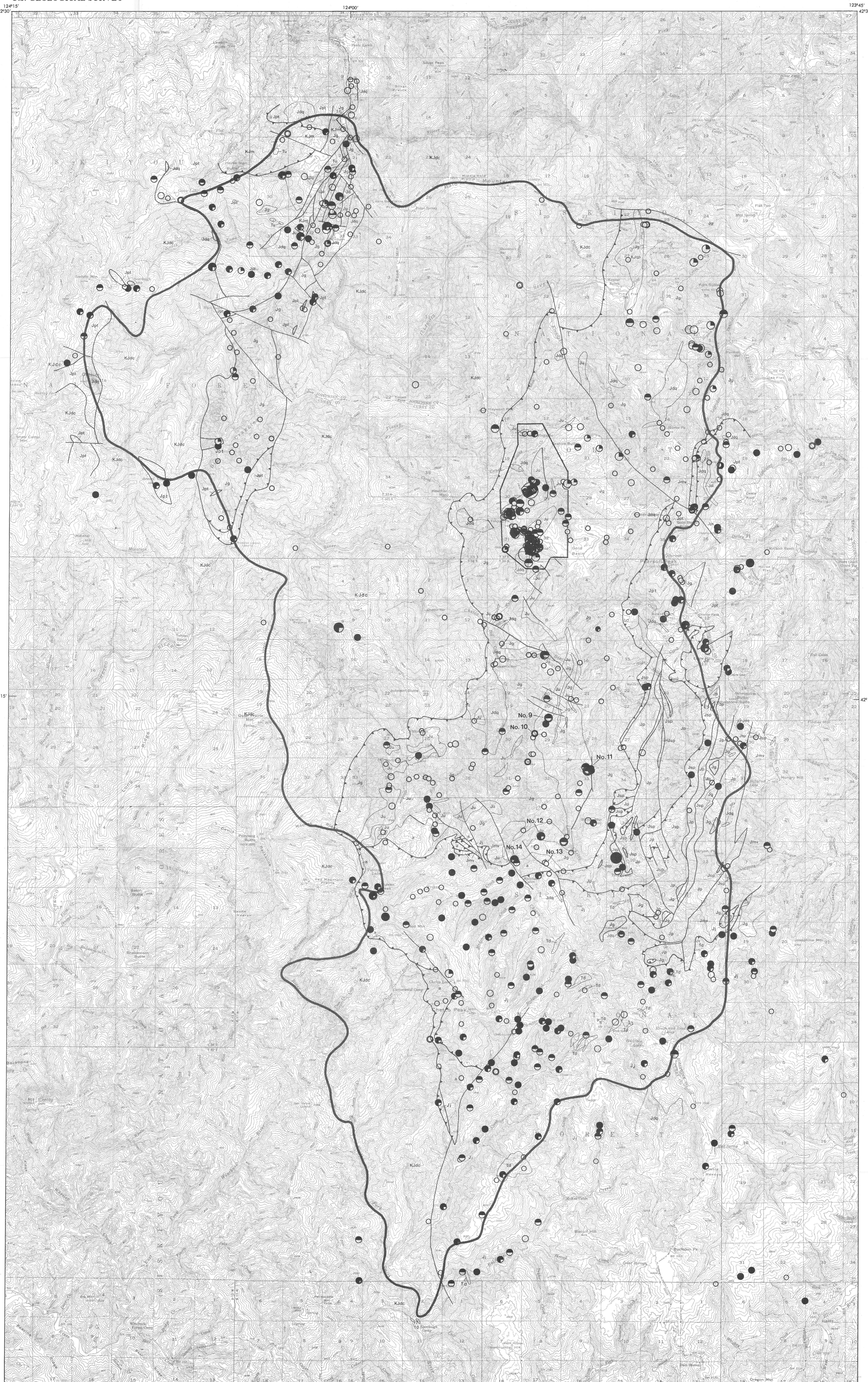
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES
MAP MF-1240-F
SHEET 1 OF 2



Base from U.S. Geological Survey
Chetco Peak, Collier Butte, Mt. Emily,
Pearsoll Peak, 1954

SCALE 1:62 500

CONTOUR INTERVAL 80 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

APPROXIMATE MEAN DECLINATION 1985

Geology generalized from
Page and others, 1981

EXPLANATION

BUREAU OF MINES TRAVERSE NUMBERED (No. 14)

THE SUM OF PLATINUM, PALLADIUM, RHODIUM, IRIDIUM, AND RUTHENIUM--Heavy circles indicate multiple samples

- Not detected to 9.9 parts per billion (ppb)
- ≥10 ppb
- ≥100 ppb
- ≥300 ppb
- ≥500 ppb
- ≥700 ppb
- ≥1,000 ppb
- ≥3,000 ppb

THE RATIO OF PLATINUM TO PLATINUM PLUS PALLADIUM

- Not detected or only one value for Pt or Pd
- 0 to 0.20
- 0.21 to 0.50
- 0.51 to 0.70
- 0.71 to 1.0

CORRELATION OF MAP UNITS

Tu — Umpqua Formation — Sandstone and shale
Td — Dacite dikes
} TERTIARY

KJm — Myrtle Group (Lower Cretaceous and Upper Jurassic) — Conglomerate, sandstone, and mudstone
KJqp — Quartz porphyry
KJdc — Dothan Formation (Cretaceous and Jurassic) and Colebrooke Schist (Upper Jurassic) — Sandstone, shale, volcanic rocks, and schist
} CRETACEOUS AND JURASSIC

Jmv — Metavolcanic rocks
Jp — Pyroxene-bearing metavolcanic rocks
Jdq, Jd, Jg, Ju — Intrusive igneous rocks
Jdq, diorite and quartz diorite
Jd, dike complex
Jg, gabbroic rocks
Ju, ultramafic rocks; predominantly metacumulate peridotite
} JURASSIC

Jpt, Jj, Jsp, Jdi — Ultramafic rocks and dikes
Jpt, peridotite
Jj, Josephine Peridotite (Jurassic or older)
Jsp, serpentinite
Jdi, diabase dikes
} JURASSIC AND JURASSIC OR OLDER

a — Amphibolite
} AGE UNKNOWN

CONTACT--Approximately located

FAULT

THRUST FAULT--Sawteeth on upper plate

APPROXIMATE BOUNDARY OF KALMIOPSIS WILDERNESS

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 Kalmiopsis Wilderness in the Siskiyou National Forest, Curry and Josephine Counties, Oregon. Kalmiopsis Wilderness (NF042) was established by Public Law 88-577, September 3, 1964.

INTRODUCTION

We have conducted an examination of platinum-group elements and gold geochemistry in the Kalmiopsis Wilderness as part of an evaluation of the mineral resources of the area. Platinum-group elements appeared to be an important part of the mineral resource evaluation, as suggested by preliminary studies by Page and others (1975) and other studies related to wilderness evaluation that include studies of the geology (Gray, 1980; Page and others, 1981), the serpentine mineralogy, rock density, and magnetic susceptibility of rocks (Barnard and others, 1981), and the geochemistry of other metallic elements (Carlson and others, 1982), as well as from aeromagnetic interpretation (Blakely and others, 1982). In addition, platinum-group elements have been recovered in southwestern Oregon as a byproduct of placer gold mining in the rivers and streams draining the study area. The placer occurrence of gold, apparently derived from an ultramafic and mafic terrane, suggested that the geochemistry of the gold in area was also important. Therefore, the geochemical distribution of platinum-group and gold elements was considered in detail, and the results are presented here in map, table, and graphical form. The analytical data on which this report is based are those of Carlson and others (1982).

GEOLOGIC SETTING

The general structural pattern of the Kalmiopsis Wilderness area of the Klamath Mountains geomorphic province consists of tectonically juxtaposed Jurassic island-arc metavolcanic rocks of the western Jurassic belt, broken and dismembered ultramafic and mafic rocks of ophiolite sequences, graywackes and shales of the Upper Jurassic and Lower Cretaceous Dothan Formation, and granitic plutonic rocks of Late Jurassic and Early Cretaceous age. Details of the geology were given by Page and others (1981), and only a generalized geologic map (sheet 1) is presented in this report.

In detail, the Kalmiopsis Wilderness area consists of a structurally complex set of thrust plates containing various rock types jumbled by normal faults. The western part of the wilderness area consists of the predominantly north-south to northeast striking Dothan Formation, which contains deep-water graywacke, mudstone, siltstone, and shale, and a thrust plate of dismembered ophiolitic rocks emplaced over part of the area. At the west edge of the area, only erosional remnants of this ophiolitic plate, such as the Big Craggies, remain. The thrust plate of dismembered ophiolitic rocks, which is well exposed to the east of the Dothan Formation, contains gabbroic and ultramafic rocks. The east-central part of the Kalmiopsis Wilderness area is underlain by faulted slices of Jurassic island-arc volcanic rocks that consist of basic to felsic calc-alkaline flows and subaqueous pyroclastic rocks, interbedded with lensoidal volcanogenic graywacke, siltstone, and shale. During Jurassic and Cretaceous time, hornblende gabbro and diorite to tonalite intruded the ophiolitic and volcanic rocks, respectively.

Particularly important in the occurrence of platinum-group elements are the ophiolitic rocks that consist of: sequences of peridotite and dunite with tectonic fabrics; cumulus dunite, wehrlite, and clinopyroxenite; layered cumulus gabbro, metagabbroic rocks, and hornblende gabbro which form part of the Chetco River complex of Hotz (1971); and older rocks. Such assemblages may host platinum-group elements in anomalous amounts, and much of our geochemical investigation focused on those rock types. During this study, we determined that gold is also present in the same rocks in anomalous amounts.

TECHNIQUES

Grab samples of rocks were collected during the summers of 1976, 1977, and 1978 in the course of detailed geologic mapping by the U.S. Geological Survey (USGS). Not all the collected samples were analyzed for platinum-group elements; ultramafic and mafic rocks and other rocks richer in copper, nickel, and chromium were selected for study. Preliminary results of analyses for platinum-group elements suggested that several areas contain rocks with higher than normal values. The U.S. Bureau of Mines (USBM) returned in 1980 and collected samples from 14 traverses (sheet 1; sheet 2, fig. 1) in areas where previous analyses found the higher values. Each of these samples consisted of chip samples or grab samples taken over several square feet of outcrop of the same lithology. Each lithologic unit along a traverse may have been sampled more than once (sheet 2, table 1). Most of the samples weighed from 2 to 5 lb.

The selected samples collected by the USGS were analyzed for platinum (Pt), palladium (Pd), rhodium (Rh), ruthenium (Ru), iridium (Ir), and gold (Au) using the fire-assay/emission spectrography techniques of Cooley and others (1976). The lower determination limits for platinum are 5 to 10 parts per billion (ppb); for palladium, 1 to 5 ppb; for rhodium, 2 to 4 ppb; for ruthenium, 200 to 400 ppb; for iridium, 100 to 200 ppb; and for gold, 1 to 2 ppb, depending on the size of sample analyzed. No ruthenium was detected, and only one sample contained iridium above the detection limit of the method. The results have been reported by Carlson and others (1982).

The samples collected along the USBM traverses were crushed, split, and pulverized at the USBM Western Field Operations Center, Spokane, Wash. Analyses for platinum, palladium, gold, and silver were done by the Reno Metallurgy and Mining Research Center of the USBM using a fire-assay/inductively-coupled-plasma/atomic-emission-spectrographic method. The lower determination limits for platinum and palladium are 0.002 troy oz per ton, and for gold and silver 0.001 troy oz per ton. Table 1 lists the analytical results. Additional splits were analyzed by the USGS by the method of Cooley and others (1976) and form part of the data plotted on the maps and figures here.

The following comparison of assay data from the USBM and USGS laboratories on splits of the same samples illustrates some of the difficulties in assaying for platinum-group elements. One of the major problems is that assay values typically are near the limits of detection, and the irregular distribution of minute scattered concentrations of platinum-group elements contributes to the irreproducibility of the assays results.

Positive values from USGS assays that are below the lower limits of determination for USBM assays are not considered here. A comparison of individual positive values for platinum, palladium, and gold shows 6 values with good correlation (less than a factor of 1 in difference for the two assay methods); 2 values with moderately good correlation (less than a factor of 2); 7 values with poor correlation (by factors of 9-100); 16 values by USGS assay that are larger than USBM determination limits by factors of 1 to 3 but were not detected by USBM assay; 7 values reported at USBM determination limits that are 2 to 7 times larger than USGS values; and 23 values reported at USBM determination limits that are 10 to 80 times larger than USGS values.

Most of these differences in assay values between the two methods are probably due to working at the determination limits for the USBM technique: relative standard deviations can easily surpass 50 percent at these limits for repeated analyses with any single fire-assay method; in addition, any contamination introduced during sampling or sample preparation has a greater effect at low metallic contents. Other differences in reported values can be attributed to the particularity of these elements and the resulting homogeneity of prepared samples: preparation techniques that are capable of producing homogeneous samples also cause greater noble-element loss and have higher contamination dangers. Finally, differences in fire-assay techniques, fire-assay flux compositions, and physical parameters of the laboratories, as well as the cumulative affect of these differences on successful total digestion and extraction processes in various rock types, can cause different noble-element recovery rates, at different times, in different laboratories.

These limitations on the interpretation of assay values for the noble elements can be surpassed either by averaging repetitious analyses of multiple samples collected at any one sample site or, as is done in this report, by giving credence to patterns of sample values that appear in relation to the geology, geography, or geochemistry.

Retrieval and statistical reduction of the chemical analyses were performed with the USGS RASS STATPAC system of computer programs described by VanTrump and Miesch (1977). The histograms (sheet 2, fig. 2) and geometric means of unqualified values (sheet 2, table 2) were derived from the statistics generated by this system. The map displays were prepared with the USGS computer programs STATE MAP and Z-MP, undocumented programs written by C. A. Carlson. Correlations between elements within major rock types (table 3), which are Spearman rank correlations significant at the 95-percent-or-better-confidence level, are based on the methods described by Snedecor and Cochran (1967, p. 193, 195).

SPATIAL DISTRIBUTION OF PLATINUM-GROUP ELEMENTS AND GOLD

The distribution of concentrations of platinum, palladium, rhodium, and gold in rock samples are shown superimposed on a simplified geologic map on sheet 2, figures 3, 4, 5, and 6, respectively. The histograms were used as guides to select symbol sizes that would emphasize highly atypical values. Figures 3, 4, and 6 emphasize the locations of samples containing platinum, palladium, or gold in excess of 100 ppb. The absence of high values within this range in figure 5 reflect the lower average and much narrower geometric deviation for rhodium abundances shown in the histograms (sheet 2, fig. 7).

Closer examination of the spatial distribution of platinum (sheet 2, fig. 3) and comparison with the simplified geologic map show that most of the high values are associated with areas underlain by cumulus ultramafic rocks. Additionally, most of these same areas contain hornblende gabbro (see Page and others, 1981) that intrudes both the cumulate ultramafic rocks and other layered gabbroic rocks which do not have high platinum-group-element contents. The most extensively examined area with this association of rocks is the Tincup Peak area (fig. 1; Gray, 1980), however, other areas, such as north of Vulcan Peak around Dry Butte also show this association but were not so extensively sampled. The two high platinum concentrations in the Dothan Formation appear to be in samples of sediment with an anomalously high content of ultramafic detritus.

Concentrations of palladium greater than 100 ppb show a similar spatial distribution and geologic association similar to those of platinum (fig. 4). An exception is a cluster of higher concentrations in the northeast corner of the Kalmiopsis Wilderness area, near the Illinois River. Samples with higher concentrations along and south of the Illinois River are associated with mapped bodies of hornblende gabbro (Page and others, 1981), however, few known ultramafic cumulus rocks are present within these areas. Two samples with higher concentrations north of the Illinois River may be associated with small unmapped hornblende gabbro masses.

The higher ~~concentrations~~ of rhodium (sheet 2, fig. 5) appear to be spatially associated with the distribution of peridotite (unit Jpt) and the Josephine Peridotite (unit Jj) (sheet 1), both of which are tectonites.

High concentrations of gold in rock samples have a spatial pattern approximately similiar to that of palladium (sheet 2, fig. 6). In detail, some of the high concentrations are associated with gossans, oxidized material of minor sulfide-mineral occurrences in gabbro.

The map of the entire Kalmiopsis Wilderness area (sheet 1) and the more detailed map of the Tincup Peak area (sheet 2, fig. 1), both of which schematically show the distribution of the sum of the platinum-group metals and the ratio of platinum to this sum, summarize and emphasize the occurrence of rock samples with high concentrations of these elements. Very few values were found above detection limits for ruthenium and iridium, and so they are not included in the sum. Samples from areas containing ultramafic cumulus rocks have higher concentrations of the sum of the platinum-group metals, as would be expected from the distribution of the individual metals. The cumulus rocks seem to contain a higher ratio of palladium to platinum and rhodium than do the other, noncumulus ultramafic rocks (sheet 1; sheet 2, fig. 1).

GEOCHEMICAL DISTRIBUTION OF THE PLATINUM-GROUP ELEMENTS AND GOLD IN THE MAJOR ROCK TYPES

Figure 2 (sheet 2) plots frequency of occurrence of concentrations of platinum, palladium, rhodium, and gold in rock samples and their geometric means for all unqualified values. Various details of the geochemistry are obscured in these histograms, and so the analytical data were examined in reference to the major rock types. Many of the map units shown on the simplified geologic map (sheet 1) contain more than one major rock type; for example, the Josephine Peridotite contains harzburgite, dunite, and pyroxenite. Because substantial variations in chemistry are apparent between such rock types, we grouped the analyses of similar rock types together, even when they came from map units of slightly different age and somewhat dissimilar environments. These rock groupings are the same as those used by Carlson and others (1982).

Except for samples grouped as gossans, the pyroxenite group of rocks has the highest geometric means for unqualified values of platinum and palladium (sheet 2, table 2), and the dunite group the highest geometric mean for rhodium. Within the groups of ultramafic and mafic rocks, the pyroxenite group also has the highest geometric mean for gold. These observations are consistent with the spatial distribution of these elements shown in figures 3, 4, 5, and 6 (sheet 2) because the pyroxenite group is largely composed of ultramafic cumulus rocks including clinopyroxenite and wehrlite, whereas the peridotites are predominately tectonites. The gabbro group and the serpentinite group have the lowest geometric means for platinum, palladium, and rhodium of the ultramafic and mafic groups.

Figure 7 (sheet 2) shows the frequency distribution of the ratio of platinum to the sum of the platinum-group elements for the samples grouped as dunite, peridotite, gabbro, and pyroxenite. The peridotite and dunite groups have a higher proportion of the larger values of this ratio, as shown by the histograms, as well as larger geometric means, than the gabbro and pyroxenite groups. This pattern also corresponds to the spatial distributions of the ratios shown on the map (sheet 1) and in figure 1 (sheet 2).

Table 2 (sheet 2) lists the maximum concentrations determined for each element. Values of 1,000, 2,000, and 3,000 ppb correspond to 0.032, 0.064 and 0.096 troy oz per ton, respectively, which are subeconomic amounts of platinum-group elements in 1982. The data on geometric means of concentrations (sheet 2, table 2) and the ratios of platinum to the sum of platinum-group elements (sheet 2, fig. 7) generally indicate that the occurrences of higher concentrations of platinum-group metals contain less platinum and more palladium.

The number of samples analyzed from the groups of volcanic rocks, sedimentary rocks, and granitic rocks is limited; however, in most of the samples analyzed, the concentrations of platinum, palladium, rhodium, and gold appear to be near background levels for the specific rock types (sheet 2, table 2 and figs. 3, 4, 5, and 6).

Significant correlations at the 95-percent-or-better-confidence level between the platinum-group elements and gold and other elements determined by semiquantitative spectrography (Carlson and others, 1982) are limited. The relatively few significant Spearman rank correlations are listed in table 3 (sheet 2); these data are difficult to interpret.

COMPARISON OF PLATINUM-GROUP ELEMENTS IN THE KALMIOPSIS WILDERNESS AREA WITH OTHER SIMILAR OCCURRENCES IN THE WORLD

One way to compare the platinum-group element data from various areas is to normalize the concentrations with respect to average concentrations in chondrites (stony meteorites) and to plot the ratios on diagrams similar in appearance to those used for rare-earth elements. For figure 8 (sheet 2) the geometric means of platinum, palladium, and rhodium from table 2 (sheet 2) and the lower limits of detection were normalized using chondrite concentrations of: Pd, 1,200 ppb; Pt, 1,500 ppb; Rh, 200 ppb; Ru, 1,000 ppb; and Ir, 500 ppb, which are the average values given by McBryde (1972). The plotted data in figure 8 (sheet 2) imply that palladium and platinum are more depleted with respect to chondrite than are rhodium and, probably, iridium and ruthenium. Figure 9 (sheet 2) shows chondrite-normalized ratios in chromite-rich rocks from other ophiolite complexes in the world. The data for Greece were reported by Agiorgitis and Wolf (1977, 1978), for Oman by Page and others (1979), for Turkey, by N. J Page and others (written commun., 1980), for northern California by J. P. Albers (unpub. data, 1981), and for New Caledonia by Page and others (1982). The negative slopes of all the chondrite-normalized curves for ophiolites indicate more depletion of platinum and palladium with respect to chondrite than of iridium and ruthenium. Comparison of these curves with these in figure 8 (sheet 2) and the average rock sample for the Kalmiopsis Wilderness area (sheet 2, fig. 9) strongly implies that the Kalmiopsis data are similar to other ophiolites in the world, although iridium and ruthenium are below the detection limits of the technique used in analysis.

CONCLUSIONS

Areas containing geologically similar associations of hornblende gabbro and cumulus ultramafic rocks, such as the Tincup Peak area, have been shown to include rocks containing anomalous amounts of platinum-group elements and gold. However, more detailed sampling has shown no continuity in the occurrences of higher concentrations, and the extent of these anomalies remains undetermined. Sampling on a close-spaced grid might be necessary to evaluate the anomalous areas.

The minute differences in the geometric means between the platinum-group elements and gold in the ultramafic and mafic rocks suggest that similar processes of concentration may have operated within the rock units of the Kalmiopsis Wilderness. However, the spatial distribution of anomalous values within the cumulus rocks and hornblende gabbro implies that the intrusion of hornblende gabbro into ultramafic cumulus rocks is important to concentration of the platinum-group elements and gold. In these localities, the generally higher palladium contents than platinum contents suggest that palladium may be more readily concentrated by the hornblende-gabbro/cumulus-ultramafic-rock interaction. High Pt/Pt+Pd ratios in the ultramafic tectonites and the negative slopes of chondrite-normalized curvess could be interpreted as representing more depletion of palladium with respect to platinum within mantle-type rocks.

The platinum-group-element contents and their respective ratios in the ultramafic and mafic rocks of the ophiolite sequence are similar to those for other ophiolite occurrences in the world.

REFERENCES CITED

Agiorgitis, G., and Wolf, R., 1977, Zur platin-Palladium-und Goldverteilung in Griechischen Chromiten: Chemie der Erde, v. 36, p. 349-351.

______1978, Aspects of osmium, ruthenium and iridium contents in some Greek chromites: Chemical Geology, v. 23, p. 267-272.

Barnard, J. B., Page, N. J, Blakely, R. J., Ziemianski, W. P., Banister, C. A., and Giusso, J. R., 1981, Map showing distribution of serpentine minerals, density, and magnetic susceptibility of rocks from the Kalmiopsis Wilderness, Oregon: U.S. Geological Survey Miscellaneous Field Studies Map MF-1240-B, scale 1:62,500.

Blakely, R. J., Page, N. J, Senior, Lisa, Ryan, H. F., and Gray, Floyd, 1982, Interpretation of aeromagnetic data over the Kalmiopsis Wilderness area, southwestern Oregon: U.S. Geological Survey Miscellaneous Field Studies Map MF-1240-D, scale 1:62,500.

Carlson, C. A., Page, N. J, Grimes, D. J., and Leinz, R. W., 1981, Map showing geochemical characteristics of rock samples from the Kalmiopsis Wilderness, southern Oregon: U.S. Geological Survey Miscellaneous Field Studies Map MF-1240- , scale 1:62,500.

Carlson, R. R., Carlson, C. A., Grimes, D. J., Leinz, R. W., and Page, N. J, 1982, Geochemical analyses of the platinum-group and other elements in rocks from the Kalmiopsis Wilderness, southwestern Oregon: U.S. Geological Survey Open-File Report 82-948, 66 p.

Cooley, E. F., Curry, K. J., and Carlson, R. R., 1976, Analysis of the platinum-group metals and gold by fire-assay emission spectrography: Applied Spectroscopy, v. 30, no. 1, p. 52-56.

Gray, Floyd, 1980, Geology of the igneous complex of Tincup Peak, Kalmiopsis Wilderness area, southwestern Oregon: U.S. Geological Survey Open-File Report 80-1243, 65 p.

McBryde, W. A. E., 1972, Platinum metals, in Fairbride, R. W., ed., The encyclopedia of geochemical and environmental sciences: New York, Van Nostrand Reinhold, v. 4a, p. 957-961.

Page, N. J, Cassard, Daniel, and Haffty, Joseph, 1982, Palladium, platinum, rhodium, ruthenium, and iridium in chromitites from the Massif du Sud and Tiebaghi Massif, New Caledonia: Economic Geology, v. 77, no. 5, p. 1571-1577.

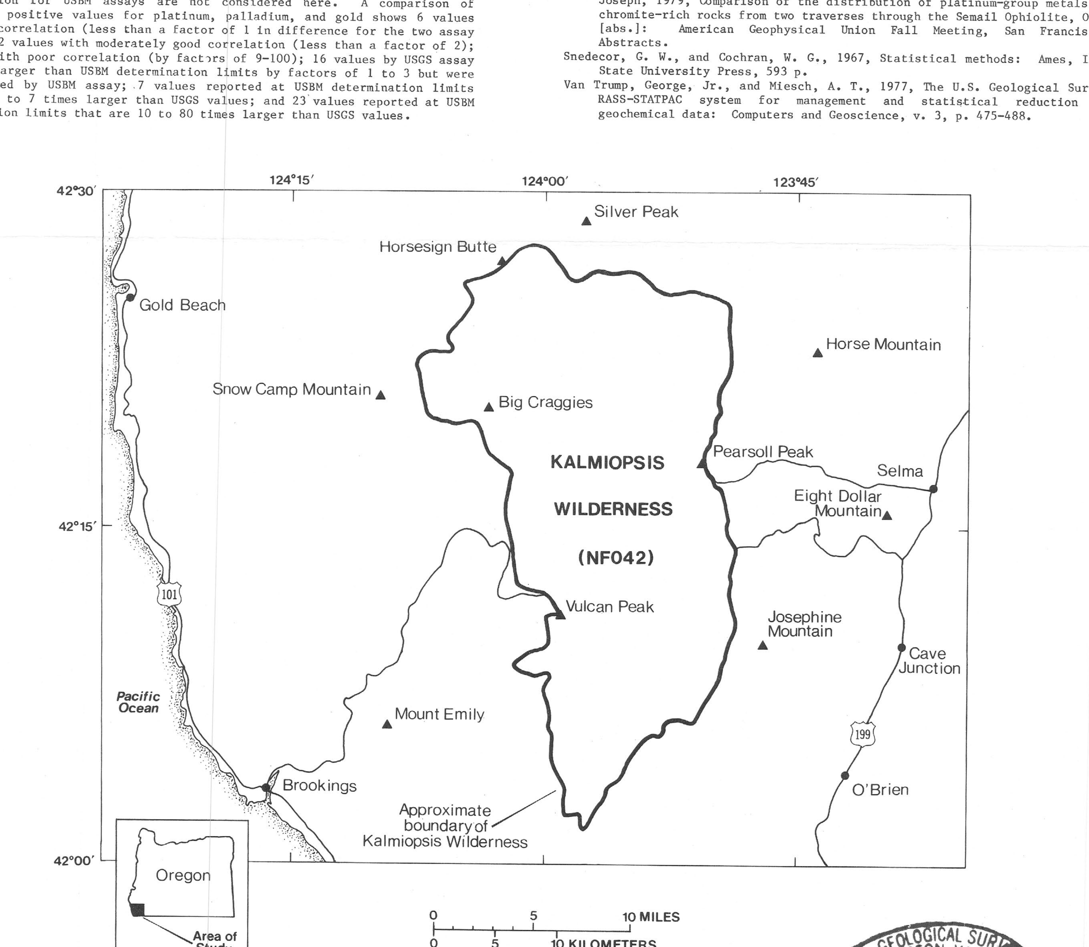
Page, N. J, Gray, Floyd, Cannon, J. K., Foose, M. P., Lipin, Bruce, Moring, B. C., Nicholson, S. W., Sawlan, M. G., Till, Alison, and Ziemianski, W. P., 1981, Geologic map of the Kalmiopsis Wilderness area, Oregon: U.S. Geological Survey Miscellaneous Field Studies Map MF-1240-A, scale 1:62,500.

Page, N. J, Johnson, M. G., Haffty, Joseph, and Ramp, Len, 1975, Occurrences of platinum-group metals in ultramafic rocks of the Medford-Coos Bay 2° quadrangle, southwestern Oregon: U.S. Geological Survey Miscellaneous Field Studies Map MF-694, scale 1:250,000.

Page, N. J, Pallister, J. S., Brown, M. A., Smewing, J. D., and Haffty, Joseph, 1979, Comparison of the distribution of platinum-group metals in chromite-rich rocks from two traverses through the Semail Ophiolite, Oman [abs.]: American Geophysical Union Fall Meeting, San Francisco, Abstracts.

Snedecor, G. W., and Cochran, W. G., 1967, Statistical methods: Ames, Iowa State University Press, 593 p.

Van Trump, George, Jr., and Miesch, A. T., 1977, The U.S. Geological Survey RASS-STATPAC system for management and statistical reduction of geochemical data: Computers and Geoscience, v. 3, p. 475-488.



Index map showing location of Kalmiopsis Wilderness, southwestern Oregon

MAPS SHOWING GEOCHEMICAL CHARACTERISTICS OF PLATINUM-GROUP ELEMENTS AND GOLD IN ROCK SAMPLES FROM THE KALMIOPSIS WILDERNESS, SOUTHWESTERN OREGON

By
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1985

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2. U.S. Bureau of Mines

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