywacke and igneous rocks is small for most elements, including copper, nickel, and cobalt. Using copper as an example Wedepohl (1968, p. 1012, Table A) shows average copper content of shales as 45 ppm, graywacke 45 ppm, and magmatic rocks of the upper continental crust as 30 ppm. He suggests that shales and graywacke may be derived from magmatic rocks of the upper continental crust (assumed composition: 44% granite, 34% granodiorite, 8% quartz diorite, 13% gabbro) by mechanical and chemical processes, and that elements that show little difference in abundance in shales or graywacke as compared with the magmatic rocks of the upper crust are derived from the magmatic rocks by mechanical accumulation rather than chemical processes that would involve fractionation. If we reverse this concept and assume that magmatic rocks of the upper continental crust may be derived from shales and graywacke by partial melting or other processes, a lack of fractionation suggests that a given metal does not escape during the reconstitution of the sedimentary rock and is therefore not likely to be concentrated in an ore deposit. The metals that have been considered in this paper Cu, Ni, and cobalt are less abundant in the magmatic rocks of the upper crust, but only cobalt shows an impoverishment by as much as a factor of two.

In the Sierra Madre, copper in phyllite is reduced by a factor of three from average shale and by a factor of sixteen from average clay. Are these phyllites with about 15 ppm copper typical or are they unusually low in copper from metamorphic rocks? Is the 250 ppm copper in clay reported by Turekian and Wedepohl unusually high for clay of sedimentary origin?

The 250 ppm copper reported by Turekian and Wedepohl in clay is an average of Atlantic and Pacific pelagic clay (essentially free of $CaCO_3$ and dissolved solids, and water permeating the sediment is considered as part of the sediment). This average is perhaps conservative for pelagic sediments (Cronan, 1969, Bostrom and Peterson, 1966) of the Pacific and perhaps high for Atlantic sediments (Weijden, Schuiling, and Das, 1970) as was suggested by Turekian and Wedepohl, but in any event pelagic clay is certainly not average clay of sedimentary origin and is probably much less abundant in the geologic column than clay-sized material deposited along continental margins. The Sierra Madre phyllite is probably derived from argillitic sediments of marine origin but the environment of deposition was probably island arc or continental margin rather than pelagic. Unfortunately little is known of the trace element content of these sediments prior to lithification, but for various reasons such as slow rates of sedimentation and possible volcanic additives in parts of the deep sea environment (Bostrom and Peterson, 1966) it seems reasonable to assume that the trace element content of island arc and continental margin sediments would be less than that of deep sea sediments. It does appear that metamorphic rocks might contain less copper than unmetamorphosed equivalents but a factor of two or three seems more realistic than the higher factor of sixteen that uses pelagic clays as an index.

Shaw (1954, p. 1159) reports copper content of low grade shales and slates as 23 ppm (S.D. 16) and he suggests a slight decrease in copper content with increasing grade of metamorphism in rocks of the Devonian Littleton Formation of New Hampshire. He also shows a decrease in nickel content with increasing grade of metamorphism but no significant change in cobalt. Paragneisses of the Adirondack Mountains of New York that are upper amphibolite facies (least altered gneiss of the area) average 15 ppm copper (Engel and Engel, 1958). These values are reasonably close to those of the Sierra Madre, but copper content varies widely (2 ppm to 59 ppm).

The data for argillite as a source of metals during diagenesis and metamorphism are not conclusive. More data are needed especially for rocks in early stages of diagenesis and from areas where diagenic as well as metamorphic transitions can be studied in rocks of the same depositional facies.

Summary

Analyses of copper and platinum group metals in mafic igneous rocks of the Sierra Madre show that these metals are not present in quantities greater than normal for these rock types. The mafic igneous rocks have been deformed and converted to amphibolite during a late stage of metamorphism but there is no evidence to support redistribution of these metals during this metamorphic episode. It has not been possible to prove or disprove Spencer's hypothesis that mafic igneous rocks were the source of copper and other metals found in mineral deposits of the Sierra Madre. Mineral deposits of the Sierra Madre are localized in various host rocks (chiefly quartzite) that have been fractured during or after metamorphism of the mafic igneous rocks. The ratios of copper and platinum group metals in mineralized rock are entirely different from that in mafic igneous rocks. If these metals were leached from mafic igneous rocks and redeposited in local areas of low temperature-pressure, the composition of solutions responsible for leaching was such that copper was far more readily leached and transported than other metals. The association of mineral deposits and the metasedimentary-volcanic succession may be of greater significance than that of mafic igneous rock.

TABLE 18

D. C. -ARC SPECTROGRAPHIC ANALYSES

MELANORITIC OR PYROXENITIC BODIES

SAMPLE NUMBER	B	Ba	Co	Cr	Cu	Mo	Nb	Ni	Pb	Sc	Sr	V	Y	Zr	Pt[2]	Pd[2]	Rh[2]
	ELEMENT IN PARTS PER MILLION[1]																
AHA-119	L	20	70	3000	30	N	N	1000	N	30	30	200	L	15	60	10	4
-122	20	15	50	1000	7	3	N	200	10	50	20	150	10	10	40	14	N
-124	L	10	50	1000	50	L	N	200	N	30	20	100	L	10	20	N	N
-125	N	10	50	1500	7	N	N	300	N	30	20	100	L	20	60	20	2
-126	N	15	50	1000	70	3	N	200	N	30	15	200	10	50	20	4	N
-127	N	50	30	500	7	N	N	150	10	30	150	150	L	10	N	14	N
-128	L	100	30	70	70	N	N	100	10	30	150	150	10	20	10	14	N
-129	L	70	30	70	15	N	N	100	N	20	500	150	10	20	N	10	N
-130	N	100	50	1500	70	3	N	500	N	30	20	100	L	10	40	2	N
-131	N	70	30	1500	150	3	N	300	N	30	20	100	L	20	100	4	N
-132	N	50	30	1500	10	N	N	300	N	30	20	100	L	10	140	140	N
-133	N	70	50	1500	20	N	N	300	N	30	20	100	L	10	N	N	N
-135	N	50	50	1500	20	L	N	200	N	20	15	100	L	10	100	14	N
-136	N	15	50	1500	70	L	N	300	N	30	15	200	L	10	10	2	N
-137	N	50	50	1000	50	L	N	200	N	30	100	150	10	20	30	20	N
-138	N	100	50	1500	15	L	N	300	N	30	30	150	L	10	40	10	N
-139	N	30	30	1500	20	L	N	300	N	30	20	100	L	10	40	10	N
-140	N	30	50	2000	30	3	N	300	N	30	20	150	L	10	20	N	N
-141	N	70	50	1500	10	N	N	300	N	30	20	100	L	N	N	N	N
-142	N	20	50	2000	70	5	N	300	N	30	70	150	L	10	60	100	40

1. Ag, As, Au, Be, Bi, Cd, La, Sb, Sn, Te, U, W, Zn, Ir, and Ru were tested but not detected in all samples. L means present but less than measurable amount. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
2. Pt, Pd, and Rh are in parts per billion.

Table 18 (Cont.)

Melanoritic or Pyroxenitic Bodies

SAMPLE NUMBER	ELEMENT IN PARTS PER MILLION[1]															
	B	Ba	Co	Cr	Cu	Mo	Nb	Ni	Pb	Sc	Sr	V	Y	Zr	Pt[2]	Pd[2]	Rh[2]
AHA-382	10	70	50	3000	5	N	10	300	10	30	L	100	10	20	N	N	N
-383	10	20	70	3000	15	N	10	500	10	30	L	100	10	20	14	N	N
-384	10	50	30	2000	7	N	10	200	10	30	150	100	L	20	N	N	N
-385	10	70	50	3000	15	N	10	300	L	30	100	150	L	50	10	N	N
-386	L	50	50	3000	7	N	10	300	L	30	L	100	L	10	10	N	N
-387	10	200	50	3000	20	N	10	300	L	30	100	150	15	50	40	10	2
-388	10	200	50	3000	7	N	10	500	L	30	100	150	10	50	N	6	N
-389	10	30	50	2000	10	N	10	300	L	30	L	100	10	50	N	N	N
-390	10	50	70	5000	30	N	15	500	L	50	100	200	20	30	20	2	2
-391	10	50	70	5000	20	N	15	500	L	50	100	200	15	50	N	N	N
-392	20	50	70	5000	7	N	10	500	L	50	100	200	20	50	30	2	N
-393	L	L	50	2000	10	N	L	300	L	20	L	70	N	20	20	2	N
-394	10	50	70	5000	50	N	10	500	L	50	100	200	10	50	10	6	N
-396	10	50	70	5000	300	N	10	500	10	30	100	150	10	50	20	4	N
-397	10	100	50	5000	7	N	10	500	10	30	100	150	10	50	14	2	N
-398	10	50	50	5000	10	N	10	500	L	30	100	150	10	50	N	N	N
-399	10	100	70	5000	20	N	10	500	L	30	100	200	15	50	N	N	N
-413	10	100	50	5000	50	N	L	500	10	50	100	200	15	50	10	10	N
-414	15	100	50	3000	50	N	10	500	L	50	300	200	15	50	N	14	N
-415	L	30	50	2000	50	N	L	300	L	20	200	150	L	20	10	6	N

1. Ag, As, Au, Be, Bi, Cd, La, Sb, Sn, Te, U, W, Zn, Ir, and Ru were tested but not detected in all samples. L means present but less than measurable amount. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley.
2. Pt, Pd, and Rh are in parts per billion.

Table 18 (Cont.)

Melanoritic or Pyroxenitic Bodies

SAMPLE NUMBER	ELEMENT IN PARTS PER MILLION[1]															
	B	Ba	Co	Cr	Cu	Mo	Nb	Ni	Pb	Sc	Sr	V	Y	Zr	Pt[2]	Pd[2]	Rh[2]
AHA-416	10	20	70	5000	50	N	L	500	10	30	150	150	10	50	20	10	N
-425	10	100	50	2000	30	N	10	300	L	20	150	150	15	50	10	6	N
-426	20	100	50	3000	30	N	10	300	L	50	300	200	20	50	10	14	N
-436	10	50	50	3000	50	N	L	300	10	30	100	150	10	50	10	6	N
-444	10	100	50	3000	100	N	10	500	10	30	150	200	10	50	10	6	N
-445	L	30	50	3000	30	N	L	500	10	30	100	100	L	50	20	10	N
-452	L	30	50	5000	L	N	L	500	10	30	100	100	L	20	N	N	N
-459	20	70	50	3000	50	N	10	500	10	30	150	100	10	50	20	4	N
-463	10	50	50	3000	100	N	10	500	10	30	100	150	10	50	20	14	N
-465	10	70	50	3000	50	N	10	700	10	30	200	200	15	50	30	10	2
-483	L	50	50	5000	50	N	10	500	L	30	L	150	10	150	10	2	N
-484	10	50	50	5000	100	N	20	500	L	30	L	150	10	50	10	2	N
-475	10	50	50	3000	20	N	10	700	L	30	100	100	10	50	10	4	N
-476	L	30	70	5000	10	N	10	700	L	30	L	100	10	20	14	10	N
-487	10	70	50	3000	20	N	20	500	10	30	100	200	10	50	N	2	N
-488	10	30	50	5000	L	N	15	1000	10	20	L	100	10	30	20	14	2

1. Ag, As, Au, Be, Bi, Cd, La, Sb, Sn, Te, U, W, Zn, Ir, and Ru were tested but not detected in all samples. L means present but less than measurable amount. Analysts, B. Wayne Lanthorn, Leon. A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
2. Pt, Pd, and Rh are in parts per billion.

TABLE 18 (Cont.)

Gabbroic Bodies

SAMPLE NUMBER	ELEMENT IN PARTS PER MILLION[1]																					
	Ag	B	Ba	Be	Bi	Co	Cr	Cu	Mo	Nb	Ni	Pb	Sc	Sr	V	Y	Zn	Zr	Pt[2]	Pd[2]	Rh[2]	Ir[2]
AHA-004	N	L	50	N	N	30	700	50	N	L	300	N	30	50	150	10	N	30	60	15	3	N
-006	N	L	70	L	50	200	70	10000	N	10	300	30	10	70	150	20	N	150	10	4	N	N
-008	N	20	70	N	L	50	700	70	N	N	200	L	30	70	150	15	N	30	30	10	N	N
-010	N	L	70	N	N	30	70	150	N	L	70	L	30	500	700	30	N	70	10	6	N	N
-012	N	L	150	1	N	30	15	70	N	N	70	L	30	300	300	20	N	70	14	4	2	N
-013	N	L	150	N	N	30	5	150	N	L	50	L	30	3000	200	30	N	70	40	2	N	N
-016	N	L	30	N	N	30	150	150	N	N	70	N	30	300	300	20	N	30	60	20	N	N
-017	N	L	30	N	N	20	300	150	N	N	70	N	30	150	200	20	N	30	-	-	-	-
-019	N	L	150	N	N	30	10	150	N	L	30	N	30	200	300	30	N	70	100	14	6	N
-020	N	L	150	N	N	20	300	70	N	10	100	N	30	300	200	15	N	30	20	10	N	N
-022	N	L	50	N	N	30	100	150	N	10	70	L	30	150	300	20	N	50	-	-	-	-
-023	N	L	70	N	N	20	70	150	N	10	70	L	30	200	200	30	N	70	-	-	-	-
-024	N	L	70	L	N	15	70	70	N	10	50	L	30	200	150	20	N	100	-	-	-	-
-025	N	L	150	1	N	30	30	150	N	10	30	N	30	300	200	30	N	70	N	N	N	N
-026	N	L	150	N	N	20	50	70	N	N	70	N	30	300	200	15	N	50	N	6	N	N
-027	N	L	200	N	N	20	150	70	N	N	70	N	30	300	150	15	N	30	10	4	N	N
-030	N	L	100	N	N	20	700	50	N	N	150	N	30	150	200	15	N	30	10	6	N	N
-031	N	L	150	L	N	30	15	100	N	N	70	L	30	300	300	20	N	70	N	4	N	N
-032	N	L	150	N	N	30	150	70	N	N	150	L	30	300	300	15	N	70	N	4	N	N
-033	N	L	70	N	N	20	500	100	N	L	150	L	30	70	150	15	N	30	50	50	2	N

1. As, Au, Cd, La, Sb, Sn, Te, U, W, and Ru were tested but not detected in all samples. N means not detected and L means present but less than measurable amount. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
2. Pt, Pd, Rh, and Ir are in parts per billion.

TABLE 18 (Cont.)

Gabbroic Bodies

SAMPLE NUMBER	Ag	B	Ba	Be	Bi	Co	Cr	Cu	Mo	Nb	Ni	Pb	Sc	Sr	V	Y	Zn	Zr	Pt[2]	Pd[2]	Rh[2]	Ir[2]
	ELEMENT IN PARTS PER MILLION[1]																					
AHA-035	N	L	70	N	N	30	150	150	N	L	100	N	30	150	200	20	N	30	50	20	N	N
-036	N	L	150	N	N	30	300	150	N	10	150	20	30	200	300	15	N	30	20	10	N	N
-038	N	L	150	N	N	30	150	100	N	N	100	N	30	200	300	15	N	30	30	20	N	N
-039	N	L	150	N	N	30	70	70	N	N	70	N	30	300	150	20	N	30	10	2	N	N
-041	N	L	20	N	N	30	500	70	N	N	150	N	30	150	150	20	N	30	30	10	N	N
-044	N	L	30	N	N	30	700	70	7	N	150	N	30	70	200	15	N	3	70	100	3	N
-045	N	20	150	N	N	30	300	70	N	L	100	N	20	200	150	15	N	50	15	10	1	N
-046	N	20	100	N	N	30	150	200	N	L	•70	N	30	150	300	30	N	70	100	20	2	N
-047	N	20	150	N	N	30	200	30	N	L	100	N	30	300	300	20	N	70	20	15	N	N
-050	N	N	70	N	N	15	700	150	N	N	150	N	70	150	500	20	N	70	14	20	N	N
-051	N	N	70	N	N	50	15	150	N	N	50	N	30	150	300	30	N	100	N	N	N	N
-052	N	N	50	N	N	30	100	100	N	N	50	N	30	150	200	15	N	30	30	4	N	N
-053	N	N	70	N	N	30	70	70	N	L	70	N	30	200	150	15	N	30	10	20	N	N
-054	N	N	50	N	N	15	700	30	N	N	150	10	50	100	300	20	N	50	N	4	N	N
-056	N	20	150	L	N	30	10	150	N	10	70	N	50	200	200	30	N	100	N	4	N	N
-057	N	N	70	N	N	20	200	70	N	L	100	N	50	300	200	20	N	50	N	N	N	N
-059	N	20	70	N	N	30	500	70	N	N	100	N	30	300	300	20	N	50	N	N	N	N
-061	N	L	70	N	N	30	70	70	N	N	70	L	30	150	200	30	N	100	N	10	N	N
-062	N	L	150	N	N	30	500	70	N	N	100	L	50	150	300	20	N	70	N	2	N	N
-065	N	N	100	L	N	20	7	100	N	N	30	L	30	200	300	30	N	150	N	N	N	N

1. As, Au, Cd, La, Sb, Sn, Te, U, W, and Ru were tested but not detected in all samples. N means not detected and L means present but less than measurable amount. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
2. Pt, Pd, Rh, and Ir are in parts per billion.

TABLE 18 (Cont.)

Gabbroic Bodies

SAMPLE NUMBER	Ag	B	Ba	Be	Bi	Co	Cr	Cu	Mo	Nb	Ni	Pb	Sc	Sr	V	Y	Zn	Zr	Pt[2]	Pd[2]	Rh[2]	Ir[2]
	ELEMENT IN PARTS PER MILLION[1]																					
AHA-066	N	L	150	N	N	30	30	150	N	N	70	L	30	200	300	20	N	70	20	N	N	N
-067	N	L	100	N	N	20	100	100	N	N	50	10	30	200	150	15	N	50	N	6	N	N
-069	N	L	100	N	N	30	300	30	N	N	150	N	30	150	150	10	N	20	40	14	N	N
-070	N	L	300	N	N	30	700	70	N	N	150	N	70	150	300	15	N	30	10	N	N	N
-071	N	N	50	N	N	30	500	70	N	N	150	N	30	150	150	15	N	30	100	14	2	N
-072	N	N	150	N	N	30	500	150	N	N	100	N	30	150	150	20	N	50	60	20	4	N
-075	N	L	150	N	N	20	100	100	N	N	100	10	30	150	200	20	N	50	20	N	N	N
-082	N	L	70	N	N	30	70	50	N	N	70	N	30	70	200	15	N	30	N	2	N	N
-086	N	L	70	N	N	50	300	30	N	N	150	N	70	150	300	15	N	30	40	20	N	N
-088	N	N	100	N	N	50	50	150	N	N	100	L	70	200	300	15	N	30	10	N	N	N
-090	N	N	100	N	N	50	50	70	N	N	100	N	70	200	300	15	N	50	N	N	N	N
-091	N	N	70	N	N	30	200	100	N	N	150	N	70	150	300	20	N	30	40	10	N	N
-104	N	N	300	N	N	30	300	70	N	N	70	N	30	150	150	15	N	30	60	20	2	N
-106	N	N	150	N	N	50	500	150	N	N	100	N	30	150	30	20	N	30	60	20	2	N
-108	N	N	30	N	N	30	300	70	N	N	70	N	30	150	150	15	N	20	40	20	N	N
-112	N	N	70	N	N	50	300	50	N	N	100	L	30	150	300	15	N	30	60	40	N	N
-113	N	20	20	N	N	30	500	70	N	N	100	N	70	150	200	15	N	30	10	4	N	N
-114	N	N	50	N	N	30	300	70	N	N	100	L	50	100	300	10	N	20	60	10	2	N
-144	N	L	70	N	N	30	500	100	3	N	100	N	30	150	150	10	N	30	40	30	N	N
-149	N	N	30	N	N	30	300	70	L	N	100	10	50	150	200	15	N	30	40	14	N	N

1. As, Au, Cd, La, Sb, Sn, Te, U, W, and Ru were tested but not detected in all samples. N means not detected and L means present but less than measurable amount. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
2. Pt, Pd, Rh and Ir are in parts per billion.

Table 18 (Cont.)

Gabbroic Bodies

SAMPLE NUMBER	Ag	B	Ba	Be	Bi	Co	Cr	Cu	Mo	Nb	Ni	Pb	Sc	Sr	V	Y	Zn	Zr	Pt[2]	Pd[2]	Rh[2]	Ir[2]
	ELEMENT IN PARTS PER MILLION[1]																					
AHA-150	N	N	30	N	N	20	500	70	L	N	100	N	50	150	150	15	N	30	40	14	N	N
-154	N	N	100	N	N	20	500	70	L	N	150	N	50	100	200	15	N	30	14	4	N	N
-155	N	N	70	N	N	20	300	70	3	N	100	N	30	100	200	15	N	30	40	4	N	N
-159	N	N	50	N	N	50	500	150	L	L	150	N	30	150	300	20	N	30	10	N	N	N
-161	N	N	100	N	N	30	500	70	N	N	100	10	50	150	200	20	N	30	20	N	N	N
-165	N	N	50	N	N	20	300	70	N	N	70	10	20	150	150	10	N	20	60	40	40	N
-166	N	N	50	N	N	30	500	70	N	N	150	N	30	150	300	10	N	30	30	6	N	N
-167	N	N	70	N	N	30	500	50	N	N	100	10	30	200	200	10	N	30	14	N	N	N
-171	N	N	50	N	N	50	300	70	N	N	100	L	30	150	200	20	N	50	40	14	N	N
-173	N	N	50	N	N	30	300	70	N	N	100	10	30	150	150	10	N	30	140	140	2	400
-193	N	N	200	N	N	20	200	100	N	N	100	N	20	150	150	10	N	50	10	N	N	N
-194	N	N	70	N	N	20	100	100	N	N	100	N	20	150	150	10	N	50	N	40	N	N
-196	N	L	150	N	N	20	100	100	N	N	100	10	20	150	150	10	N	50	N	6	N	N
-197	N	N	70	N	N	20	500	30	N	N	200	10	30	150	150	10	N	30	60	100	N	N
-198	N	N	20	N	N	20	150	50	N	N	100	N	30	150	200	10	N	30	N	10	N	N
-199	N	N	30	N	N	30	300	50	N	N	150	N	50	20	200	10	N	30	N	10	N	N
-201	N	N	50	N	N	20	100	300	N	N	50	N	50	150	150	20	N	30	40	60	N	N
-208	N	N	70	N	N	20	100	300	N	N	70	N	30	150	200	10	N	50	40	60	N	N
-212	N	N	30	N	N	30	1000	100	N	N	200	N	50	70	200	10	N	30	30	10	N	N
-218	N	N	150	N	N	30	100	30	N	N	100	N	50	150	300	30	N	50	100	30	N	N

1. As, Au, Cd, La, Sb, Sn, Te, U, W, and Ru were tested but not detected in all samples. N means not detected and L means present but less than measurable amount. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
2. Pt, Pd, Rh, and Ir are in parts per billion.

Table 18 (Cont.)

Gabbroic Bodies

SAMPLE NUMBER	Ag	B	Ba	Be	Bi	Co	Cr	Cu	Mo	Nb	Ni	Pb	Sc	Sr	V	Y	Zn	Zr	Pt[2]	Pd[2]	Rh[2]	Ir[2]
	ELEMENT IN PARTS PER MILLION[1]																					
AHA-219	N	N	30	N	N	20	100	50	N	N	100	N	50	150	300	30	N	70	40	14	N	N
-220	N	N	50	N	N	20	70	150	N	N	70	N	30	150	300	20	N	50	20	14	N	N
-221	N	L	70	N	N	20	30	70	N	N	50	N	30	200	300	30	N	70	N	N	N	N
-222	N	L	30	N	N	20	70	50	N	N	70	N	30	200	300	20	N	70	40	4	N	N
-227	N	N	50	N	N	20	30	150	N	N	50	N	30	200	300	30	N	100	10	N	N	N
-229	N	N	100	N	N	30	70	150	N	N	70	N	30	150	300	20	N	30	20	10	N	N
-232	N	N	70	N	N	20	100	10	N	N	50	N	30	200	200	20	N	30	40	10	N	N
-234	N	N	30	N	N	20	100	20	N	N	100	N	30	150	200	15	N	30	10	N	N	N
-246	N	L	70	N	N	15	70	200	N	10	30	N	70	200	300	30	N	70	N	N	N	N
-247	N	L	70	N	N	30	150	70	N	N	70	30	50	200	200	20	N	50	20	20	N	N
-248	N	L	100	N	N	30	150	150	3	10	70	30	70	150	300	30	N	50	N	N	N	N
-249	N	L	100	N	N	30	100	150	5	10	70	10	70	300	300	30	N	50	40	60	N	N
-253	N	L	150	N	N	20	70	70	N	L	50	10	70	10	300	30	N	30	N	N	N	N
-254	N	20	150	N	N	30	20	50	5	10	50	10	70	300	500	50	N	70	N	N	N	N
-256	N	L	200	N	N	30	150	30	3	L	70	10	70	200	300	30	N	50	N	N	N	N
-311	N	L	30	N	N	70	150	200	3	N	150	N	70	150	300	20	N	50	10	40	N	N
-325	L	20	100	N	N	30	70	300	5	L	50	700	70	100	300	20	700	70	N	N	N	N
-327	N	20	150	N	N	50	70	100	5	L	50	20	70	200	300	20	N	70	N	N	N	N
-328	N	20	200	N	N	70	50	100	5	L	50	15	70	150	500	30	N	100	N	N	N	N
-329	N	70	20	N	N	30	1000	150	N	N	200	N	50	70	200	20	N	30	30	10	N	N

1. As, Au, Cd, La, Sb, Sn, Te, U, W, and Ru were tested but not detected in all samples. N means not detected and L means present but less than measurable amount. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
2. Pt, Pd, Rh, and Ir are in parts per billion.

Table 18 (Cont.)

Gabbroic Bodies

SAMPLE NUMBER	Ag	B	Ba	Be	Bi	Co	Cr	Cu	Mo	Nb	Ni	Pb	Sc	Sr	V	Y	Zn	Zr	Pt[2]	Pd[2]	Rh[2]	Ir[2]
	ELEMENT IN PARTS PER MILLION[1]																					
AHA-330	.7	20	50	N	N	50	700	2000	5	N	150	N	70	100	300	15	N	50	20	10	N	N
-331	L	20	30	N	N	30	100	5000	5	N	200	N	50	70	200	20	N	100	60	100	10	N
-332	N	L	50	N	N	50	700	2000	5	N	200	N	70	150	300	15	N	30	20	14	N	N
-340	N	20	100	N	N	50	1500	100	N	10	150	20	30	200	200	20	N	70	10	10	N	N
-341	N	20	70	N	N	50	1500	70	N	10	150	10	30	200	200	20	N	70	40	30	2	N
-342	N	20	70	N	N	50	2000	50	N	10	150	10	30	200	200	20	N	70	40	14	2	N
-343	N	20	50	N	N	50	1500	30	N	10	150	L	30	200	200	20	N	70	60	30	2	N
-344	N	20	50	N	N	50	1500	20	N	10	150	L	30	200	200	20	N	50	10	4	N	N
-345	N	20	50	N	N	50	1500	100	N	10	150	L	30	200	300	20	N	70	30	10	N	N
-346	N	10	50	N	N	50	1500	50	N	10	150	15	30	200	200	20	N	50	10	10	N	N
-347	N	10	50	N	N	50	1500	30	N	10	150	10	30	200	200	20	N	50	14	6	N	N
-348	N	10	50	N	N	50	1000	30	N	10	100	10	30	200	200	20	N	50	30	14	2	N
-349	N	10	50	N	N	50	1000	30	N	10	100	10	30	200	200	20	N	50	10	6	N	N
-350	N	20	50	N	N	50	1500	50	N	10	150	L	50	300	200	30	N	70	60	20	2	N
-352	N	20	150	N	N	50	1500	100	N	10	150	L	30	300	200	20	N	70	60	30	2	N
-354	N	20	70	N	N	50	1500	100	N	10	150	10	30	300	200	30	N	70	10	10	N	N
-361	N	10	100	N	N	50	1500	100	N	10	150	L	30	200	200	20	N	70	10	20	N	N
-362	N	10	70	N	N	50	1500	20	N	10	150	L	30	200	200	20	N	70	10	10	N	N
-367	N	10	70	N	N	50	1000	30	N	10	150	L	30	200	200	30	200	50	N	4	N	N
-376	N	10	20	N	N	50	1500	50	N	10	150	10	50	100	200	10	N	50	N	N	N	N

1. As, Au, Cd, La, Sb, Sn, Te, U, W, and Ru were tested but not detected in all samples. N means not detected and L means present but less than measurable amount. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
2. Pt, Pd, Rh, and Ir are in parts per billion.

TABLE 18 (Cont.)

Gabbroic Bodies

SAMPLE NUMBER	ELEMENT IN PARTS PER MILLION[1] Ag	B	Ba	Be	Bi	Co	Cr	Cu	Mo	Nb	Ni	Pb	Sc	Sr	V	Y	Zn	Zr	Pt[2]	Pd[2]	Rh[2]	Ir[2]
AHA-378	N	10	70	N	N	50	1000	50	N	10	100	L	30	200	200	20	N	50	N	2	N	N
-381	N	10	50	N	N	50	1500	50	N	10	150	10	30	200	200	20	N	50	20	14	N	N
-355	N	10	50	N	N	50	1000	15	N	10	150	L	30	100	200	20	N	70	10	4	N	N
-359	N	10	50	N	N	20	500	70	N	10	100	10	30	200	200	20	N	50	N	14	N	N
-360	N	10	150	N	N	30	150	150	N	10	50	L	30	100	200	10	N	50	N	N	N	N
-363	N	10	70	N	N	50	300	70	N	10	70	10	30	200	150	20	N	50	N	4	N	N
-365	N	20	300	N	N	50	1500	70	N	10	150	L	30	200	200	20	N	50	10	14	N	N
-366	N	30	700	N	N	70	300	50	N	10	100	L	30	200	300	30	500	70	N	N	N	N
-368	N	10	100	N	N	30	300	20	N	10	100	10	30	150	200	20	L	50	N	N	N	N
-370	N	20	100	N	N	50	700	100	N	10	150	10	30	200	200	30	L	70	N	2	N	N
-372	N	20	70	N	N	30	300	100	N	10	150	10	50	300	200	30	N	70	N	N	N	N
-373	N	15	100	N	N	50	200	70	N	10	100	50	30	500	300	30	300	50	N	N	N	N
-375	N	10	50	N	N	30	1000	70	N	10	100	L	50	200	200	10	N	50	N	4	N	N
-377	N	20	100	N	N	50	200	30	N	10	100	10	50	300	200	30	N	70	N	2	N	N
-379	N	30	70	N	N	50	1000	70	N	10	150	10	30	200	200	20	N	50	10	14	N	N
-380	N	20	100	N	N	50	1500	50	N	10	150	10	30	200	200	20	N	50	30	40	N	N

1. As, Au, Cd, La, Sb, Sn, Te, U, W, and Ru were tested but not detected in all samples. N means not detected and L means present but less than measurable amount. Analysts, H. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
2. Pt, Pd, Rh, and Ir are in parts per billion.

TABLE 18 (Cont.)

Hydrothermally(?) Altered Amphibolite

SAMPLE NUMBER	ELEMENT IN PARTS PER MILLION[1]													
	B	Ba	Be	Co	Cr	Cu	Ni	Sc	Sr	V	Y	Zr	Pt[2]	Pd[2]
AHA-300	20	50	1.5	30	150	20	70	70	30	300	10	30	20	10
-302	20	70	1	20	100	150	50	30	70	150	15	30	10	30

1. Ag, As, Au, Bi, Cd, La, Pb, Sb, Sn, Te, U, W, Zn, Ir, Rh, and Ru were tested but not detected in both samples. Analyst, B. Wayne Lanthorn. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
2. Pt and Pd are in parts per billion.

Table 18 (Cont.)

Other Rocks

SAMPLE NUMBER	Fe[2]	Mg[2]	Ca[2]	Ti[2]	Mn	Ag	As	B	Ba	Be	Bi	Co	Cr	Cu	La	Mo
	ELEMENT IN PARTS PER MILLION[1]															
AHA-001	0.7	0.15	0.1	0.07	70	-N	N	1	500	N	N	10	30	15	N	N
-002	7.	10.	G10.	0.15	1000	N	N	L	70	2	N	30	100	70	30	N
-003	0.3	0.15	0.15	0.05	30	N	N	20	50	N	N	3	15	50	N	N
-005	5.	5.	3.	0.15	1500	3	N	L	30	1	10	300	30	1500	N	N
-007	5.	3.	2.	0.07	500	N	N	L	70	1	200	5000	30	3000	N	N
-009	1.	0.7	0.7	0.15	150	N	N	L	30	1	N	20	70	20	N	N
-011	5.	G10.	G10.	0.15	700	N	N	L	30	1	N	15	70	10	100	N
-014	0.15	0.07	0.7	0.015	30	N	N	L	70	N	N	3	10	7	N	N
-015	0.5	0.15	0.7	0.07	70	N	N	L	50	N	N	5	30	30	N	N
-018	0.3	0.15	0.15	0.015	70	N	N	L	70	N	N	3	15	7	30	N
-021	0.07	0.015	0.1	0.015	30	N	N	L	30	N	N	N	5	15	N	N
-028	0.07	0.03	0.07	0.2	3	N	N	L	200	N	N	N	15	3	N	N
-029	7.	5.	G10.	0.02	1500	N	N	L	70	2	N	15	70	50	150	N
-034	7.	5.	7.	0.3	1000	N	N	20	500	1	N	20	150	50	30	N
-037	0.3	0.15	0.5	0.03	70	N	N	L	50	N	N	3	10	30	N	N
-042	0.5	0.07	0.07	0.07	20	N	N	20	200	N	N	15	30	30	N	N
-043	3.	7.	7.	0.15	700	N	N	20	2000	1	N	10	70	10	N	N
-048	0.3	0.1	0.1	0.07	70	N	N	20	500	N	N	5	30	10	N	N
-049	5.	3.	1.5	0.3	200	N	N	70	700	1.5	N	15	100	15	50	N
-055	1.5	3.	G10.	0.07	500	N	N	N	20	1	N	7	70	3	N	N

1. Au, Cd, Sn, Te, U, W, Ru, and Ir were tested but not detected in all samples. N means not detected, L means present but less than measurable amount, and G means greater than the value shown. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
2. Fe, Mg, Ca, and Ti are in wt. per cent.

TABLE 18 (Cont.)

Other Rocks

SAMPLE NUMBER	Nb	Ni	Pb	Sb	Sc	Sr	V	Y	Zn	Zr	Pt[3]	Pd[3]	Rh[3]	COMMENTS
							ELEMENT IN PARTS PER MILLION[1]							
AHA-001	10	20	15	N	5	20	15	10	N	100	N	N	N	Quartzite
-002	10	70	15	N	15	300	150	20	N	150	N	N	N	do. , altered
-003	10	10	N	N	N	15	7	L	N	70	N	N	N	Quartzite
-005	10	1000	10	N	7	15	70	10	N	70	N	N	N	do. , supergene copper
-007	10	5000	30	N	7	30	200	15	N	150	N	N	N	do. , supergene copper
-009	10	50	L	N	5	30	50	L	N	70	N	N	N	Quartzite, altered
-011	L	30	N	N	10	150	70	30	N	70	N	N	N	do. , altered
-014	N	2	N	N	N	20	7	N	N	50	N	N	N	Quartzite
-015	L	10	N	N	N	70	10	L	N	30	N	N	N	do.
-018	L	10	N	N	N	20	10	N	N	30	N	N	N	do.
-021	10	L	N	N	N	7	L	N	N	30	N	N	N	do.
-028	10	L	N	N	N	10	L	N	N	30	N	N	N	do.
-029	10	50	10	N	15	700	70	30	N	70	N	6	N	do. , altered
-034	10	70	L	N	30	150	30	30	N	70	40	N	N	do. , altered
-037	10	15	N	N	N	70	10	N	N	20	N	N	N	Quartzite
-042	N	10	N	N	N	10	15	N	N	150	N	N	N	do.
-043	N	30	15	N	10	150	70	20	N	200	N	N	N	do. , altered
-048	N	15	N	N	N	30	15	N	N	50	N	N	N	Quartzite
-049	10	70	N	N	15	150	70	30	N	200	N	N	N	do. , altered
-055	N	15	N	N	7	200	50	20	N	70	N	N	N	do. , altered

1. Au, Cd, Sn, Te, U, W, Ru, and Ir were tested but not detected in all samples. N means not detected, L means present but less than measurable amount, and G means greater than the value shown. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
3. Pt, Pd, and Rh are in parts per billion.

Table 18 (Cont.)

Other Rocks

SAMPLE NUMBER	Fe[2]	Mg[2]	Ca[2]	Ti[2]	Mn	Ag	As	B	Ba	Be	Bi	Co	Cr	Cu	La	Mo
	ELEMENT IN PARTS PER MILLION[1]															
AHA-058	0.3	0.1	0.15	0.02	30	N	N	L	50	N	N	10	10	30	N	N
-060	0.2	0.07	0.07	0.02	10	N	N	20	300	N	N	N	10	3	N	N
-063	0.15	0.05	0.07	0.02	30	N	N	L	20	N	N	L	15	2	N	N
-064	0.5	0.07	0.07	0.03	50	N	N	L	500	N	N	7	15	7	N	N
-068	0.15	0.03	0.1	0.03	20	N	N	L	30	N	N	3	30	70	N	N
-073	0.3	0.15	0.3	0.05	70	N	N	20	70	N	N	N	20	10	N	N
-076	0.3	0.05	0.07	0.03	30	N	N	20	300	N	N	L	10	3	N	N
-077	0.2	0.1	0.05	0.03	50	N	N	20	300	N	N	N	15	3	N	N
-079	0.3	0.1	0.07	0.03	50	N	N	20	500	N	N	L	20	2	N	N
-080	0.3	0.07	0.07	0.03	30	N	N	20	300	N	N	3	10	20	N	N
-153	1.5	0.5	1.5	0.1	50	N	N	L	300	1	N	7	50	10	30	3
-156	1.	0.7	G10.	0.05	1000	N	N	N	100	N	N	3	30	10	30	N
-158	0.1	0.1	0.05	0.2	50	N	N	20	15	N	N	N	10	1	N	N
-163	0.3	0.02	0.03	0.02	10	N	N	L	50	N	N	N	5	3	N	N
-169	1.	0.7	10.	0.1	500	N	N	L	150	N	N	10	50	20	30	N
-170	0.15	0.02	0.1	0.02	20	N	N	N	30	N	N	N	10	2	N	N
-175	0.2	0.05	0.05	0.1	100	N	N	N	30	N	N	N	20	2	N	N
-176	0.1	0.02	0.05	0.01	10	N	N	L	50	N	N	N	2	1	N	N
-178	0.15	0.03	0.02	0.01	10	N	N	N	50	N	N	N	5	1	30	N
-195	0.5	0.2	0.1	0.1	50	N	N	L	150	1	N	3	20	10	N	N

1. Au, Cd, Sn, Te, U, W, Ru, and Ir were tested but not detected in all samples. N means not detected, L means present but less than measurable amount, and G means greater than the value shown. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
2. Fe, Mg, Ca, and Ti are in wt. per cent.

TABLE 18 (Cont.)

Other Rocks

SAMPLE NUMBER	Nb	Ni	Pb	Sb	Sc	Sr	V	Y	Zn	Zr	Pt[3]	Pd[3]	Rh[3]	COMMENTS
	ELEMENT IN PARTS PER MILLION[1]													
AHA-058	N	7	N	N	N	15	7	N	N	30	N	N	N	Quartzite
-060	N	5	N	N	N	10	7	N	N	30	N	N	N	do.
-063	N	5	N	N	N	5	N	N	N	50	N	N	N	do.
-064	N	7	N	N	N	15	15	N	N	70	N	N	N	do.
-068	N	L	10	N	N	10	7	N	N	70	N	N	N	do.
-073	N	7	10	N	N	30	7	L	N	70	N	N	N	do.
-076	N	L	N	N	N	10	7	N	N	70	N	N	N	do.
-077	N	5	N	N	N	20	7	N	N	100	N	N	N	do.
-079	N	L	N	N	N	30	15	N	N	30	N	N	N	do.
-080	N	5	10	N	N	50	7	N	N	100	N	N	N	do.
-153	N	15	L	N	7	50	50	10	N	70	N	N	N	do. , slightly altered
-156	N	10	N	N	5	150	20	10	N	30	N	N	N	Limey Quartzite
-158	L	5	N	N	N	5	7	N	N	30	N	N	N	Quartzite
-163	N	5	N	N	N	10	L	N	N	50	N	N	N	do.
-169	N	20	L	N	7	200	50	10	N	50	N	N	N	Limey Quartzite
-170	N	5	N	N	N	15	7	N	N	30	N	N	N	Quartzite
-175	N	5	N	N	N	10	10	N	N	70	N	N	N	do.
-176	N	N	N	N	N	5	L	N	N	30	N	N	N	do.
-178	N	L	N	N	N	5	N	N	N	30	N	N	N	do.
-195	L	20	N	N	N	15	20	N	N	100	N	N	N	do.

1. Au, Cd, Sn, Te, U, W, Ru, and Ir were tested but not detected in all samples. N means not detected, L means present but less than measurable amount, and G means greater than the value shown. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
3. Pt, Pd, and Rh are in parts per billion.

Table 18 (Cont.)

Other Rocks

ELEMENT IN PARTS PER MILLION[1]

SAMPLE NUMBER	Fe[2]	Mg[2]	Ca[2]	Ti[2]	Mn	Ag	As	B	Ba	Be	Bi	Co	Cr	Cu	La	Mo
AHA-200	0.2	0.1	0.05	0.01	20	N	N	L	70	N	N	3	10	70	N	N
-203	0.1	0.1	0.05	0.02	20	N	N	N	50	N	N	N	7	20	N	N
-205	0.07	0.02	0.05	0.02	7	N	N	L	50	N	N	N	5	20	N	N
-209	0.5	0.03	0.05	0.015	7	1	N	N	70	N	10	N	7	1000	N	N
-210	0.5	0.03	0.05	0.01	7	5	N	N	20	N	20	N	3	G10%	N	N
-230	0.1	0.05	0.1	0.02	30	N	N	N	50	N	N	N	5	10	N	N
-231	0.1	0.02	0.05	0.015	20	N	N	N	20	N	N	N	2	10	N	N
-251	1.	0.07	0.1	0.03	50	N	N	20	50	N	N	3	2	15	N	N
-252	0.3	0.1	0.07	0.02	20	N	N	20	70	N	N	N	15	5	N	N
-265	7.	0.1	0.07	0.07	30	N	N	70	70	N	N	N	30	7	30	N
-266	1.5	0.3	0.15	0.15	20	N	N	150	150	2	N	N	70	1.5	50	N
-268	1.	0.03	0.07	0.02	50	N	N	20	50	N	N	N	15	7	L	N
-270	0.15	0.03	0.05	0.02	20	N	N	20	50	N	N	N	10	3	L	N
-271	0.7	0.05	0.05	0.003	50	N	N	20	100	N	N	15	1.	3	N	N
-273	G10.	0.02	0.03	0.03	30	N	N	L	70	N	N	70	2	15	N	10
-274	G10.	0.07	0.07	0.15	300	N	N	N	70	N	N	70	7	30	N	15
-296	7.	0.5	G10.	0.005	2000	N	N	30	70	N	N	7	7	7	N	15
-298	G10.	0.1	0.07	0.07	150	N	N	N	100	N	N	300	70	150	N	N
-299	10.	0.3	0.7	0.2	200	N	N	70	200	2	N	20	100	7	50	N
-301	2.	0.7	1.	0.3	500	N	N	150	300	5	N	5	200	2	50	N

1. Au, Cd, Sn, Te, U, W, Ru, and Ir were tested but not detected in all samples. N means not detected, L means present but less than measurable amount, and G means greater than the value shown. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
2. Fe, Mg, Ca, and Ti are in wt. per cent.

Table 18 (Cont.)

Other Rocks

SAMPLE NUMBER	Nb	Ni	Pb	Sb	Sc	Sr	V	Y	Zn	Zr	Pt[3]	Pd[3]	Rh[3]	COMMENTS
	ELEMENT IN PARTS PER MILLION[1]													
AHA-200	N	5	N	N	N	N	L	N	N	70	N	N	N	Quartzite
-203	N	L	N	N	N	N	7	N	N	30	N	N	N	do.
-205	N	N	N	N	N	5	L	L	N	50	N	N	N	do.
-209	N	L	N	N	N	N	10	N	N	50	N	N	N	do. , wall rock of 210
-210	N	L	N	N	N	N	20.	10	N	20	N	N	N	Quartzite, supergene copper
-230	N	N	N	N	N	10	L	N	N	50	N	N	N	Quartzite
-231	N	N	N	N	N	10	L	N	N	30	N	N	N	do.
-251	L	10	N	N	N	300	30	N	N	20	N	N	N	do.
-252	N	7	10	N	N	5	10	N	N	50	N	N	N	do.
-265	L	5	N	N	N	7	15	10	N	150	N	N	N	Quartzite, altered
-266	10	30	N	N	10	30	70	15	N	150	N	N	N	do. , altered
-268	10	N	N	N	N	5	10	N	N	70	N	N	N	do. , altered
-270	N	N	N	N	N	5	N	N	N	50	N	N	N	Quartzite
-271	N	5	N	N	N	L	N	L	N	N	N	N	N	do.
-273	10	15	N	N	5	N	70	20	N	N	N	N	N	do. , specular hematite
-274	10	20	30	N	20	N	200	100	N	30	N	N	N	do. , specular hematite
-296	N	30	30	N	30	150	30	30	N	N	N	N	N	Quartzite, hematite
-298	10	70	N	N	30	N	300	15	N	N	N	N	N	do. , hematite
-299	10	50	N	N	15	20	150	15	N	150	20	N	N	do. , hematite
-301	10	50	N	N	20	30	200	30	N	300	N	N	N	Quartzite

1. Au, Cd, Sn, Te, U, W, Ru, and Ir were tested but not detected in all samples. N means not detected, L means present but less than measurable amount, and G means greater than the value shown. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
3. Pt, Pd, and Rh are in parts per billion.

Table 18 (Cont.)

Other Rocks

SAMPLE NUMBER	Fe[2]	Mg[2]	Ca[2]	Ti[2]	Mn	Ag	As	B	Ba	Be	Bi	Co	Cr	Cu	La	Mo
					ELEMENT IN PARTS PER MILLION[1]											
AHA-303	1.5	0.3	0.5	0.15	300	N	N	20	100	1	N	10	70	2	N	N
-307	5.	2.	7.	0.3	1500	N	N	L	50	N	N	150	200	70	N	N
-310	7.	0.05	0.15	0.02	70	2	N	20	50	N	N	20	70	7000	N	3
-320	7.	0.7	0.3	0.15	70	3	N	L	50	N	N	20	70	30000	N	3
-321	2.	0.7	0.15	0.07	50	0.5	N	L	15	N	N	30	50	7000	N	N
-322	G10.	0.7	1.5	0.7	500	5	N	N	70	N	L	50	150	30000	N	7
-323	0.7	0.15	0.05	0.07	20	1	N	20	100	N	N	7	15	7000	N	N
-324	0.15	0.05	0.07	0.07	10	N	N	20	30	1	N	N	30	5000	N	N
-334	0.3	0.07	0.15	0.02	30	N	N	N	15	N	N	7	10	50	N	N
-335	0.3	0.15	0.07	0.03	20	N	N	N	30	N	N	7	15	15	N	N
-351	5.	2.	5.	0.1	700	N	N	10	200	N	N	20	300	50	N	N
-406	2.	1.	2.	0.1	1000	N	N	10	1000	1.5	N	20	100	L	N	N
-417	2.	0.05	10.	0.07	2000	N	N	10	1500	1	N	15	100	10	N	N
-428	10.	0.02	15.	0.1	2000	N	N	10	100	N	N	10	1500	20	N	N
-430	7.	1.[illegible]	3.	0.2	1000	N	N	10	500	1	N	20	20	50	N	N
-437	1.	0.1	2.	0.1	500	N	N	L	700	L	N	20	50	7	N	N
-446	1.5	0.5	7.	0.15	1000	N	N	L	1000	2	N	10	50	20	N	N
-453	1.	0.5	0.1	0.15	100	N	N	10	1000	1	N	N	100	5	N	N
-489	10.	5.	7.	0.5	1500	N	N	10	70	N	N	70	500	300	N	N
-490	10.	7.	7.	0.5	3000	N	N	10	500	N	N	30	150	100	N	N

1. Au, Cd, Sn, Te, U, W, Ru, and Ir were tested but not detected in all samples. N means not detected, L means present but less than measurable amount, and G means greater than the value shown. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
2. Fe, Mg, Ca, and Ti are in wt. per cent.

Table 18 (Cont.)

Other Rocks

SAMPLE NUMBER	ELEMENT IN PARTS PER MILLION[1]													COMMENTS
	Nb	Ni	Pb	Sb	Sc	Sr	V	Y	Zn	Zr	Pt[3]	Pd[3]	Rh[3]	
AHA-303	L	20	N	N	7	30	50	10	N	150	N	N	N	Quartzite
-307	L	50	N	N	30	70	200	15	N	50	20	10	N	do. , altered?
-310	N	20	N	N	N	N	10	30	N	N	20	10	N	Quartzite, sulfides
-320	N	30	N	N	5	70	30	10	N	100	N	N	N	do. , sulfides
-321	N	15	N	N	L	50	20	N	N	70	N	N	N	do. , sulfides
-322	10	50	N	N	10	150	70	10	N	100	N	N	N	do. , sulfides
-323	L	20	N	N	N	10	15	N	N	70	N	N	N	Quartzite, supergene copper
-324	L	7	N	N	7	15	15	300	N	50	N	N	N	do. , supergene copper
-334	N	10	N	N	N	10	7	N	N	30	N	N	N	Quartzite
-335	N	15	N	N	N	10	15	N	N	50	N	N	N	do.
-351	20	100	10	N	15	200	100	30	N	200	N	N	N	do. , inclusion
-406	20	50	20	N	15	200	70	20	N	150	N	N	N	Quartzite, impure
-417	20	20	20	N	7	200	70	15	N	70	N	N	N	do. , impure
-428	20	10	50	N	20	5000	200	30	N	100	N	N	N	do. , impure
-430	20	10	20	N	10	200	100	20	N	100	N	N	N	do. , impure
-437	L	10	15	N	N	100	10	L	N	30	N	N	N	do. , impure
-446	20	20	10	N	10	200	50	10	N	100	N	N	N	do. , impure
-453	20	5	20	N	N	200	30	L	N	100	N	N	N	do. , impure
-489	20	150	10	N	50	150	300	20	N	70	14	20	N	do. , impure
-490	20	100	10	N	50	300	300	20	N	70	20	20	N	do. , impure

1. Au, Cd, Sn, Te, U, W, Ru, and Ir were tested but not detected in all samples. N means not detected, L means present but less than measurable amount, and G means greater than the value shown. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
3. Pt, Pd, and Rh are in parts per billion.

Table 18 (Cont.)

Other Rocks

SAMPLE NUMBER	Fe[2]	Mg[2]	Ca[2]	Ti[2]	Mn	Ag	As	B	Ba	Be	Bi	Co	Cr	Cu	La	Mo
	ELEMENT IN PARTS PER MILLION[1]															
AHA-081	5.	2.	0.7	0.3	500	N	N	L	300	L	N	10	70	15	N	N
-083	5.	1.5	3.	0.3	500	N	N	L	70	L	N	10	50	15	N	N
-084	5.	1.5	3.	0.15	300	N	N	L	300	L	N	10	50	20	L	N
-087	5.	1.5	3.	0.3	300	N	N	L	300	N	N	15	70	5	30	N
-089	5.	2.	0.7	0.3	300	N	N	L	150	L	N	20	50	15	N	N
-092	3.	1.	3.	0.3	500	N	N	N	300	N	N	15	50	30	30	N
-095	7.	0.7	1.5	0.7	700	N	N	N	700	1	N	50	70	50	300	N
-096	3.	1.5	3.	0.3	300	N	N	L	500	L	N	10	50	15	N	N
-097	3.	1.5	3.	0.2	300	N	N	L	500	L	N	15	50	15	50	N
-098	3.	1.5	2.	0.2	300	N	N	N	500	L	N	15	50	20	L	N
-099	5.	1.5	1.5	0.3	300	N	N	N	300	1	N	15	70	20	N	N
-100	5.	1.5	0.3	0.3	200	N	N	N	500	L	N	15	70	7	N	N
-101	3.	1.5	0.2	0.2	200	N	N	L	500	L	N	15	50	7	30	N
-102	7.	2.	3.	0.3	500	N	N	N	500	L	N	20	70	2	70	N
-103	3.	0.3	0.2	0.3	300	N	N	20	700	1	N	7	50	30	30	N
-105	3.	1.	3.	0.2	300	N	N	L	500	L	N	15	70	15	50	N
-107	3.	1.	3.	0.2	500	N	N	N	300	L	N	15	50	15	L	N
-109	3.	1.5	2.	0.15	500	N	N	20	100	N	N	10	30	15	N	N
-110	3.	1.	3.	0.2	500	N	N	N	500	N	N	15	50	10	30	N
-111	5.	1.5	3.	0.3	500	N	N	N	300	N	N	15	20	20	N	N

1. Au, Cd, Sn, Te, U, W, Ru, and Ir were tested but not detected in all samples. N means not detected, L means present but less than measurable amount, and G means greater than the value shown. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
2. Fe, Mg, Ca, and Ti are in wt. per cent.

Table 18 (Cont.)

Other Rocks

SAMPLE NUMBER	Nb	Ni	Pb	Sb	Sc	Sr	V	Y	Zn	Zr	Pt[3]	Pd[3]	Rh[3]	COMMENTS
	ELEMENT IN PARTS PER MILLION[1]													
AHA-081	N	30	N	N	15	500	100	20	N	100	N	N	N	Granitic Schist
-083	N	30	N	N	15	300	70	20	N	150	N	N	N	do.
-084	N	20	L	N	15	500	70	20	N	100	N	N	N	do.
-087	N	30	N	N	15	500	100	15	N	150	N	N	N	do.
-089	N	30	N	N	15	200	100	10	N	150	N	N	N	do.
-092	N	30	N	N	15	500	70	15	N	150	N	N	N	do.
-095	15	70	L	N	30	200	300	30	N	300	N	N	N	do.
-096	10	30	L	N	15	500	70	15	N	100	N	N	N	do.
-097	L	20	L	N	7	500	70	10	N	150	N	N	N	do.
-098	L	30	L	N	10	500	70	15	N	100	N	N	N	do.
-099	N	30	L	N	15	500	70	15	N	150	N	N	N	do.
-100	N	30	N	N	15	300	100	10	N	150	N	N	N	do.
-101	N	20	N	N	10	200	70	10	N	70	N	N	N	do.
-102	N	30	10	N	15	700	150	20	N	150	N	N	N	do.
-103	N	20	L	N	15	300	100	20	N	200	N	N	N	do.
-105	N	30	N	N	10	300	100	20	N	150	N	N	N	do.
-107	N	20	N	N	10	300	70	15	N	150	N	N	N	do.
-109	N	20	N	N	10	200	70	10	N	70	N	N	N	do.
-110	N	30	10	N	10	300	70	10	N	150	N	N	N	do.
-111	N	30	L	N	15	500	100	15	N	70	N	N	N	do.

1. Au, Cd, Sn, Te, U, W, Ru, and Ir were tested but not detected in all samples. N means not detected, L means present but less than measurable amount, and G means greater than the value shown. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
3. Pt, Pd, and Rh are in parts per billion.

Table 18 (Cont.)

Other Rocks

SAMPLE NUMBER	Fe[2]	Mg[2]	Ca[2]	Ti[2]	Mn	Ag	As	B	Ba	Be	Bi	Co	Cr	Cu	La	Mo
	ELEMENT IN PARTS PER MILLION[1]															
AHA-115	3.	0.7	1.5	0.2	300	N	N	N	200	N	N	10	30	20	30	N
-116	2.	0.7	2.	0.2	300	N	N	N	70	N	N	7	30	15	50	N
-117	3.	0.7	3.	0.2	300	N	N	L	300	L	N	10	30	15	30	N
-118	2.	2.	0.5	0.3	300	N	N	L	300	L	N	15	70	3	30	N
-121	1.5	0.3	0.3	0.15	100	N	N	L	500	2	N	7	7	10	30	3
-123	1.3	0.3	2.	0.15	200	N	N	L	300	1	N	10	50	7	N	N
-312	10.	0.3	0.2	0.3	1000	N	N	20	1000	N	N	50	100	300	N	7
-313	5.	0.2	0.2	0.3	300	N	N	30	700	1.5	N	100	70	70	100	3
-315	3.	0.7	0.7	0.2	300	N	N	20	200	1	N	15	50	10	30	N
-316	3.	1.	3.	0.2	500	N	N	L	500	1	N	15	30	10	70	N
-317	10.	0.15	1.5	0.7	1000	N	N	20	1500	2	N	30	300	7	100	10
-318	7.	3.	1.	0.2	700	N	N	L	150	N	N	20	70	15	N	L
-319	5.	1.	1.5	0.2	700	N	N	L	500	1.5	N	10	70	20	30	N
-152	1.	1.	10.	0.05	500	N	N	20	300	1	N	5	70	30	30	N
-214	0.5	10.	10.	0.007	100	N	N	N	20	N	N	N	20	50	N	N
-215	0.5	10.	10.	0.01	70	N	N	N	15	N	N	N	20	20	N	N
-216	0.7	10.	10.	0.02	150	N	N	20	30	N	N	5	30	30	N	N
-217	1.	5.	5.	0.1	200	N	N	70	100	N	N	10	50	15	30	N
-223	1.	1.	7.	0.1	150	N	N	L	200	N	N	3	50	10	30	N
-224	0.5	1.	G10.	0.02	500	N	N	N	300	N	N	N	20	10	N	N

1. Au, Cd, Sn, Te, U, W, Ru, and Ir were tested but not detected in all samples. N means not detected, L means present but less than measurable amount, and G means greater than the value shown. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
2. Fe, Mg, Ca, and Ti are in wt. per cent.

Table 18 (Cont.)

Other Rocks

SAMPLE NUMBER	Nb	Ni	Pb	Sb	Sc	Sr	V	Y	Zn	Zr	Pt[3]	Pd[3]	Rh[3]	COMMENTS
	ELEMENT IN PARTS PER MILLION[1]													
AHA-115	N	15	10	N	5	300	50	L	N	70	N	N	N	Granitic Schist
-116	N	15	10	N	7	500	70	10	N	70	N	N	N	do.
-117	N	20	N	N	10	300	70	10	N	100	N	N	N	do.
-118	N	150	N	N	15	500	70	10	N	100	N	N	N	do.
-121	L	7	10	N	7	150	30	20	N	150	N	N	N	do.
-123	N	20	10	N	10	200	70	10	N	100	N	N	N	do.
-312	N	100	N	N	70	150	300	20	N	70	40	40	4	do., altered
-313	L	70	N	N	15	100	150	15	N	200	N	N	N	do., altered
-315	L	20	N	N	10	300	100	10	N	100	N	N	N	Granitic Schist
-316	L	20	N	N	10	300	70	15	N	150	N	N	N	do.
-317	L	100	N	N	50	150	300	30	N	200	N	N	N	do.
-318	L	50	N	N	15	150	100	10	N	150	N	N	N	do.
-319	L	50	N	10	10	150	70	10	N	100	N	N	N	do.
-152	N	15	L	N	5	150	50	10	N	50	N	N	N	Limestone
-214	N	7	20	N	N	200	15	N	N	N	N	N	N	do.
-215	N	7	20	N	N	200	10	N	N	N	N	N	N	do.
-216	N	10	15	N	5	200	20	N	N	20	N	N	N	do.
-217	L	20	10	N	7	70	50	L	N	50	N	N	N	do., altered
-223	N	20	10	N	10	30	50	10	N	50	N	N	N	do., altered
-224	N	10	N	N	N	150	50	L	N	N	N	N	N	Limestone

1. Au, Cd, Sn, Te, U, W, Ru, and Ir were tested but not detected in all samples. N means not detected, L means present but less than measurable amount, and G means greater than the value shown. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
3. Pt, Pd, and Rh are in parts per billion.

TABLE 18 (Cont.)

Other Rocks

SAMPLE NUMBER	Fe[2]	Mg[2]	Ca[2]	Ti[2]	Mn	Ag	As	B	Ba	Be	Bi	Co	Cr	Cu	La	Mo
	ELEMENT IN PARTS PER MILLION[1]															
AHA-225	2.	5.	3.	0.15	200	N	N	150	100	L	N	10	50	10	30	N
-226	0.3	7.	7.	0.007	100	N	N	N	10	N	N	5	10	7	N	N
-228	0.2	5.	10.	0.01	100	N	N	N	10	N	N	N	10	7	N	N
-233	0.2	10.	10.	0.003	300	N	N	N	5	N	N	10	7	20	N	N
-235	0.1	10.	10.	0.003	500	N	N	N	15	N	N	15	10	30	N	N
-236	0.1	7.	10.	0.001	500	N	N	N	10	N	N	10	7	30	N	N
-237	0.1	10.	10.	0.001	300	N	N	N	5	N	N	5	2	30	N	N
-238	0.5	1.	2.	0.15	150	N	N	L	15	N	N	N	70	7	30	N
-239	1.	5.	7.	0.15	500	N	N	N	10	N	N	5	70	20	30	N
-240	G10.	3.	5.	0.002	300	N	N	N	10	N	N	7	300	20	N	10
-241	10.	2.	3.	0.5	300	N	N	L	20	N	N	15	150	15	N	10
-242	10.	5.	1.5	0.7	200	N	N	L	30	N	N	30	200	10	N	7
-243	7.	5.	1.5	0.7	200	N	N	L	30	N	N	30	200	10	N	3
-244	10.	5.	2.	0.5	300	N	N	L	20	N	N	30	200	30	N	7
-245	0.3	7.	10.	0.003	500	N	N	N	7	N	N	15	10	10	N	N
-257	G10.	1.5	1.5	1.	300	N	N	L	100	1.5	N	15	70	20.	N	10
-258	5.	7.	10.	0.3	1000	N	N	N	10	N	N	15	70	70	N	10
-262	7.	3.	3.	0.5	500	N	N	L	70	N	N	15	100	30	N	5
-264	0.3	G10.	G10.	0.007	500	N	N	N	15	N	N	15	10	15	N	N
-276	0.7	0.5	0.02	0.2	15	N	N	100	500	2	N	N	70	30	N	N

1. Au, Cd, Sn, Te, U, W, Ru, and Ir were tested but not detected in all samples. N means not detected, L means present but less than measurable amount, and G means greater than the value shown. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley.
2. Fe, Mg, Ca, and Ti are in wt. per cent.

Table 18 (Cont.)

Other Rocks

ELEMENT IN PARTS PER MILLION[1]

SAMPLE NUMBER	Nb	Ni	Pb	Sb	Sc	Sr	V	Y	Zn	Zr	Pt[3]	Pd[3]	Rh[3]	COMMENTS
AHA-225	L	20	15	N	10	70	70	20	N	50	N	N	N	Limestone, altered
-226	N	10	15	N	N	150	15	N	N	N	N	N	N	Limestone
-228	N	5	20	N	N	200	15	N	N	N	N	N	N	do.
-233	N	7	N	N	N	30	7	N	N	N	N	N	N	do.
-235	N	L	N	N	N	30	L	N	N	N	N	N	N	do.
-236	N	L	N	N	N	50	N	N	N	N	N	N	N	do.
-237	N	N	N	N	N	15	N	N	N	N	N	N	N	do.
-238	N	7	N	N	5	15	30	L	N	100	N	N	N	do. , altered
-239	N	7	10	N	15	30	50	10	N	50	N	N	N	do. , altered
-240	N	5	L	N	N	20	70	N	N	N	N	N	N	Limestone, hematite
-241	N	50	10	N	50	70	500	20	N	30	N	N	N	do. , hematite
-242	N	70	N	N	70	70	500	15	N	50	N	N	N	do. , hematite
-243	N	70	10	N	50	50	300	15	N	30	10	4	N	do. , hematite
-244	N	150	N	N	30	70	300	10	N	30	N	N	N	do. , hematite
-245	N	7	10	N	N	30	7	N	N	N	N	N	N	Limestone
-257	N	150	10	N	30	150	1000	20	N	70	N	N	N	do. , hematite
-258	N	20	10	N	70	70	200	30	N	30	N	N	N	do. , hematite
-262	N	70	N	N	30	70	200	20	N	30	N	N	N	do. , hematite?
-264	N	10	N	N	N	200	L	10	N	N	N	N	N	Limestone
-276	10	10	N	N	15	15	100	30	N	70	N	N	N	do. , altered?

1. Au, Cd, Sn, Te, U, W, Ru, and Ir were tested but not detected in all samples. N means not detected, L means present but less than measurable amount, and G means greater than the value shown. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
3. Pt, Pd, and Rh are in parts per billion.

TABLE 18 (Cont.)

Other Rocks

ELEMENT IN PARTS PER MILLION[1]

SAMPLE NUMBER	Fe[2]	Mg[2]	Ca[2]	Ti[2]	Mn	Ag	As	B	Ba	Be	Bi	Co	Cr	Cu	La	Mo
ABA-277	1.	0.7	3.	0.07	300	N	N	20	300	N	N	5	30	20	N	N
-278	0.7	7.	G10.	0.003	500	N	N	N	70	N	N	3	5	3	N	N
-305	3.	1.	G10.	0.15	2000	N	N	N	30	N	N	15	70	15000	N	N
-308	10.	0.2	2.	0.1	700	3	N	L	70	N	N	10	30	100000	N	7
-309	3.	0.5	5.	0.15	1500	N	N	20	100	N	N	30	70	5000	N	N
-477	20.	1.5	5.	0.2	1500	1	N	20	20	N	N	100	100	2000	N	N
-478	15.	2.	7.	0.2	3000	1	N	50	500	N	N	200	50	2000	N	N
-479	15.	2.	7.	0.7	5000	1	700	50	700	N	N	300	100	700	N	N
-143	2.	1.	0.15	0.1	100	N	N	20	50	N	N	10	50	20	N	3
-145	1.5	1.	2.	0.05	500	N	N	20	150	N	N	5	50	15	N	N
-146	2.	1.	0.15	0.15	100	N	N	50	150	1	N	10	70	20	N	N
-148	3.	0.5	0.1	0.15	500	N	N	70	200	5	N	10	100	50	30	3
-151	2.	2.	0.3	0.15	200	N	N	150	500	2	N	10	70	10	50	3
-162	1.	1.	0.7	0.15	100	N	N	50	700	1.5	N	10	70	5	30	N
-172	3.	2.	0.1	0.2	100	N	N	L	150	L	N	10	100	7	30	N
-174	1.	0.7	0.1	0.1	5C	N	N	L	150	N	N	5	50	5	N	N
-206	2.	1.	0.1	0.15	100	N	N	N	300	1	N	7	70	10	N	N
-207	3.	1.	0.1	0.2	100	N	N	L	300	2	N	15	100	50	30	N
-211	7.	1.5	1.	0.5	500	N	N	N	100	L	N	30	50	300	N	N
-400	10.	3.	3.	0.5	1500	N	N	10	500	N	N	50	200	100	N	N

1. Au, Cd, Sn, Te, U, W, Ru, and Ir were tested but not detected in all samples. N means not detected, L means present but less than measurable amount, and G means greater than the value shown. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
2. Fe, Mg, Ca, and Ti are in wt. per cent.

Table 18 (Cont.)

Other Rocks

SAMPLE NUMBER	Nb	Ni	Pb	Sb	Sc	Sr	V	Y	Zn	Zr	Pt[3]	Pd[3]	Rh[3]	COMMENTS
	ELEMENT IN PARTS PER MILLION[1]													
AHA-277	10	15	N	N	7	30	20	N	N	20	N	N	N	Limestone, altered?
-278	N	10	10	N	N	100	L	N	N	N	N	N	N	Limestone
-305	N	20	N	N	30	500	70	200	N	20	20	10	N	do. , sulfides
-308	N	10	N	N	10	20	50	10	N	N	N	N	N	do. , sulfidos
-309	N	15	N	N	20	70	150	N	N	20	N	6	N	do. , sulfides
-477	10	100	20	N	15	150	100	20	300	50	N	N	N	do. , sulfides
-478	10	100	50	N	20	200	150	30	200	70	N	N	N	do. , sulfides
-479	10	100	50	N	50	200	300	50	L	70	N	N	N	do. , sulfides
-143	L	20	10	N	5	5	30	L	N	100	20	6	6	Quartz-mica Schist
-145	N	15	10	N	5	50	30	L	N	50	N	N	N	do.
-146	L	20	10	N	10	20	70	L	N	50	N	N	N	do.
-148	L	20	N	N	10	20	70	L	N	100	N	N	N	do.
-151	10	30	N	N	10	20	70	30	N	150	N	N	N	do.
-162	10	10	10	N	10	70	70	20	N	200	N	N	N	do.
-172	N	50	L	N	10	50	100	10	N	70	N	N	4	do.
-174	N	20	N	N	7	20	50	L	N	70	N	N	N	do.
-206	L	20	N	N	10	100	70	L	N	150	N	N	N	do.
-207	L	30	15	N	15	100	100	20	N	70	N	N	N	do.
-211	L	20	10	N	50	150	200	20	N	50	N	N	N	do.
-400	20	70	20	N	30	200	200	30	N	70	N	N	N	do.

1. Au, Cd, Sn, Te, U, W, Ru, and Ir were tested but not detected in all samples. N means not detected, L means present but less than measurable amount, and G means greater than the value shown. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
3. Pt, Pd, and Rh are in parts per billion.

Table 18 (Cont.)

Other Rocks

SAMPLE NUMBER	Fe[2]	Mg[2]	Ca[2]	Ti[2]	Mn	Ag	As	B	Ba	Be	Bi	Co	Cr	Cu	La	Mo
	ELEMENT IN PARTS PER MILLION[1]															
AHA-427	15.	7.	10.	1.	3000	N	N	20	300	N	N	50	500	70	N	N
-466	10.	7.	10.	0.7	3000	N	N	20	200	N	N	50	300	70	N	N
-467	10.	7.	7.	0.5	3000	N	N	10	200	N	N	50	500	50	N	N
-469	10.	5.	10.	0.5	3000	N	N	10	500	N	N	30	300	30	N	N
-470	10.	7.	10.	0.7	3000	N	N	20	300	N	N	50	300	70	N	N
-471	10.	7.	10.	1.	3000	N	N	20	500	N	N	50	700	70	N	N
-472	10.	3.	10.	1.	3000	N	N	20	500	N	N	50	200	30	N	N
-474	5.	2.	2.	0.3	1000	N	N	L	1000	N	N	20	100	30	N	N
-181	7.	0.2	0.2	0.2	100	N	N	N	100	1	N	15	2	20	50	N
-182	3.	0.2	0.1	0.15	100	N	N	N	150	1	N	15	50	3	30	N
-184	3.	2.	0.15	0.15	70	N	N	N	70	L	N	10	30	1	70	N
-186	2.	0.2	0.05	0.2	70	N	N	50	500	2	N	7	50	20	30	N
-187	3.	0.5	0.07	0.2	100	N	N	50	300	1.5	N	10	30	20	30	N
-188	1.5	0.2	0.2	0.15	100	N	N	50	300	1.5	N	5	30	7	30	N
-189	1.	0.2	0.05	0.15	100	N	N	20	500	1	N	10	20	10	70	N
-190	1.	0.3	0.07	0.15	100	N	N	20	500	2	N	5	20	50	70	N
-191	1.	0.3	0.05	0.15	50	N	N	20	500	2	N	N	15	5	70	N
-192	1.5	0.5	0.07	0.2	100	N	N	20	300	3	N	15	30	10	70	N
-279	7.	3.	3.	0.3	1000	N	N	20	15	N	N	30	150	150	N	3
-280	10.	3.	5.	0.5	1500	N	N	L	15	N	N	70	70	300	N	5

1. Au, Cd, Sb, Te, U, W, Ru, and Ir were tested but not detected in all samples. N means not detected, L means present but less than measurable amount, and G means greater than the value shown. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
2. Fe, Mg, Ca, and Ti are in wt. per cent.

Table 18 (Cont.)

Other Rocks

ELEMENT IN PARTS PER MILLION[1]

SAMPLE NUMBER	Nb	Ni	Pb	Sb	Sc	Sr	V	Y	Zn	Zr	Pt[3]	Pd[3]	Rh[3]	COMMENTS
AHA-427	20	150	10	N	70	300	500	50	N	100	N	N	N	Quartz-mica Schist
-466	20	150	20	N	50	300	300	30	N	100	N	N	N	do.
-467	15	150	20	N	50	150	300	30	N	70	N	N	N	do.
-469	20	150	20	N	50	200	300	30	N	70	N	N	N	do.
-470	20	150	20	N	50	200	300	30	N	70	N	N	N	do.
-471	20	150	50	N	50	200	300	50	N	100	N	N	N	do.
-472	15	50	20	N	50	200	300	50	N	150	N	N	N	do.
-474	20	50	20	N	10	150	100	10	N	100	N	N	N	do.
-181	L	L	L	N	15	50	20	30	N	150	N	N	N	Phyllite, altered?
-182	L	10	L	N	5	20	50	20	N	500	N	N	N	Phyllite
-184	L	20	N	N	10	30	50	20	N	100	N	N	N	do.
-186	10	10	10	N	10	70	70	20	N	100	N	N	N	do.
-187	10	20	L	N	10	50	50	20	N	200	N	N	N	do. , conglomeratic
-188	L	10	L	N	7	50	50	20	N	100	N	N	N	Phyllite
-189	10	7	10	N	7	50	20	20	N	200	N	N	6	do.
-190	10	5	L	N	7	50	30	30	N	200	N	N	N	do.
-191	10	5	L	N	7	50	20	20	N	150	N	N	N	do.
-192	10	15	L	N	10	50	50	20	N	150	N	N	N	do.
-279	10	100	N	N	50	150	300	15	N	30	10	10	N	Limey Schist
-280	[illegible]	70	N	N	70	200	300	20	N	30	N	N	N	do.

1. Au, Cd, [illegible]n, Te, U, W, Ru, and Ir were tested but not detected in all samples. N means not detected, L means present but less than measurable amount, and G means greater than the value shown. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
3. Pt, Pd, and Rh are in parts per billion.

Table 18 (Cont.)

Other Rocks

SAMPLE NUMBER	Fe[2]	Mg[2]	Ca[2]	Ti[2]	Mn	Ag	As	B	Ba	Be	Bi	Co	Cr	Cu	La	Mo
	ELEMENT IN PARTS PER MILLION[1]															
AHA-281	7.	5.	3.	0.2	1000	N	N	L	30	N	N	50	70	100	N	5
-282	7.	3.	3.	0.3	700	N	N	20	20	N	N	30	70	70	30	N
-283	7.	3.	2.	0.5	700	N	N	20	150	N	N	30	150	150	N	5
-284	7.	1.5	10.	0.2	1000	N	N	L	70	N	N	20	100	70	N	N
-285	5.	3.	7.	0.2	1000	N	N	L	50	N	N	30	70	200	N	N
-286	7.	2.	5.	0.5	1500	N	N	L	150	N	N	50	150	150	N	5
-287	7.	3.	5.	0.3	1000	N	N	20	100	N	N	30	200	70	N	3
-288	7.	3.	3.	0.3	1000	N	N	20	70	N	N	30	150	150	N	5
-289	7.	3.	3.	0.3	1500	N	N	20	30	N	N	20	70	70	N	3
-290	7.	2.	7.	0.15	1000	N	N	L	30	N	N	20	50	70	N	5
-291	7.	3.	3.	0.3	1500	N	N	20	150	N	N	30	300	100	N	5
-292	5.	2.	3.	0.2	1500	N	N	20	150	N	N	30	70	100	N	N
-293	5.	3.	3.	0.2	700	N	N	L	30	N	N	20	50	70	N	N
-402	15.	5.	10.	G1.	3000	N	N	20	700	N	N	70	150	70	N	N
-403	10.	5.	5.	1.	2000	N	N	10	1000	N	N	50	150	50	N	N
-405	10.	3.	5.	1.	3000	N	N	10	70	N	N	50	150	50	N	N
-407	10.	3.	10.	1.	3000	N	N	20	70	N	N	50	100	50	N	N
-408	10.	3.	7.	1.	2000	N	N	20	100	N	N	50	150	70	N	N
-418	10.	5.	7.	1.	2000	N	N	20	300	N	N	30	150	100	N	N
-420	10.	3.	5.	0.5	2000	N	N	10	500	N	N	30	50	50	N	N

1. Au, Cd, Sn, Te, U, W, Ru, and Ir were tested but not detected in all samples. N means not detected, L means present but less than measurable amount, and G means greater than the value shown. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
2. Fe, Mg, Ca, and Ti are in wt. per cent.

Table 18 (Cont.)

Other Rocks

SAMPLE NUMBER	Nb	Ni	Pb	Sb	Sc	Sr	V	Y	Zn	Zr	Pt[3]	Pd[3]	Rh[3]	COMMENTS
						ELEMENT IN PARTS PER MILLION[1]								
AHA-281	10	300	N	N	20	150	150	10	N	20	60	40	N	Limey Schist
-282	N	70	N	N	30	150	150	15	N	30	10	6	N	do.
-283	L	70	N	N	50	100	300	20	N	50	10	2	N	do.
-284	L	70	N	N	30	150	150	15	N	30	N	10	N	do.
-285	N	70	N	N	30	70	150	15	N	30	100	140	N	do.
-286	L	70	N	N	50	200	300	20	N	50	30	14	N	do.
-287	L	100	N	N	70	200	300	20	N	50	40	14	N	do.
-288	N	70	N	N	50	70	200	15	N	50	40	14	N	do.
-289	N	50	N	N	50	150	300	20	N	50	30	20	N	do.
-290	10	70	N	N	30	70	150	15	N	30	20	6	N	do.
-291	N	100	N	N	100	200	300	20	N	50	30	30	N	do.
-292	N	70	N	N	50	150	200	15	N	30	N	6	N	do.
-293	N	50	N	N	30	100	200	15	N	50	N	4	N	do.
-402	20	70	20	N	70	500	500	50	N	200	N	N	N	Metavolcanic
-403	20	50	20	N	50	150	300	20	N	100	N	N	N	do.
-405	20	50	10	N	50	200	300	50	N	100	N	N	N	do.
-407	20	50	10	N	50	300	300	50	N	150	N	N	N	do.
-408	20	70	10	N	50	200	300	50	N	150	N	N	N	do.
-418	20	50	20	N	50	500	300	50	N	150	N	N	N	do.
-421	15	50	10	N	30	200	200	30	N	100	N	N	N	do.

1. Au, Cd, Sn, Te, U, W, Ru, and Ir were tested but not detected in all samples. N means not detected, L means present but less than measurable amount, and G means greater than the value shown. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
3. Pt, Pd, and Rh are in parts per billion.

Table 18 (Cont.)

Other Rocks

SAMPLE NUMBER	Fe[2]	Mg[2]	Ca[2]	Ti[2]	Mn	Ag	As	B	Ba	Be	Bi	Co	Cr	Cu	La	Mo
	ELEMENT IN PARTS PER MILLION[1]															
AHA-422	10.	2.	7.	0.7	2000	N	N	10	200	N	N	50	100	50	N	N
-423	10.	3.	7.	1.	3000	N	N	10	200	N	N	50	150	100	N	N
-424	15.	5.	7.	1.	3000	N	N	10	300	N	N	70	300	100	N	N
-433	10.	5.	5.	1.	2000	N	N	10	1000	N	N	50	150	70	N	N
-434	10.	5.	7.	1.	5000	N	N	15	500	N	N	30	100	50	N	N
-438	7.	3.	2.	0.3	500	N	N	L	1000	N	N	30	10	30	50	N
-439	10.	5.	0.7	1.	2000	N	N	10	1500	N	N	70	100	100	N	N
-441	10.	5.	10.	1.	3000	N	N	20	300	N	N	50	150	100	N	N
-442	10.	5.	7.	1.	3000	N	N	15	300	N	N	50	150	100	N	N
-443	10.	5.	5.	1.	2000	N	N	10	200	N	N	70	150	70	N	N
-448	10.	3.	5.	0.5	2000	N	N	10	1000	N	N	50	150	50	N	N
-450	10.	3.	5.	1.	2000	N	N	10	200	N	N	50	150	50	N	N
-451	10.	5.	7.	1.	3000	N	N	20	200	N	N	70	150	30	N	N
-454	10.	3.	7.	1.	2000	N	N	20	70	N	N	50	150	70	N	N
-455	10.	3.	7.	1.	2000	N	N	20	300	N	N	50	150	20	N	N
-457	10.	3.	7.	0.7	3000	N	N	15	100	N	N	50	100	50	N	N
-462	10.	5.	7.	0.5	2000	N	N	10	100	N	N	50	200	50	N	N
-485	15.	2.	7.	1.	5000	N	N	30	200	N	N	100	150	700	N	N
-486	10.	1.	5.	0.5	2000	N	N	L	100	N	N	50	50	300	N	N
-409	10.	3.	7.	1.	2000	N	N	10	100	N	N	50	150	50	N	N

1. Au, Cd, Sn, Te, U, W, Ru, and Ir were tested but not detected in all samples. N means not detected, L means present but less than measurable amount, and G means greater than the value shown. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
2. Fe, Mg, Ca, and Ti are in wt. per cent.

Table 18 (Cont.)

Other Rocks

SAMPLE NUMBER	Nb	Ni	Pb	Sb	Sc	Sr	V	Y	Zn	Zr	Pt[3]	Pd[3]	Rh[3]	COMMENTS
	ELEMENT IN PARTS PER MILLION[1]													
AHA-422	15	50	20	N	50	200	300	50	N	100	N	N	N	Metavolcanic
-423	20	70	20	N	50	200	300	50	N	100	N	N	N	do.
-424	20	100	15	N	50	200	300	50	N	70	N	N	N	do.
-433	15	50	10	N	50	200	300	50	N	100	N	N	N	do.
-434	20	50	15	N	50	500	300	50	N	100	N	N	N	do.
-438	10	50	20	N	20	200	200	20	N	70	N	N	N	do.
-439	20	70	20	N	50	100	200	20	N	100	N	N	N	do.
-441	20	70	10	N	50	200	300	50	N	100	N	N	N	do.
-442	15	70	10	N	50	300	300	50	N	100	N	N	N	do.
-443	15	70	10	N	50	200	300	30	N	100	N	N	N	do.
-448	15	70	30	N	20	500	200	30	N	100	N	N	N	do.
-450	20	50	15	N	30	200	200	30	N	100	N	N	N	do.
-451	20	70	10	N	50	200	200	50	N	150	N	N	N	do.
-454	20	50	50	N	50	200	200	30	N	100	N	N	N	do.
-455	20	50	10	N	30	200	200	30	N	100	N	N	N	do.
-457	20	20	10	N	30	200	200	30	N	100	N	N	N	do.
-462	15	100	10	N	30	200	200	20	N	100	N	N	N	do.
-485	10	70	L	N	70	200	300	70	500	150	N	N	N	do. , sulfides
-486	10	50	L	N	20	100	150	30	200	70	N	2	N	do. , sulfides
-409	15	50	10	N	50	200	300	30	N	150	N	N	N	Pillow Lava

1. Au, Cd, Sn, Te, U, W, Ru, and Ir were tested but not detected in all samples. N means not detected, L means present but less than measurable amount, and G means greater than the value shown. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
3. Pt, Pd, and Rh are in parts per billion.

Table 18 (Cont.)

Other Rocks

SAMPLE NUMBER	Fe[2]	Mg[2]	Ca[2]	Ti[2]	Mn	Ag	As	B	Ba	Be	Bi	Co	Cr	Cu	La	Mo
					ELEMENT IN PARTS PER MILLION[1]											
AHA-412	10.	3.	7.	1.	2000	N	N	20	500	N	N	50	150	70	N	N
-419	10.	3.	7.	1.	2000	N	N	15	150	N	N	50	100	30	N	N
-420	10.	3.	7.	1.	2000	N	N	10	150	N	N	50	150	30	N	N
-429	10.	2.	5.	0.7	2000	N	N	10	500	N	N	50	150	70	N	N
-431	10.	5.	7.	0.5	2000	N	N	10	500	N	N	50	500	100	N	N
-432	10.	3.	7.	1.	2000	N	N	10	200	N	N	50	150	50	N	N
-440	10.	5.	7.	1.	5000	N	N	20	100	N	N	50	150	70	N	N
-449	10.	3.	7.	1.	2000	N	N	10	500	N	N	50	150	30	N	N
-456	10.	5.	5.	1.	2000	N	N	15	700	N	N	50	200	50	N	N
-458	10.	5.	10.	0.5	2000	N	N	10	100	N	N	50	200	30	N	N
-460	10.	5.	7.	0.5	2000	N	N	10	70	N	N	50	150	30	N	N
-461	10.	3.	3.	0.3	1000	N	N	10	200	N	N	50	200	50	N	N
-093	0.7	0.07	0.15	0.07	150	N	N	L	150	N	N	3	3	7	N	N
-263	0.3	0.05	0.07	0.07	150	N	N	20	70	N	N	N	7	3	N	N
-267	7.	0.07	0.07	0.02	30	N	N	L	50	N	N	N	7	150	N	7
-304	5.	0.05	1.5	0.015	200	N	N	L	50	N	N	10	10	30000	N	N
-314	7.	0.07	0.07	0.05	500	N	N	20	200	N	N	50	30	100	N	N
-356	0.07	0.03	0.05	0.002	50	N	N	10	50	N	N	N	L	L	N	N
-364	0.05	0.05	0.07	0.002	50	N	N	10	100	N	N	N	L	L	N	N
-371	0.1	0.05	L	0.002	30	N	N	50	50	N	N	N	L	100	N	N

1. Au, Cd, Sn, Te, U, W, Ru, and Ir were tested but not detected in all samples. N means not detected, L means present but less than measurable amount, and G means greater than the value shown. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, L. R. Carlson, Z. C. Stephenson, and E. F. Cooley
2. Fe, Mg, Ca, and Ti are in wt. per cent.

TABLE 18 (Cont.)

Other Rocks

SAMPLE NUMBER	Nb	Ni	Pb	Sb	Sc	Sr	V	Y	Zn	Zr	Pt[3]	Pd[3]	Rh[3]	COMMENTS
	ELEMENT IN PARTS PER MILLION[1]													
AHA-412	50	70	20	N	50	500	300	30	N	100	N	N	N	Pillow Lava
-419	50	70	10	N	50	300	300	50	N	100	N	N	N	do.
-420	50	50	10	N	50	200	300	30	N	100	N	N	N	do.
-429	30	50	30	N	50	300	300	30	N	100	N	N	N	do.
-431	50	150	20	N	50	200	200	20	N	50	10	6	N	do.
-432	50	70	10	N	50	200	300	50	N	100	N	N	N	do.
-440	50	70	10	N	50	200	300	50	N	150	N	N	N	do.
-449	30	70	30	N	50	200	300	30	N	150	N	N	N	do.
-456	50	70	20	N	50	200	300	50	N	150	N	N	N	do.
-458	50	100	10	N	30	200	200	30	N	70	10	N	N	do.
-460	50	100	10	N	30	200	200	30	N	70	N	N	N	do.
-461	10	100	10	N	30	200	200	30	N	70	N	N	N	do.
-093	N	5	N	N	N	15	20	N	N	30	N	N	N	Quartz Vein
-263	N	N	N	N	N	30	15	10	N	N	N	N	N	do.
-267	L	30	N	N	7	N	150	30	N	70	N	N	N	do.
-304	N	50	N	N	N	10	7	N	N	N	N	N	N	do. , sulfides
-314	N	100	20	N	N	N	50	N	N	20	N	N	N	Quartz Vein
-356	L	5	10	N	N	L	L	L	N	N	N	N	N	do.
-364	20	5	L	N	N	L	L	L	N	N	N	N	N	do.
-371	L	5	L	N	N	L	L	L	N	N	N	N	N	do.

1. Au, Cd, Sn, Te, U, W, Ru, and Ir were tested but not detected in all samples. N means not detected, L means present but less than measurable amount, and G means greater than the value shown. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
3. Pt, Pd, and Rh are in parts per billion.

Table 18 (Cont.)

Other Rocks

SAMPLE NUMBER	Fe[2]	Mg[2]	Ca[2]	Ti[2]	Mn	Ag	As	B	Ba	Be	Bi	Co	Cr	Cu	La	Mo
					ELEMENT IN PARTS PER MILLION[1]											
AHA-411	0.2	0.03	0.05	0.01	50	N	N	L	70	L	N	N	L	5	N	N
-481	0.1	0.1	0.2	0.03	70	N	N	L	70	N	N	N	L	L	N	N
-357	0.5	0.5	0.5	0.1	150	N	N	30	100	N	N	L	30	5	N	N
-358	5.	3.	1.	0.15	500	N	N	30	70	N	N	20	150	5	N	N
-374	15.	7.	1.	0.1	1500	N	N	30	70	N	N	70	150	70	N	N
-395	5.	2.	1.	1.	500	N	N	50	300	N	N	30	100	500	N	N
-401	7.	2.	3.	0.5	700	N	N	L	5000	N	N	30	150	20	N	N
-404	7.	2.	2.	0.3	700	N	N	L	1500	L	N	30	200	10	N	N
-410	5.	1.	1.5	0.2	500	N	N	10	200	N	N	20	100	20	N	N
-369	7.	3.	5.	0.5	1000	N	N	10	100	N	N	30	150	100	N	N
-353	5.	3.	1.5	0.3	700	N	N	10	200	N	N	20	200	20	N	N
-480	7.	7.	15.	0.03	5000	N	N	L	70	N	N	20	150	20	N	N
-177	5.	2.	0.1	0.15	200	N	N	N	100	L	N	20	10	70	N	N
-179	3.	2.	0.1	0.15	200	N	N	N	100	N	N	20	10	70	N	F
-180	5.	1.	3.	0.5	500	N	N	N	100	N	N	50	2	150	150	N
-261	G10.	3.	0.07	0.7	300	N	N	L	50	N	N	50	70	20	N	L
-306	2.	1.	G10.	0.15	1500	N	N	N	30	N	N	10	70	100	N	N
-336	10.	7.	10.	0.3	1000	N	N	L	70	N	N	30	50	70	N	5
-338	10.	5.	7.	0.3	1500	N	N	L	15	N	N	30	150	50	N	5
-468	10.	0.5	0.7	0.3	700	N	N	10	500	N	N	30	100	100	N	N

1. Au, Cd, Sn, Te, U, W, Ru, and Ir were tested but not detected in all samples. N means not detected, L means present but less than measurable amount, and G means greater than the value shown. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
2. Fe, Mg, Ca, and Ti are in wt. per cent.

TABLE 18 (Cont.)

Other Rocks

ELEMENT IN PARTS PER MILLION[1]

SAMPLE NUMBER	Nb	Ni	Pb	Sb	Sc	Sr	V	Y	Zn	Zr	Pt[3]	Pd[3]	Rh[3]	COMMENTS
AHA-411	15	5	L	N	N	L	L	L	N	N	N	N	N	Quartz Vein
-481	10	5	L	N	N	L	L	L	N	N	N	N	N	do.
-357	L	10	10	N	N	200	15	N	N	70	N	N	N	Felsic "Rind" on Quartz Vein
-358	10	100	10	N	10	200	100	20	N	100	N	N	N	do.
-374	10	150	20	N	5	100	150	10	1500	10	N	N	N	Chlorite-epidote Vein
-395	20	150	20	N	20	500	150	30	N	100	N	N	N	Diorite? Dike, sulfides
-401	20	50	30	N	20	700	150	20	N	70	N	N	N	Diorite? Dike
-404	20	50	30	N	20	500	150	20	N	200	N	N	N	do.
-410	20	30	20	N	15	300	150	20	N	100	N	N	N	do.
-369	10	100	10	N	30	200	200	30	N	100	N	N	N	Pegmatitic Amphibolite
-353	10	50	10	N	10	200	50	15	N	150	10	N	N	Felsic Inclusion?
-480	10	50	20	N	30	200	20	30	N	N	N	N	N	Carbonate Vein
-177	N	50	10	N	20	15	50	L	N	20	N	N	N	Altered Amphibolite?
-179	N	30	10	N	15	15	70	N	N	30	N	N	N	do.
-180	N	20	L	N	30	200	300	20	N	50	N	N	N	do.
-261	N	70	10	N	50	200	700	30	N	30	N	N	N	do.
-306	N	20	N	N	15	150	150	20	N	20	N	4	N	do.
-336	N	1000	10	N	100	70	500	20	200	70	N	15	30	Amphibolite
-338	L	70	15	N	50	70	300	20	N	30	N	N	N	Snowy Range Amphibolite
-468	10	100	50	N	20	200	200	30	N	70	N	N	N	Gossan

1. Au, Cd, Sn, Te, U, W, Ru, and Ir were tested but not detected in all samples. N means not detected, L means present but less than measurable amount, and G means greater than the value shown. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
3. Pt, Pd, and Rh are in parts per billion.

Table 18 (Cont.)

Other Rocks

SAMPLE NUMBER	ELEMENT IN PARTS PER MILLION[1] Nb	Ni	Pb	Sb	Sc	Sr	V	Y	Zn	Zr	Pt[3]	Pd[3]	Rh[3]	COMMENTS
AHA-294	15	10	15	N	N	70	10	30	N	150	N	N	N	Red Granite
-295	20	L	10	N	N	50	15	70	N	150	N	N	N	do.

1. Au, Cd, Sn, Te, U, W, Ru, and Ir were tested but not detected in all samples. N means not detected, L means present but less than measurable amount, and G means greater than the value shown. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
3. Pt, Pd, and Rh are in parts per billion.

Table 18 (Cont.)

Other Rocks

SAMPLE NUMBER	Fe^2	Mg^2	Ca^2	Ti^2	Mn	Ag	As	B	Ba	Be	Bi	Co	Cr	Cu	La	Mo
	ELEMENT IN PARTS PER MILLION[1]															
AHA-294	0.7	0.1	0.7	0.03	200	N	N	30	300	2	N	N	3	10	70	N
-295	1.	0.15	0.15	0.07	70	N	N	50	300	5	N	N	3	3	30	N

1. Au, Cd, Sn, Te, U, W, Ru, and Ir were tested but not detected in all samples. N means not detected, L means present but less than measurable amount, and G means greater than the value shown. Analysts, B. Wayne Lanthorn, Leon A. Bradley, and E. F. Cooley. Pt-group analysts, R. R. Carlson, Z. C. Stephenson, and E. F. Cooley
2. Fe, Mg, Ca, and Ti are in wt. per cent.

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