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U.S. GEOLOGICAL SURVEY

**GEOCHEMISTRY OF THE PAYETTE NATIONAL FOREST, IDAHO**

**By**

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## INTRODUCTION

The Payette National Forest, located in central Idaho (fig. 1), includes 2.3 million acres. Boundaries of the Payette National Forest and Ranger Districts in relation to geographic features of the area are shown in a diagrammatic map (fig. 2). This report presents an interpretation of reconnaissance geochemical data from the Payette National Forest (usually referred to as the PNF, or the Forest, in this report). This geochemical study was made to assist the U.S. Forest Service in fulfilling requirements of Title 36, Chapter 2, part 219.22, Code of Federal Regulations, and to supply resource information and interpretations so that the mineral resources of this Forest can be considered with other resources in land use planning. A report consisting of description and probabilistic estimation of potential mineral resources of the Payette National Forest has been previously released (Bookstrom and others, 1998).

Geochemical data are used to identify areas that may contain concealed or subsurface mineral deposits, to determine metallogenic controls and solution pathways, and to characterize deposits that are known. Metal abundances from samples collected in unmineralized terrane, often referred to as baseline data, provide comparative information for environmental assessments. During the formation of host rocks and their enclosed mineral deposits, element mobilities were usually controlled by high temperature solutions. During weathering, element mobilities are based on surficial chemical and physical processes. Known mineral deposits in any given mineral district often constitute only a small part of the total metal endowment. Many of these deposits were discovered because they were exposed at the surface. Concealed mineral deposits with subtle surface characteristics and related dispersions of characteristic suites of elements can be identified using geochemistry.

## GEOCHEMICAL SURVEYS

### Data Compilation and Sample Collection

Prior to any field work, we compiled all existing geochemical data from the PNF area. These data chiefly consisted of geochemical analyses from: (1) past geologic and geochemical studies of wilderness areas in the vicinity of the study area, (2) the Conterminous United States Mineral Appraisal Program (CUSMAP) of the USGS and (3) the National Uranium Resource Evaluation (NURE) program of the Department of Energy.

The initial data compilation produced a large file of all available geochemical analyses in the region that included both the Payette National Forest and surrounding areas. For the present PNF assessment, these pre-existing data were further augmented by re-analyses of samples from the NURE program using USGS analytical methods, and by new field sampling and analysis by the USGS (table 1). Data used in the present study of the PNF have been released as U.S. Geological Survey Open-File Reports numbers 93-527 (McHugh and others, 1993) and 96-535 (Hopkins and others, 1996).

Data from previous USGS investigations were derived from: (1) stream sediment samples and rock chip samples from the Hells Canyon and Rapid River Wilderness study (Simmons and others, 1983); (2) stream sediment and heavy-mineral concentrate samples collected from USGS

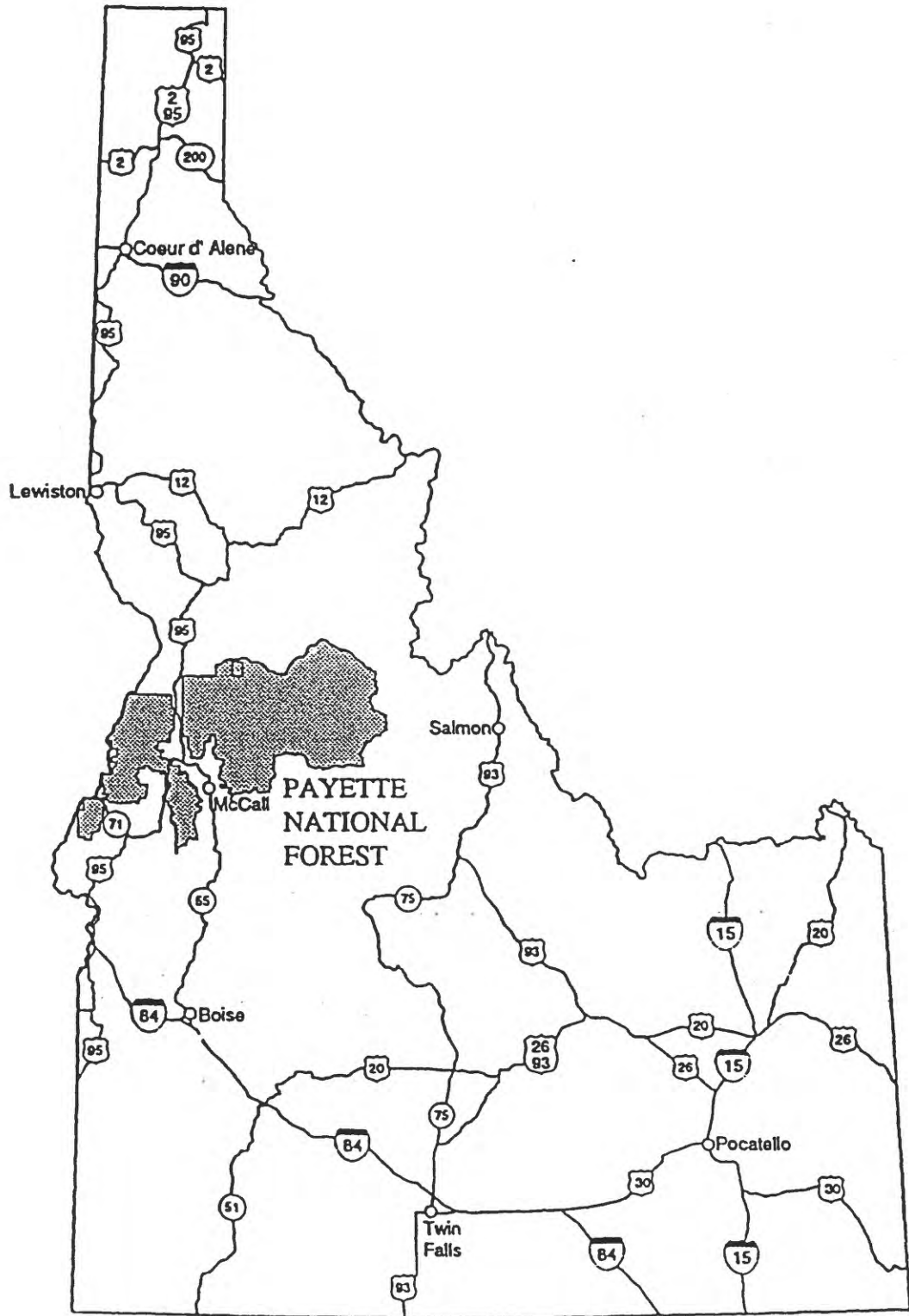


Figure 1. Map of Idaho showing the location of the Payette National Forest.

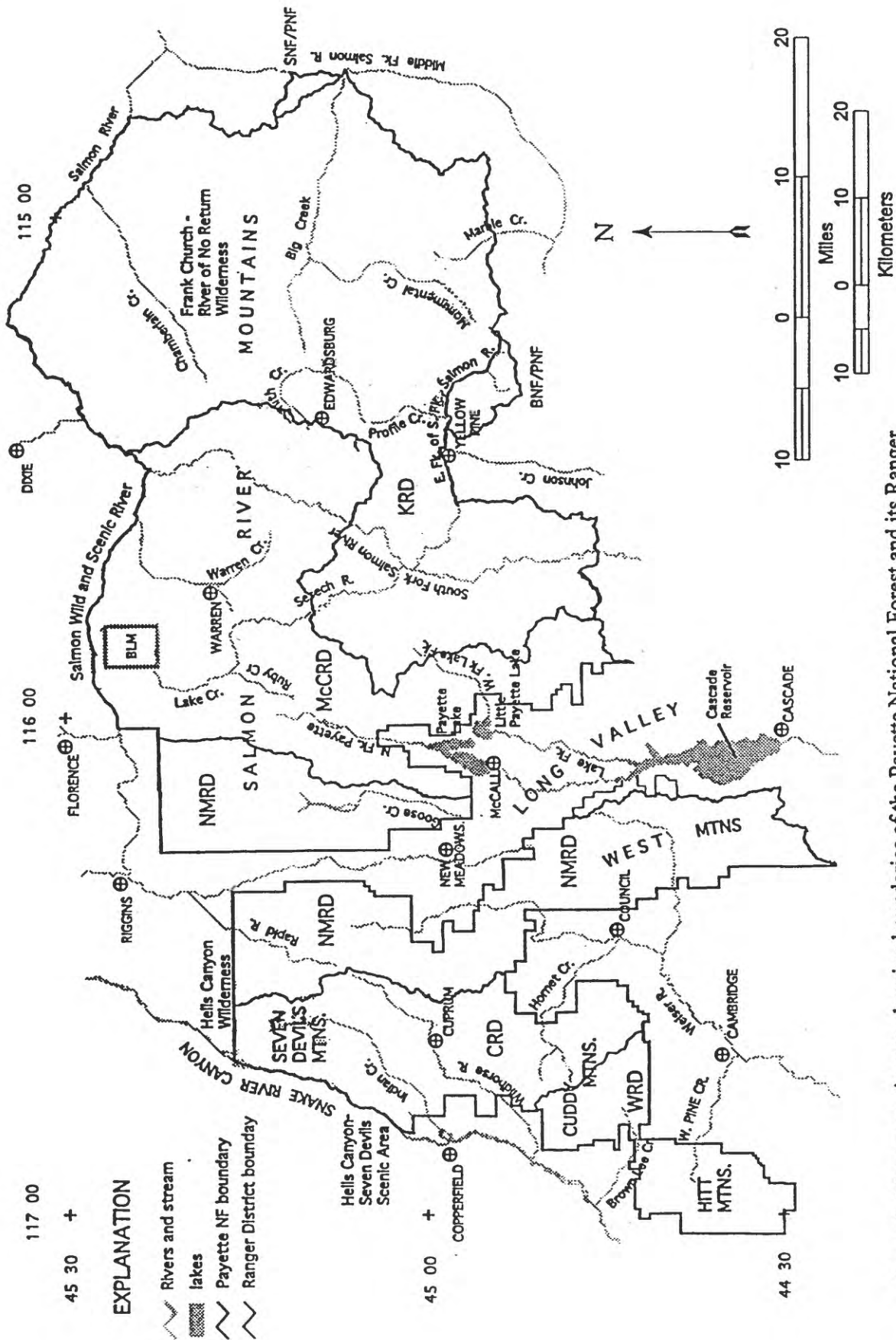


Figure 2. Diagrammatic map showing boundaries of the Payette National Forest and its Ranger Districts in relation to geographic features of the area. Ranger District (RD) names are: Weiser RD=WRD, New Meadows RD=NMRD, McCall RD=McCRD, Krasel RD=KR. Areas outside PNF but administered by PNF are Boise NF administered by PNF (BNF/PNF) and Salmon NF administered by PNF (SNF/PNF).

Table 1. Sources of data and analytical methods used.

[E-Spec, Emission Spectrography; F-AA, Flameless Atomic Absorption; GF-AA, Graphite Furnace; Inst, Instrumental; ICP-AES, Inductively-Coupled Plasma-Atomic Emission Spectrography; NAA, Neutron Activation; XRF, X-Ray Fluorescence; RX, Rock; SS, Stream Sediment; HM, Heavy-Mineral Concentrate]

| Method  | Sample Type | Elements   | Number of Samples | Source                        |
|---------|-------------|--|-------------------|-------------------------------|
| E-Spec  | RX          | Fe, Mg, Ca, Ti, Mn, Ag, B, Ba, Be, Bi, Cd, Co, Cr, Cu, La, Mo, Nb, Ni, Pb, Sc, Sn, Sr, V, W, Y, Zn, Zr                                       | 1307              | Hells Canyon Wilderness Study |
| F-AA    | RX          | Au   | 196               | Hells Canyon Wilderness Study |
| Inst    | RX          | Hg   | 788               | Hells Canyon Wilderness Study |
| E-Spec  | SS          | Fe, Mg, Ca, Ti, Mn, Ag, B, Ba, Be, Bi, Cd, Co, Cr, Cu, La, Mo, Nb, Ni, Pb, Sc, Sn, Sr, V, W, Y, Zn, Zr                                       | 577               | Hells Canyon Wilderness Study |
| F-AA    | SS          | Au   | 577               | Hells Canyon Wilderness Study |
| Inst    | SS          | Hg   | 577               | Hells Canyon Wilderness Study |
| NAA     | SS          | Ag, Al, As, Ba, Be, Ca, Ce, Co, Cr, Cu, Dy, Eu, Fe, K, La, Li, Lu, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, Sc, Se, Sm, Sn, Th, Ti, U, V, W, Y, Yb, Zn | 488               | Baker Quad (NURE)             |
| XRF     | SS          | Ag, As, Bi, Cd, Cu, Nb, Ni, Pb, Se, Sn, W, Zr  | 247               | Baker Quad (NURE)             |
| E-Spec  | SS          | Ca, Fe, Mg, Na, P, Ti, Ag, As, Au, B, Ba, Be, Bi, Cd, Co, Cr, Cu, Ga, Ge, La, Mn, Mo, Nb, Ni, Pb, Sb, Sc, Sr, Th, V, W, Y, Zn, Zr            | 980               | Baker Quad (reanalysis)       |
| GF-AA   | SS          | Au   | 1118              | Baker Quad (reanalysis)       |
| ICP-AES | SS          | Ag, As, Au, Bi, Cd, Cu, Mo, Pb, Sb, Zn   | 634               | Baker Quad (reanalysis)       |
| ICP-AES | SS          | Ag, As, Au, Bi, Cd, Cu, Mo, Pb, Sb, Zn   | 449               | USGS Collection               |
| E-Spec  | HM          | Ca, Fe, Mg, Na, P, Ti, Ag, As, Au, B, Ba, Be, Bi, Cd, Co, Cr, Cu, Ga, Ge, La, Mn, Mo, Nb, Ni, Pb, Sb, Sc, Sr, Th, V, W, Y, Zn, Zr            | 631               | USGS Collection               |
| NAA     | SS          | Al, Au, Ba, Be, Ca, Ce, Co, Cr, Cs, Dy, Eu, Fe, Hf, K, La, Lu, Mg, Mn, Na, Rb, Sb, Sc, Sm, Sr, Ta, Tb, Th, Ti, U, V, Yb, Zn                  | 1122              | Elk City (NURE)               |
| XRF     | SS          | Ag, As, Bi, Cd, Cu, Nb, Ni, Pb, Se, Sn, W, Zr  | 1122              | Elk City (NURE)               |



studies of additions to the River of No Return Wilderness (Adrian and others, 1984; Hopkins and others, 1985 a-d), and (3) stream sediment and heavy-mineral concentrate samples from the French Creek/ Patrick Butte and South Fork Salmon River Special Management Areas and the Payette Crest (Needles) and Secesh Proposed Wilderness areas (Barton and King, unpublished data; Bullock and others, 1991). Data on stream sediment, soil, and rock samples collected in the Idaho Primitive area study (Cater and others, 1973) were examined but they were not used in the data compilation, because they were not in digital form.

The methods of sample collection used in the NURE program are described by Price and Jones (1979). The NURE data for this report included 1,122 stream sediment samples from the PNF part of the Elk City (Broxton and Beyth, 1980) National Topographic Map Series (NTMS) 1° x 2° quadrangle. A preassessment of the Elk City quadrangle by the USGS used some of these same NURE geochemical data (Lund and others, 1990). These data are the main source of geochemical information for the part of Payette National Forest east of longitude 115° 15'. In addition, data from spring water and stream water samples from the NURE study of the Elk City NTMS quadrangle were examined for areas of the quadrangle within the forest.

Stream sediment samples were collected from the Baker NTMS quadrangle and analyzed during the NURE program (Bernardi and Robins, 1982; Cook, 1981), but few of these samples were analyzed for elements of interest in this study.

Analyses of a few samples from the Challis NTMS quadrangle (Thayer and Cook, 1980) were included in our data base for the area south of latitude 45 degrees in the eastern part of the Forest, but elements analyzed by NURE did not include many of interest for this study, and hence were of limited value.

No samples were collected during the NURE program in the Grangeville NTMS quadrangle, in the northwestern part of the forest.

Several areas lacking geochemical data were sampled by the USGS in the summer of 1992. The principle focus of this supplemental sampling was the western part of the PNF where there was little existing geochemical data. In total, 247 stream sediment samples and an equal number of heavy mineral samples were collected. Compilation of data from sources cited above resulted in a total data set containing analyses for 631 heavy mineral concentrates collected from the PNF and contiguous areas. The chemistry and mineralogy of these heavy-mineral-concentrate samples were used chiefly as a supplement to the stream sediment data.

## **Analytical Techniques**

All USGS stream sediment and heavy-mineral concentrate samples used in this study were analyzed for 30 elements by a direct-current arc-emission spectrographic (E-Spec) method (Grimes and Marranzino, 1968). Samples were analyzed for gold by a flameless graphite furnace (GF-AA) method (O'Leary and Meier, 1986). Some of the older gold analyses, such as those for the Hells Canyon area, were done by a flame atomic absorption (AA) method modified from Thompson and others (1968). A partial extraction, inductively coupled plasma-atomic emission spectroscopy (ICP-AES) method (Motooka, 1988) was used to analyze samples for this study, and most of the recent wilderness studies whose data are used here. The method gives analyses for ten elements (Ag, As, Au, Bi, Cd, Cu, Mo, Pb, Sb, and Zn), provides lower limits of determination for these elements than are obtained using E-Spec, and is particularly useful for mineral resource and environmental investigations. This is because this method chiefly extracts

metals held in non-silicate lattice positions in minerals, which are the positions where metal-rich products usually accumulate when weathering from mineral deposits.

Relevant stream sediment samples from the NURE program in the Baker quadrangle were selected from USGS archives and reanalyzed using E-Spec, GF-AA, and ICP-AES (table 1). Data from these reanalyzed samples were then combined with data collected by the USGS to form separate data sets for E-Spec, GF-AA, and ICP-AES analyses.

## **GEOCHEMICAL SIGNIFICANCE OF SAMPLE MATERIALS**

Each material sampled and method of analysis has specific interpretational significance relative to the primary and secondary geochemical environment. Proper interpretation of the data requires that the geochemical and mineralogical significance of the reported analytical values be considered in the context of the sample media and analytical method used, as well as the geologic processes controlling the element distributions in the bedrock, soil, water, and stream sediment.

### **Stream Sediments**

Stream sediment samples are collected in broad regional geochemical surveys because large areas can be covered in a short time based on the assumption that the stream sediment sample represents the overall chemistry of the drainage basin above the point where the sample was collected. However, the ideal representative sample is rarely achieved because of numerous factors that enter into element dispersion processes. Some of the considerations made during this study include differences in procedures used during the NURE program and by the USGS. As one example, the stream sediment material collected during the NURE program was sieved to less than 149 microns and thus consisted of very fine sand to clay-sized material. Materials of this size range are commonly collected with the assumption that any metals dispersed in ground and surface waters might be measured as a result of their concentration in the stream bed through direct coprecipitation and sorption on the fine sediment grains. Metals that have moved mechanically in discrete mineral grains, other than zircon and sometimes scheelite, are not commonly a significant component of these fine-grained sediments. The XRF and NAA analyses produced by the NURE program have high sensitivity and precision, and, in many cases, provide analyses for a number of elements not normally determined in geochemical surveys. For the geochemical and mineralogical considerations just stated, the reported concentrations of elements in the sediments should not be taken as a direct indication of mineral endowment within the drainage basin.

In contrast to the fine size fraction of sediment collected by the NURE program, the USGS routinely collects and analyzes a slightly coarser-grained stream sediment material. Thus, the USGS samples commonly include both sorbed metals and some discrete mineral grains dispersed mechanically. However, the E-spec method used to analyze the USGS samples is not very precise, but is a quick and inexpensive method of recognizing orders of magnitude differences in element concentrations. The NURE samples were reanalyzed by E-spec only because it helped to compare similar data from other USGS samples, not because it is a superior analytical method to those employed by NURE. Samples analyzed by E-spec are total analyses, however, in that the method attacks the lattice of silicate minerals and requires no chemical

predigestion.

The partial-extraction ICP-AES analyses of stream sediments is a useful analytical method because the metal content of each sample consists of only the loosely-held, labile metals and excludes the metals found in the silicate lattices of common rock-forming minerals. Thus, metals that were liberated by the decomposition of mineral deposits can be measured by this method. Moreover, very subtle metal dispersion, such as that of cadmium, an element often enriched in hydrothermally mineralized rocks, can be determined.

### **Stream Sediment Concentrates**

Heavy mineral concentrates processed from stream sediment often indicate the type of minerals being shed into a given drainage basin. The removal of barren clay as a diluent often results in an increase in contrast between anomalous element concentrations and normal background concentrations in stream alluvium. As a consequence, minerals rich in Sn, W, rare earth elements, Cr, and other elements, that might otherwise go undetected, can be identified. The large orders of magnitude in variation between background and anomalous values and the "total" analyses provided by E-Spec make it an appropriate analytical method for these samples. This type of sample media also provides direct mineralogical information.

### **Rocks**

If the sampling is sufficiently systematic and detailed, rock samples can provide some of the most direct information on mineral deposit processes. The geochemical assessment of Payette National Forest was so tightly time-constrained that extensive rock geochemical surveys were not feasible. The Hells Canyon area in the northwest corner of the Forest had been extensively surveyed using rock samples in a previous investigation (Simmons and others, 1983). The data from that survey were used extensively in this areal evaluation for that part of the present study area. E-Spec analyses were well suited to analyses of the rock samples.

### **Data Reduction and Software**

Statistical reductions of the data were accomplished using several USGS software programs called STATPAC (Statistical Package) (VanTrump and Miesch, 1977). Means, standard deviations, correlation coefficients, histograms, and percentiles were calculated for a number of data sets. Statistics were used to establish regional background values for a large number of chemical elements. These background values were then compared to reported concentrations within areas of the PNF. Data subsets were used to evaluate individual geochemical tracts. Data summaries are shown on tables 2-5.

The data were further examined by R-mode factor analysis. The purpose of R-mode factor analysis is to determine suites of elements that group together based on underlying mineralogical or geochemical associations. The method reduces a large number of chemical variables to fewer, more readily explainable groups of variables. Details of the mathematical theory can be found in standard textbooks, such as Harmon (1960). Although the associations of elements can be determined from R-mode factor analysis, the results are of little use if they make no sound geochemical, mineralogical, or geologic sense. In the Payette National Forest, the results

Table 2. Summary of E-Spec data from stream sediments, Payette National Forest and surrounding areas.  
 [Ca, Fe, Mg, and Ti in percent, all others in parts per million; --, not determined; N=2593]

| Element | DR<br>I/ | Observed range |       | Geometric<br>mean 2/ | Percentile |      |      |      | Determination limits |       | Regional<br>threshold 3/ |       |
|---------|----------|----------------|-------|----------------------|------------|------|------|------|----------------------|-------|--------------------------|-------|
|         |          | Min.           | Max   |                      | 50         | 75   | 90   | 95   | 99                   | lower |                          | upper |
| Ca      | 1        | 0.05           | 20    | 1.1                  | 1          | 2    | 3    | 5    | 7                    | 0.05  | 20                       | 3     |
| Fe      | 1        | 0.07           | 15    | 3.5                  | 3          | 5    | 7    | 10   | 15                   | 0.05  | 20                       | 7     |
| Mg      | 1        | 0.02           | 7     | 0.64                 | 0.7        | 1    | 1.5  | 2    | 5                    | 0.02  | 10                       | 1.5   |
| Ti      | 0.89     | 0.05           | 2     | 0.5                  | 0.7        | 1    | 1    | --   | --                   | 0.001 | 1                        | 0.7   |
| Ag      | 0.08     | 0.5            | 300   | 1.1                  | --         | --   | --   | 0.7  | 2                    | 1.5   | 5000                     | 1     |
| As      | 0.003    | 200            | 10000 | 648                  | --         | --   | --   | --   | --                   | 200   | 5000                     | <200  |
| B       | 0.7      | 10             | 500   | 20                   | 10         | 20   | 50   | 70   | 150                  | 10    | 2000                     | 30    |
| Ba      | 1        | 20             | 5000  | 513                  | 500        | 700  | 1000 | 1500 | 1500                 | 5     | 5000                     | 1000  |
| Be      | 0.63     | 1              | 50    | 1.9                  | 1          | 2    | 3    | 7    | 10                   | 1     | 1000                     | 5     |
| Bi      | 0.001    | 10             | 100   | 37                   | --         | --   | --   | --   | --                   | 10    | 1000                     | <10   |
| Cd      | 0.001    | 20             | 50    | 27                   | --         | --   | --   | --   | --                   | 20    | 500                      | <20   |
| Co      | 0.82     | 5              | 300   | 20                   | 15         | 30   | 50   | 70   | 70                   | 5     | 2000                     | 50    |
| Cr      | 0.89     | 10             | 1500  | 50                   | 50         | 100  | 150  | 200  | 300                  | 5     | 5000                     | 150   |
| Cu      | 0.93     | 5              | 10000 | 26                   | 20         | 50   | 100  | 150  | 200                  | 2     | 20000                    | 70    |
| La      | 0.62     | 20             | 1500  | 95                   | 50         | 100  | 200  | 500  | 1000                 | 20    | 1000                     | 100   |
| Mn      | 1        | 30             | 5000  | 704                  | 700        | 1000 | 2000 | 3000 | 3000                 | 10    | 5000                     | 1500  |
| Mo      | 0.04     | 5              | 50    | 8                    | --         | --   | --   | --   | 10                   | 5     | 2000                     | 10    |
| Nb      | 0.3      | 10             | 150   | 27                   | --         | 20   | 30   | 50   | 70                   | 10    | 2000                     | 30    |
| Ni      | 0.87     | 5              | 700   | 20                   | 20         | 30   | 50   | 70   | 100                  | 2     | 5000                     | 50    |
| Pb      | 0.94     | 10             | 50000 | 24                   | 20         | 30   | 50   | 70   | 150                  | 10    | 20000                    | 50    |
| Sb      | 0.01     | 100            | 3000  | 303                  | --         | --   | --   | --   | --                   | 100   | 10000                    | <100  |
| Sc      | 0.73     | 5              | 70    | 12                   | 10         | 15   | 20   | 30   | 50                   | 5     | 100                      | 15    |
| Sn      | 0.02     | 10             | 200   | 19                   | --         | --   | --   | --   | 20                   | 10    | 1000                     | 15    |
| Sr      | 0.93     | 100            | 2000  | 302                  | 300        | 500  | 700  | 700  | 1000                 | 50    | 5000                     | 500   |
| V       | 0.99     | 10             | 1000  | 104                  | 100        | 200  | 300  | 300  | 500                  | 10    | 10000                    | 200   |
| W       | 0.01     | 20             | 10000 | 124                  | --         | --   | --   | --   | --                   | 50    | 10000                    | <20   |
| Y       | 1        | 7              | 1500  | 33                   | 30         | 50   | 70   | 150  | 300                  | 10    | 2000                     | 50    |
| Zn      | 0.04     | 200            | 1500  | 285                  | --         | --   | --   | --   | 300                  | 200   | 10000                    | <200  |
| Zr      | 0.96     | 20             | 1000  | 175                  | 200        | 300  | 700  | 1000 | --                   | 20    | 1000                     | 500   |

1/ Detection ratio (DR) is the number of uncensored or untruncated values divided by the total number of samples analyzed for each element.

2/ Geometric mean is based on log-transformed concentrations of reported values; the calculations do not include censored or truncated data.

3/ Regional threshold value is based on frequency curves, and statistical parameters such as percentiles.

Table 3. Summary of combined ICP-AES (USGS) and XRF (Elk City NURE) data for stream sediments, Payette National Forest and surrounding areas.  
 [All values in parts per million (ppm); N=2630; --, not determined]

| Element | DR<br>1/ | Observed range |       | Geometric<br>mean 2/ | Percentiles |     |     |     | Lower determination limits |         | Regional<br>threshold 3/ |
|---------|----------|----------------|-------|----------------------|-------------|-----|-----|-----|----------------------------|---------|--------------------------|
|         |          | Min.           | Max.  |                      | 50          | 75  | 90  | 95  | 99                         | ICP-AES |                          |
| Ag      | 0.583    | 0.067          | 71    | 1.6                  | --          | 2.5 | 2.9 | 8   | 0.067                      | 5       | 3                        |
| As      | 0.817    | 0.67           | 5900  | 5.5                  | 2.9         | 11  | 24  | 139 | 0.67                       | 5       | 24                       |
| Cu      | 1        | 0.13           | 43000 | 19                   | 21          | 39  | 69  | 167 | 0.67                       | 10      | 69                       |
| Pb      | 1        | 1              | 1200  | 8.1                  | 9           | 13  | 19  | 72  | 0.67                       | 5       | 20                       |
| Zn      | 1        | 2.5            | 1800  | 50                   | 82          | 110 | 150 | 317 | 2.5                        | 20      | 150                      |

1/ Detection ratio (DR) is the number of uncensored values divided by the total number of samples analyzed for a given element.

2/ Geometric mean is based on the log-transformed concentrations of reported values; calculations do not include censored values.

3/ Regional threshold value is based on frequency curves, and statistical parameters such as percentiles.

Table 4. Summary of stream-sediment concentrate geochemical data, Payette National Forest and surrounding areas.

[Ca, Fe, Mg, and Ti in percent, all others in parts per million; N=631; --, not determined]

| Element | DR   |      | Observed range | Geometric |       | Percentile |       |      |        |        | Lower limit | Upper limit | Regional threshold 3/ |
|---------|------|------|----------------|-----------|-------|------------|-------|------|--------|--------|-------------|-------------|-----------------------|
|         | 1/   | 2/   |                | mean      | 2/    | 50         | 75    | 90   | 95     | 99     |             |             |                       |
| Ca      | 1    | 0.1  | 30             | 4.6       | 7     | 10         | 15    | 20   | 30     | 30     | 0.1         | 50          | 10                    |
| Fe      | 1    | 0.1  | 7              | 1.04      | 1     | 2          | 3     | 3    | 5      | 5      | 0.1         | 50          | 3                     |
| Mg      | 0.99 | 0.05 | 10             | 0.47      | 0.5   | 1          | 1.5   | 2    | 10     | 10     | 0.05        | 20          | 1                     |
| Ti      | 0.53 | 0.1  | 2              | 1.03      | 2     | >2         | --    | --   | --     | --     | 0.005       | 2           | 2                     |
| Mn      | 1    | 30   | 3000           | 468       | 500   | 1000       | 1500  | 1500 | 2000   | 2000   | 20          | 10000       | 1000                  |
| Ag      | 0.07 | 1    | 500            | 25        | --    | --         | --    | 10   | 85     | 85     | 1           | 10000       | 3                     |
| Au      | 0.04 | 20   | 700            | 173       | --    | --         | --    | <20  | 200    | 200    | 20          | 1000        | <20                   |
| As      | 0.01 | 500  | 15000          | 1831      | --    | --         | --    | --   | 500    | 500    | 500         | 20000       | <500                  |
| B       | 0.26 | 20   | 500            | 34        | --    | 20         | 30    | 70   | 150    | 150    | 20          | 5000        | 30                    |
| Ba      | 0.89 | 50   | 10000          | 165       | 150   | 200        | 700   | 3000 | >10000 | >10000 | 50          | 10000       | 200                   |
| Be      | 0.14 | 2    | 200            | 4.9       | --    | --         | 2     | 7    | 15     | 15     | 2           | 2000        | 5                     |
| Bi      | 0.09 | 20   | 1000           | 119       | --    | --         | --    | 100  | 500    | 500    | 20          | 2000        | 10                    |
| Co      | 0.08 | 10   | 50             | 22        | --    | --         | --    | 20   | 30     | 30     | 20          | 5000        | 20                    |
| Cr      | 0.77 | 20   | 1000           | 78        | 50    | 100        | 200   | 300  | 700    | 700    | 20          | 10000       | 150                   |
| Cu      | 0.39 | 10   | 20000          | 27        | --    | 20         | 30    | 50   | 300    | 300    | 10          | 50000       | 30                    |
| La      | 0.57 | 50   | 2000           | 572       | 700   | 2000       | >2000 | --   | --     | --     | 50          | 2000        | 700                   |
| Mo      | 0.26 | 10   | 300            | 23        | --    | 10         | 20    | 30   | 100    | 100    | 10          | 5000        | 10                    |
| Nb      | 0.52 | 50   | 500            | 96        | 50    | 100        | 150   | 200  | 300    | 300    | 50          | 5000        | 150                   |
| Ni      | 0.31 | 10   | 100            | 19        | --    | 10         | 20    | 30   | 70     | 70     | 10          | 10000       | 20                    |
| Pb      | 0.61 | 20   | 10000          | 65        | 30    | 70         | 150   | 500  | 5000   | 5000   | 20          | 50000       | 100                   |
| Sb      | 0.02 | 200  | 2000           | 397       | --    | --         | --    | --   | 250    | 250    | 200         | 20000       | <200                  |
| Sc      | 0.81 | 10   | 200            | 36        | 30    | 50         | 100   | 100  | 150    | 150    | 10          | 200         | 100                   |
| Sn      | 0.42 | 20   | 2000           | 89        | --    | 70         | 150   | 300  | 1500   | 1500   | 20          | 2000        | 100                   |
| Sr      | 0.24 | 200  | 3000           | 490       | --    | --         | 500   | 700  | 1750   | 1750   | 200         | 10000       | 700                   |
| V       | 0.98 | 20   | 700            | 100       | 100   | 200        | 200   | 300  | 300    | 300    | 20          | 20000       | 300                   |
| W       | 0.21 | 50   | 10000          | 295       | --    | --         | 300   | 500  | 2000   | 2000   | 100         | 20000       | <50                   |
| Y       | 0.96 | 20   | 3000           | 499       | 700   | 1000       | 1500  | 1500 | 2000   | 2000   | 20          | 5000        | 1000                  |
| Zn      | 0.01 | 500  | 3000           | 966       | --    | --         | --    | --   | 500    | 500    | 500         | 20000       | <500                  |
| Zr      | 0.19 | 20   | 2000           | 569       | >2000 | --         | --    | --   | --     | --     | 20          | 2000        | 700                   |
| Th      | 0.41 | 200  | 5000           | 572       | --    | 500        | 1000  | 1000 | 2000   | 2000   | 200         | 5000        | 1000                  |

1/ Detection ratio (DR) is the number of uncensored or untruncated values divided by the total number of samples analyzed for each element.

2/ Geometric mean is based on log-transformed concentrations of reported values; the calculations do not include censored or truncated data.

3/ Regional threshold value is based on frequency curves, and other statistical parameters such as percentiles; median value was chosen as the lowest plot class in order to show the complete gradient from background to anomalous concentrations.

Table 5. Summary and comparison of gold analyses (in parts per million) of stream-sediment samples, Payette National Forest and surrounding areas. [--, not determined]

| Method/<br>Area 1/ | DR<br>2/ | Observed range |      | Geometric<br>mean 3/ | Percentile |       |       |      | Lower determin-<br>ation limit | Regional<br>threshold 4/ |
|--------------------|----------|----------------|------|----------------------|------------|-------|-------|------|--------------------------------|--------------------------|
|                    |          | Min.           | Max. |                      | 50         | 75    | 90    | 95   |                                |                          |
| GF-AA-W            | 0.62     | 0.001          | 2.9  | 0.002                | --         | --    | --    | --   | 0.001                          | --                       |
| GF-AA-C            | 0.25     | 0.002          | 5    | 0.025                | --         | 0.02  | 0.4   | 1.65 | 0.001, 0.05                    | --                       |
| NAA-E              | 0.08     | 0.05           | 8.97 | 0.45                 | --         | --    | 0.23  | 1.55 | 0.01                           | --                       |
| Au-T               | 0.54     | 0.001          | 70   | 0.005                | --         | 0.002 | 0.013 | 0.94 | 0.001, 0.05                    | 0.005                    |

1/ Method/ Area codes:

GF-AA-W Graphite furnace, western forest and surrounding areas (N=1118)

GF-AA-C Graphite furnace, north-central forest (suture zone) (N=219)

NAA-E Neutron activation (Elk City NURE), eastern forest and surroundings (N=1294)

Au-T Combined instrumental analyses (GF-AA, AA, ICP-AES, NAA and E-Spec) for PNF and surroundings (N=3744)

2/ Detection ratio (DR) is the number of uncensored values divided by the total number of samples analyzed for each element.

3/ Geometric mean is based on log-transformed concentrations of reported values; the calculations do not include censored or truncated data.

4/ Regional threshold value is based on frequency curves, and statistical parameters such as percentiles.

of R-mode analysis were quite useful.

A USGS computer program called Relative Element Magnitude (REM) (VanTrump and Alminas, 1978) was also used extensively in these studies to assist in our evaluations. The REM program is designed as an aid in characterizing geochemical anomalies. The program ranks the magnitudes of anomalies of individual elements within a multielement geochemical anomaly.

## Maps

Element concentrations in rock and sediment samples were plotted on maps in order to identify spatial distributions, and to relate these distributions to geologic and environmental factors. These plots were produced using standard USGS plotting programs (VanTrump and Miesch, 1977; Selner and Taylor, 1993). Key elements were selected for plotting on the basis of the statistical data and on the relevance each element may have to mineral-deposit-forming processes. Data were then plotted on the maps as site-specific symbols. Where the range of data allowed, the plots used classes of data based on the 50th, 75th, 90th, 95th, and 99th percentiles of the statistical distribution. These percentiles were used as a general guide to class selection, but there was no strict adherence where the data range did not allow such values to be used. For example, the E-Spec data give censored or truncated data for certain elements. Censored distributions occur for elements such as Bi, Cd, W, and Zn, which could not be determined in their entirety because of poor instrumental sensitivity or calibration. Truncated distributions for some elements (Ti, Mn, and Ba) exist where concentrations exceed the upper limits of determination for the analytical method.

The limitations of data compilation precluded using a single analytical method for stream sediments in the entire PNF. It was decided that the ICP-AES analyses for stream sediment samples provided data on key elements that were highly pertinent to mineral resource assessment. These data were used in the regional map plots. Because this type of analysis was not run on most samples from the extreme eastern PNF, a combined data set of the key elements was made with data available from the XRF analyses in the Elk City NURE data base. The regional point-plot maps on Figures 4-6, and 8 are therefore derived from this combined file. With respect to the elements plotted on these maps, the data for this combined file are summarized in table 3. Molybdenum was not analyzed in the NURE Elk City samples and, therefore, the map for Mo (fig. 7) shows only results for analyses by ICP-AES.

A derivative map for titanium-related elements (fig. 10) was generated from the combined distributions of above-median values (>50th percentile) of Ti-Cr-Mg-Nb (NURE-NAA, E-Spec) in stream sediments. This derivative map for the titanium suite was manually compiled using a set of transparent overlays with plots of the individual elements in the titanium suite. In order to plot the full range of titanium, which frequently is reported in concentration ranges above the highest reporting level for E-Spec analyses, a replacement value was assigned that corresponds to the next analytical reporting interval above the upper limit of determination (table 2).

## REGIONAL GEOCHEMICAL ANOMALIES

The maps (figs. 4-10) show the regional distributions of geochemical anomalies for the Forest and surrounding areas. A simplified geologic map of the area of the PNF (fig. 3) redrawn







Figure 3a. Explanation for figure 3.

**BRIEF DESCRIPTION OF MAP UNITS**  
(Simplified from Bond, 1978)

|      |  |
|------|--|
| Tm   | <b>Columbia River Basalt Group undivided (Pleistocene and Lower Pliocene)-</b><br>Includes basalt feeders and sills  |
| Tev  | <b>Challis Volcanics (Eocene)-</b> Mixed silicic and basaltic volcanic ejecta, flows and reworked debris   |
| Tei  | <b>Intrusive Rocks (Eocene)-</b> Plutons and felsic to intermediate dike swarms  |
| Ki   | <b>Idaho Batholith (Cretaceous)-</b> Granite, quartz monzonite, granodiorite, and migmatite  |
| Km   | <b>Highly metamorphosed rocks undivided (Age Unknown)-</b> Origin unknown  |
| Kji  | <b>Intermediate intrusives (Lower Cretaceous and Upper Jurassic)-</b> Granodiorite, quartz diorite, and gabbro   |
| Jw   | <b>Submarine volcanics (Jurassic)-</b> Island-arc volcanoclastic wackes, metagraywacke, slate, and phyllite with minor conglomerate, tuff, chert, and limestone  |
| JTRi | <b>Intermediate to mafic intrusives (Lower Jurassic and Upper Triassic)-</b> Gabbro, quartz diorite, and granodiorite  |
| PTRv | <b>Seven Devils Group Undivided (Lower Triassic and Upper Permian)-</b> Greenschist, facies island-arc basalt and andesite flows, keratophyre, submarine volcanoclastics, volcanic breccias, tuff, and chert, with minor shale overlying reefal limestone and dolomite of the Martin Bridge Formation                                      |
| Pv   | <b>Upper Permian submarine volcanic complex</b>  |
| Pz   | <b>Metamorphosed Paleozoic rocks</b>   |
| Ys   | <b>Metamorphosed sedimentary rocks undifferentiated (Lower Paleozoic?, Upper and Middle Proterozoic)-</b> Metamorphosed clastics; includes units of the Yellowjacket Formation equivalent to Belt Supergroup (Middle Proterozoic) and metamorphosed carbonate rocks related to a Late Proterozoic-Paleozoic(?) miogeosyncline (Lund, 1984) |
| p Ci | <b>Ramey Ridge syenite complex (Middle Proterozoic)</b>  |
| p C  | <b>PreCambrian igneous and metamorphic rocks undifferentiated</b>  |
| mig  | <b>Mixed highly altered and migmatitic rocks</b>   |

**GEOLOGIC SYMBOLS**

|   |  |
|---|--|
|  | <b>Normal Fault-</b> Dashed where inferred   |
|  | <b>Thrust Fault-</b> Sawteeth on upper plate |

by Watts from the state geologic map (Bond, 1978), is included in this report as a guide to geologic features mentioned in the following discussion of geochemical anomalies.

## Copper

Copper (fig. 4) is a dominant element in the western part of the PNF, but is far less important in the eastern part. Some strong copper anomalies are present east of the PNF in areas north and east of Blackbird Mtn. These anomalies are probably related to known Co-Cu deposits in the Blackbird and Yellowjacket mine areas.

In the western PNF, a northwest-trending fault zone along Wildhorse Creek north and west of Cuddy Mt., may be mineralized with copper. This inference is based on spatial correspondence of copper highs with the fault zone and the pattern formed by the individual anomalies. These copper zones also continue westward, across the Snake River.

Similarly, copper highs form a pattern that extends west, across the Snake River from the town of Mineral, in the southwestern corner of the PNF.

Several previously unrecognized zones of possible copper mineralization occur in the Council Mt. area (eastern edge of western PNF) in linear zones, both to the north and south. With one exception, the copper highs occur in areas underlain by Columbia River Basalt (Tm on figure 3). This coextensive distribution of rock type and copper highs could be attributed to normal but Cu-rich lithology, but it should be noted that copper highs are not present in all areas of basalt; rather, the patterns apparently follow specific basalt flows. However it should be also noted that leakage of metal-bearing fluids along the numerous fault zones could also be a source of the copper highs. More detailed discussion of the geochemical signature in the area follows in a later section.

## Zinc

The eastern and western blocks of the Forest appear about equally endowed with anomalous zinc (fig. 5). In the eastern PNF, a well-defined arcuate pattern of zinc anomalies to the east of Acorn Peak follows a contact zone between outcrops of Precambrian rocks and rocks of the Idaho batholith. The contact zone itself is assumed to be at least partially controlling the zinc anomalies. A large northeast-trending fault along Crooked Creek, just to the east of Acorn Peak seems to influence the change in trend of the zinc pattern from one with a nearly east-west trend to one with a northeast-southwest trend. The fault therefore may have displaced zinc mineralization laterally. A northeast-trending linear pattern of zinc anomalies to the northeast on Cottonwood Creek in the Frank Church Wilderness is on projection of the fault zone and may indicate further zinc mineralization on this or a similar structure.

Zinc anomalies were also found in the Chamberlain Basin area, centered on Lodgepole Creek. Numerous andesite dikes were noted in the field in this area during geochemical sampling. These zinc anomalies could be related to hypogene migration of zinc from depth along dike-country rock contacts.

A linear, northerly pattern of zinc anomalies is present in a zone just west of Big Creek and may connect mineral deposits near Yellow Pine with similar deposits near Big Creek.

Zinc anomalies are present in the upper reaches of drainages near Warren and probably reflect fissure veins in the area of the Warren mining district which were reported to contain

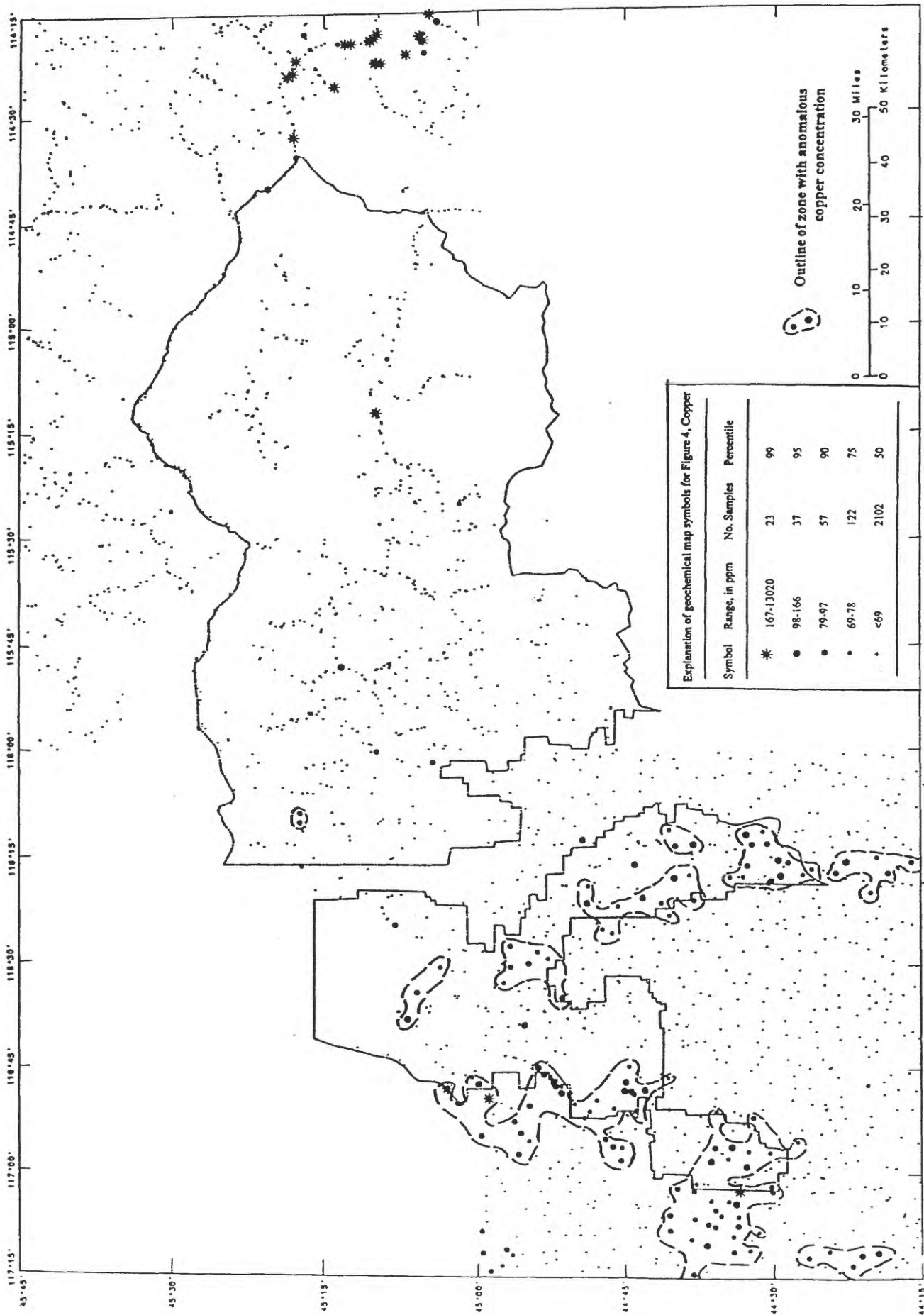


Figure 4. Geochemical map showing the distribution and abundance of copper in stream-sediment samples from the Payette National Forest and contiguous areas.

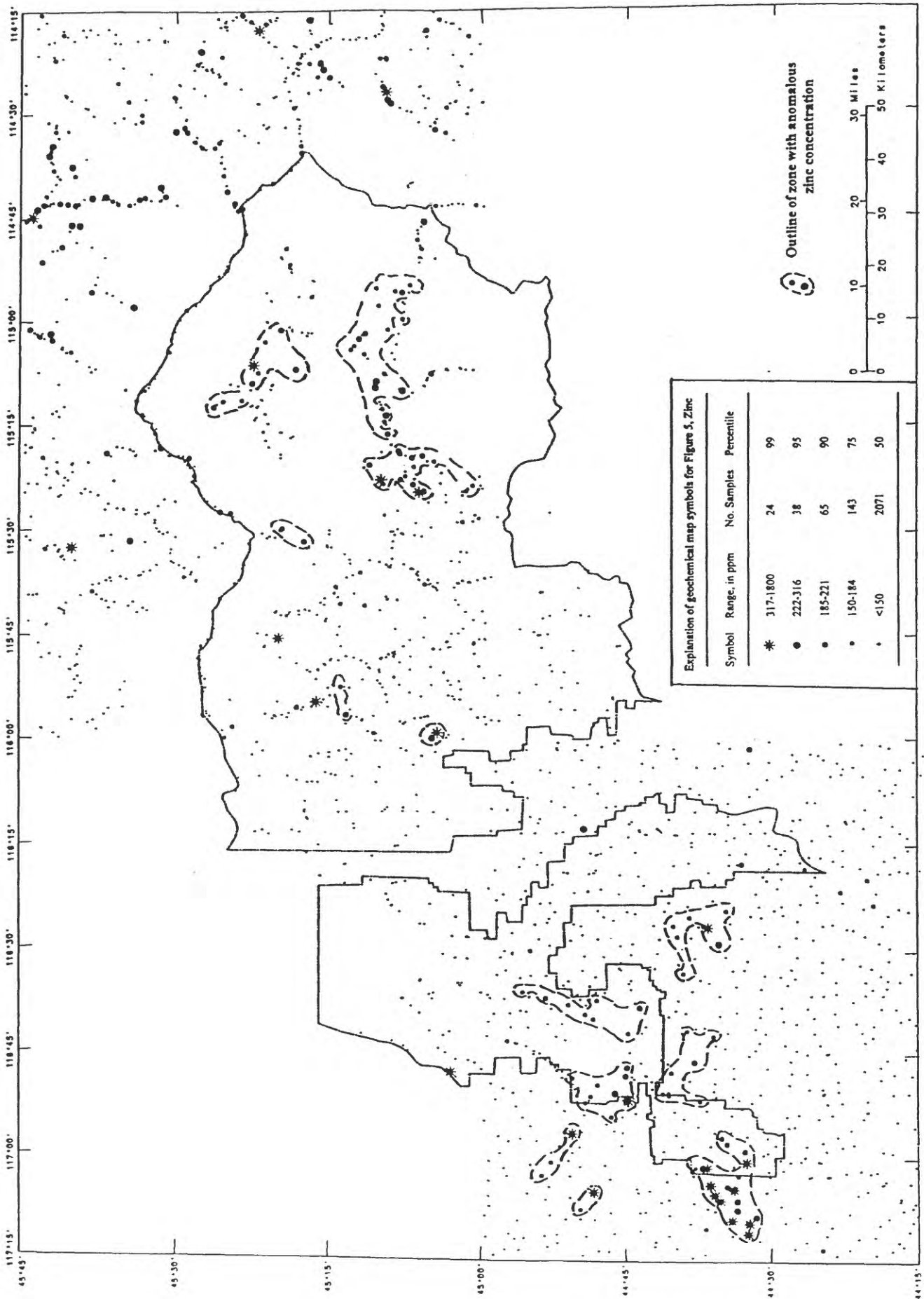


Figure 5. Geochemical map showing the distribution and abundance of zinc in stream-sediment samples from the Payette National Forest and contiguous areas.

small amounts of the zinc sulfide, sphalerite (Reed, 1937).

In the western PNF, zinc anomalies are found in areas west of Cuddy Mt. (west-central PNF) and southwest of Sturgill Peak (southwest corner of PNF). Both of these areas are known to have mineral deposits, but these geochemical anomalies may closely demarcate the extent of this mineralization with respect to zinc. The concentration levels and anomaly patterns indicate that zinc mineralization is strongest west of the PNF and that some mineralization extends west of the Snake River.

Also in the western PNF, near Rush Peak, a north- to northwest-trending pattern of geochemical anomalies extends northward and passes through the area near Peck Mt. (just west of Council, ID). The pattern is subparallel to the strike of numerous north to northwest-striking late extensional faults in the area, which suggests that hypogene leakage along a fault or fault zone may be the source of the zinc anomalies.

## **Lead**

Lead anomalies show similar patterns to those of zinc in the eastern PNF (fig. 6). Zones of nearly coincident Pb-Zn anomalies are as follows: (1) a broad north-trending zone west of Big Creek and extending south to a point just north of Yellow Pine, (2) the Chamberlain Basin area, near Lodgepole Point, (3) Cottonwood Creek, to the northeast of Big Creek in the Frank Church Wilderness, and (4) near Warren. However, in contrast to the lead anomalies, zinc anomalies do not form an elliptical pattern passing through Acorn Butte on the Proterozoic-Idaho batholith contact. Zonal differences of metals will be further discussed with respect to tract comparisons in a later section.

In the western PNF, lead anomalies are more sporadic and not as extensive as those of zinc; yet, where the lead anomalies occur, a spatial correlation with zinc is usually evident. In comparison with zinc and copper, lead is not a significant base metal component of the anomaly suite in the western PNF.

## **Molybdenum**

As noted earlier, molybdenum was not analyzed in the NURE Elk City quadrangle samples. Therefore, the map for molybdenum (fig. 7) shows the distribution and abundance of the element chiefly in the western part of the PNF. Molybdenum anomalies in the eastern PNF occur in a north-trending zone somewhat coincident with lead and zinc, but much more restricted, between East Fork of the South Fork of the Salmon River and Elk Pass. High values for tin and tungsten (not shown in this report) correlate well with the distribution of molybdenum. A large part of this area is underlain by a mineralized shear zone in granitic rocks of the Idaho batholith and Precambrian metasedimentary rocks wherein small amounts of molybdenite and other sulfides have been reported along with gold deposits of the area (Shenon and Ross, 1936, p. 20).

The strongest and most extensive molybdenum anomalies in the western PNF occur in the southwestern corner, in the Mineral district. A prospect, which is tentatively classified as a porphyry copper-molybdenum prospect (Henricksen, 1975, p.118-120), is in the Mineral district, west of the PNF. Most of the anomalous zone is west of the PNF boundary.

An interesting north- to northeast-trending pattern of molybdenum anomalies

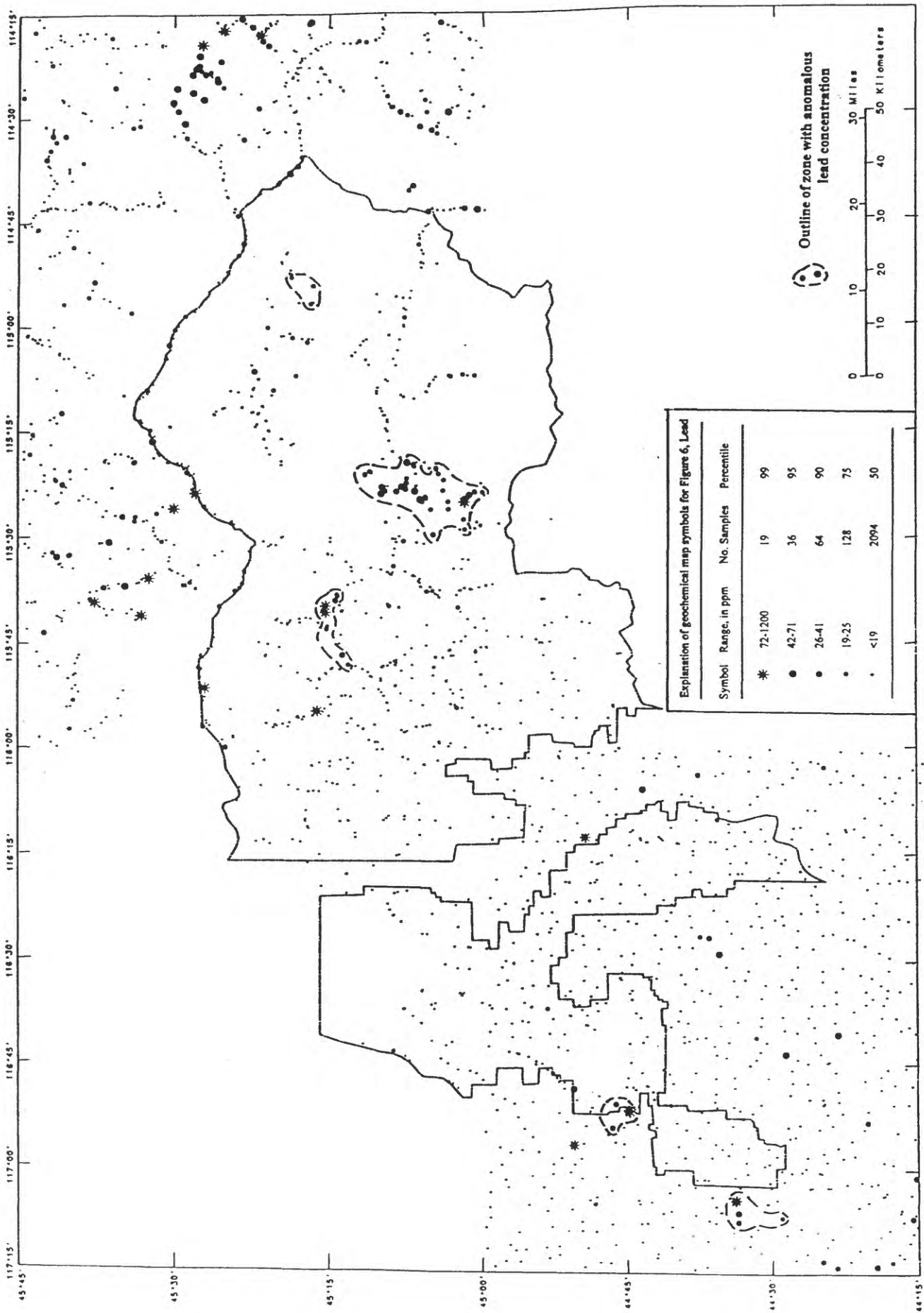


Figure 6. Geochemical map showing the distribution and abundance of lead in stream-sediment samples from the Payette National Forest and contiguous areas.

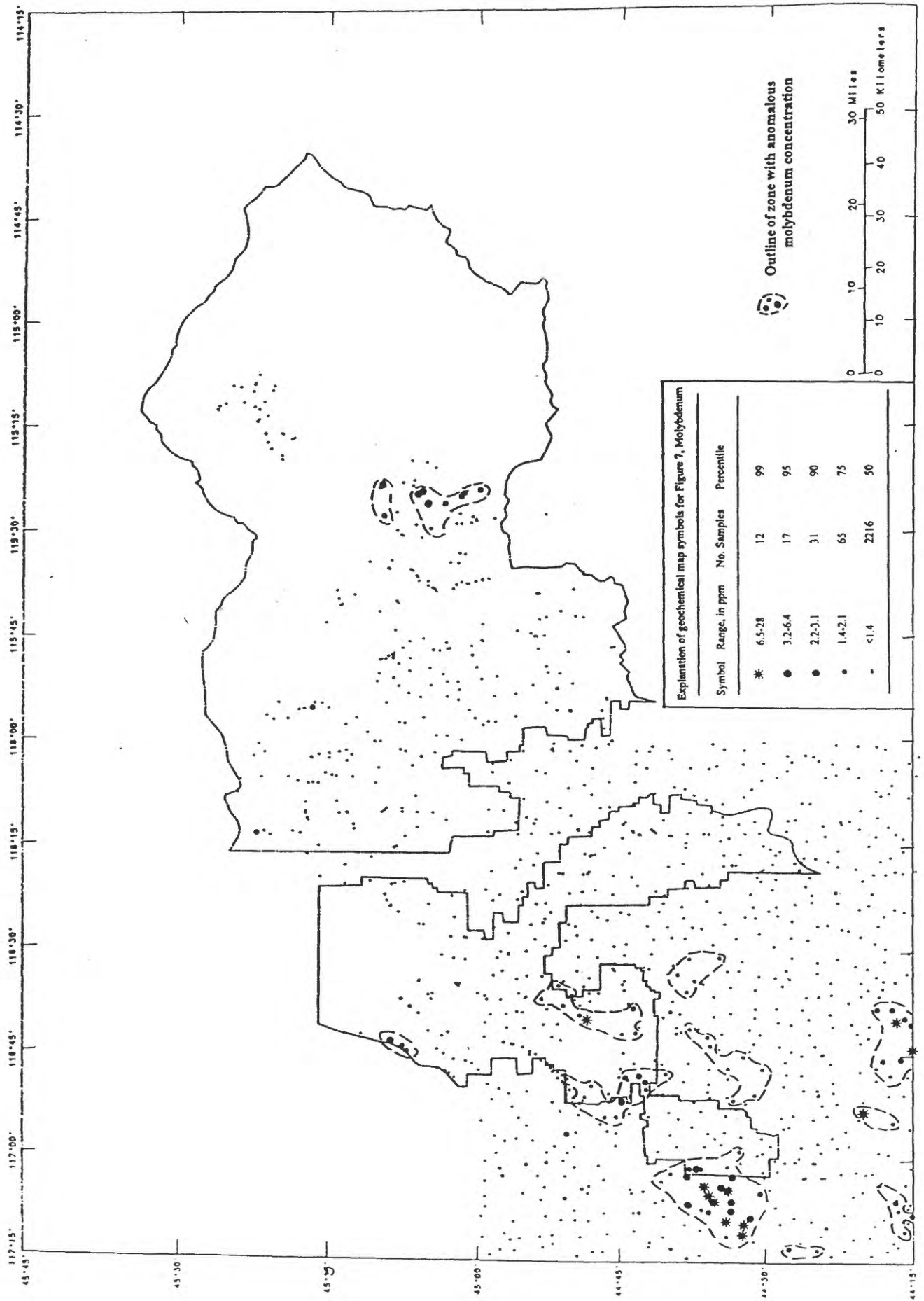


Figure 7. Geochemical map showing the distribution and abundance of molybdenum in stream-sediment samples from the Payette National Forest and contiguous areas.



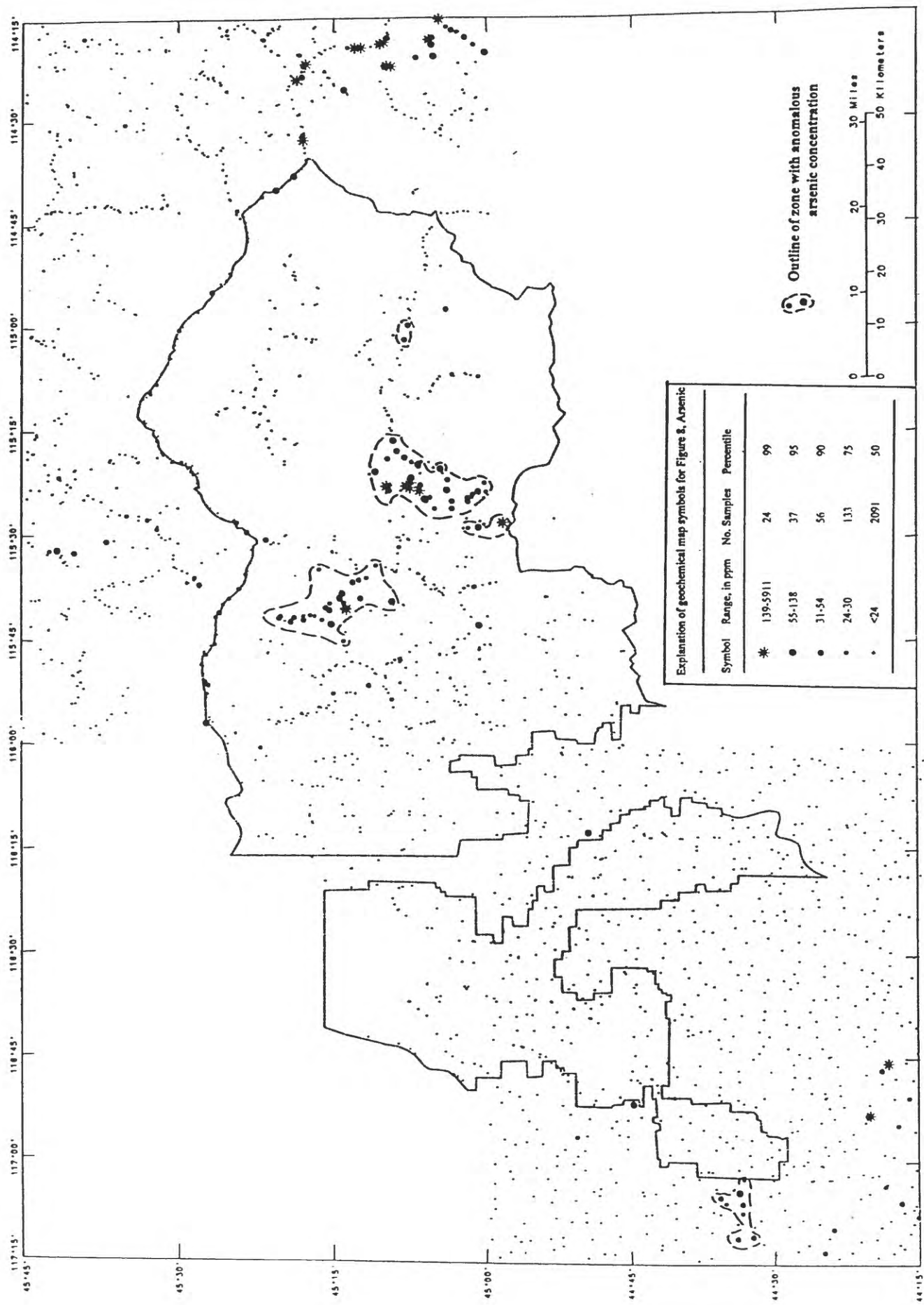


Figure 8. Geochemical map showing the distribution and abundance of arsenic in stream-sediment samples from the Payette National Forest and contiguous areas.

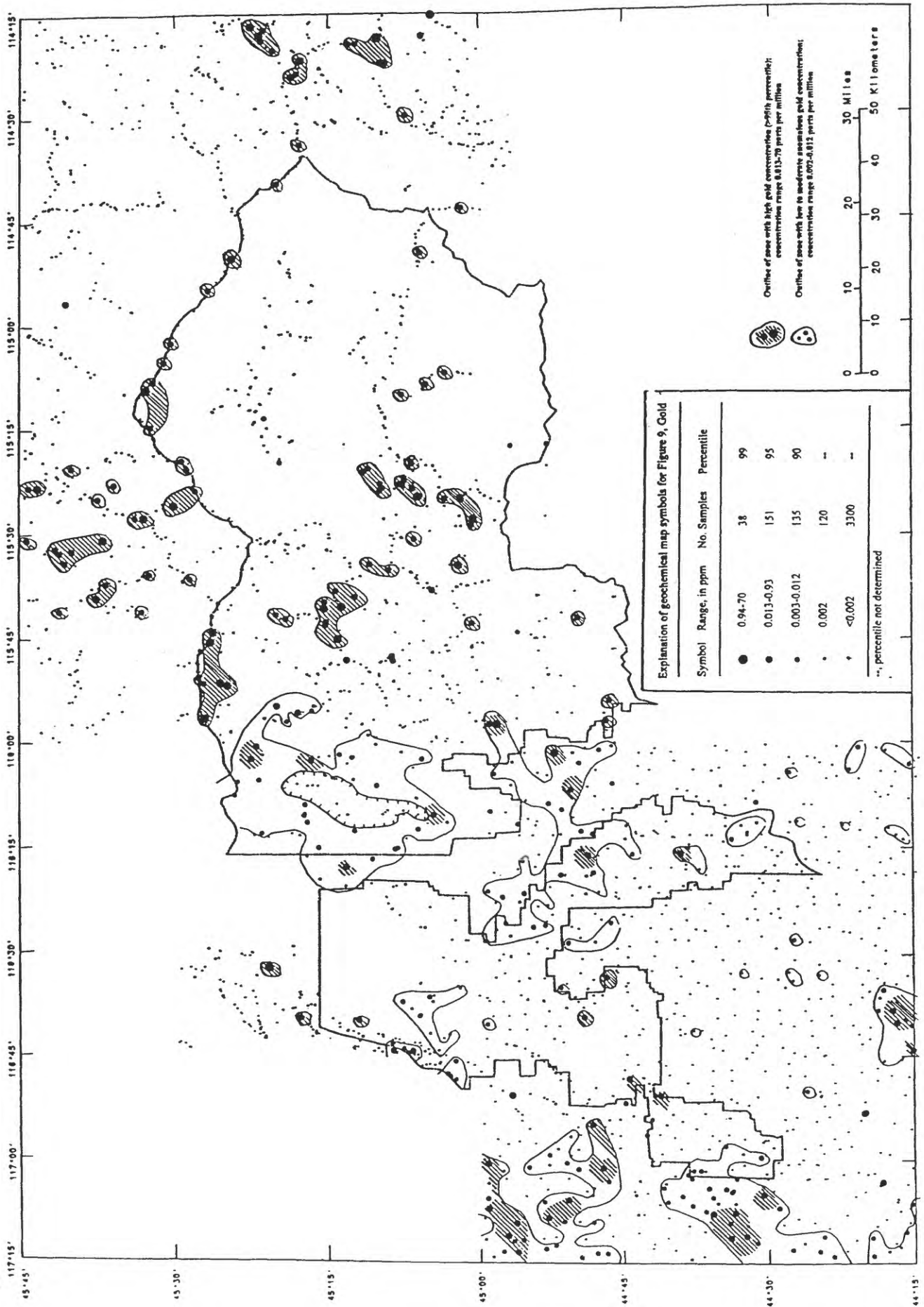


Figure 9. Geochemical map showing the distribution and abundance of gold in stream-sediment samples from the Payette National Forest and contiguous areas.

encompasses a zone between Rush Peak and Peck Mt. that is coextensive with a similar zone of zinc anomalies. The presence of anomalous molybdenum in the zone suggests that this is a mineralized fault or fracture zone, as previously suggested for zinc. This zone is probably part of the fracture system that controlled emplacement of a tourmaline-Mo breccia pipe immediately west of Cuddy Mt.

Other zones of molybdenum anomalies occur west and southeast of the Cuddy Mt. area. The zone to the west straddles the boundary of the PNF. The zone to the southeast is entirely outside the PNF. We postulate that these molybdenum anomalies and Rush Peak-Peck Mt. zone are genetically linked and should be considered part of a single igneous-hydrothermal system.

## **Arsenic**

By far the largest concentrations of arsenic in stream sediments were found in the eastern PNF (fig. 8). Prominent zones of arsenic anomalies in this area include: (1) the zone of multielement anomalies (Pb-Zn-Mo and Au) that extends north to northeasterly from the vicinity of East Fork of the South Fork Salmon River to Smith Creek north of Mt. Eldridge (zone west of Big Creek), (2) a northeast-trending zone of probable fault-controlled anomalies present in an area north of Lookout Mt. to just west of Black Butte, and (3) a strongly anomalous zone of anomalies near Warren. The quartz fissure veins that supplied gold to the placer deposits at Warren contained arsenopyrite as a minor constituent (Lindgren, 1900, p. 245; Reed, 1937, p. 37).

There are also a few scattered arsenic anomalies in the eastern PNF, in a zone that extends from Split Creek Point on the south, northwesterly to Lake Creek. A tenuous spatial coincidence between a large northwest-trending fault in the area and the scattered arsenic anomalies could indicate fault-controlled arsenic mineralization.

Arsenic anomalies were found in the Mineral district west of the southwestern corner of the PNF, but none were found within the western PNF.

## **Gold**

Gold anomalies were found in most of the areas of known past production in the eastern PNF (fig. 9). Placer accumulations at Warren are delineated by gold anomalies in the stream sediment data. Areas of lode gold deposits in the Edwardsburg and Profile districts also show gold anomalies in the stream sediment data.

Mostly low-level, but anomalous concentrations of gold were found in stream sediments within a broad area extending from Goose Creek on the south to Riggins Hot Springs on the north. The western Idaho suture zone (Lund and Snee, 1988; Hyndman, 1989), a north-trending zone of highly deformed and metamorphosed rocks, interpreted as the zone along which the oceanic Blue Mountains Island Arc was accreted to the North American continent extends through this area. Samples were found devoid of detectable gold within a central area (hachured area on map), which coincides with a zone of high titanium-suite metals (discussed below). The close spatial relationship of the area containing gold anomalies with the encircled area of high titanium-suite elements, and the position of the anomalies within the suture zone, suggest that the gold anomalies are zonally related to ultramafic rock bodies.

Farther south in the western PNF, and also within the suture zone, another group of gold

anomalies were found. The areas of these anomalies are covered by Columbia River basalts (Tm), which could not be the source of these gold anomalies. On the other hand, the extensive faults in the area may have exposed subjacent suture-zone granitoids that may be mineralized with gold. Distribution patterns of these anomalies moreover suggest that these bedrock source areas may have contributed gold to placers to the east in the Payette River Valley. In a similar manner, a source area near the Ponderosa State Park, across the Payette River Valley, appears to have contributed gold from the east to the alluvium of the Payette River Valley. Unlike the suggestion that copper anomalies in this area (discussed above) could be related to basalts, gold is not a notably rich constituent of the basalts; this strengthens the case that most copper anomalies are similarly unrelated to basaltic lithologies. Other aspects of the geochemical signature (discussed below as tract D) support the contention that geochemical anomalies in the area are related to subjacent mineralization.

Other zones of gold anomalies in the western PNF include: (1) the Mineral district in the southwestern corner, where the anomalies form a northeast-trending cluster, which is present chiefly outside the boundary of the PNF; (2) isolated but high concentrations of gold near Cuddy Mt., and (3) a northwest trending (fault controlled?) zone in the Indian Creek area, in the northwestern corner of the PNF.

### **Titanium-Chromium-Magnesium-Niobium**

The combined geochemical signature of titanium-chromium-magnesium-niobium, identified some areas in the suture zone as containing ultramafic rocks or zones of lamproite pipes (fig. 10). In one instance the signature also shows a zonal relationship with a broad area of stream sediment gold (fig. 9) anomalies, as discussed above.

The titanium suite delineates the Ramey Ridge syenitic complex (Leonard, 1963) in the eastern PNF. High titanium in this rock type is common.

Geochemical mapping of areas in which the titanium suite of elements predominate may delineate areas of rocks hosting lamproite pipes (with potential for diamonds), or ultramafic bodies with possibilities of podiform chromite deposits. As discussed above, the titanium-element suite appears to show a zonal pattern with gold anomalies within the suture zone. The distribution of this suite of elements thus provides fundamental information on the geologic framework that may not always be obvious from direct rock observation.

## **GEOCHEMICAL TRACTS**

Evaluation of the geochemical data in conjunction with geologic factors were used to select geochemical tracts, which were further evaluated separately from the regional overview. The tracts of geochemical anomalies discussed below mostly correspond with known mining districts and their immediate surroundings.

Six distinct tracts of land in the national forest (tracts A, B, C, F, G, and H on fig. 11) contain elevated concentrations of a variety of metals, are known to be moderately to highly mineralized, and were actively mined in the past.

Two additional tracts (D and E on fig. 11) were identified through geochemical interpretation. These two tracts contain few if any mines, but contain elevated metal concentrations and metal associations similar to tracts that have been mined. Tracts D and E,

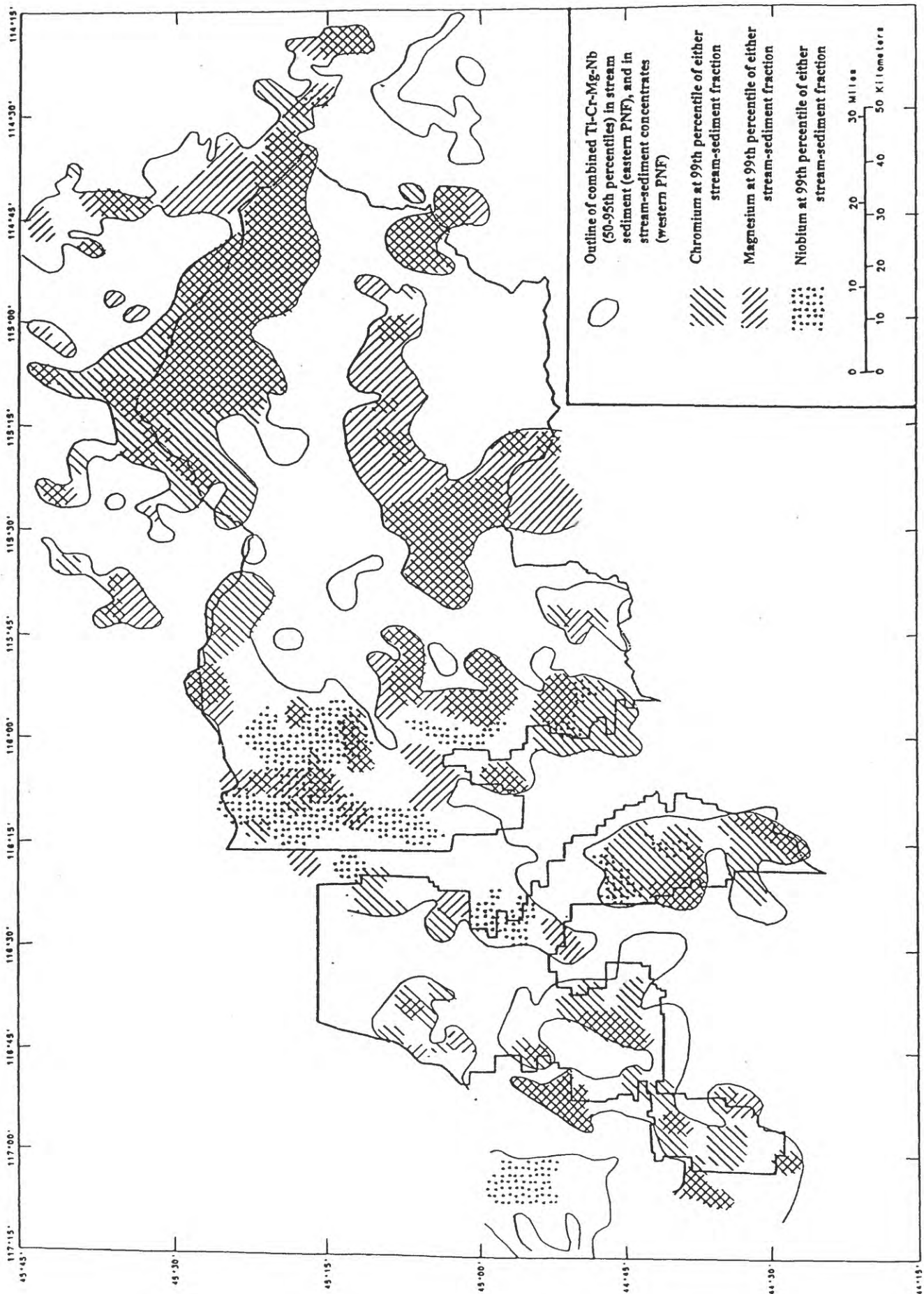


Figure 10. Geochemical map showing the distribution of titanium, chromium, magnesium, and niobium in stream-sediment samples from the Payette National Forest and contiguous areas.

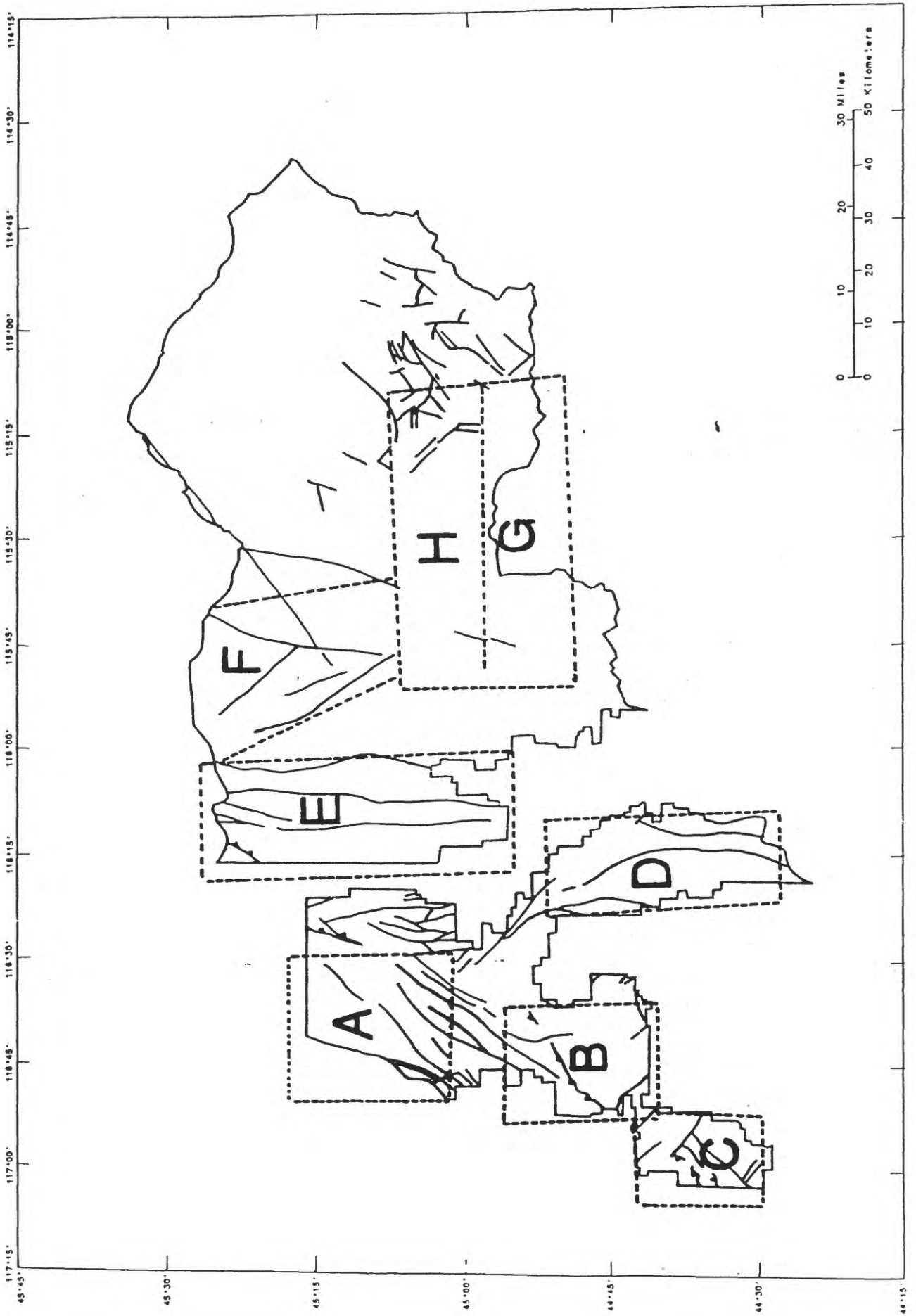


Figure 11. Geochemical tracts and major faults in the Payette National Forest.

therefore, could provide a basis for comparison between an unmined, but potentially mineralized area, with the geologically similar, but mined areas of the other geochemical tracts. Often areas of past mining are thoroughly exposed to surface geochemical and biogeochemical processes that may cause acidic mine waters enriched in heavy metals. With all other conditions equal, undisturbed areas usually have more muted geochemical signatures than those that have been mined.

Geochemical signatures for each tract were determined for stream sediment fractions by using the Relative Element Magnitude (REM) program (VanTrump and Alminas, 1978) (table 6). R-mode factor analysis of stream-sediment concentrates provided information on ore and gangue mineralogy, and on lithologies associated with mineral deposits in the geochemical tracts. The tracts also were evaluated using detailed geochemical maps. Geochemical associations in each terrane were determined by (1) interpreting the results of stream-sediment concentrates, which provided definitive data on detrital mineral associations in the stream sediments, and (2) R-mode factor analysis of various data subsets, which provided additional information on the element dispersion processes prevalent in each of the geochemical tracts. The geochemical anomalies that are not part of a named mining district are geographically referenced.

## **Tract A--Hells Canyon-Seven Devils-Rapid River**

### **Mineral deposits**

Known deposits in Tract A include Permian and Triassic island arc-related volcanic-hosted, stratabound and disseminated copper deposits; Sierran Kuroko massive sulfide deposits; Cu (W-Mo) skarn; and Cu-dominant volcanic-hosted high sulfur veins within the Permian and Triassic Seven Devils Group volcano-sedimentary sequence (Bookstrom and others, 1998).

### **Geochemical signature**

Copper is the chief anomalous metal, both in bedrock and in the stream sediment. The prominence of iron, manganese, and nickel are also apparent from the computations on stream sediment. Because of the concentration process, heavy-mineral concentrates from stream sediments often identify minerals that might go unnoticed in the bedrock, such as wulfenite (lead molybdate), a secondary mineral derived from Pb-Mo veins, and barite (barium sulfate), a constituent of both veins and lithologic units within the Seven Devils Group.

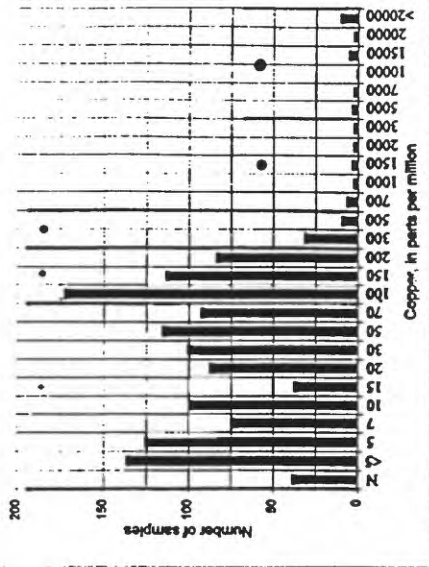
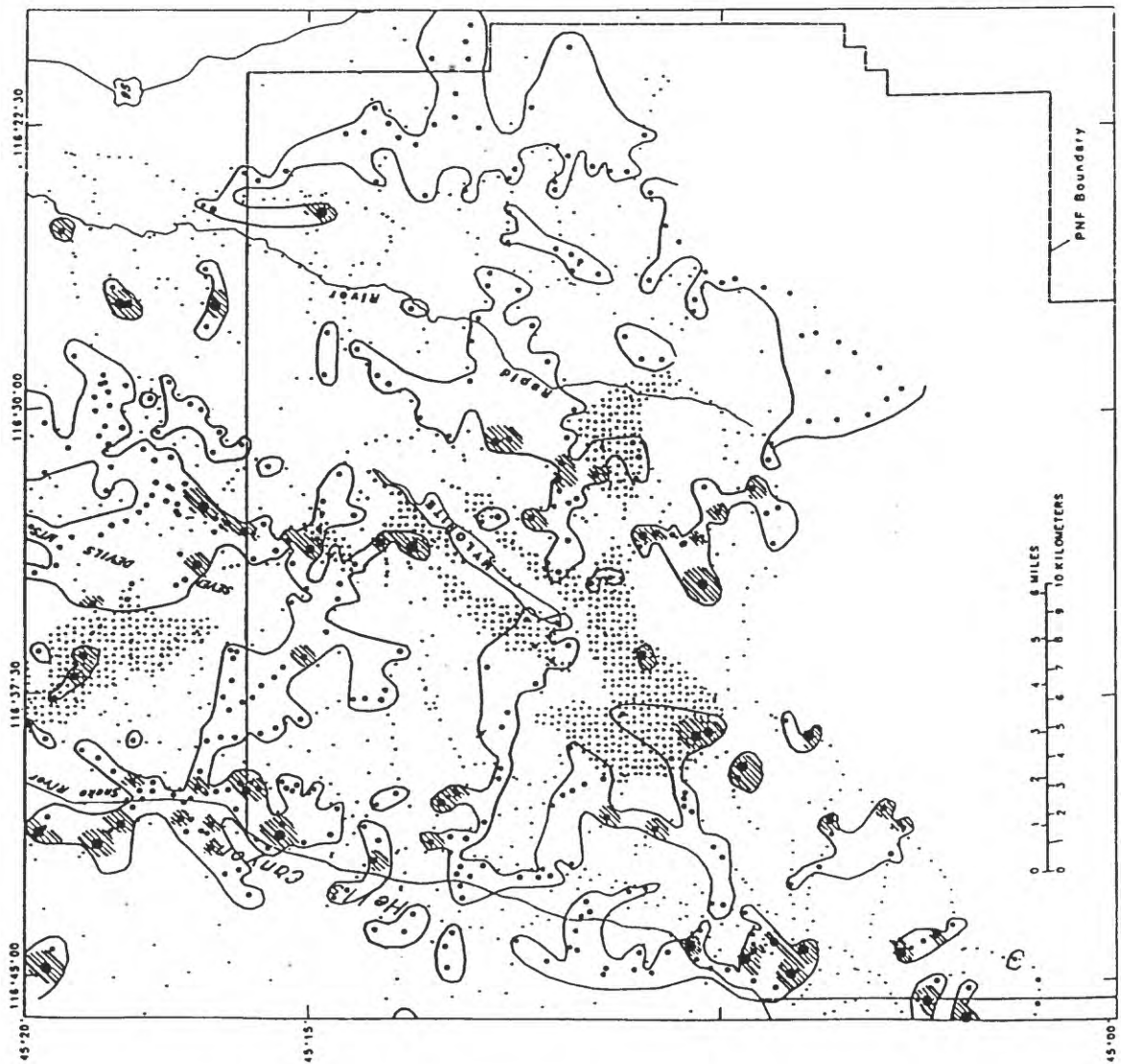
### **Map distributions**

Copper, nickel, and cobalt are inherently high in the bedrock of the area. This suite is also characteristic for volcanogenic-related mineral deposits. Detailed geochemical patterns of distributions for Cu, Ni, and Co (figs. 12-14) probably reflect the distribution of favorable lithologic units for targeting. These metals may have been extensively mobilized along wide zones in this tract as a result of primary dispersion related to mineralization and secondary dispersion due to weathering.

Table 6. Ranking of elements on the basis of REM (Van Trump and Alminas, 1978) computations. [Elements are ranked in decreasing REM value; only values >3.0 were used; --, no data]

| Tract   | Baker Quad. NURE                                   |  | Elk City Quad. NURE                                |  | E-Spec   |  | ICP-AES  |  | Heavy-Mineral Concentrates |
|---|--|--|--|--|--|--|--|--|----------------------------|
|   | Stream sediments-- re-analyzed, plus NURE NAA data | Stream sediments-- re-analyzed, plus NURE NAA data | Stream sediments-- re-analyzed, plus NURE NAA data | Stream sediments-- re-analyzed, plus NURE NAA data | Stream sediments-- USGS and re-analyzed NURE samples | Stream sediments-- USGS and re-analyzed NURE samples | Stream sediments-- USGS and re-analyzed NURE samples |  |                            |
| A   | --   | --   | --   | Cu>Mn>Fe>Ni>As>Y>Cr>Co>B>Sr                        | Cu>Cd>Zr>Mo>Pb                                       | Pb>Mo>Ba>Co>Sr>Ti>Cu>Cr                              |  |  |                            |
| B   | Fe>Cu>Ni>As>P>Mn>Zn>Ag>Co>Ba>Pb                    | --   | Cr>Co>Ni>Fe>Mn>Zn                                  | Cu>Zn>Cd>Mo>Pb>As                                  | Pb>Ag>Ni>Co>Ba>Sr>Cr>B>Ti                            |  |  |  |                            |
| C   | Fe>Mn>As>Ag=Cu=Ni>P                                | --   | Cr>Ni>Co>Cu>Fe>B=Zn                                | Cd>Mo>Zn>Cu>As>Sb>Pb>Ag                            | Ba>B>Pb>Sr>Mo>Ni>Co>Ti>Bi                            |  |  |  |                            |
| D   | Fe>Cu>As>Ni>Ag>Mn>P>Sm>La>Zn                       | --   | Cr>As>Co>Ni>Fe>Cu>Mn                               | Cd>Cu>Pb>Zn  | Pb>Co>Ni>Cu>Sr>Cr=Ti                                 |  |  |  |                            |
| E   | Sm>As>Ag=Ce=Cu=Ni>P>La>Th>Mn>Fe                    | --   | Sr>Fe>Y>Mn>Cr>Ni>La>Co>Ba                          | Cu>Zn>Au>Pb  | Nb>Mo>Ti>Zr>Sr>Mn>Ba>Sn>B=Cr>Ni                      |  |  |  |                            |
| F   | --   | Ag>Au>Ce>Ba>Be>Pb                                  | W>Ag>Y>La>B>Sr>Ba>Cu>Cr>Be                         | As>Ag>Au>Mo  | Ag>Ti>Zr>Ni=La>Nb>Th>Be                              |  |  |  |                            |
| G   | --   | Ag>Pb>Li>Mn>As>Ba=Rb>Be                            | Y>Cr>Sr>La>Be>Ba>Nb>B>Fe                           | As>Pb>Mo>Cd  | Bi>As>Sn>W>Cr>B>Mn>Ti=Ag=Nb>Zr>Mo                    |  |  |  |                            |
| H   | --   | Ag>Cu>Au>As>Co>Be=Bi>Ti>Mn                         | Sr>Y>Cr>Ba>B>La>Ni>Mo>Mn                           | As>Pb>Mo>Ag>Cd>Zn>Sb                               | W>Sn>Be>Cr>Nb>B>Ti>Zr>Bi>Mn=Pb                       |  |  |  |                            |
| Tract A-Hells Canyon-Seven Devils-Rapid River |  |  | Tract E-Suture Zone                                |  |  |  |  |  |                            |
| Tract B-Cuddy Mtn                             |  |  | Tract F-Warren                                     |  |  |  |  |  |                            |
| Tract C-Sturgill Peak                         |  |  | Tract G-Yellow Pine-Stibnite                       |  |  |  |  |  |                            |
| Tract D-Council Mtn                           |  |  | Tract H-Big Creek-Edwardsburg                      |  |  |  |  |  |                            |





**EXPLANATION**





- 
 Mafic to intermediate plutons (Triassic, Jurassic, and Cretaceous)
- 
 Zone of slightly elevated element concentration in rock samples; mostly delineates patterns of hydrothermal alteration and distribution of favorable lithologies
- 
 Zone of high element concentration in rock samples; sample often contains ore minerals or gossan
- 
 Sample site--various symbols are shown at sample sites and represent element values or ranges of values as explained in the histogram

Figure 12. Geochemical map and histogram showing the distribution and abundance of copper in rock samples from tract A.

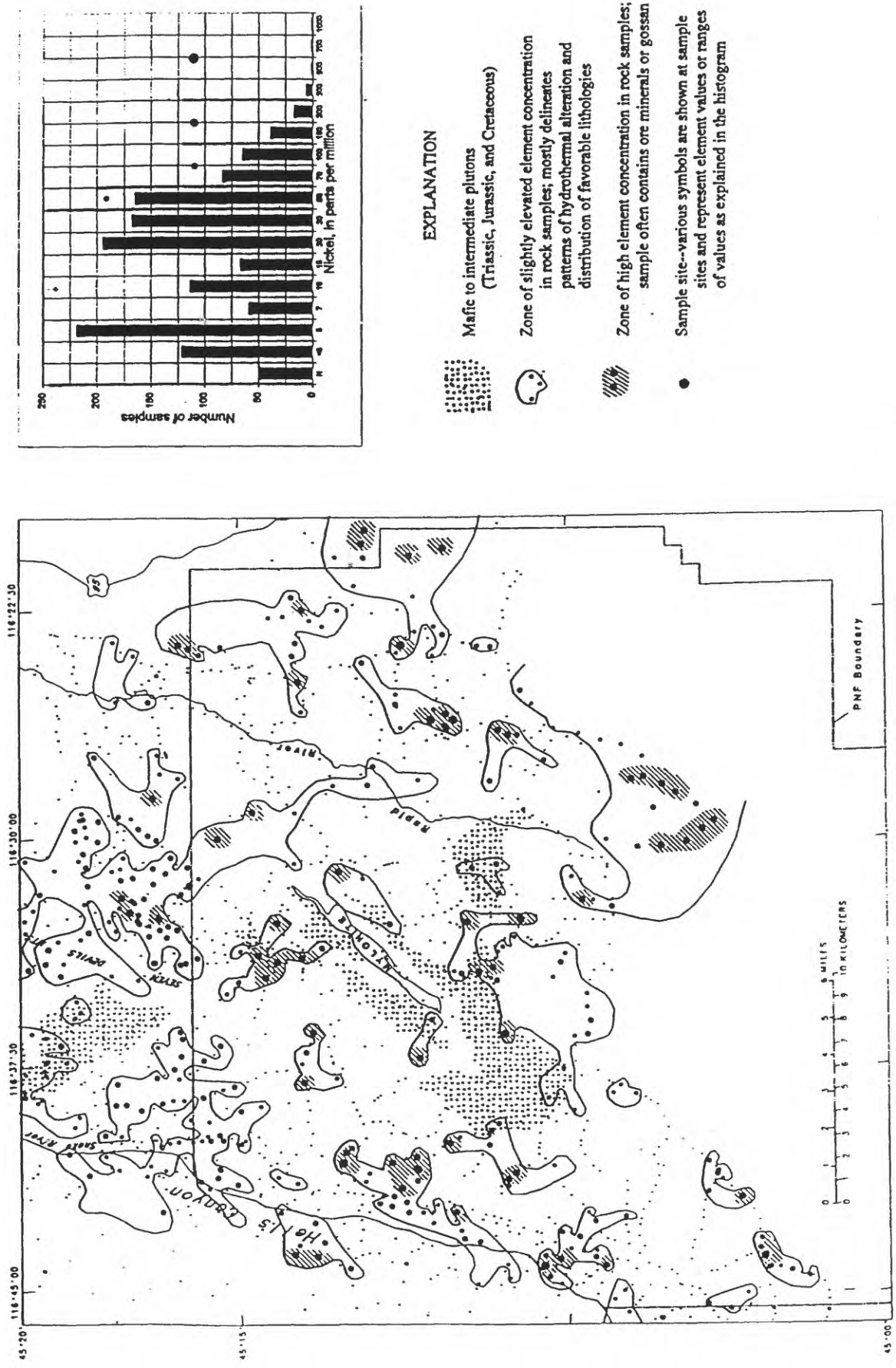


Figure 13. Geochemical map and histogram showing the distribution and abundance of nickel in rock samples from tract A.

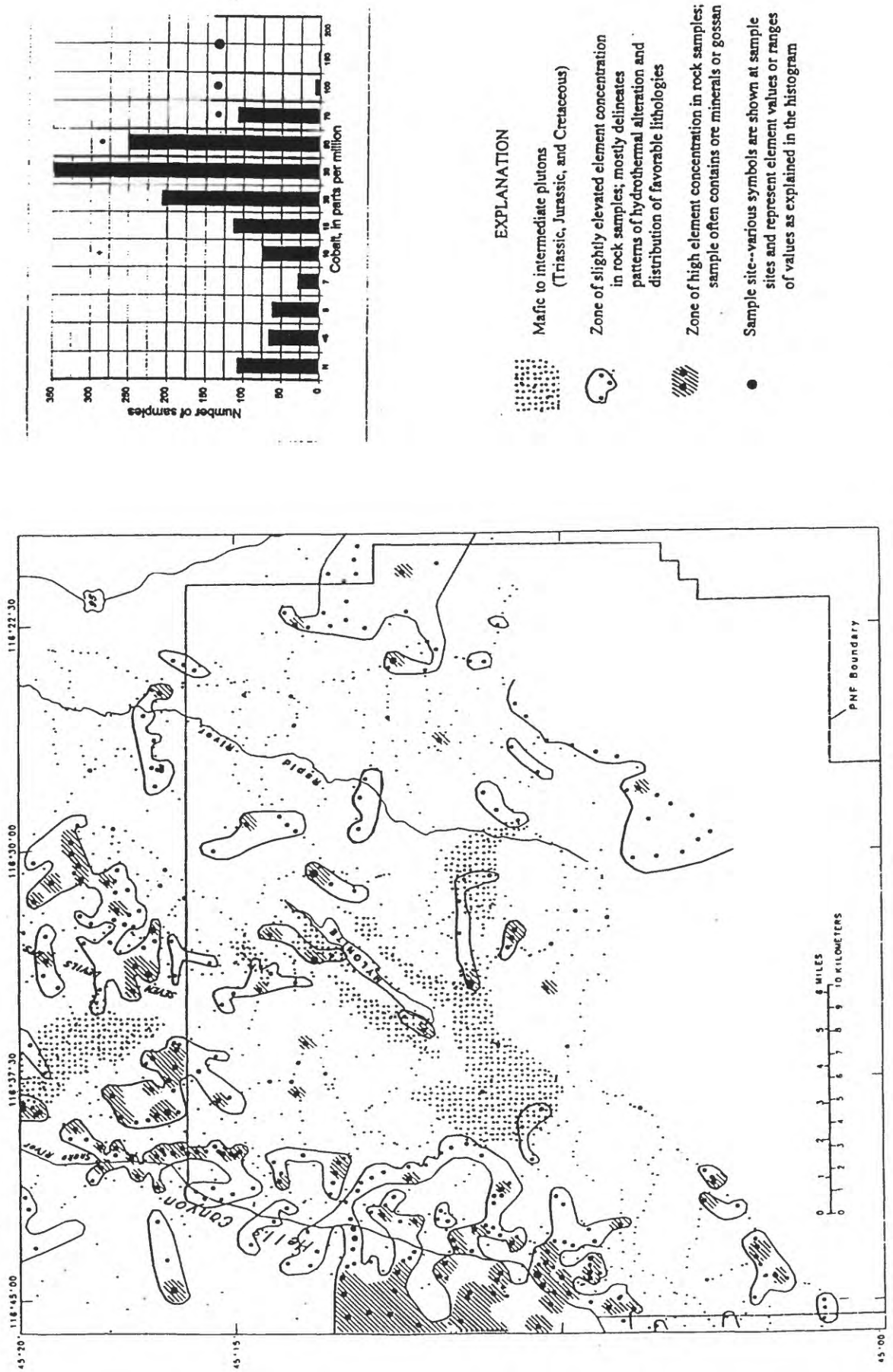


Figure 14. Geochemical map and histogram showing the distribution and abundance of cobalt in rock samples from tract A.

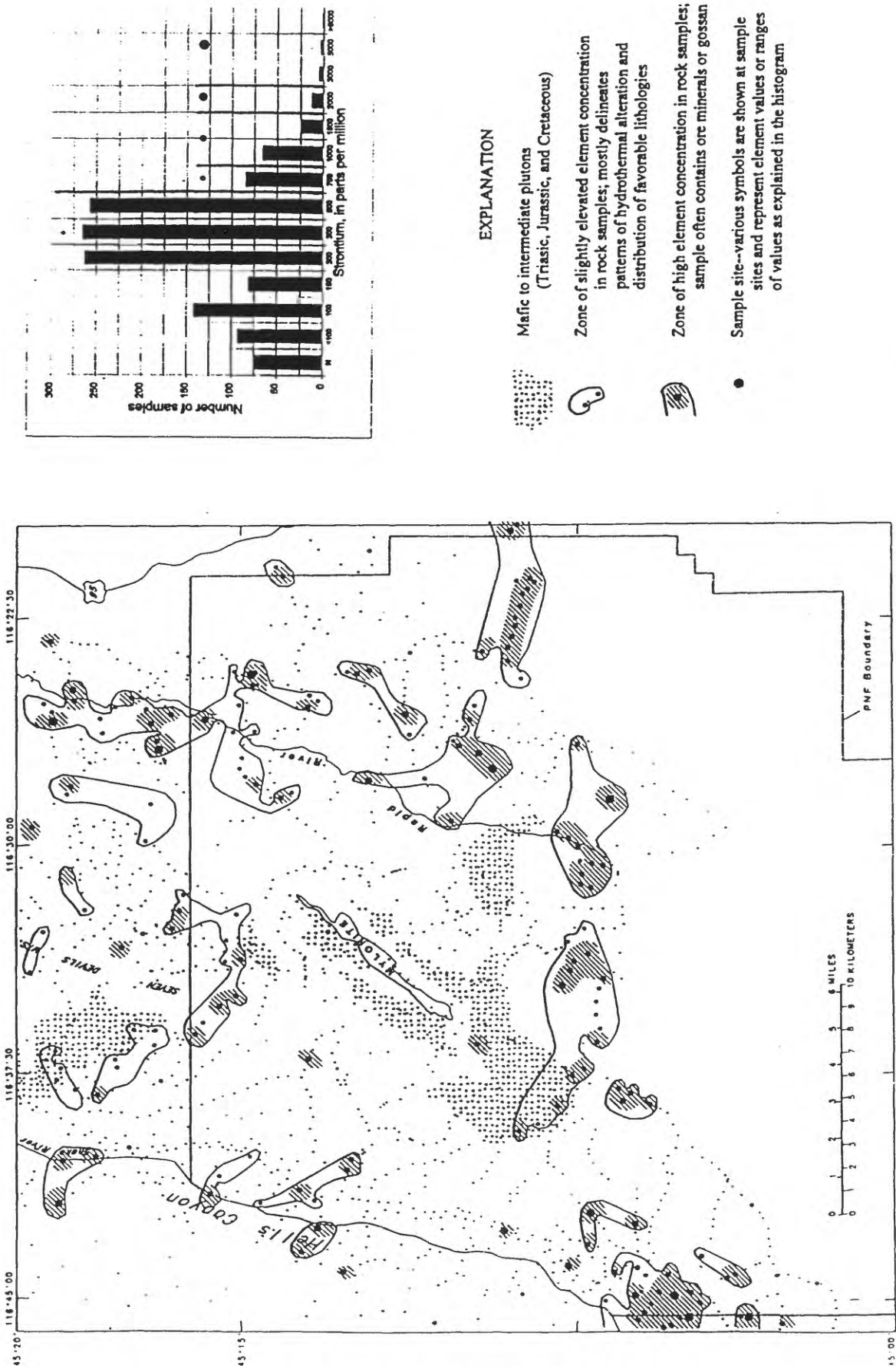


Figure 15. Geochemical map and histogram showing the distribution and abundance of strontium in rock samples from tract A.

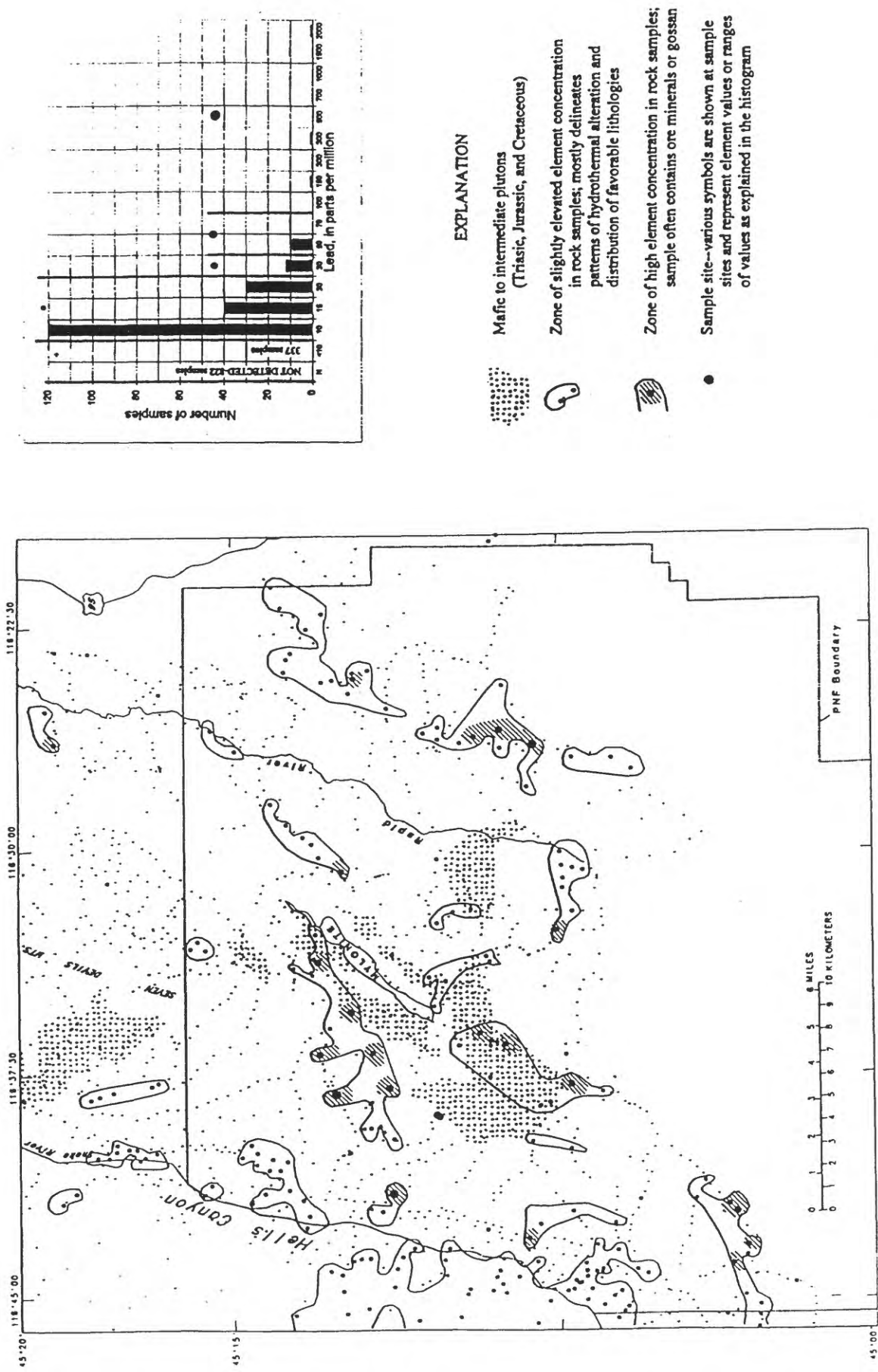
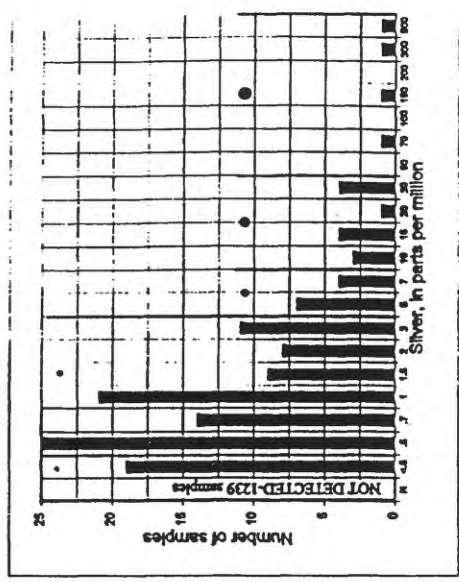
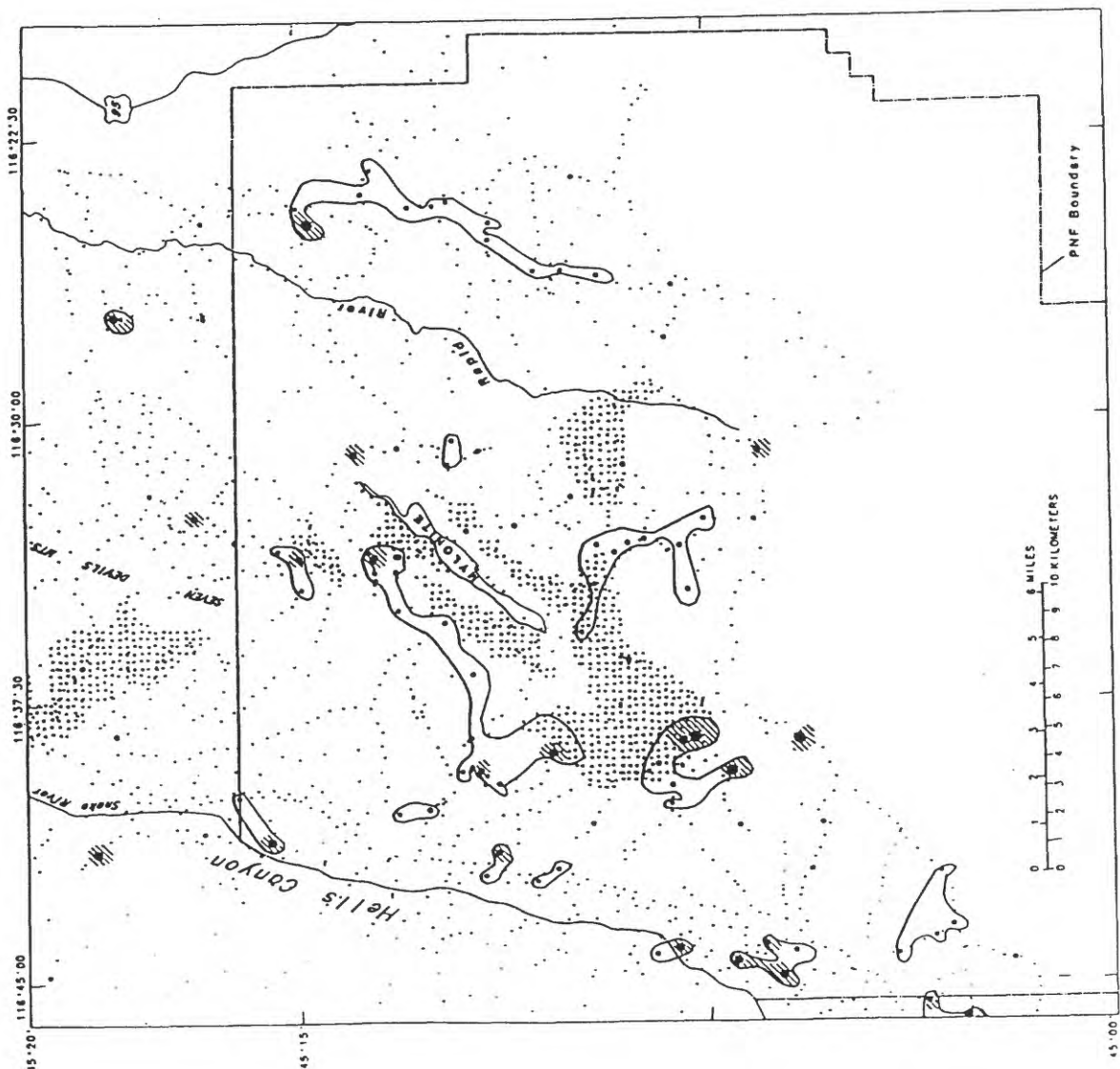


Figure 16. Geochemical map and histogram showing the distribution and abundance of lead in rock samples from tract A.



**EXPLANATION**





-  Mafic to intermediate plutons (Triassic, Jurassic, and Cretaceous)
-  Zone of slightly elevated element concentration in rock samples; mostly delineates patterns of hydrothermal alteration and distribution of favorable lithologies
-  Zone of high element concentration in rock samples; sample often contains ore minerals or gossan
-  Sample site—various symbols are shown at sample sites and represent element values or ranges of values as explained in the histogram

Figure 17. Geochemical map and histogram showing the distribution and abundance of silver in rock samples from tract A.

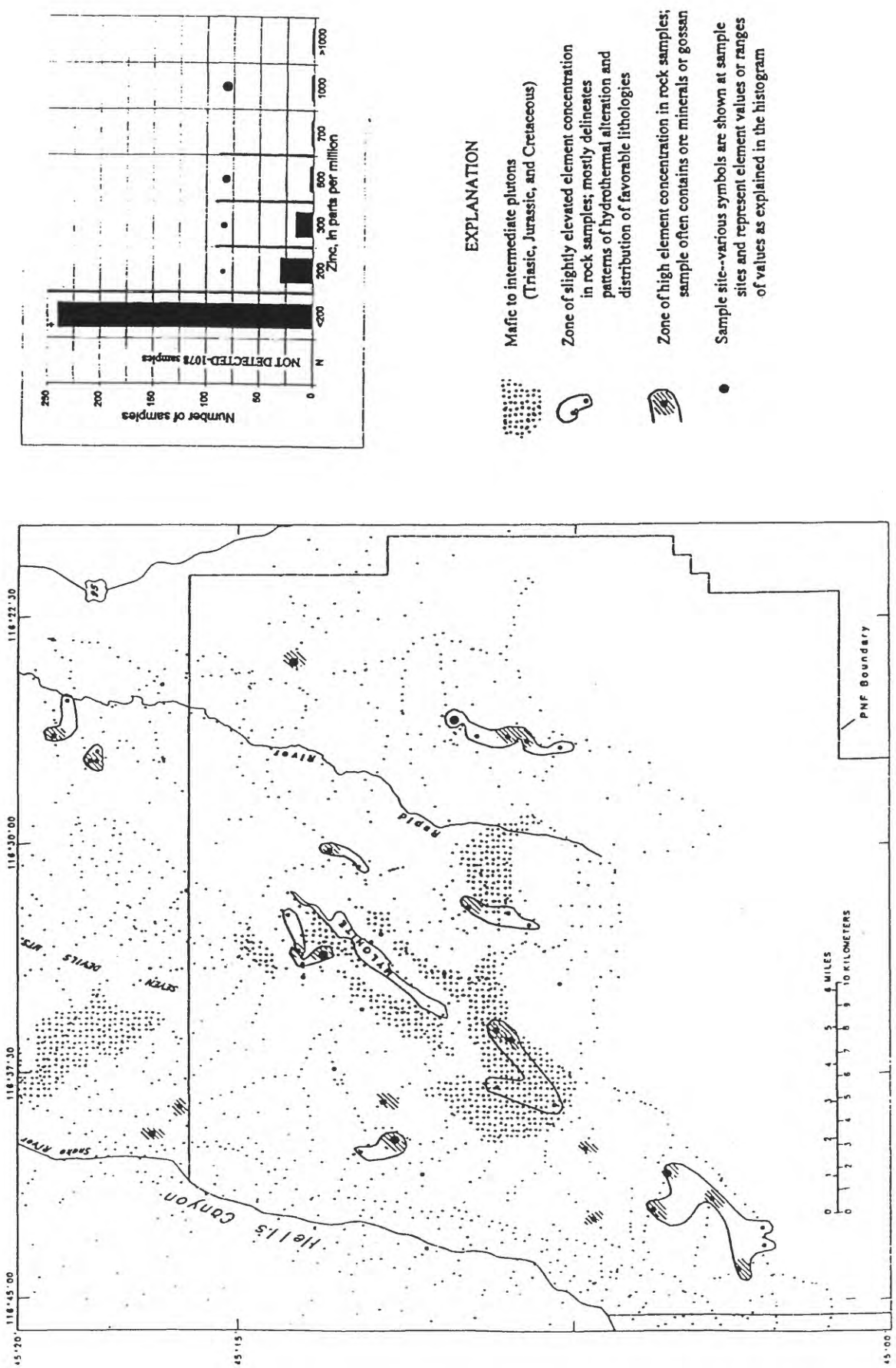
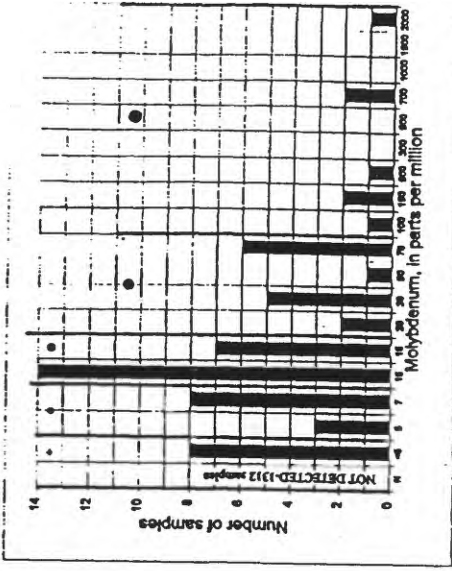
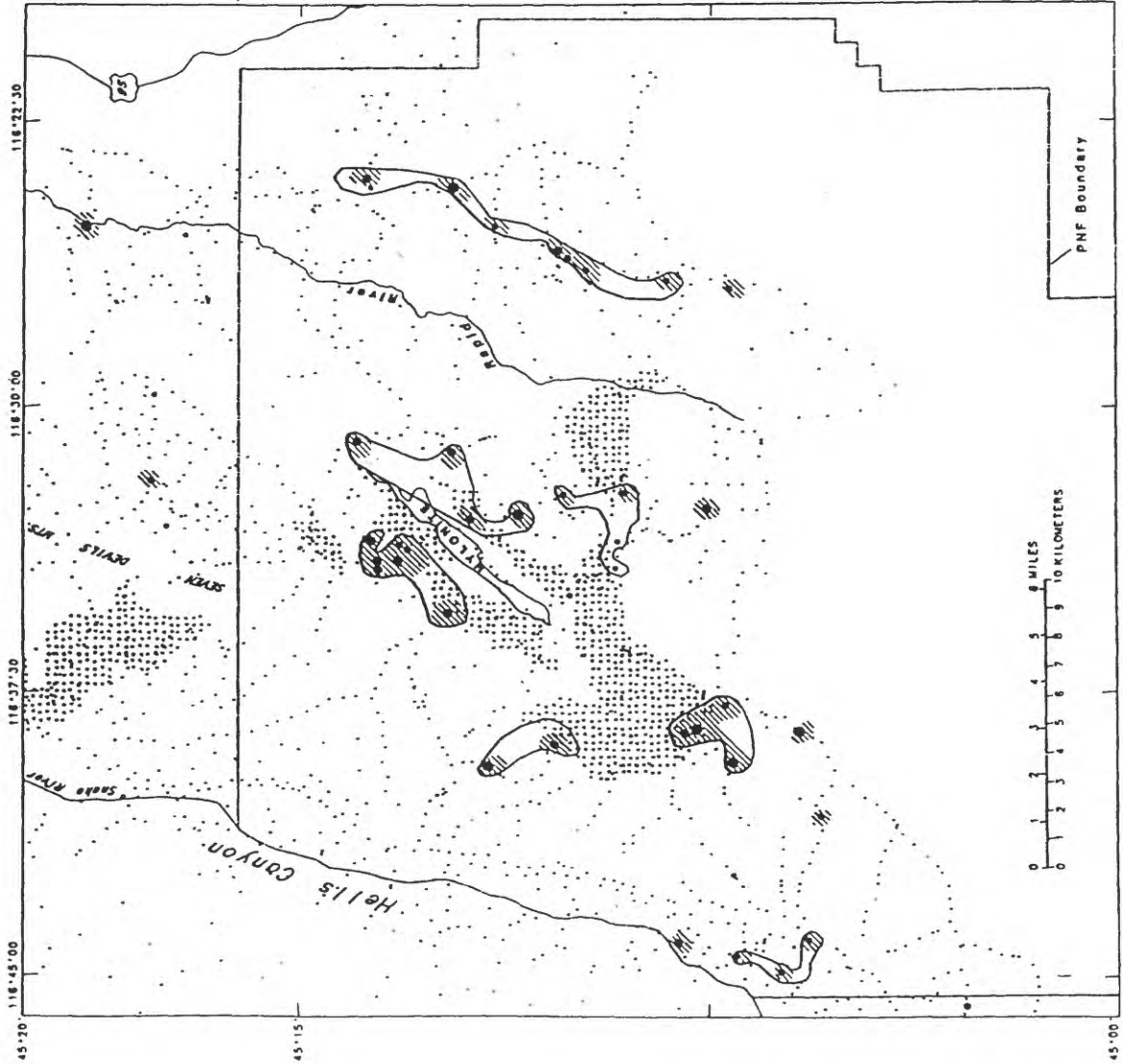


Figure 18. Geochemical map and histogram showing the distribution and abundance of zinc in rock samples from tract A.



EXPLANATION





-  Mafic to intermediate plutons (Triassic, Jurassic, and Cretaceous)
-  Zone of slightly elevated element concentration in rock samples; mostly delineates patterns of hydrothermal alteration and distribution of favorable lithologies
-  Zone of high element concentration in rock samples; sample often contains ore minerals or gossan
-  Sample site--various symbols are shown at sample sites and represent element values or ranges of values as explained in the histogram

Figure 19. Geochemical map and histogram showing the distribution and abundance of molybdenum in rock samples from tract A.



Other relevant key elements that were plotted on figures 15-19 include: Ag, Mo, Pb, Sr, and Zn. Tungsten and gold, both elements of interest in the area, were not found in a sufficient number of samples to warrant map plots. Mafic to intermediate composition plutons (shown on the geochemical maps, figures 12-19; after Gaston and Bennett, 1979) and the wall rocks surrounding these plutons are the focus for many of the geochemical anomalies. A northeast trending mylonite zone, located near the center of tract A, probably represents a major shear or fracture zone and seems also to control a northeasterly trend of sporadic rock geochemical anomalies (for example, zinc). Copper-nickel-cobalt distributions delineate specific lithologic units that could host volcanogenic massive sulfide deposits. Zinc, silver, and lead appear to be skarn-related. Barium and strontium probably delineate zones of sulfate-rich metasedimentary rocks, specifically evaporite deposits. Strontium can be a particularly useful pathfinder element for evaporites because it is a measure of marine salinity at the time the sedimentary rocks were deposited.

Multi-element anomalies, usually dominated by copper, are associated with the following nearby geographic features: (1) Pepperbox Hill, (2) Echols Mt., (3) Ant Butte-Cold Springs Saddle, (4) the town of Cuprum, (5) Allison-Eckels Creek, (6) Monument Peak, (7) Boulder-Huntley Creek, and (8) adjacent to the Snake River.

## **Tract B-Cuddy Mt.**

### **Mineral deposits**

Known deposits include magmatic Fe and Cu in Permian and Triassic island arc gabbro, epigenetic porphyry Cu-Mo, Cu-Mo-tourmaline breccia pipe, Fe-skarn, and epithermal veins in volcanic rocks of island-arc terrane (Bookstrom and others, 1998; Bruce, 1971). This tract has similar mineral deposit environments to tract A.

### **Geochemical signature**

Statistical analyses of stream-sediment concentrate data (table 6) using the REM program (VanTrump and Alminas, 1978) show that the dominant associations are: (1) Fe, Cu, Ni, and As dispersed in clay-silt-size materials, (2) Cr, Co, Ni, and Fe in coarser silt-sand-size materials, (3) Cu-Zn and Cd, that precipitated either from groundwater seepages or directly from stream water, and dominating the more readily available metals in such materials as amorphous Fe-Mn oxyhydroxides in stream sediment, and (4) Pb, Ag, Ni, Co, and Ba dispersed in the heavy detrital fraction of stream sediments, probably as relatively unweathered Pb-Ag minerals, pyrite, and barite.

The Cu-Mo tourmaline breccia pipe near Cuddy Mt. (Bruce, 1971) is small and would be expected to produce a very limited geochemical signal. The most diagnostic geochemical signal from a deposit of this type is boron, which indicates the presence of tourmaline. As discussed under the regional geochemistry section, some of the plumbing system for these pipes may have been delineated by Zn-Mo anomalies along a north-trending linear zone east of Cuddy Mt.

## **Tract C-Sturgill Peak**

### **Mineral deposits**

Known deposits include island-arc sedimentary-volcanic and plutonic associations as in tracts A and B. Skarn mineralization associated with plutons is the principle type of deposit in this area and most of these deposits are on the western edge of the PNF. The skarn is developed in marble of the Martins Bridge limestone-marble unit of the Permian and Triassic Seven Devils Group. Iron skarn deposits formed where the host-rock consists of mafic volcanic rocks.

### **Geochemical signatures**

Statistical tests of stream sediment and stream-sediment concentrate data (table 6), using the REM program (VanTrump and Alminas, 1978) provide the following inferences: (1) the fine-silt and clay size materials contain dominant amounts of Fe, Mn, and As, suggesting that these elements were deposited from solution onto the surface of the stream sediments of the area, (2) the E-spec analyses show a similar signature to that of tract B; (3) the readily extractable metals in the area are dominated by Cd, followed by Mo, Zn, Cu, and As (mobilization of Cd, to the extent that it is scavenged in amorphous iron sites, generally requires the breakdown of sphalerite); (4) Ba, B, Pb, Sr, and Mo in the heavy detrital minerals is a direct reflection of the known mineral deposits and indicates that barite and (or) Ba-Sr carbonate minerals are important constituents along with tourmaline, galena, and probably molybdenite, or possibly secondary minerals of Pb and Mo, such as wulfenite.

## **Tract D-Council Mtn.**

### **Mineral deposits**

Metallic mineral deposits are not reported from this area. However, this tract contains anomalies of some of the same elements that characterize tracts B and C. Thus, undiscovered mineral deposits similar to those in tracts B and C could be present. Deposits typical of the suture zone might be expected (see tract E below).

### **Geochemical signature**

The following inferences are based on statistical (REM) analysis of the stream sediment and heavy-mineral concentrate data sets (table 6) from tract D: (1) Fe, Cu, As, and Ni similar to tract B probably represent a mafic rock-massive sulfide association, (The signature differs in also containing rare earth elements and P related to monazite deposited in the suture zone.); (2) Cr, As, Co, and Ni in E-Spec data are probably a signature similar to (1), ( The presence of arsenic in the first assemblages indicate they are not strictly lithologic but include sulfide and arsenic-rich phases.); (3) Cd, Cu, Pb, and Zn is another mineralization signature, (Dominance of Cd suggests breakdown of sphalerite.); (4) Pb, Co, Ni, Cu, and Zn in heavy detrital minerals is due to the dispersion of ore minerals into the drainage basin; (5) Similar to tract B, zinc is dispersed in stream water, probably as a result of sphalerite breakdown, as suggested by the association in (3)

above.

## **Tract E-Suture Zone**

### **Mineral deposits**

Known deposits in this tract include chromite pods related to ultramafic rocks, diamond placers related to lamproite pipes, and gold, garnet, and monazite placers (Bookstrom and others, 1998).

### **Geochemical Signature**

(1) Statistical (REM) analysis of the NURE stream sediment data (table 6) suggests a REE-phosphate association, that is probably related to the REE-enriched placers known within the suture zone. (2) The association Sr>Fe>Y>Mn>Cr>Ni>La>Co>Ba may be related to carbonate minerals and suggests carbonatite-lamproite-ultramafic sources. (3) Gold is present in this tract, reflecting the widespread distribution of weakly anomalous levels of gold in several stream samples from the area. (4) The heavy mineral association of Nb>Mo>Ti>Zr supports the premise mentioned above in (2) of a carbonatite source for these geochemical signatures. Niobium is often diagnostic because of its frequent enrichment in lamproites and carbonatite complexes.

## **Tract F-Warren District**

### **Mineral deposits**

Quartz vein deposits in dilatant Proterozoic metasedimentary roof pendants of the Yellowjacket Formation lie above the syenite of the Ramey Ridge plutonic complex. These veins provided gold for placer deposits, which were exploited in the Warren district (Reed, 1937, p. 26).

### **Geochemical signature**

(1) Stream-sediment data show Ag>Au>Ce for the placers of the tract (table 6). (2) The dominant elements are W>Ag>Y>La>B>Sr>Ba>Nb. From this we infer that possible sources may include: tungsten skarn and vein deposits, REE veins, quartz-tourmaline veins, veins with carbonate and (or) barite gangue, and possible carbonatite (Nb). (3) Some results suggest that a significant amount of arsenic is being sequestered by hydrous Fe-Mn oxides in this part of the PNF. Map plots of arsenic in stream sediments show it to be very widespread in anomalous concentrations within this tract. (4) Silver dominates the metals enriched in heavy mineral concentrates, followed by titanium (probably as sphene or rutile from veins and as accessories in the Ti-rich Ramey Ridge syenite). A pegmatitic or peralkaline granite (syenite) source is also suggested for the suite Zr, Ni, La, Nb, Th, and Be that also characterizes the heavy mineral suite in the tract.

## **Tract G-Yellow Pine-Stibnite**

### **Mineral deposits**

This tract contains veins and skarns related to the Idaho batholith, to the Ramey Ridge syenite pluton, and to shear-zone related deposits, skarn deposits, and antimony veins.

### **Geochemical signature**

(1) Statistical analysis (table 6) of NURE stream sediment data shows a geochemical signature that might be expected for some of the known deposits in the tract. Lithium is clearly anomalous and appears high up in the ranking of elements. Speculatively, the source of this lithium is sheet silicates (micas) associated with pegmatites, granites, or greisens. (2) The E-spec association suggests carbonate-REE vein sources (indicated by Y, Sr, Fe, and La) along with barite, tourmaline, and Be and Nb minerals. (3) As also found in tract F, arsenic is very widespread in the stream sediments of tract G and is probably concentrated in the Fe-Mn hydroxides where it is readily available for extraction and detection by the ICP-AES method. Unlike tract F however, Pb and Mo are closely associated with the arsenic in this tract, whereas in tract F, arsenic is part of the Ag-Au suite. (4) The heavy mineral concentrate signature from this area suggests a mineral association typically found in high temperature veins and associated skarn. The high ranking of Bi in the suite suggests the possibility that bismuthinite is present in the samples, along with arsenopyrite, cassiterite, scheelite, and tourmaline. The close association of these veins to peraluminous granite or the syenite of Ramey Ridge is suggested by the presence of Ti, Nb, and Mo in the heavy mineral association.

## **Tract H-Big Creek-Edwardsburg**

### **Mineral deposits**

Deposits types in this tract include Au-Ag-Cu quartz veins and mineralized shear zones and skarns related to the Proterozoic Ramey Ridge syenite complex (Leonard, 1963) and overlying roof pendants of metasedimentary rocks of the Precambrian Yellowjacket Formation.

### **Geochemical signature**

Geochemical signatures in this tract (table 6 ) reflect the composition of the Ramey Ridge syenite pluton and the associated hydrothermal mineralization and skarn. There appears to be a zonal distribution of metals between the Yellow Pine area, also associated with the Ramey Ridge complex, and the Big Creek area.

(1) Statistical study of the NURE stream sediment geochemistry indicates the association Ag>Cu>Au>As>Co which reflects the association of gold-chalcopyrite-arsenopyrite-pyrite in the mineral deposits (Cater and others, 1973). (2) Hydrothermal carbonate (Sr-Y-Mn), barite (Ba), and tourmaline (B) are reflected in the E-Spec fraction of the stream-sediment samples. (3) Arsenic again is the dominant element in the readily extractable fraction (Fe-Mn hydroxides) of the stream-sediment samples consistent with the other tracts within the Idaho batholith portion of

the PNF. Antimony is a significant part of the anomalous suite in this tract, in contrast to the other tracts in the PNF, probably reflecting antimony veins in the area. (4) The elements of prominence in the heavy- mineral-concentrate samples (W>Sn>Be>Cr>Nb>B>Ti) directly indicate the mineralogical composition of the Ramey Ridge syenite pluton and the mineralized zones surrounding it. Minerals in the heavy mineral concentrates from the area include scheelite (W), cassiterite (Sn), a beryllium mineral of probable skarn origin (possibly helvite, a common skarn mineral containing Be and Mn), tourmaline (B), rutile (Nb, Ti), zircon, and a bismuth mineral (bismuthinite?).

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