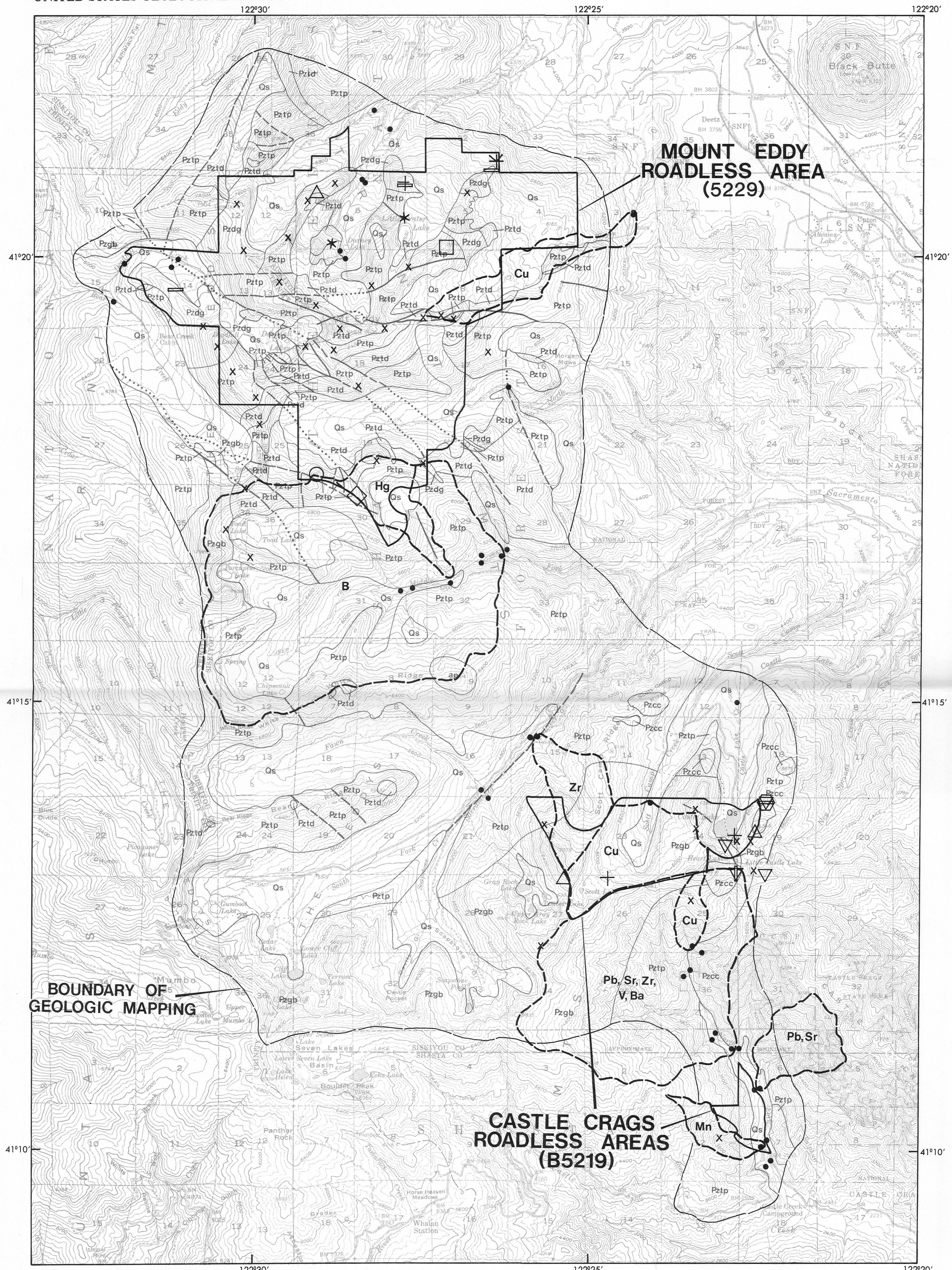
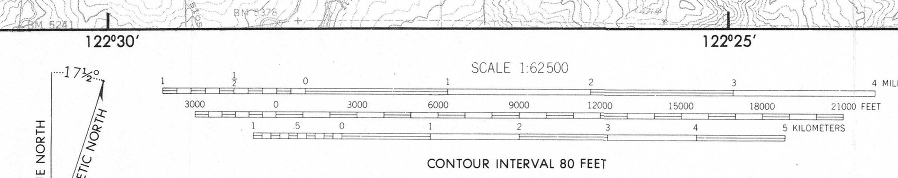


Base from U.S. Geological Survey Dunsmuir, Weed, 1954; Bonanza King, China Mountain, 1955

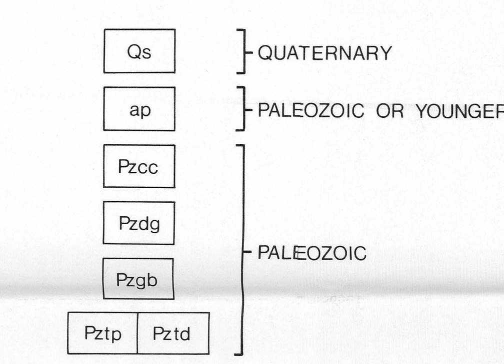


Geology mapped by Peterson and Caress, 1982; Quick, 1981; Throckmorton, 1978; and Vennum, 1971

ROCK SAMPLE LOCATIONS

- × Sample containing no anomalous values
- Boron ≥ 150 ppm
- Barium ≥ 1,500 ppm
- Cobalt ≥ 200 ppm
- Chromium ≥ 5,000 ppm
- Copper ≥ 100 ppm
- Manganese ≥ 1,500 ppm
- Nickel ≥ 3,000 ppm
- Lead ≥ 20 ppm
- Strontium ≥ 1,000 ppm
- Vanadium ≥ 300 ppm
- Zirconium ≥ 150 ppm
- • STREAM-SEDIMENT SAMPLE LOCATION
- Zr STREAM DRAINAGE CONTAINING ANOMALOUS GEOCHEMICAL VALUES

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

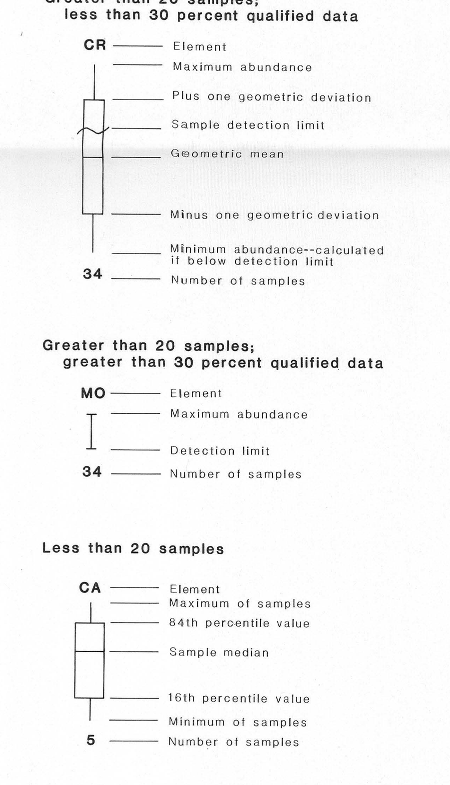
- Qs SURFICIAL DEPOSITS (QUATERNARY)--Alluvium, talus, and glacial till
- ap APLITIC ROCKS (PALEOZOIC OR YOUNGER)--Granodiorite
- Pzcc CASTLE CRAGS PLUTON (PALEOZOIC)--Sodic granodiorite and alkalic trondhjemite plus adjacent granodioritic hypabyssal dikes and plugs
- Pzdg HORNBLENDE DIORITE AND GRANODIORITE (PALEOZOIC)
- Pzgb GABBRO (PALEOZOIC)
- TRINITY ULTRAMAFIC SHEET (PALEOZOIC)--As mapped, consists of:
  - Pztd Dunite
  - Pztp Peridotite

- APPROXIMATE CONTACT--Dotted where concealed
- FAULT--Dashed where inferred, dotted where concealed
- APPROXIMATE BOUNDARY OF ROADLESS AREA

EXPLANATION FOR CORRELATION DIAGRAMS (Figs. 6, 8)

- High positive correlation--Equal to or greater than +0.5
- Low positive correlation--Between +0.3 and +0.5
- Low negative correlation--Between -0.3 and -0.5
- High negative correlation--Equal to or greater than -0.5
- 34 Number of sample pairs used in computing correlations

EXPLANATION FOR ABUNDANCE DIAGRAMS (Figs. 2-5, 7)



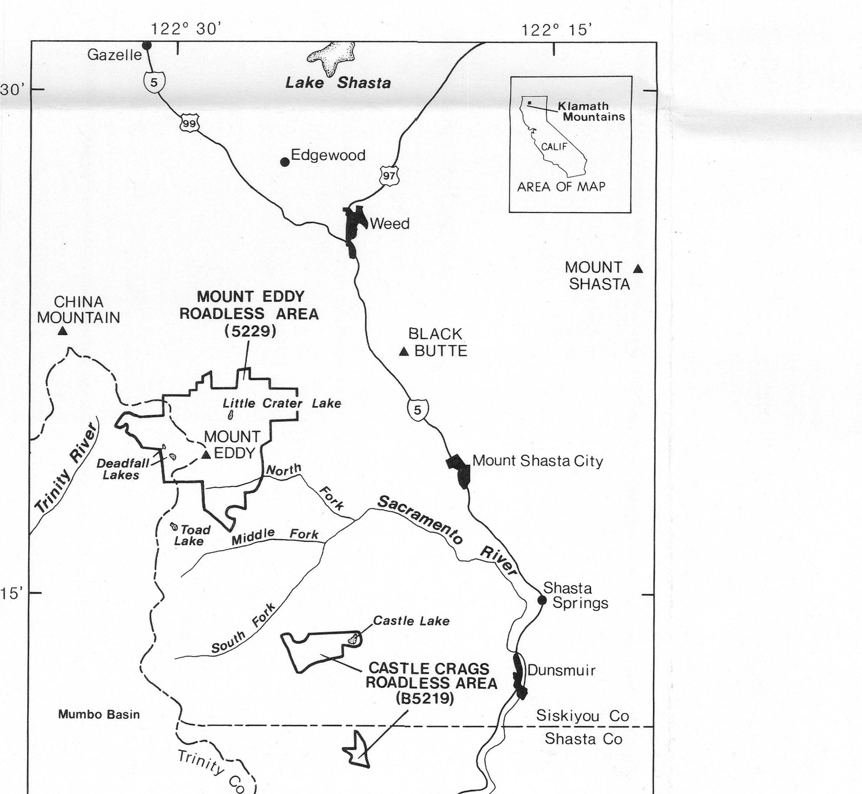


Figure 1.--Index map showing location of Mount Eddy and Castle Crags Roadless Areas.

GEOCHEMICAL MAP OF THE MOUNT EDDY AND CASTLE CRAGS ROADLESS AREAS, SHASTA, SISKIYOU, AND TRINITY COUNTIES, CALIFORNIA

By

Jocelyn A. Peterson and Mary E. Caress

1983

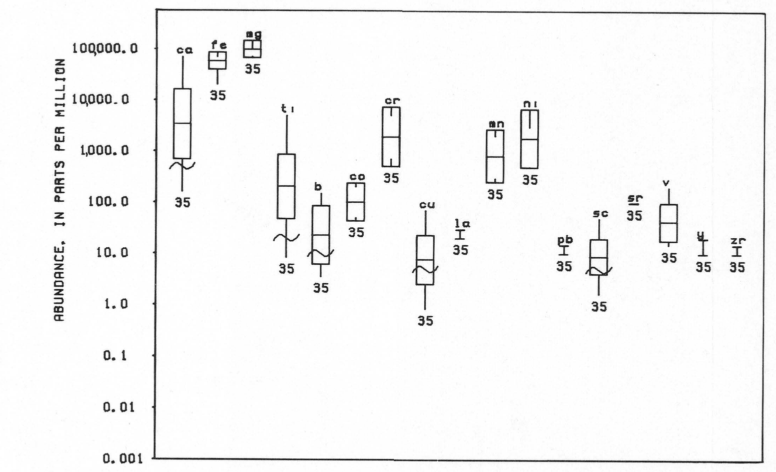


Figure 2.--Element abundance diagram for ultramafic rock samples.

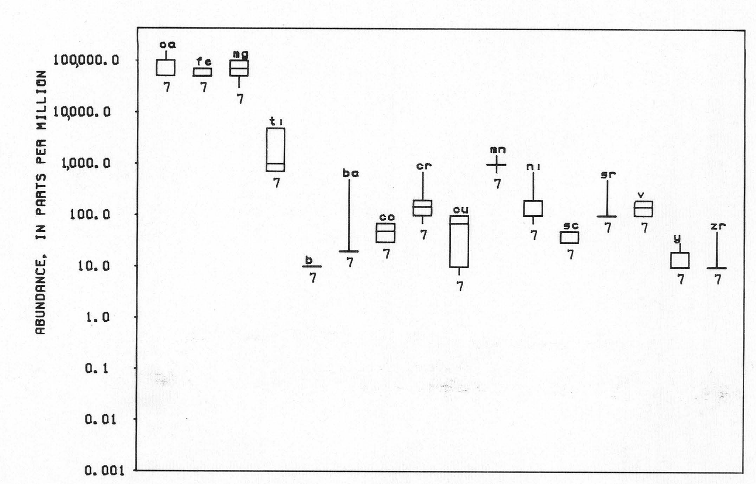


Figure 3.--Element abundance diagram for gabbro samples.

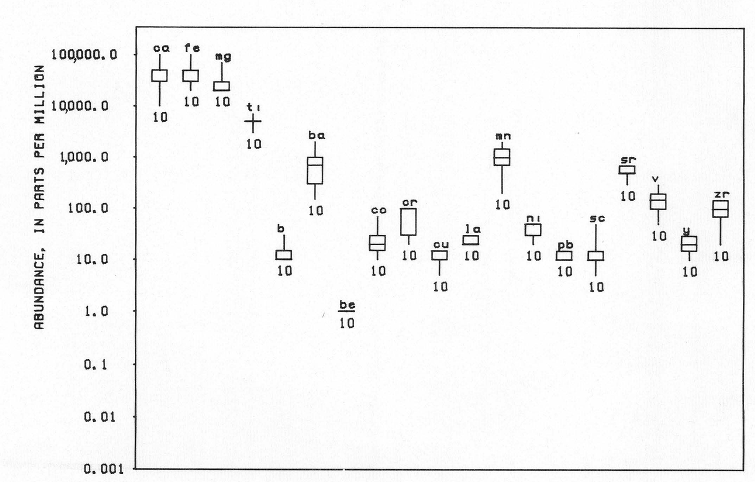


Figure 4.--Element abundance diagram for hornblende diorite samples.

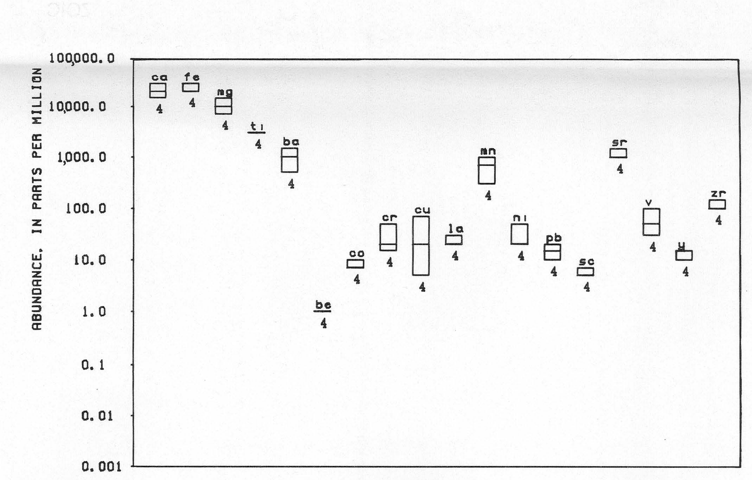


Figure 5.--Element abundance diagram for granitic rocks.

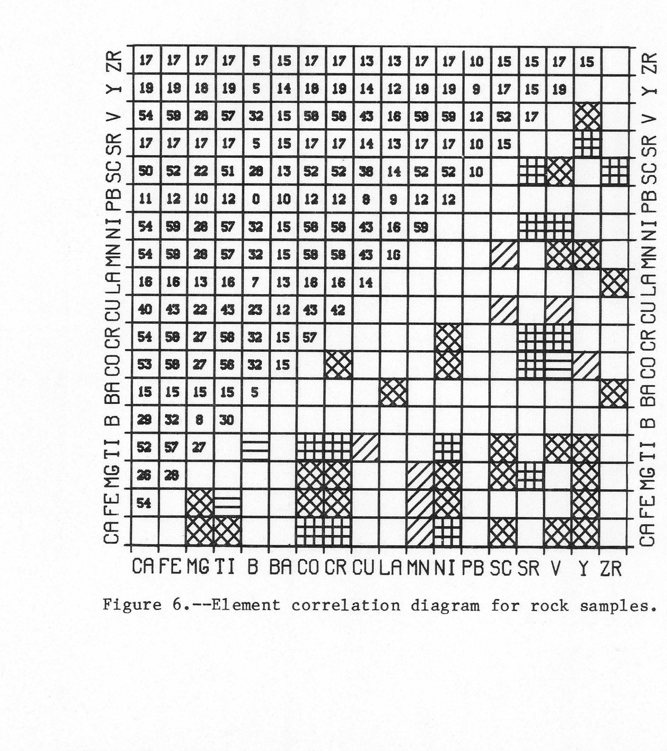


Figure 6.--Element correlation diagram for rock samples.

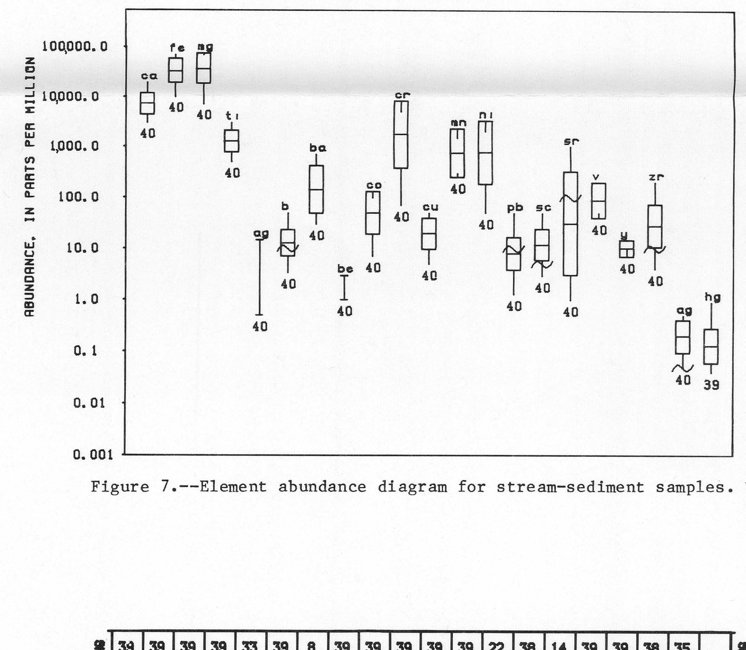


Figure 7.--Element abundance diagram for stream-sediment samples.

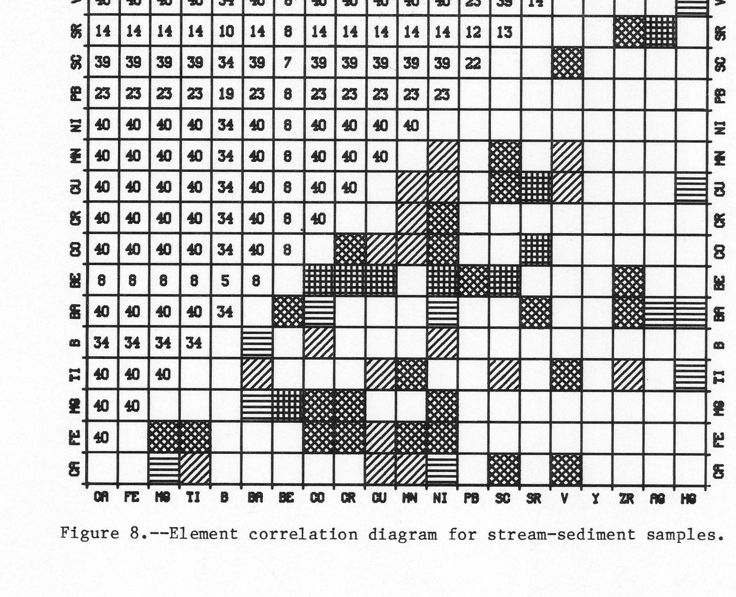


Figure 8.--Element correlation diagram for stream-sediment samples.

STUDIES RELATED TO WILDERNESS

The Wilderness Act (Public Law 88-577, September 3, 1964) and related acts require the U.S. Geological Survey and the U.S. Bureau of Mines to survey certain areas on Federal lands to determine their mineral resource potential. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a geochemical survey of the Mount Eddy (5229) and Castle Crags (B5219) Roadless Areas in the Shasta-Trinity National Forest, Shasta, Siskiyou, and Trinity Counties, California. These roadless areas were classified as further planning areas during the Second Roadless Area Review and Evaluation (RARE II) by the U.S. Forest Service, January, 1979.

INTRODUCTION

The Mount Eddy and Castle Crags Roadless Areas occupy 9,600 acres (39 km^2) and 3,300 acres (13 km^2), respectively, in Shasta, Siskiyou, and Trinity Counties, Calif., approximately 8 mi (13 km) west of the towns of Mount Shasta City and Dunsmuir (fig. 1). Access is provided by secondary roads and trails from Interstate Highway 5, which passes through Mount Shasta City and Dunsmuir. The areas are located in rugged terrane in the easternmost part of the Klamath Mountains where altitudes range from about 2,500 ft (762 m) in the southern Castle Crags area to 9,025 ft (2,751 m) on Mount Eddy. Manzanita and other brush are ubiquitous at lower elevations whereas vegetation is lacking at higher elevations except for occasional gnarled conifers and ground-level plants.

GEOLOGIC SUMMARY

Underlying the Mount Eddy and Castle Crags Roadless Areas is part of the Trinity ultramafic sheet, one of the largest ultramafic bodies in the United States covering 400 mi^2 (1,050 km^2) (Lipman, 1964). The ultramafic rocks have been intruded by large gabbro bodies, hornblende-diorite stocks, and younger granitic plutons. All of these units are Paleozoic in age.

The Trinity ultramafic sheet dips to the east and is several miles (kilometers) thick. Its rocks include harzburgite, dunite, and plagioclase lherzolite with minor amounts of other ultramafic rocks, frequently emplaced as dikes (Quick, 1981). The amount of serpentinized rocks varies considerably and in general increases southward. In the Mount Eddy area the ultramafic rock types are readily distinguishable in the field, whereas to the south serpentinization has obscured the original rock type. Dunite forms small bodies inches to feet (centimeters to meters) in size and large thick (up to 300 ft (100 m)), tabular bodies more than 0.6 mi (1 km) long. Where rock types are distinguishable, dunite is estimated to constitute 15 to 20 percent of the peridotite. Peridotite of the Trinity ultramafic sheet crops out in both roadless areas.

Gabbro and related cumulate ultramafic rocks intrude the Trinity ultramafic sheet. A large gabbro body underlies most of the northern Castle Crags Roadless Area (Throckmorton, 1978). The gabbro comprises both cumulate and non-cumulate phases. The cumulate peridotite is at the bottom of the mass. This grades to cumulate gabbro and then to massive coarse grained gabbro. Dikes from this gabbro and other similar gabbro bodies near Mount Eddy intrude joint and shear zones within the Trinity peroditite.

A unit which includes both hornblende diorite and granodiorite occurs as small plugs in the northern part of the Mount Eddy Roadless Area. The rock consists almost totally of amphibole and feldspar but sometimes also contains abundant quartz. Inclusions of peridotite and gabbro provide evidence that intrusion of the gabbro preceded that of the hornblende diorite (Quick, 1981).

Granitic rocks of the Castle Crags pluton lie east of the Castle Crags Roadless Areas. The zoned pluton consists of an alkalic trondhjemite core and a granodiorite rim adjacent to the peridotite, but most of the pluton is a sodic granodiorite (Vennum, 1971). The pluton and adjacent areas including the northern Castle Crags area are intruded by a variety of dikes and small plugs related to the pluton.

Much of the area is covered by Quaternary deposits, including talus, alluvial material, and glacial debris. Broad glacial valleys are covered with these surficial deposits that obscure the bedrock geology.

GEOCHEMICAL SUMMARY

Samples were collected and analyzed as described in Peterson and others (1982). Semiquantitative data for 31 elements were presented for rock, stream-sediment, and stream-sediment-concentrate samples (table 1). Additionally, one quartz sample was analyzed for gold by atomic absorption; the stream-sediment samples were analyzed for gold, silver, and mercury by atomic absorption; the stream-sediment-concentrate samples were analyzed for gold and platinum-group elements by fire assay.

This report presents box diagrams depicting chemical abundance, correlation charts when appropriate, and a map showing the locations of samples with high chemical values. These data representations were generated on the Honeywell Multics System in Denver, Colo., and plotted on a Zeta 3600s drum plotter[1] using programs designed to read STATPAC data sets (Van Trump and Miesch, 1976).

The box-diagram program of Carlson (1982) provides graphical representation of chemical abundances for each data set. It directly accesses a STATPAC file to produce its results. Of the several options available, we chose those that could be used with qualified data, that is, nonnumerical data elements such as those less than or greater than the limits of analytical determination. Box diagrams were constructed differently for elements from each data set depending upon the number of samples in the data set and the number of qualified values for the element. If a data set consisted of at least 20 samples and if at least 30 percent of the values for an element were unqualified, means and standard deviations of the logged data were computed using methods for treating truncated data (see Cohen, 1959, 1961). The upper and lower edges of the box for each element, then, represent one standard deviation from the mean of the logged data and the horizontal line in the middle of that box represents that mean. Values higher or lower than the standard deviations are represented by lines extending away from the box. In some instances, the maximum and minimum values are less than the computed standard deviation, in which case lines extend into the boxes from either end. The curved line accompanying some of the boxes indicates the lower determination limit for that element. Portions of the box and minimum value lines extending below the determination limit are estimated using the assumption that the element abundances are log-normally distributed (Ahrens, 1957). If, however, less than 30 percent of the values for a given element are unqualified, the values above the determination limit are represented by a line with bars at either end. For data sets having less than 20 samples the median, 16th, and 84th percentiles were calculated. These values constitute the box, and higher or lower values are represented by lines extending above or below the box. When values extend below the determination limit, the boxes or lines are truncated at the limit.

Spearman Rank Correlations were computed using the STATPAC program d0136 (Correlation Analysis - Spearman or Kendall) and put into graphical form using an unpublished correlation diagram program written by Carl A. Carlson of the U.S. Geological Survey. Correlations shown are significant at the 95-percent level or better. Because many of the data are qualified, some significant correlations may have been omitted due to lack of a means of handling such qualified data.

Rocks

Rock samples were divided into four groups: ultramafic rocks, gabbro, hornblende diorite, and granitic rocks. Box diagrams were constructed for each element having at least one unqualified value and the results are compared with reported crustal abundances.

Ultramafic rock.--Figure 2 shows the distribution of elements in peridotite samples which include harzburgite, dunite, and plagioclase lherzolite. Most of the values fall within an order of magnitude of the average crustal abundances for ultramafic rocks reported in Turekian and Wedepohl (1961)[2]. Many of the boron values, which span a wide range from not detected to 150 parts per million (ppm), are significantly above the average crustal abundance. This might be accounted for by boron-bearing residual liquids derived from the younger plutons, particularly the Castle Crags pluton and the hornblende diorite, or from hydrothermal fluids from an unknown source. These intrusive units, however, contain much lower amounts of boron even though it might be expected to occur in feldspars. Samples 82CC16M and 82CC18M collected from outside of the southern boundary of the Mount Eddy Roadless Area near Toad Lake (see Peterson and others, 1982, for locations by sample number) have lanthanum values of 30 ppm whereas average ultramafic rocks have less than 1 ppm. Enrichment in lanthanum may have resulted from residual fluids migrating through the ultramafic rocks from later plutonic events. Average ultramafic lead contents are around 1 ppm. Sample 82ED21P, collected about 0.6 mi (1 km) east of Mount Eddy, contains 15 ppm lead, which is high but may still be within variations of a single log-normally distributed population.

Gabbro.--Except for boron, which is 10 ppm in two samples, the element distributions (fig. 3) are well within an order of magnitude of normal mafic rocks. As in the ultramafic rocks, the high boron values were probably derived from later fluids migrating through the rocks, possibly the same fluids depositing quartz veins in the gabbro. The boron possibly occurs in plagioclase. Sample 82CC07P collected 0.2 mi (0.3 km) east of Castle Lake contains 500 ppm barium. The source for this high amount of barium in a gabbro is unknown but it also may have been derived from later hydrothermal fluids. The manganese "box" (fig. 3) is a straight line because the median, 16th, and 84th percentiles are all 1,000 ppm.

Hornblende diorite.--All elements within the diorites (fig. 4) show values within an order of magnitude of the average crustal values. The titanium "box" is merely a straight line because all but two of the titanium values are 0.5 percent. Therefore the median, 16th, and 84th percentiles all have the same value.

Granitic rocks.--Vennum (1971) describes the granitic rocks of the Castle Crags pluton as soda granodiorite near the outer part of the pluton. His chemical analyses show 0.7 to 2.89 percent CaO. These values are midway between high- and low-calcium granites, a fact born out by the calcium distribution shown in figure 5. All elements except strontium occur at values within an order of magnitude of those expected for granitic rocks. The strontium content in all our granitic samples is greater than 1,000 ppm, whereas the average high-calcium granite has 440 ppm (Turekian and Wedepohl, 1961). Strontium can frequently substitute in plagioclase or K-feldspar structures, which is possibly the case in these rocks. The values may be so high because of the high content of feldspars noted in hand specimen.

Generalized information can be obtained by examining a correlation chart of the combined rock samples (fig. 6). Iron and magnesium, major components in all mafic minerals from olivine to biotite, have positive correlations with elements occurring in a wide variety of geologic environments. Magnesium, more prevalent in minerals of mafic and ultramafic rocks is negatively correlated with strontium, which typically is associated with plagioclase and potassium feldspar in felsic rocks. Although titanium occurs in spinels and thus would be expected to have a positive correlation with iron, it is actually negatively correlated, probably because iron and titanium are negatively correlated within olivine and pyroxene (see analyses in Quick, 1981, p. 192-194). Titanium abundance is lowest in olivine and highest in clinopyroxene, so the negative correlation of titanium with the olivine-associated elements cobalt, chromium, and nickel and the positive correlation with scandium, vanadium, yttrium, and copper, which are often associated with pyroxene, is expected. Calcium occurs in major rock-forming minerals including plagioclase, amphiboles, and certain clinopyroxenes and thus shows positive correlations with a number of elements. Calcium does show strong negative correlations with cobalt, chromium, and nickel because they occur in dunites, which contain no major calcium-bearing minerals. Cobalt, chromium, and nickel, all common to dunite, have high positive correlations with each other. Positive correlations between manganese, yttrium, scandium, copper, and vanadium probably reflect the incorporation of these elements into hornblende in the hornblende diorite, gabbro, and granitic rocks, pyroxene in the gabbro and peridotite, and possibly biotite in the granitic rocks. Vanadium shows negative correlations with the dunite-associated elements because it does not usually occur in olivine. Strontium, which occurs in felsic environments, shows negative correlations with the elements associated with ultramafic and mafic rocks. Zirconium-barium, zirconium-lanthanum, and barium-lanthanum positive correlations reflect the occurrence of these elements in very felsic environments such as the granitic rocks in the Castle Crags pluton.

The above correlations and abundances suggest several suites of elements. First is an olivine-spinel association in dunite in which iron, cobalt, and chromium may be present in spinel and iron, magnesium, and nickel may be present in the olivine. Second is a pyroxene-spinel association in the harzburgite and plagioclase lherzolite in which iron, magnesium, calcium, manganese, titanium, vanadium, scandium, yttrium, and copper might be present in pyroxene, and iron, titanium, and vanadium may be present in spinels. Third is a feldspar-hornblende-zircon association with barium, zirconium, lanthanum, and strontium in the granitic rocks of the Castle Crags pluton. The strontium and barium probably substitute for potassium in orthoclase, the lanthanum may substitute for calcium in hornblende, and zirconium occurs in zircon, an abundant accessory mineral in the pluton (Vennum, 1971). Complete chemical analyses are not available for the minerals mentioned above. The inferences above were drawn on the basis of evidence from Rose and others (1979) and Wedepohl (1969-1978) regarding which major rock-forming minerals frequently contain small amounts of the trace elements discussed above.

Stream sediments

Stream sediments represent material derived from all of the lithologic environments described above. Often two or three rock units contributed material to the streams where the samples were collected.

Element distributions (fig. 7) in the stream sediments show a wider range of values than do the distributions for individual rock types because they represent input from ultramafic to felsic terranes. Distributions for the combined rock samples (not shown in this report) have a similar wide spread in values. When the geographic distribution of the values is noted (see anomaly map) they show few deviations from those expected for the lithologic environments present in the drainage systems.

The correlation diagram (fig. 8) shows that elements occurring in ultramafic environments (nickel, cobalt, and chromium) have positive correlations and those of more felsic environments (barium, beryllium, zirconium, and strontium) have positive correlations. The major rock-forming elements and titanium show correlations similar to those of the rock samples. Felsic-associated elements correlate negatively with the ultramafic elements despite the mixing of material from peridotite and granite terranes in a few samples. Negative correlations of magnesium-barium and magnesium-beryllium probably reflect magnesium concentrations in mafic minerals such as olivine and pyroxene as opposed to barium and beryllium occurring in felsic minerals. Since manganese substitutes in a variety of mafic minerals it has positive correlations with elements from a variety of geologic environments. Scandium and vanadium, which both substitute in mafic minerals, have a positive correlations to manganese. Some of the same inferences can be drawn from the stream-sediment data as were drawn from the rock correlations.

Stream-sediment concentrates

Because platinum-group metals occur in ultramafic environments, three stream-sediment-concentrate samples were collected to determine the platinum-group metal content. These elements were not detected by fire-assay methods. Two of the samples had detectable gold: DOBKINS (0.01 ppm) near the northern boundary of the Mount Eddy Roadless Area and DEADFALL (0.2 ppm) near the western boundary of the Mount Eddy Roadless Area. This gold was probably derived from quartz veins that are prevalent in the hornblende diorite and gabbro. A quartz sample analyzed for gold by atomic absorption, however, contained no detectable gold.

GEOCHEMICAL ANOMALIES

Several methods may be used to determine threshold values of anomalies. Lepeltier (1969) and Sinclair (1974) present techniques for examining frequency distributions. When few values are greater than or equal to the determination limits, these values may be considered anomalous. Visual inspection of histograms may indicate anomalous values, and map plots delineate geographic areas in which high values cluster. A combination of these techniques was used in evaluating the Mount Eddy and Castle Crags Roadless Areas, but emphasis in selecting thresholds was placed on visual methods because of the small number of samples, particularly of different lithologies.

Ahrens (1957) demonstrates that in many cases trace elements show a lognormal distribution. Departures from this theoretical distribution could indicate multiple populations or mineralization (Lepeltier, 1969), sample contamination, widespread low-grade mineralization, or analytical error (Miesch, 1967).

For both rocks and stream sediments approximately the upper 5 percent of values for elements were plotted and evaluated as potential anomalies. Several rock samples that contain strontium in amounts greater than 1,000 ppm were collected in and near the northern Castle Crags Roadless Area. These constitute all the granitic samples analyzed. The strontium levels in rocks associated with the Castle Crags pluton probably indicate a high background level and not mineralization. Granitic sample 82CC11M, from south of Castle Lake, additionally contains 20 ppm lead, and sample 82CC12M, from east of Castle Lake, contains 150 ppm zircon and 1,500 ppm barium. These values are interpreted as fluctuations within the background levels.

Quartz sample 82ED27P, collected from a prospect pit on the ridge west of Dobkins Lake near the north boundary of the Mount Eddy Roadless Area, contains 700 ppm copper. At the time the sample was collected, we thought that the prospect was for gold. No gold, however, was detected in the sample. Other quartz veins analyzed did not contain significant copper. Although anomalous for the data here, 700 ppm copper is of little importance in an absolute sense. Gabbro sample 82CC22P, from east of Gray Rock Lake just west of the northern Castle Crags Roadless Area, contains 100 ppm copper, which is not unusually high for gabbroic rocks.

Zirconium values of 150 ppm occur in three of the hornblende diorite samples. Such values are not high for the rocks in which they are found. Manganese values of 1,500 ppm in the peridotite and gabbro are not unusually high. Additionally hornblende diorite samples 82ED31P and 82ED7M, from the northern part of the Mount Eddy Roadless Area, contain 1,500 and 2,000 ppm manganese, respectively. These amounts are somewhat higher than expected, but the lack of evident mineralization most probably indicates fluctuations in background levels. The single vanadium value of 300 ppm in sample 82ED17M is also likely a background fluctuation.

Nickel values of 3,000 ppm occur in small dunite bodies by Dobkins Lake and nearby Little Crater Lake in samples 82ED24P and 82ED30P. Because these are higher than the other nickel values of the peridotite and because they occur in dunite, a favorable host for nickel, they may represent mineralization. It is more probable, however, that they are merely variations in the background levels of nickel occurring in olivine (Quick, 1981) because sulfide minerals were not seen in the rocks and 3,000 ppm nickel is within ranges typically cited for ultramafic rocks. The cobalt value of 200 ppm in sample 82ED5P, from the southern edge of the Mount Eddy Roadless Area, may also be a fluctuation in background levels. The 5,000-ppm chromium value of nearby sample 82ED2P was taken from a small dunite pod containing 1-2 percent euhedral chromite crystals up to 0.04 in. (1 mm) across. X-ray diffraction of this opaque mineral confirmed that it is chromite.

Stream-sediment values corroborate those of the rocks for the most part. Three scattered copper values and manganese values probably represent background variations because they are not exceedingly high for the geologic terranes from which they were derived. Sample 81E36S, from east of the southern Castle Crags Roadless Area, contains 30 ppm lead and 1,000 ppm strontium. Sample 81E34S, from north of the southern area, contains 700 ppm barium, 1,000 ppm strontium, 200 ppm vanadium, 100 ppm zirconium, and 50 ppm lead. The stream from which sample 81E36S was collected drains granite and the values may therefore reflect background variations in this felsic unit. The large number of high values associated with 81E34S is puzzling because many of the elements are felsic affiliated. Yet the stream drains ultramafic, gabbroic, and felsic rocks, and none of the samples collected farther upstream contain high amounts of these elements. Possibly a small stream in the granite north of this sample location is carrying this material into the stream.

To summarize the geochemical information, most of the high values do not point to mineralization. One quartz sample high in copper with respect to the other rocks analyzed may be slightly mineralized, and two nickel samples may contain low-grade nickel mineralization although there is no visible evidence to support this. One dunite sample from the southern part of the Mount Eddy Roadless Area contains a high chromium value, supported by 1-2 percent of visible chromium in the sample. Between the two Castle Crags Roadless Areas a stream-sediment sample contains high values of barium, lead, strontium, vanadium, and zirconium. The source of these metals cannot be accurately pinpointed, but it is thought they may come from the Castle Crags pluton about 0.12 miles (0.2 km) upstream about 0.5 mi (0.8 km) north of the southern Castle Crags Roadless Area.

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Table 1.--Elements analyzed and anomaly threshold values representing approximately the upper 5 percent of values in rock, stream-sediment, and stream-sediment-concentrate samples in the Mount Eddy and Castle Crags Roadless Areas
[s, spectrographic; aa, atomic absorption; as, fire assay]

Element	Analytical method	Rock threshold parts per million	Stream-sediment threshold parts per million
Calcium (Ca)	s	--	--
Iron (Fe)	s	--	--
Magnesium (Mg)	s	--	--
Titanium (Ti)	s	--	--
Silver (Ag)	s	--	--
Silver (Ag)	aa[1]	--	--
Arsenic (As)	s	--	--
Gold (Au)	s	--	--
Gold (Au)	aa[1]	--	--
Gold (Au)	as[2]	--	--
Boron (B)	s	150	50
Barium (Ba)	s	1,500	700
Beryllium (Be)	s	--	--
Bismuth (Bi)	s	--	--
Cadmium (Cd)	s	--	--
Cobalt (Co)	s	200	--
Chromium (Cr)	s	5,000	--
Copper (Cu)	s	100	50
Mercury (Hg)	aa[1]	--	.5
Lanthanum (La)	s	--	--
Manganese (Mn)	s	1,500	1,500
Molybdenum (Mo)	s	--	--
Niobium (Nb)	s	--	--
Nickel (Ni)	s	3,000	-
Lead (Pb)	s	20	30
Platinum group elements	as[2]	--	--
Antimony (Sb)	s	--	--
Scandium (Sc)	s	--	--
Tin (Sn)	s	--	--
Strontium (Sr)	s	1,000	1,000
Thorium (Th)	s	--	--
Vanadium (V)	s	300	200
Tungsten (W)	s	--	--
Yttrium (Y)	s	--	--
Zinc (Zn)	s	--	--
Zirconium (Zr)	s	150	100

[1]Sediments only.

[2]Sediment concentrates only.

[1]Any use of trade names is for descriptive purposes only and does not imply endorsement by the USGS.

[2]In this report all comparisons with crustal abundances are with Turekian and Wedepohl (1961).

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