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Geochemical studies in the Stensgar Mountain quadrangle,
Stevens County, Washington

by

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Introduction

The Stensgar Mountain quadrangle is 60 km north-northwest of Spokane, Wash., and 10 km west of the town of Valley (fig. 1). The study area, is near the middle of the northeast-trending "magnesite belt," which was named by Weaver (1920, p. 319) for its deposits of crystalline magnesite. The quadrangle contains a section of the Middle Proterozoic Deer Trail Group, the Middle and Late Proterozoic Windermere Group and Lower Cambrian strata (fig. 2). The quadrangle was included in the geologic map of the magnesite belt by Campbell and Loofbourow (1962, pl. 1) and was mapped in detail by Evans (1987).

The Middle Proterozoic Deer Trail Group consists of at least 4,000 m of sedimentary rocks divided into the following formations, listed from oldest to youngest: Togo Formation (slate, siltite, quartzite), Edna Dolomite, McHale Slate, Stensgar Dolomite, and Buffalo Hump Formation (slate, quartzite, conglomerate). These rocks have been correlated with the Priest River Group east of Metaline Falls, 80 km northeast of the Stensgar Mountain quadrangle (Becraft and Weis, 1963, p. 16), and with part of the Belt Supergroup 15 km east of the quadrangle (Campbell and Loufbourow, 1962, p. F20; Miller and Clark, 1975, p. 18).

The Middle and Late Proterozoic Windermere Group overlies the Deer Trail Group along a thrust fault and consists of at least 1,600 m of sedimentary and volcanic rocks divided into the following formations: the older Huckleberry Formation (a lower conglomerate, an upper basalt flow, and basaltic tuff), and the younger Monk Formation (slate, dolomite, conglomerate). Gabbro and metabasalt feeder dikes of the volcanic rock member of the Huckleberry Formation intruded the Deer Trail Group and the conglomerate member of the Huckleberry Formation. Intrusion of the gabbro and metabasalt dikes produced low-grade contact metamorphism in narrow aureoles in the Deer Trail Group.

Lower Cambrian strata in the quadrangle, totaling 2,540 m, unconformably overlie the Windermere and Deer Trail Groups, and consist of Addy Quartzite and the Old Dominion Limestone of Weaver (1920). After deposition of the Paleozoic rocks, the section from Togo Formation through Addy Quartzite underwent greenschist-grade regional metamorphism, probably as a result of deep burial.

The entire Deer Trail Group is enclosed in a Late Triassic to Cretaceous duplex thrust with the Lane Mountain thrust as the floor thrust and the Stensgar Mountain thrust as the roof thrust. Contemporaneously with thrusting, the rocks were subjected to greenschist-facies dynamothermal metamorphism during which slaty cleavage formed in the predominantly argillaceous Deer Trail Group and the conglomerate member of the Huckleberry Formation and folding occurred in the Proterozoic rocks and the Addy Quartzite. During this metamorphism most sedimentary sections were thinned, and bedding and older faults were rotated parallel to the cleavage.

The Deer Trail Group in the Stensgar Mountain Quadrangle was intruded by a few felsic dikes in the Mesozoic and Tertiary and by andesite dikes, possibly

in the Tertiary. The aeromagnetic highs shown on figure 2 probably reflect Mesozoic plutons concealed beneath the Lower Cambrian and Proterozoic strata.

Known Resources Magnesite

Magnesite was the principal commodity mined in the study area (fig. 2, deposits indicated by "Mg"). Present economic demand for these deposits is nil because magnesium compounds are now derived mostly from dolomite, seawater, and brines (Bodenlos and Thayer, 1973, p. 380). The deposits of the area are described in detail by Campbell and Loofbourow (1962, p. F36-F46). All of them occur in the Stensgar Dolomite.

Campbell and Loofbourow (1962, p. F39-F40) summarized the history of the magnesite industry in Stevens County. The magnesite deposit at the Keystone Quarry, was originally worked in the early 1900's as a marble quarry. Later, the demand for domestic sources of refractory-grade magnesite for use in manufacturing steel during World War I led to discovery and development of the magnesite deposits. Production continued until after World War II. A total of 6.75 million tons of magnesite may have been mined (Campbell and Loofbourow, 1962, p. F40-F46, and assuming only half the magnesite originally at Red Marble Quarry was mined). The magnesite belt may still contain another 2 to 5 million tons of magnesite.

Previous work summarized by Campbell and Loofbourow (1962, p. F36-F38) favored a hydrothermal origin for the magnesite deposits. Campbell and Loofbourow proposed that magnesitization accompanied or followed dedolomitization of the Edna or parts of the Stensgar Dolomite. The magnesium produced by dedolomitization was transported by hydrothermal solutions to parts of the Stensgar Dolomite and deposited there as magnesite. The low content of pelitic and silicic impurities in the host dolomite has been suggested as a controlling factor in localizing the deposits (Schroeder, 1948). Campbell and Loofbourow suggested that the magnesite must have been deposited after the regional deformation because the magnesite lacks folds and large faults, and, therefore, must be hydrothermal in origin. The study of joints in the magnesite of the Red Marble Quarry by Thole and Mills (1979, p. 154) suggests that the magnesite-bearing veins there developed during or subsequent to emplacement of the nearby Loon Lake batholith, dated at 93-63 Ma, or Cretaceous, by Ludwig and others (1981, p. 96-98, Pb/U, Pb/Th, and fission track methods) and is consistent with a hydrothermal origin. However, hydrothermal activity in the Stensgar Mountain quadrangle is probably older than Cretaceous as the Lane Mountain pluton in the adjacent Waitts Lake quadrangle was dated at 161 Ma (Miller and Engels, 1975), or Middle Jurassic.

The evidence cited above may be interpreted another way. If the magnesite-bearing veins and other replacement features were formed by late hydrothermal redistribution of the magnesite, then the veins provide little information about the origin of the magnesite. The strain history of the magnesite is partly related to its competence and provides no clear information regarding the relative age of the magnesite with respect to regional deformation, contrary to what Campbell and Loofbourow (1962) suggested. Parts of the Edna Dolomite are as free of pelitic and silicic

impurities as the Stensgar Dolomite, and moderately pure dolomite is also present in the Togo and Monk Formations. If purity of the host dolomite was a major ore control, it is not clear why the Stensgar Dolomite is the only dolomitic unit to contain magnesite deposits. The veins of quartz, barite, and copper-bearing minerals (chalcopyrite, azurite, malachite) in the Edna Dolomite indicate that hydrothermal solutions had access to this unit, but magnesite was not deposited in these rocks.

Kinsman (1967), when describing an occurrence of huntite $[\text{CaMg}_3(\text{CO}_3)_4]$ from a carbonate-evaporite environment along the Persian Gulf, suggested that some magnesite may have formed from huntite precipitated during early diagenesis. If his suggestion is applied to magnesite in the Stensgar Dolomite, it would help explain this unique occurrence of magnesite in the Deer Trail Group. Fox and Rinehart (1968), who studied magnesite deposits in Triassic rocks of northern Okanogan County, Wash., concluded that the deposits were sedimentary in origin because of their wide distribution, restriction to a narrow stratigraphic interval, and interlayering with other sedimentary rocks. Similar reasoning applied to the Deer Trail Group suggests that the magnesite deposits of Stevens County may also have had a sedimentary (or diagenetic) origin. However, until a detailed study of the magnesite deposits is made, a hydrothermal origin for the magnesite cannot be ruled out.

Barite

Barite veins (fig. 2, deposits indicated by "Ba") occur in the quadrangle in Edna Dolomite, in slate, and in magnesitized Stensgar Dolomite. Shipments of barite were made from veins in the magnesite belt southwest of the study area (Valentine, 1949). Barite production was recorded from within the Stensgar Mountain quadrangle (Bunning, 1984, table 4, p. 11; 1983, table 4, p. 10; see David Beck Co.).

Copper

Copper is the principal metal at the Edna and Admiral Mines (fig. 2, deposits indicated by "Cu"), both in the Edna Dolomite (fig. 2). Shipment (three "cars") of copper ore is recorded from the Edna Mine (Weaver, 1920, p. 181-182).

Antimony

Antimony, in stibnite, occurs at the Wells Fargo Mine (fig. 2, deposit indicated by "Sb") in quartz veins in slate of the Buffalo Hump Formation. One small ore shipment was made (Purdy, 1951). Another antimony deposit occurs 5 km southwest of the study area at the Cleveland Mine (Campbell and Loofbourow, 1962, p. F46).

Rare Minerals

Rare minerals found at the Wells Fargo Mine are described by Lasmanis (1983), who cited past minor lead, silver, and antimony production from the mine. The rare minerals include zinkenite $[\text{Pb}_6\text{Sb}_{14}\text{S}_{27}]$, jamesonite $[\text{Pb}_4\text{FeSb}_6\text{S}_{14}]$, gearksutite $[\text{CaAl}(\text{OH})\text{F}_4\cdot\text{H}_2\text{O}]$, and robinsonite $[\text{Pb}_9(\text{Sb},\text{Bi})_{12}\text{S}_{27}]$. Gold, copper, and arsenic have also been detected at the mine. In the late 1960's the zinkenite was stockpiled for sale as mineral specimens.

Geochemical studies

Methods

During geologic mapping, 62 rock, 41 stream-sediment, and 13 panned-concentrate samples were collected for analysis. In sampling rock, the most mineralized-looking parts of veins or outcrops were taken to maximize the chances of obtaining detectable quantities of trace elements. The favored sample sites favored contain rock with hematite, pyrite, quartz veins, copper minerals (chalcopyrite, azurite, malachite), or other indications of possible mineralization such as black (manganese?) staining or bleaching. The rock sample sites (fig. 2) crudely outline the areas of visible alteration and mineralization (exclusive of magnesitization) in the quadrangle. The main belt of mineralization (Ag, As, Au, Ba, Cu, Hg, Pb, Sb, and Zn) trends northeastward from the preospects south of the Wells Farge Mine to the vicinity of the Wabash-Detroit Mine (fig. 2). It is about 3 km wide from the Red Marble Quarry on the northwest to the Admiral Mine on the southeast. Whatever mineral resource potential exists in the quadrangle is most likely south of Huckleberry Creek and east of the crest of Huckleberry Mountain. However, most of the study area is covered by forest and deep regolith, which may conceal mineralized or altered rock.

The rock and stream-sediment samples were analyzed by spectrographic methods (Grimes and Marranzino, 1968) for 31 elements (Ag, As, Au, B, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, La, Mg, Mn, Mo, Nb, Ni, Pb, Sb, Sc, Sn, Sr, Th, Ti, V, W, Y, Zn, and Zr). In addition, the samples were analyzed by atomic absorption methods for gold (Ward and others, 1969) and for mercury (Vaughn and McCarthy, 1964). Uranium analyses of rock samples were by the fluorimetric method (Centanni and others, 1956).

Table 1 of Evans and Peterson (1987) lists the lithologies of the rock samples. Two thirds of the samples are quartz veins, many of them bearing sulfide minerals, especially copper sulfides. Other lithologies, in diminishing proportion, are altered and mineralized dolomite (Stensgar and Edna Dolomites), brecciated and mineralized quartzite (Togo Formation, Edna Dolomite, Buffalo Hump Formation), siltite (Togo Formation), phyllite (Edna Dolomite), leached and silicified Edna Dolomite, a pyrite vein, and a mineralized and quartz veined granitic dike (Edna mine).

Of the elements analyzed, Ag, As, Au, Ba, Cu, Hg, Mn, Pb, Sb, and Zn are discussed in this report because they occur in concentrations significantly greater than crustal abundance or greater than background (table 1).

The background values of Ag, As, Au, Sb, and Zn are less than the lower limits of determination; all samples with measurable concentrations of these elements are plotted on the accompanying figures. Background values of Ba, Cu, Hg, Pb, and Mn are median values determined from histograms. Threshold values for these five elements were obtained by examining the histograms for each of these elements to determine whether a subpopulation of anomalous values occurred in the sample populations. Another method for determining threshold values by finding the nickpoints of log-log cumulative frequency diagrams (Lepeltier, 1969, p. 544-546), did not produce clearly defined values.

Table 1
Background and threshold values of certain elements (Ag, As, Au, Ba,
Cu, Hg, Mn, Pb, Sb, and Zn) in rock and stream sediment samples,
Stensgar Mountain Quadrangle, Stevens County, Washington

| Element | Background | | Threshold | | Percentage of sample population defined as anomalous | |
|-----------|------------|-----------------|-----------|-----------------|--|-----------------|
| | Rock | Stream sediment | Rock | Stream sediment | Rock | Stream Sediment |
| Antimony | <100 | <100 | 100 | -- | 24 | -- |
| Arsenic | < 200 | <200 | 200 | -- | 23 | -- |
| Barium | 150 | 500 | 1,500 | -- | 19 | -- |
| Copper | 150 | 50 | 500 | -- | 32 | -- |
| Gold | <0.05 | <0.05 | 0.05 | -- | 27 | -- |
| Lead | 20 | 30 | 150 | -- | 21 | -- |
| Manganese | 700 | 700 | 1,500 | 1,500 | 24 | 7 |
| Mercury | 0.15 | 0.25 | 0.5 | 0.5 | 24 | 17 |
| Silver | <0.5 | <0.5 | 0.5 | 0.5 | 42 | 5 |
| Zinc | < 200 | <200 | 200 | -- | 29 | -- |

Table 1 summarizes the background and threshold values used in this study and indicates the proportions of the rock and stream-sediment samples that are defined as anomalous. The proportions of anomalous rock samples are much higher than the 2.5 percent that would be obtained using a method suggested by Lepeltier (1969, p. 544-546), because the sample population is already biased towards mineralized rock with expectations of greater than crustal abundance of the elements under study.

Correlations between elements were determined by Spearman's rank-correlation techniques (Siegel, 1956; Lovering, 1963). In this report correlation coefficients greater than 0.50 are significant at 95 percent and higher confidence levels. Elements having statistically significant correlations are given in table 2.

Gold

Anomalous gold values (threshold=0.05 ppm, see table 1) are shown in figure 3. The largest gold value (22.4 ppm) is at the Wells Fargo Mine. Scattered, generally low, gold concentrations occur at prospects, magnesite quarries, and outcrops. The 2.6 ppm gold concentration in the non-magnetic heavy-mineral fraction of a panned-concentrate from a branch of the North Fork Deer Creek, may reflect low gold concentrations in the Red Marble Quarry area. A panned-concentrate from North Fork Huckleberry Creek yielded a non-magnetic heavy-mineral fraction containing 57 ppm gold. This gold could reflect unrecognized mineralization in the drainage, especially as the drainage is on the flank of a small aeromagnetic high that may indicate a concealed granitic intrusion (fig. 2). Caution should be used in assessing the possibility of significant gold concentrations based on these two panned-concentrate samples because the sample weights were very low (0.38 and 0.28 gm, respectively). Clearly non-magnetic heavy minerals are in very low concentration in the stream sediment, and the analytical results obtained here may not be reproducible in another sample. Additional sampling for gold should probably involve processing of large volumes of sediment. Low gold concentrations were found in Addy Quartzite and Togo Formation near the Lane Mountain thrust, suggesting leakage of gold-bearing hydrothermal fluids along the thrust.

Silver

Locations of anomalous silver concentrations (threshold=0.5 ppm) are shown in figure 4. The greatest silver value is at the Double Eagle Quarries (2,000 ppm). Other high concentrations occur at an unnamed prospect about 2 km east of the Double Eagle Quarries (700 ppm) and at the Wells Fargo Mine (70 ppm max). Other scattered silver concentrations are as much as 15 ppm. Two ppm silver occurs in Addy Quartzite near the Lane Mountain thrust and in a stream-sediment sample northeast of the Edna Mine.

Arsenic

Locations of anomalous arsenic values (threshold=200 ppm) are shown in figure 5. The greatest concentration (10,000 ppm, the upper limit of determination) is at an unnamed prospect about 1.5 km northeast of the Wells.

Table 2. Spearman correlation coefficients for the elements
that are statistically correlated with one another,
directly or indirectly, at a confidence level of 95 percent or higher.

| | Correlation Coefficient | Degrees of freedom | Student's t test | Percent confidence level |
|--------|----------------------------|-----------------------|---------------------|--------------------------------|
| Gold | | | | |
| Ba | 0.63 | 134 | 2.91 | 98 |
| Hg | 0.63 | 12 | 2.84 | 98 |
| Silver | | | | |
| Sb | 0.71 | 9 | 3.05 | 98 |
| Copper | | | | |
| Pb | 0.53 | 39 | 3.88 | 99 |
| Hg | 0.56 | 51 | 4.87 | 99 |
| Lead | | | | |
| Zn | 0.59 | 12 | 2.55 | 95 |

Fargo Mine, which itself contains arsenic as much as 7,000 ppm. Other high arsenic concentrations occur at the Edna and Admiral Mines.

Barium

Locations of anomalous barium concentrations (threshold=1,500 ppm) are shown in figure 6. Very high concentrations (greater than 5,000 ppm, the upper limit of determination) occur at unnamed prospects 1.5 km northeast of the Wells Fargo Mine and 3 km and 4 km south of the mine, and at an outcrop about 0.5 km south of the Admiral Mine.

Copper

Locations of samples with anomalous concentrations of copper (threshold=500 ppm) are shown in figure 7. Very high concentrations (greater than or equal to 20,000 ppm, the upper limit of determination) occur at the Edna, Wabash-Detroit, and Admiral Mines, at the Double Eagle Quarries, and at unnamed prospects northeast and south of the Wells Fargo Mine. The Addy Quartzite near the Lane Mountain thrust contains 500 ppm copper.

Mercury

Locations of samples with anomalous concentrations of mercury (threshold=0.5 ppm) are shown in figure 8. Very high concentrations of mercury (greater than 10 ppm, the upper limit of determination) occur at the Double Eagle Quarries, at an unnamed prospect east of the quarries, and at an unnamed prospect northeast of the Wells Fargo Mine. Mercury concentrations between 0.5 and 1 ppm occur in stream-sediment samples in a tributary to North Fork Deer Creek near the Red Marble Quarry, along Cedar Creek and some tributaries, near the Wabash-Detroit and Edna Mines, and in the southwest corner of the quadrangle.

Manganese

Locations of samples with anomalous concentrations of manganese (threshold=1,500 ppm) are shown in figure 9. Very high concentrations (greater than 5,000 ppm, or equal to the upper limit of determination) occur in rocks at and near the Admiral Mine and in the southeast part of the quadrangle northeast of the Middle Fork Deer Creek. Anomalous concentration occur in a stream-sediment samples north of Huckleberry Creek, near the Lane Mountain thrust, and along the south boundary of the quadrangle.

Lead

Locations of samples with anomalous concentrations of lead (threshold=150 ppm) are shown in figure 10. Very high lead concentrations (greater than 20,000 ppm, the upper limit of determination) occur at the Wells Fargo Mine and Double Eagle Quarries.

Antimony

Locations of samples with anomalous concentrations of antimony (threshold=100 ppm) are shown in figure 11. Very high antimony concentrations

(greater than or equal to 10,000 ppm, the upper limit of determination) occur at the Wells Fargo Mine and at an unnamed prospect southwest of the Edna Mine. The Addy Quartzite near the Lane Mountain thrust contains 150 ppm antimony.

Zinc

Locations of samples with anomalous concentrations of zinc (threshold=200 ppm) are shown in figure 12. Very high concentrations (greater than 10,000 ppm, the upper limit of determination) occur at the Wells Fargo Mine.

Summary

Figure 13 summarizes the geochemical data. The areas outlined by dotted lines are drainages in which stream sediments and panned concentrates contain anomalous amounts of Ag, Au, Hg, and Mn. The areas outlined by dotted and dashed lines contain several rock samples rich in Mn. The circles surround sites in which rock samples are especially rich in one or more of the following elements: Ag, As, Au, Ba, Cu, Hg, Pb, Sb, and Zn. Especially high values of several elements occur at the Wells Fargo Mine and Double Eagle Quarries and two unnamed prospects, one 1.6 km southwest of the Edna Mine and the other 1.6 km northeast of the Wells Fargo Mine. Copper is the principal metal at the Admiral, Edna, and Wabash-Detroit Mines. Manganese is in especially high concentrations in two zones that are largely separated from other mineralized areas. Some of the manganese, however, is near some rock samples containing anomalous concentrations of barium.










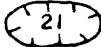




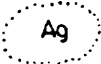
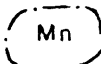

No clear zone of mineralization is indicated by the data although anomalous values of several elements occur in many samples taken from a broad band trending northeast across the center of the quadrangle, confined to the Deer Trail Group. A zone of weak mineralization (Ag, Au, Cu, Hg, Mn, Sb) occurs in rocks near the Lane Mountain thrust (see figs. 3, 4, 7, 8, 9, 11). Some lithological control is suggested by the occurrences of very high copper concentrations in Edna Dolomite at the Admiral, Edna, and Wabash-Detroit Mines and by the occurrence of most gold and silver mineralization higher in the section (and closer to the Stensgar Mountain thrust) in the stratigraphic interval McHale Slate to Buffalo Hump Formation. This apparent control, however, may be more closely related to proximity of the formations to sources of mineralizing solutions. Most of the anomalous values occur in the broad aeromagnetic trough between the two aeromagnetic highs on figure 2 which can be interpreted as concealed plutons. It is not clear from the data whether more highly mineralized rock or broader zones of mineralization are present at depth where the Deer Trail Group, or possibly lower Cambrian rocks beneath the Lane Mountain thrust, would be closer to the plutons.

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EXPLANATION (figures 2-13)

| | |
|---|---|
|  | Old Dominion Limestone of Weaver (1920) |
|  | Addy Quartzite |
|  | Windermere Group Monk Formation |
|  | Huckleberry Formation |
|  | Deer Trail Group |
|  | Contact |
|  | Fault |
|  | Thrust fault, Sawteeth on upper plate. |
|  | Aeromagnetic contour. Contour interval 10 gammas. |
|  | Aeromagnetic low |
|  | Sample type |
|  | Rock |
|  | Stream sediment |
|  | Panned concentrate |
|  | Area containing anomalous concentrations of one or more of the following metals: Ag, silver; Au, gold; Hg, mercury; Mn, manganese. |
|  | Area containing numerous rock samples rich in manganese. |
|  | Sample site containing high concentrations of one or more of the following elements: Ag, silver; Au, gold; Ba, barium; Cu, copper; Hg, mercury; Pb, lead; Sb, antimony; Zn, zinc. |

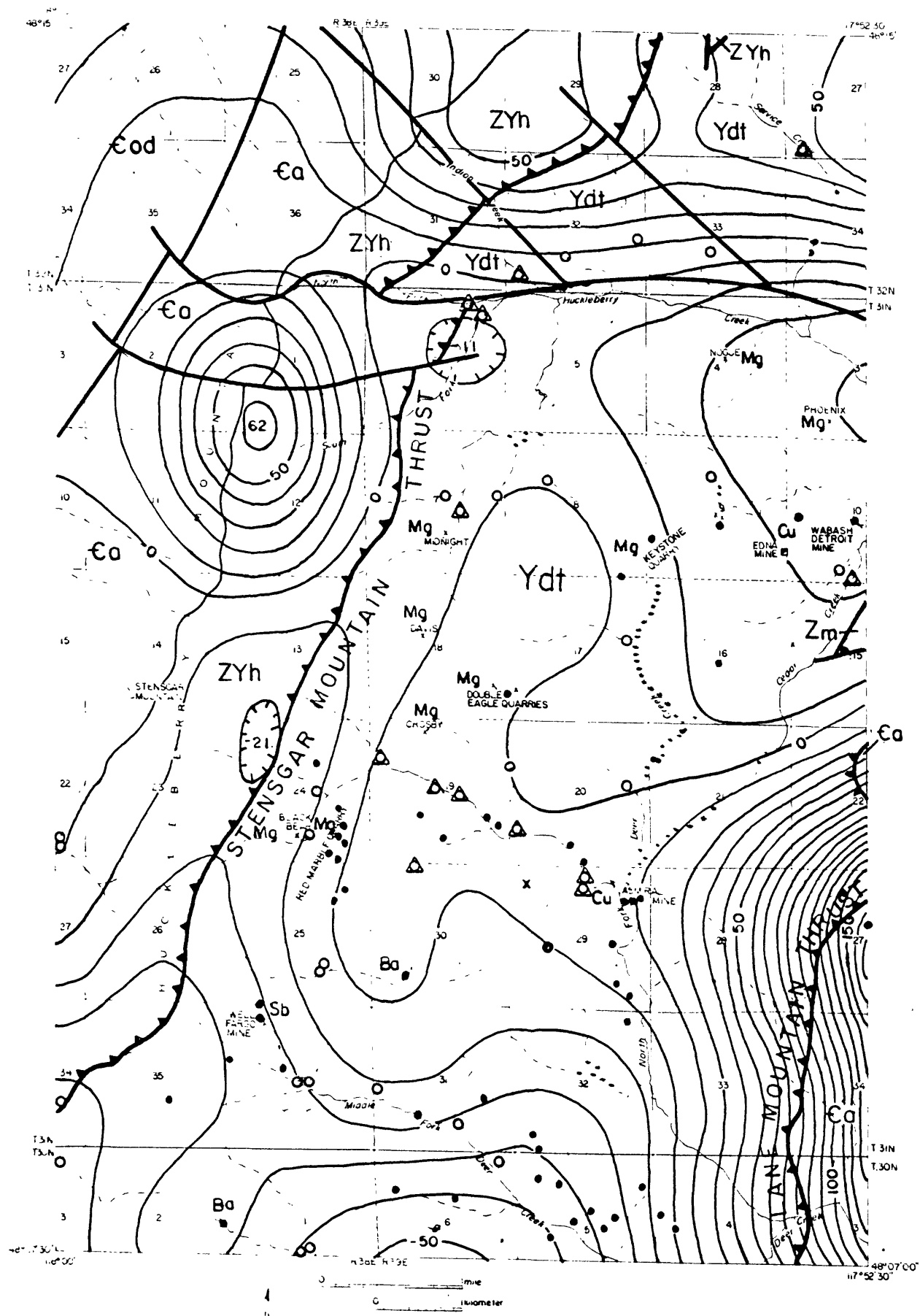


Figure 2. Geologic map.

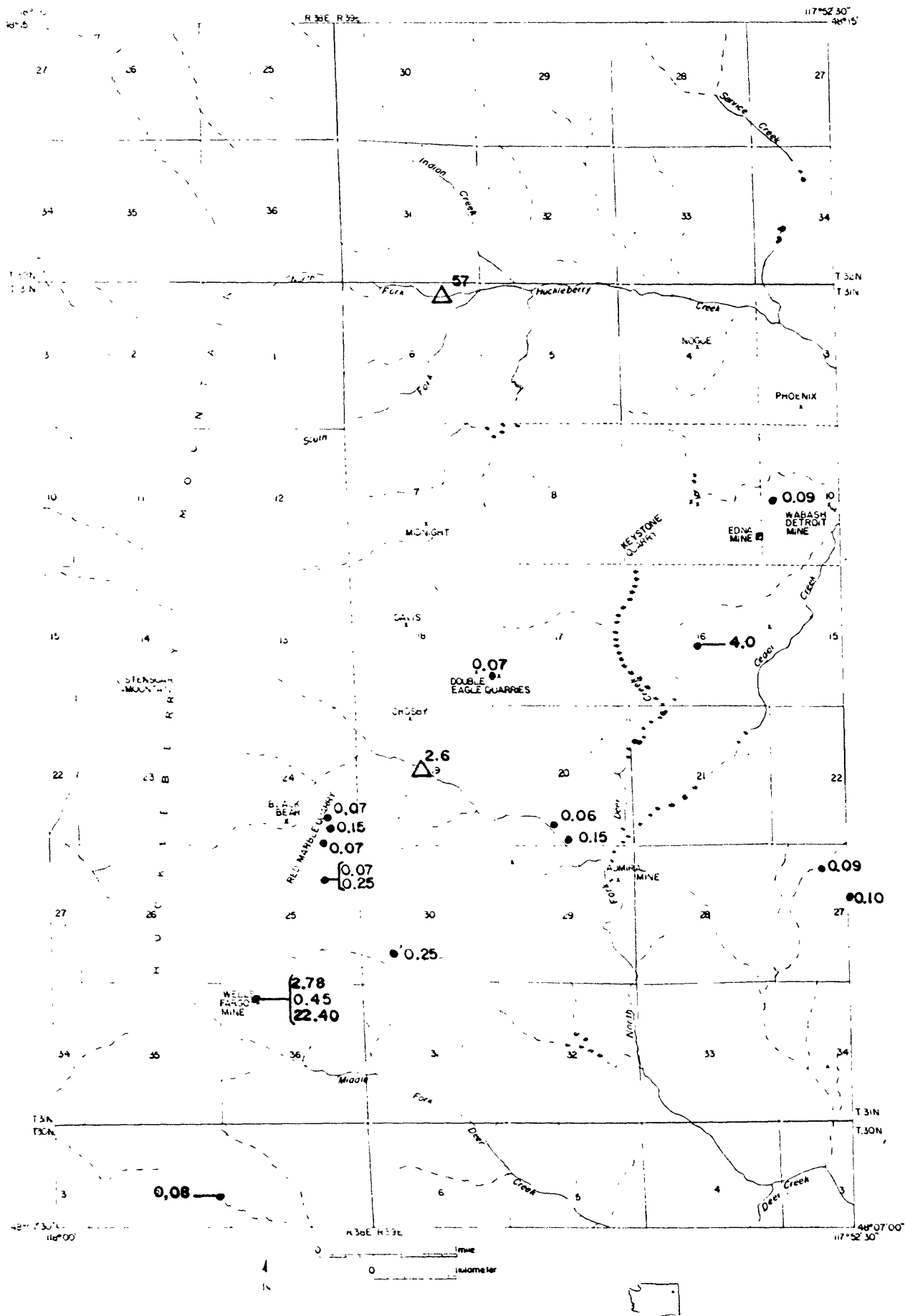


Figure 3. Rock and panned concentrate samples containing more than 0.05 ppm gold.

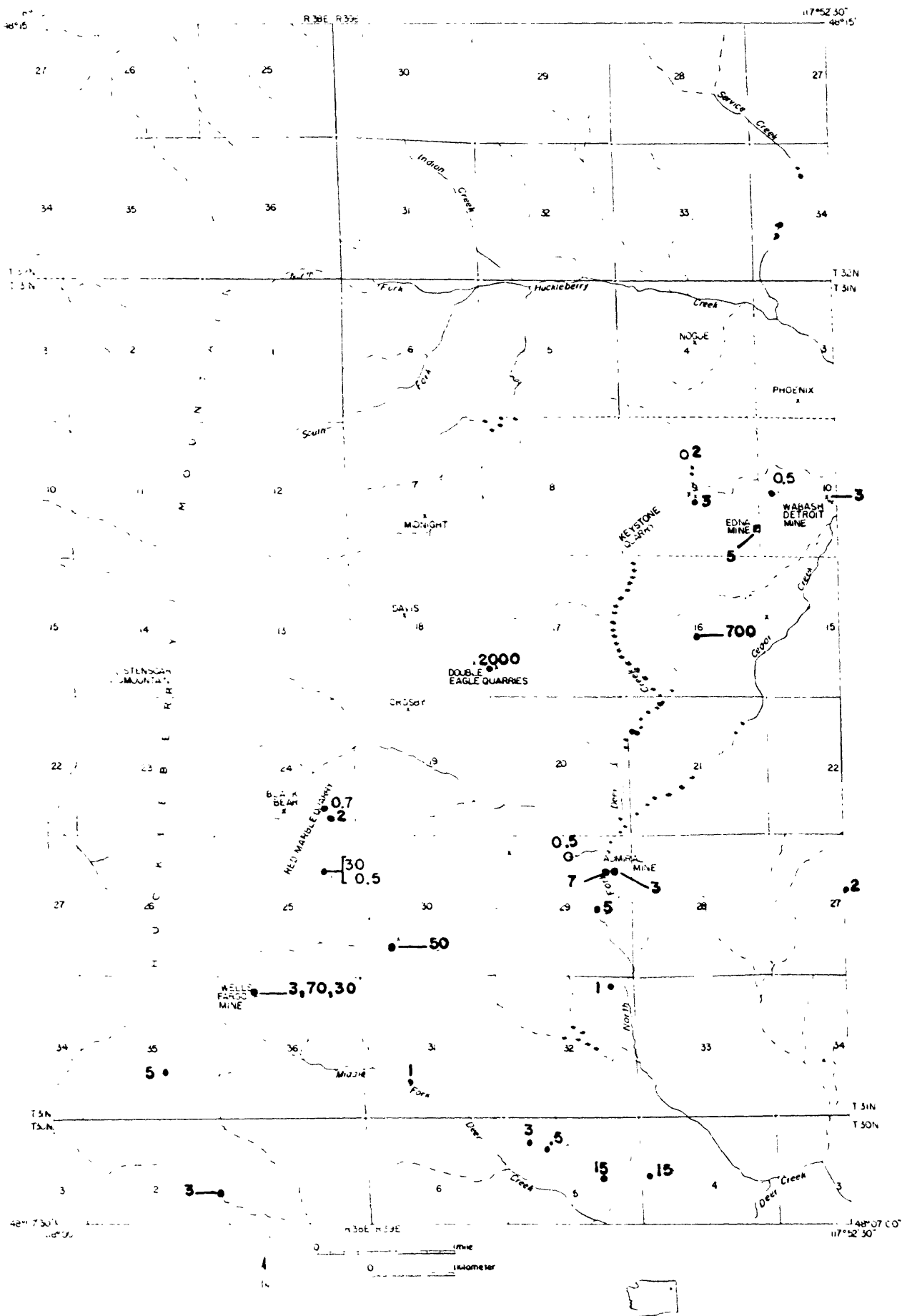


Figure 4. Rock and stream sediment samples containing 0.5ppm or more silver.

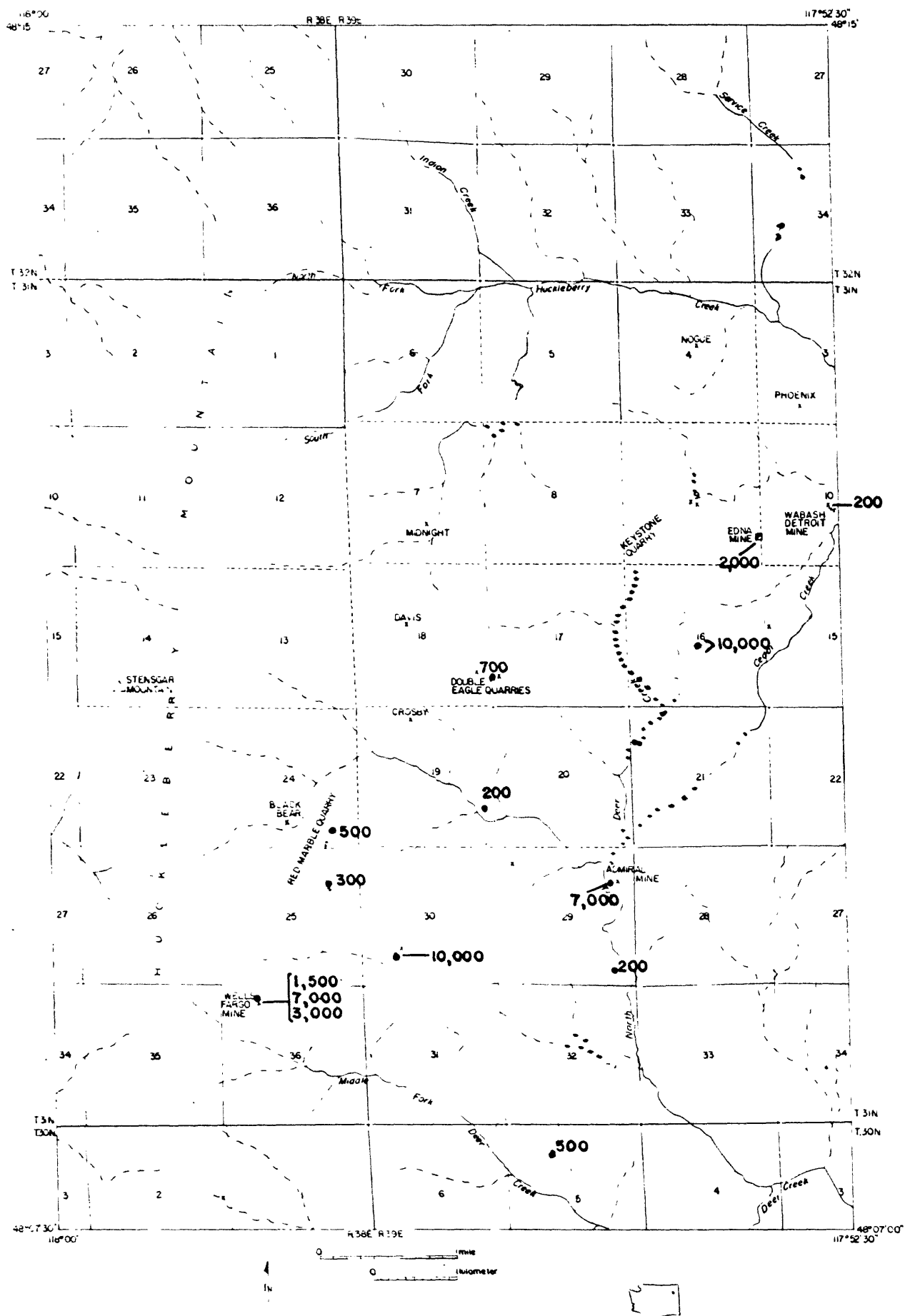


Figure 5. Rock samples containing 200 ppm or more arsenic.

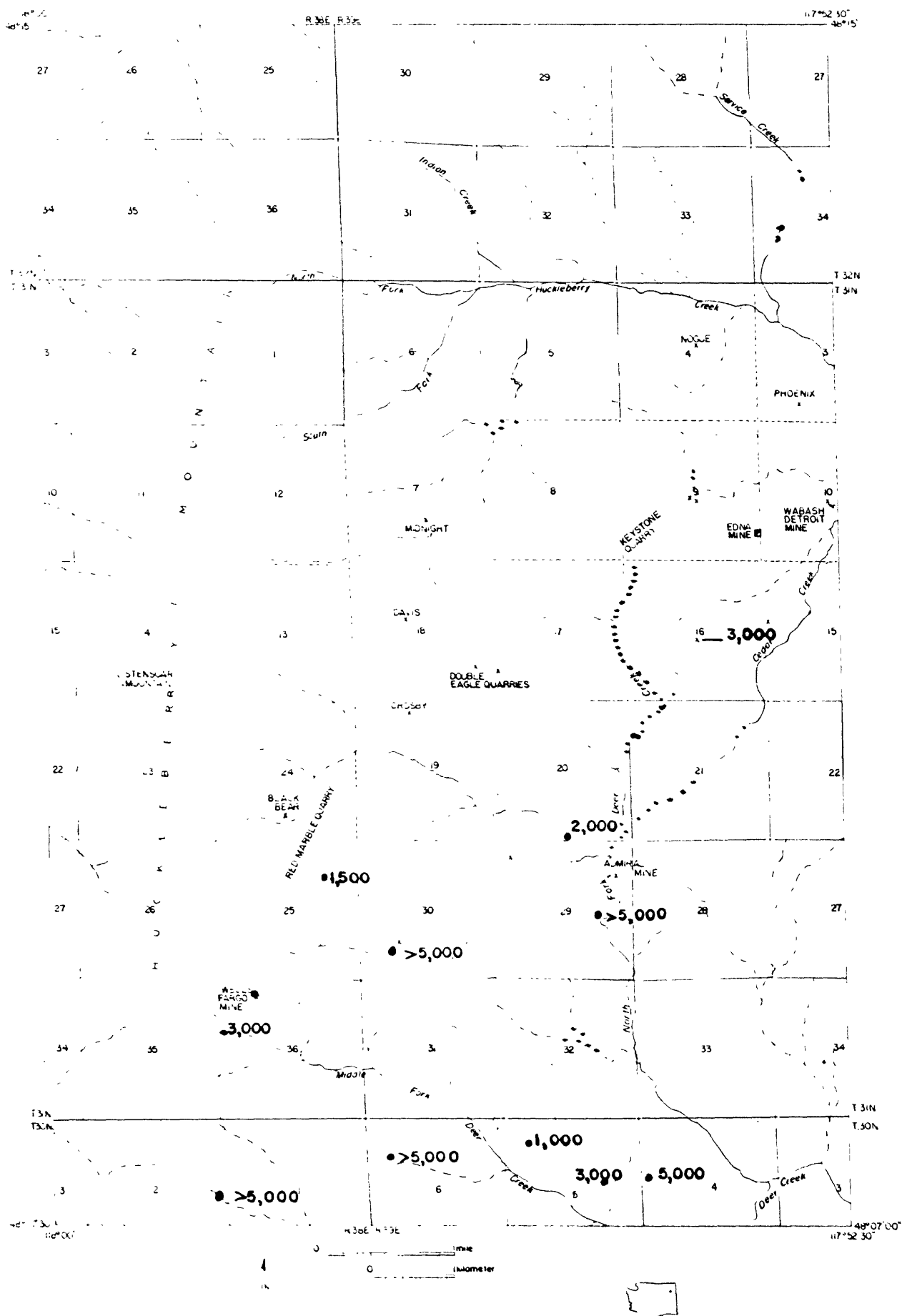


Figure 6. Rock samples containing 1,500ppm or more barium.

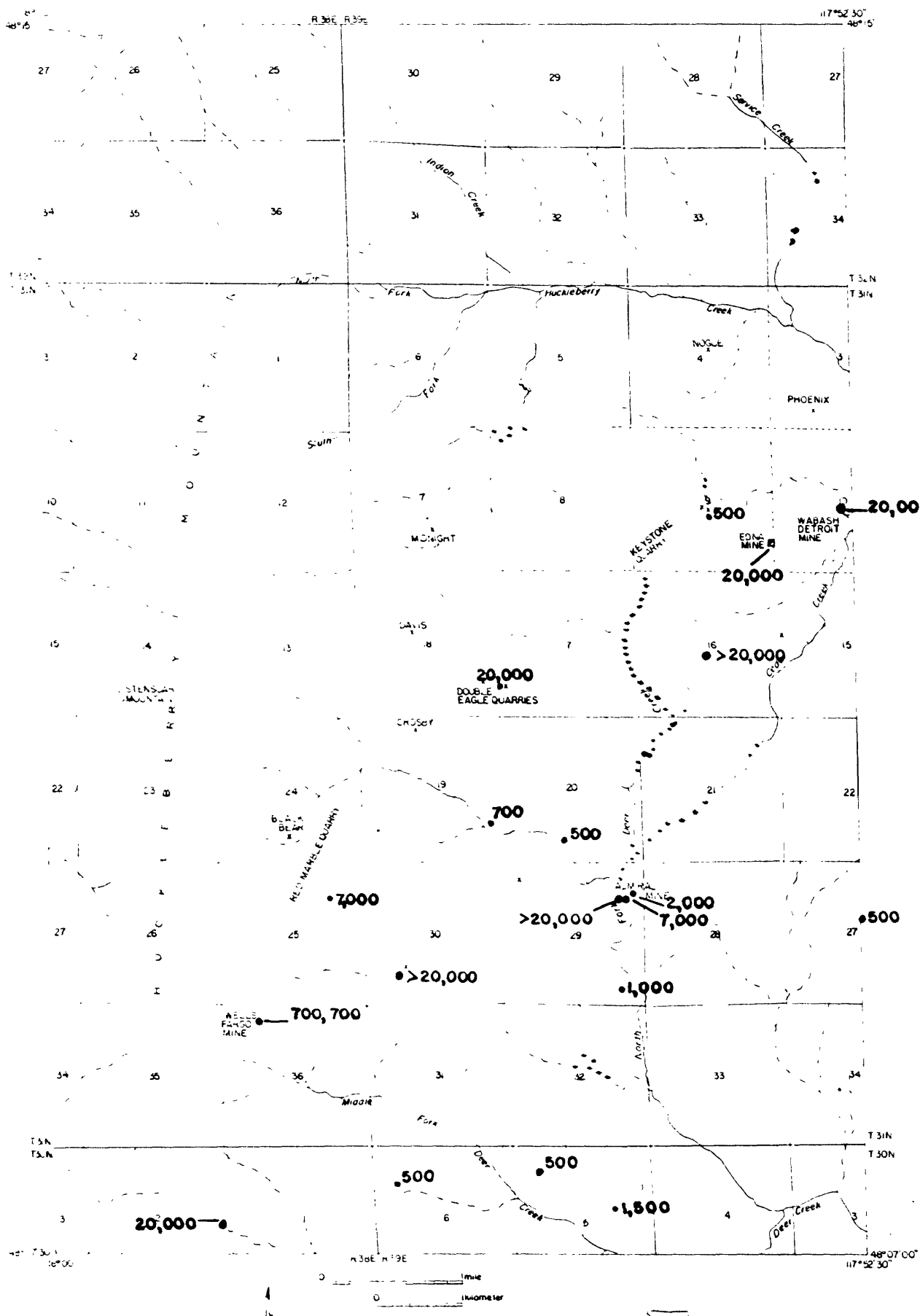


Figure 7. Rock samples containing 500 ppm or more copper.

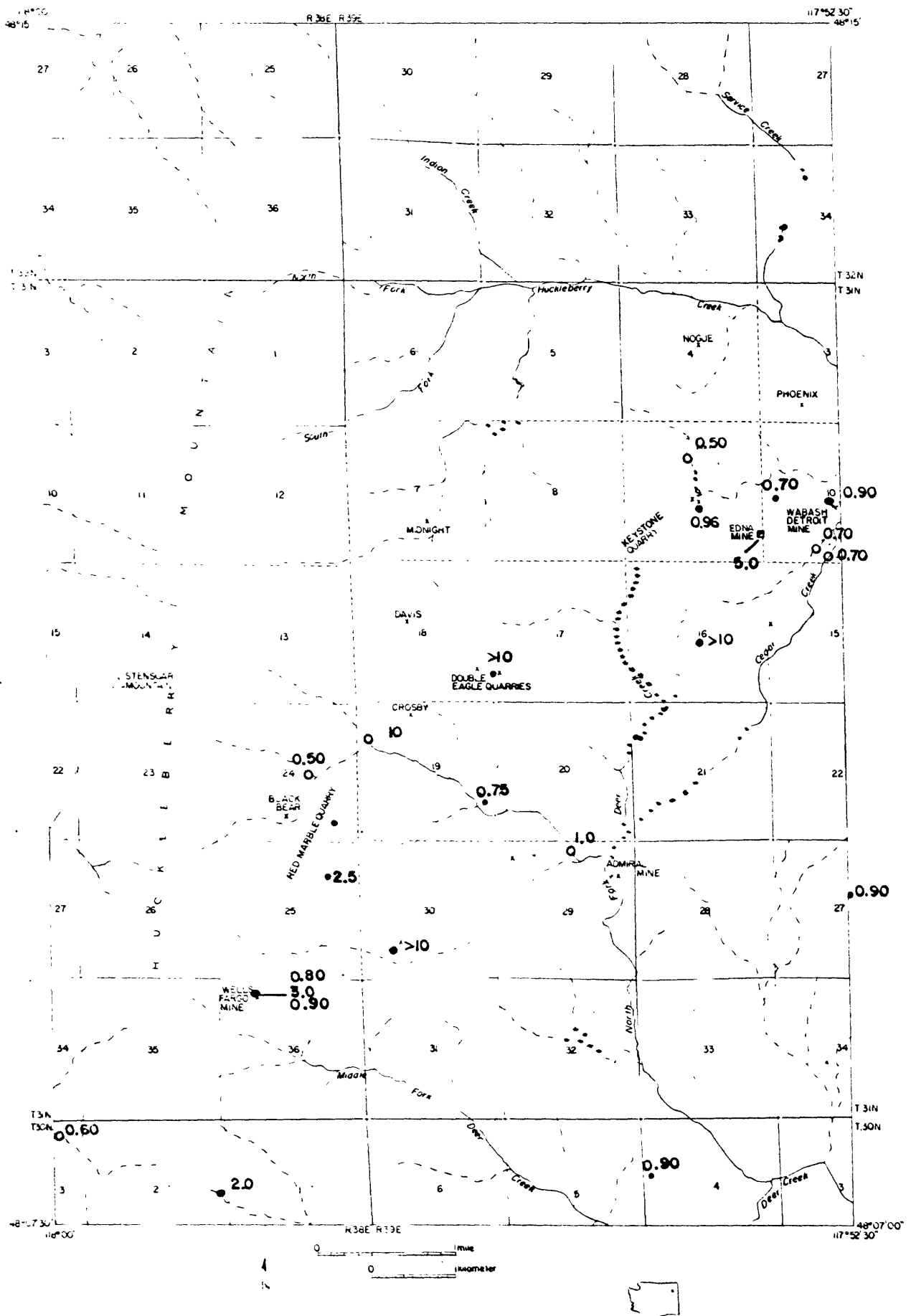


Figure 8. Rock and stream sediment samples containing 0.50 ppm or more mercury.

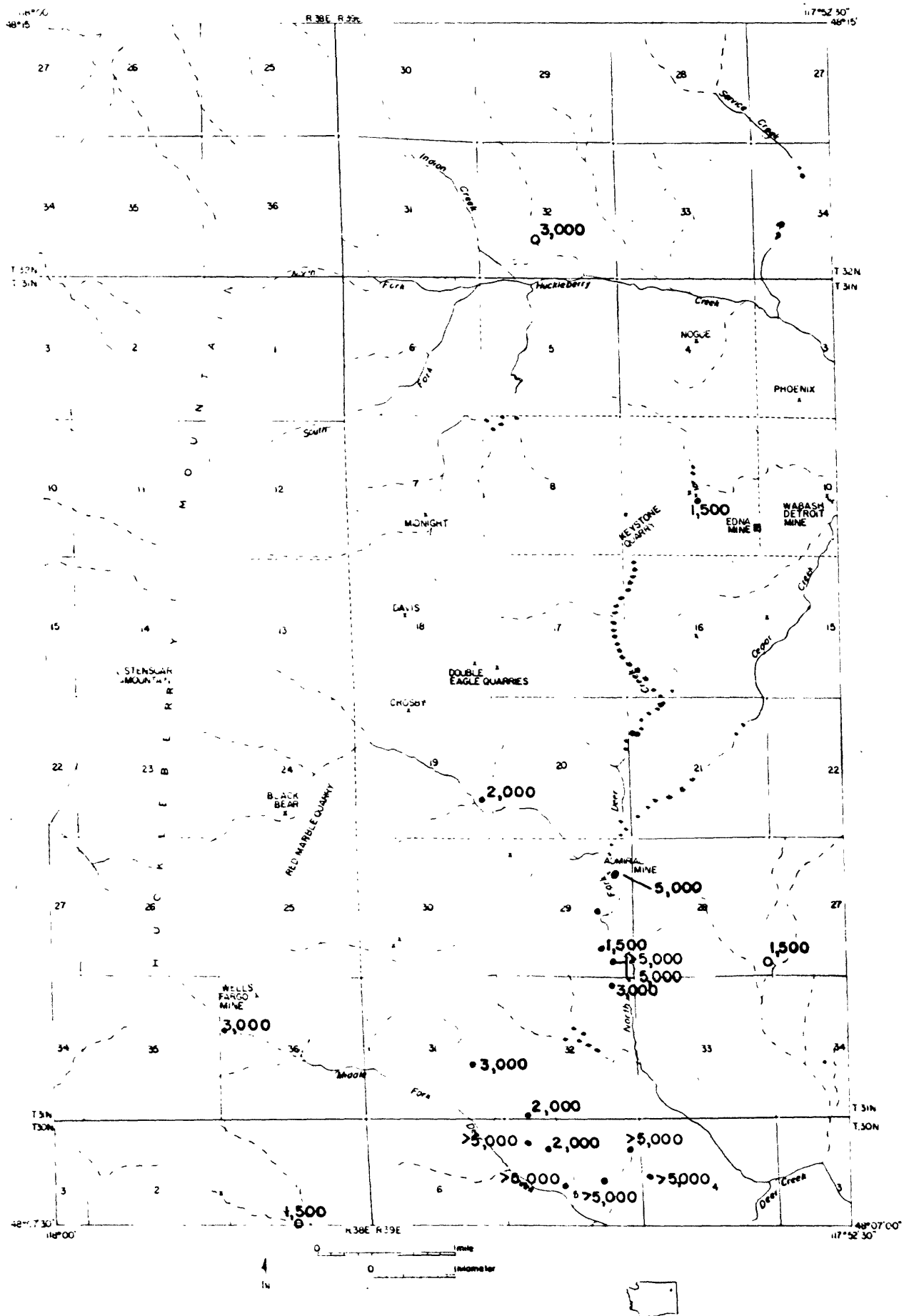


Figure 9. Rock and stream sediment samples containing 1,500 ppm or more manganese.

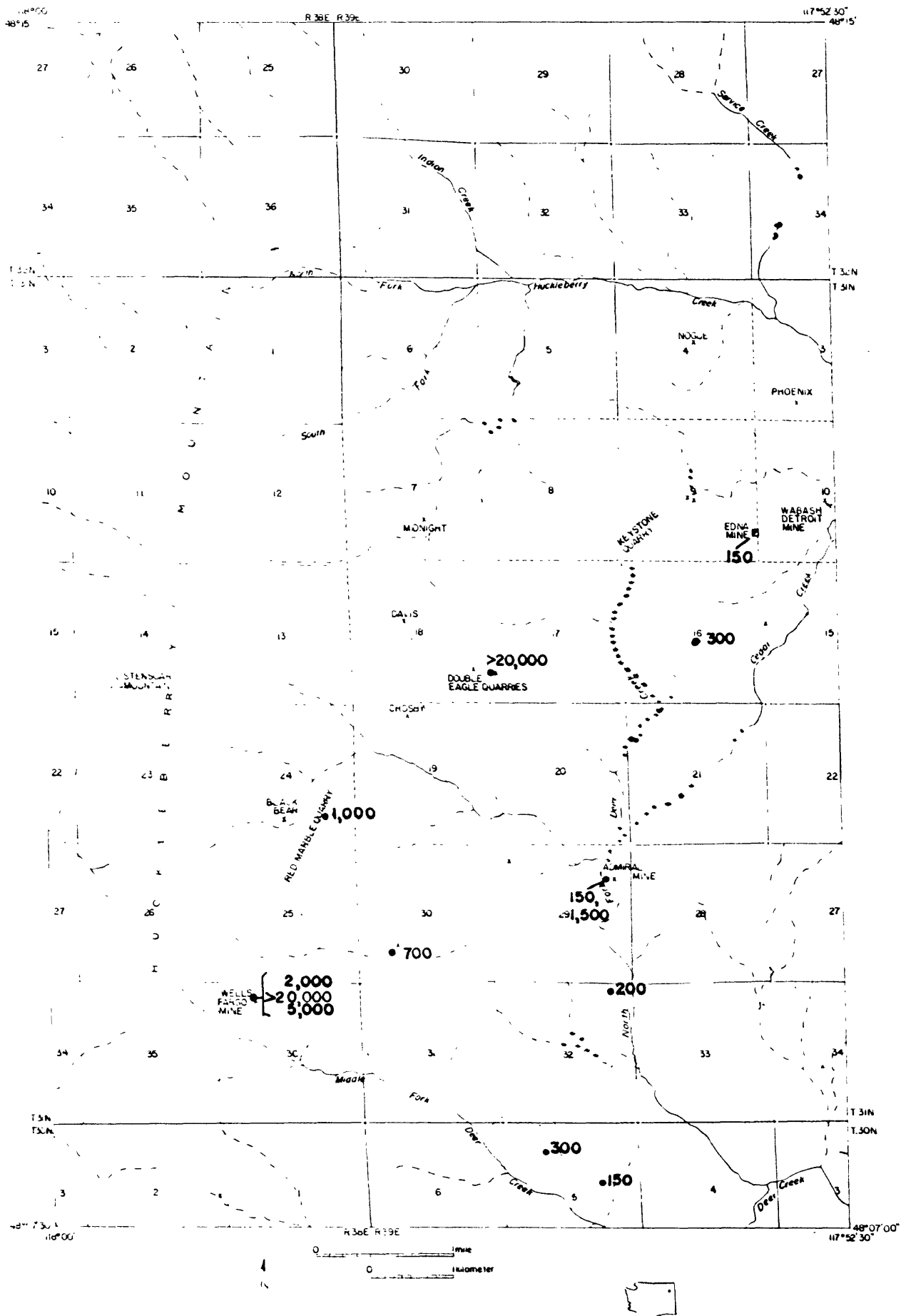


Figure 10. Rock samples containing 150 ppm or more lead.

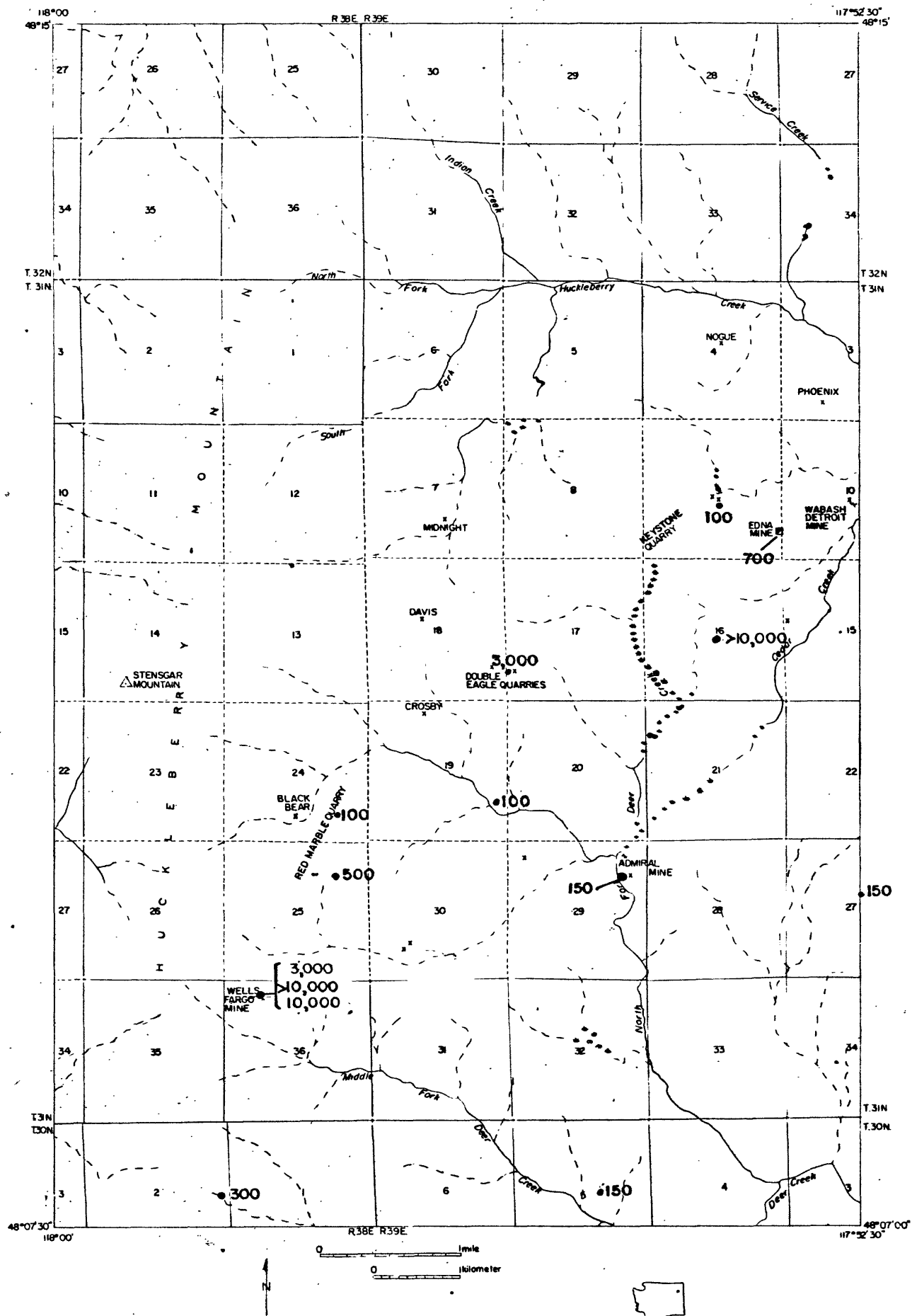


Figure 11. Rock samples containing 100 ppm or more antimony.

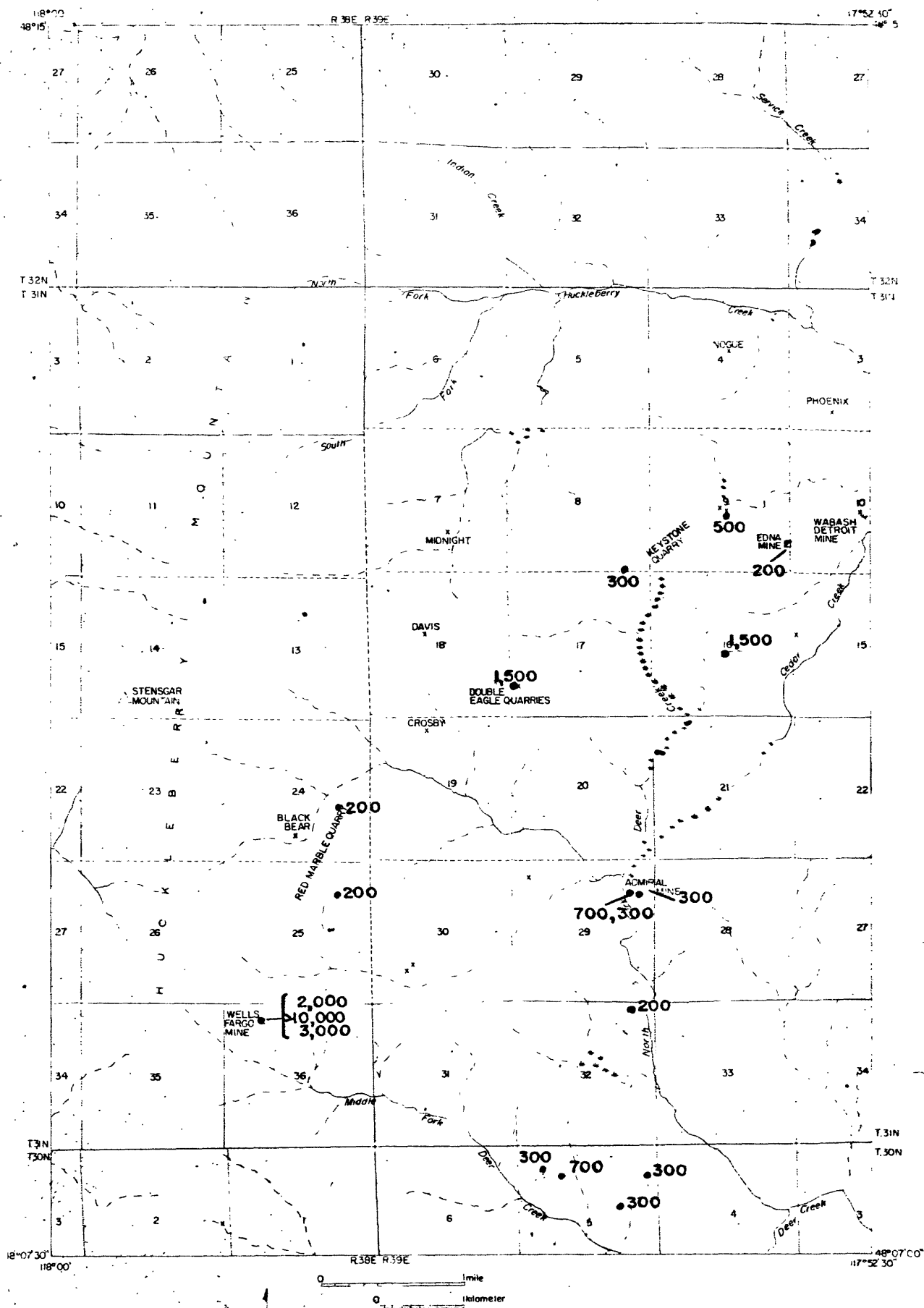


Figure 12. Rock samples containing 200ppm or more zinc.

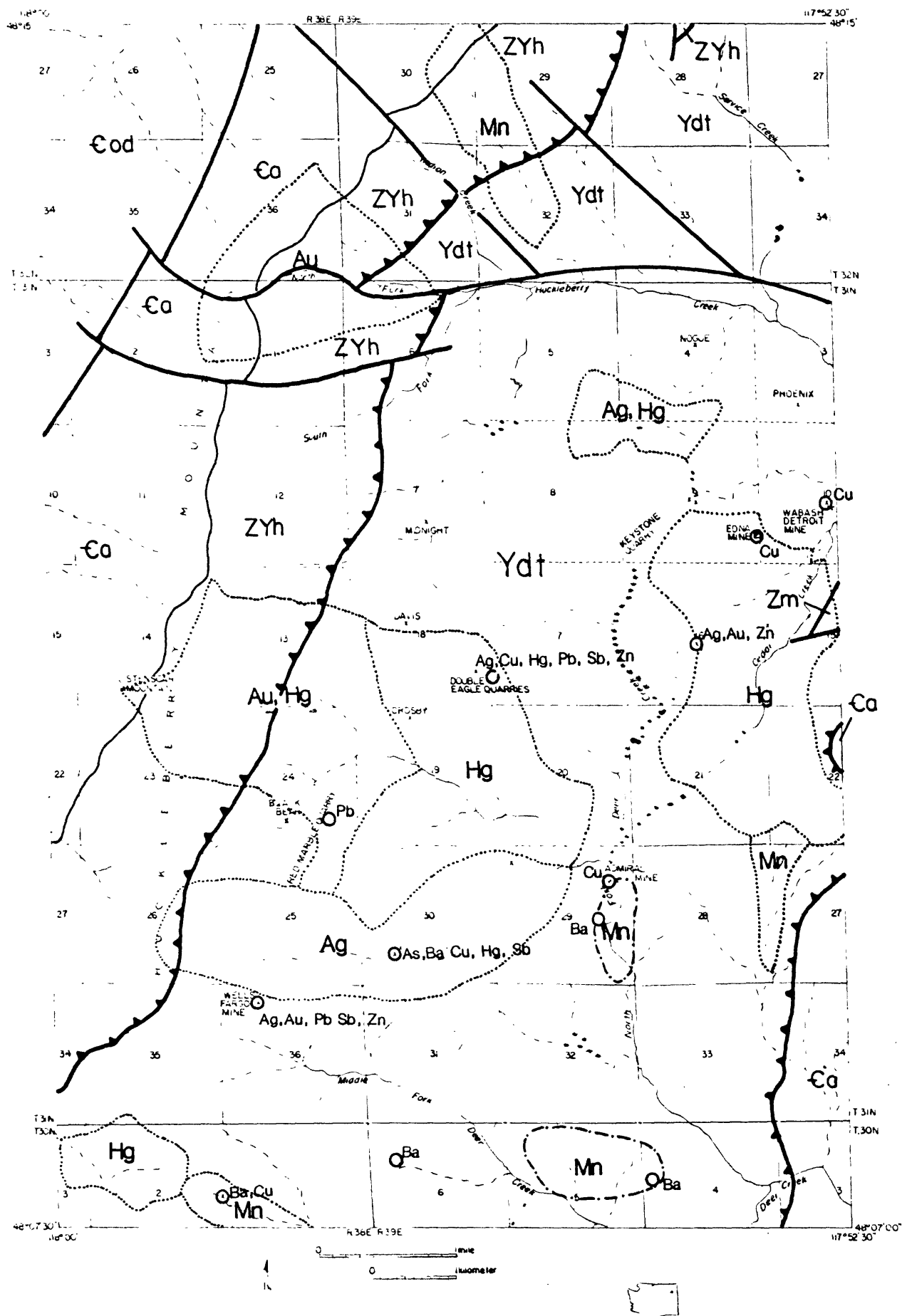


Figure 13. Geochemical summary.