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MINERAL RESOURCE POTENTIAL OF THE LOWER SAN FRANCISCO WILDERNESS STUDY AREA AND CONTIGUOUS ROADLESS AREA, GREENLEE COUNTY, ARIZONA, AND CATRON AND GRANT COUNTIES, NEW MEXICO

By

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Studies Related To Wilderness

Under the provisions of the Wilderness Act (Public Law 88-577, September 3, 1964) and the Joint Conference Report on Senate Bill 4, 88th Congress, the U.S. Geological Survey and the U.S. Bureau of Mines have been conducting mineral surveys of wilderness and primitive areas. Areas officially designated as "wilderness," "wild," or "canoe" when the act was passed were incorporated into the National Wilderness Preservation System, and some of them are presently being studied. The act provided that areas under consideration for wilderness designation should be studied for suitability for incorporation into the Wilderness System. The mineral surveys constitute one aspect of the suitability studies. The act directs that the results of such surveys are to be made available to the public and be submitted to the President and the Congress. This report discusses the results of a mineral survey of the Lower San Francisco Wilderness Study Area, and contiguous Roadless Area in the Apache National Forest, Greenlee County, Arizona and the Gila National Forest, Grant and Catron Counties, New Mexico.

MINERAL RESOURCE POTENTIAL SUMMARY STATEMENT

The Lower San Francisco Wilderness Study Area consists of a narrow strip 1-2 mi (2-3 km) wide between the rims of the San Francisco River canyon. The wilderness study area has a moderately high potential for geothermal resources, a low to moderate potential for base metal or precious metal resources in middle to upper Tertiary volcanic rocks, essentially no oil, gas, or coal potential, and a largely unassessable potential for metal deposits related to Laramide igneous intrusions in pre-Tertiary or lower Tertiary rocks that underlie the area. The contiguous roadless area, which borders the New Mexico half of the wilderness study area, mainly on the north side of the San Francisco River, has a low to moderate potential for molybdenum or copper deposits related to intrusive igneous rocks in the core of a volcano of dacitic composition at Goat Basin.

INTRODUCTION

The Lower San Francisco Wilderness Study Area and contiguous Roadless Area consists of 25,560 acres (1600 hm^2) in a strip between 1 and 6 mi (2-10 km) wide along a 20-30 mi (30-50 km) stretch of the San Francisco River in Catron and Grant Counties, New Mexico and Greenlee County, Arizona (fig. 1). The wilderness study area is almost equally divided between the two states, but the contiguous roadless area is entirely in New Mexico. Thus, the study area essentially encompasses the San Francisco River Canyon, from rim to rim, between the mouth of Dry Creek in New Mexico and the mouth of the Blue River in Arizona. Clifton and Morenci, Arizona are the closest towns downriver, about 10 mi (15 km) from the west edge of the study area, and Glenwood, New Mexico is about 5 mi (8 km) upriver from the area (fig. 1). Elevations along the San Francisco River range from about 4500 ft (1370 m) at the east edge of the study area to about 3800 ft (1160 m) at the mouth of the Blue River at the west end. Elevations along the rim of the inner gorge of the San Francisco canyon are generally between 5900 ft (1800 m) and 6000 ft (1830 m), but where the rim breaks back from the river along tributary canyons, elevations along the rim are somewhat higher as at the head of Goat Basin at more than 6600 ft (2000 m).

The study area is within the transition zone between the relatively stable Colorado Plateau and the more tectonically active Basin and Range structural and physiographic provinces. Within the area of this study, the transition zone is covered entirely by upper Cenozoic volcanic rocks and continentally derived sedimentary rocks. Earlier, the transition zone was the site of intensive faulting and igneous intrusion during Laramide time (Late Cretaceous to early Tertiary), which

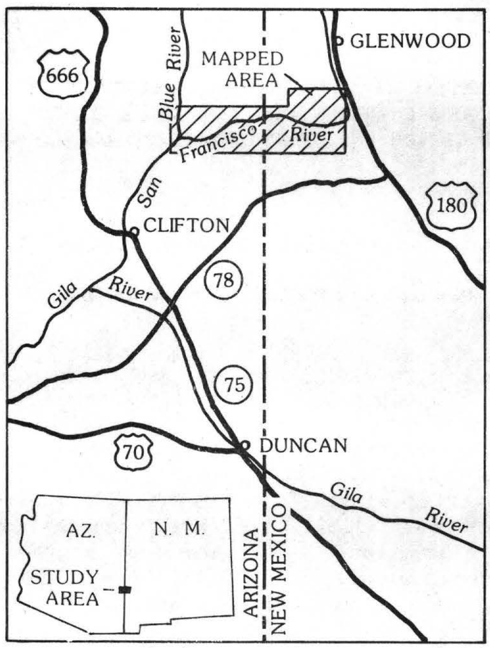

Figure 1.--Index map showing location of mapped area.

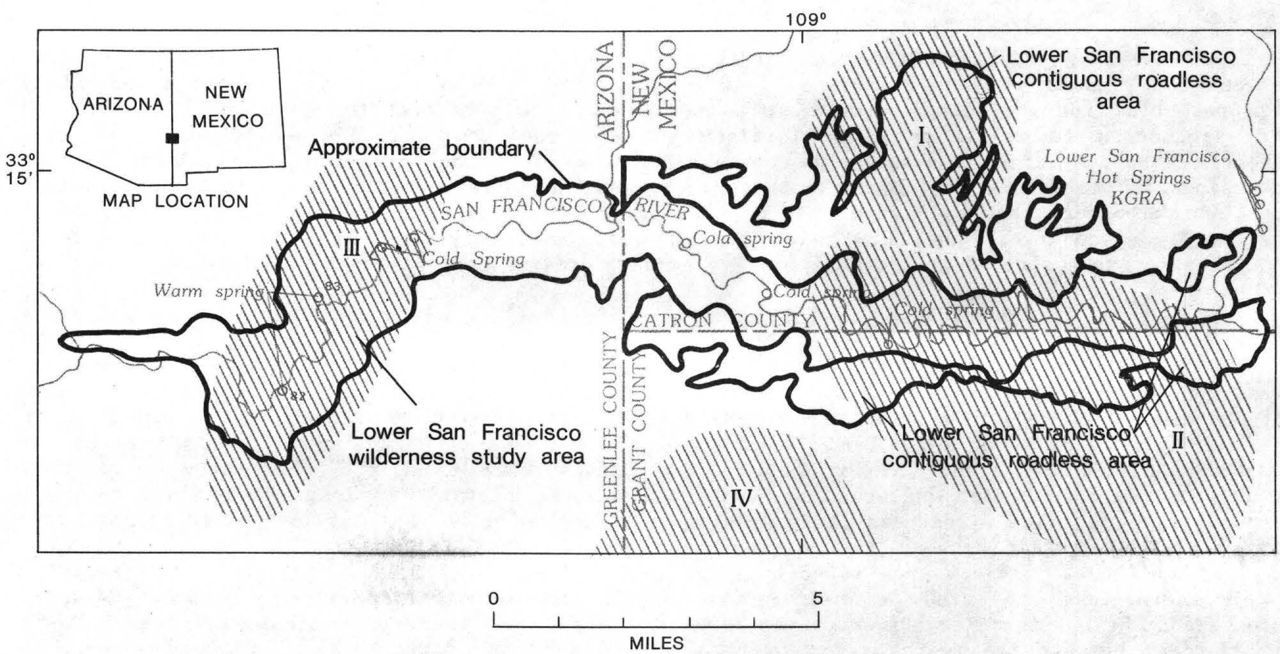

Figure 2.--Mineral resource potential areas (I-IV) in and adjacent to the Lower San Francisco Wilderness Study Area and contiguous Roadless Area.

was the time when most of the important copper deposits of the southwestern United States were formed. In middle Tertiary time, large volumes of basaltic to rhyolitic volcanic rocks were erupted along the transition zone, and subvolcanic intrusive centers associated with this volcanism commonly have ore deposits of precious metals, base metals, and fluorite, and indications of tin mineralization.

Mining activity within the study area has been practically nil, and at the time of this investigation (1980, 1981), there were no active mining claims within the area. However, major copper deposits of Laramide age occur close by in both Arizona and New Mexico. The Morenci and Metcalf mines, which have produced more than 3 million tons of copper, are less than 15 mi (25 km) southwest of the western end of the study area.

GEOLOGY, GEOPHYSICS, AND GEOCHEMISTRY

Within the Lower San Francisco Wilderness Study Area and contiguous Roadless Area, the San Francisco River has cut a spectacular steep-walled canyon nearly 2000 ft (600 m) deep in volcanic rocks of middle Tertiary age. The volcanic rocks are mainly andesite and basalt lava flows and subordinate rhyolite flows and pyroclastic rocks. Volcaniclastic sedimentary rocks are interlayered with the volcanic rocks. The rock sequence is capped in some places by fanglomerate and conglomerate of the Gila Conglomerate. Volcanic vents and other centers of volcanic activity are exposed along the San Francisco River canyon within and adjacent to the study area. They include a dacitic volcanic cone in Goat Basin; rhyolite plugs, breccia pipes, and pyroclastic vents on both sides of Mule Creek and at the mouth of Goat Basin Canyon; and andesitic or basaltic cinder cones, such as the one south of the San Francisco River about 1 mi (2 km) east of the Arizona-New Mexico State Line.

A few miles south of the study area, the middle Tertiary volcanic rocks overlie pre-Tertiary rocks that include Precambrian and Paleozoic sedimentary and igneous rocks, at an elevation of about 5000 ft (1525 m) above sea level. Thus, pre-Tertiary rocks might be expected to be present within a few hundred feet beneath the bed of the San Francisco River in parts of the study area where the same stratigraphic position in middle Tertiary volcanic rocks, as that to the south, can be recognized. However, less than 10 mi (15 km) north of the study area, exploration drilling has shown pre-Tertiary rocks to be 2000-3000 ft (600-900 m) deep, or about 3000 ft (900 m) above sea level, indicating an increased thickness of middle-Tertiary volcanic rocks, or down-faulting of the entire sequence, or both. Therefore, the depth to pre-Tertiary rocks beneath the San Francisco River, within the study area, is probably between a few hundred and a couple thousand feet, but cannot be predicted much more accurately than that.

The rocks within the mapped area are cut by three sets of high-angle normal faults that trend north-northeast, northwest, and west-northwest. Displacements range from a few tens of feet to hundreds of feet on faults in each set. Veins occur mainly along north-northeast and northwest faults. The Dix Canyon fault block, in the western part of the area, is a narrow block about 1 mi (2 km) wide that has a north-northeast trend. This scissored fault block appears to be a graben south of the San Francisco River, but a horst north of the river. Calcite and quartz veins occur on both sides of the block, and both north and south of the river.

The Potholes Country graben in the southeast part of the study area is bounded by northwest-trending faults. The main graben block is about two mi (3 km) wide and is down-dropped 600-800 ft (180-240 m).

Most of the major geological structures that have a bearing on the mineral resources of this study area have some geophysical expression particularly in the aeromagnetic patterns. An elongate magnetic low is centered over the Dix Canyon fault block in the western part of the area. The causative source of this negative anomaly of about 60 gammas is not obvious in the surface geology, although the volcanic rocks of Maverick Spring within this block north of the San Francisco River include hornblende andesite and rhyolite that differ from the thick pyroxene andesite that surrounds the block. The spacing of magnetic contours of this anomaly suggests a moderately deep source of several thousand feet.

The Goat Basin volcano is expressed as a magnetic low of nearly 100 gammas, which corresponds quite well to the outcrop area of the dacite cone. Propylitically altered dacite in the eroded, breached center of the cone is cut by small, silicified and argillically altered and mineralized rhyolite dikes, which indicate that this magnetic low may be related to a sizeable silicic intrusion at shallow depth beneath the volcano.

A magnetic low of similar size and amplitude to the Goat Basin anomaly is centered about 2 mi (3 km) south of that anomaly, over the junction of Mule Creek and the San Francisco River. From its center, the anomaly extends southeast along the Potholes Country graben, where rhyolite flows and pyroclastics merge in depth with plugs and breccia pipes that are exposed in canyon walls on both sides of Mule Creek. However, the center of the magnetic low corresponds to an area dominated by thick andesite flows, except for a large breccia pipe about 1500 ft (450 m) long and 300 ft (100 m) wide. At the level of the San Francisco River, this diatreme gives way to a glassy rhyolite plug. Quartz veins north of the breccia pipe on both sides of Goat Basin Canyon have weak metal anomalies.

Another magnetic low corresponds to the rhyolite center near Harden Cienega at the south edge of the mapped area, outside the boundaries of the study area.

The geophysical expression of the Potholes Country graben and its rhyolitic centers is further enhanced by extensive magnetic highs on both sides of the graben. The highs correspond to large thicknesses of andesites and basalts and their underlying feeder dikes or other vents. A nearly circular magnetic high centered over Outlaw Mountain in the southeast corner of the mapped area is expressed as a magnetic dipole, and may be related to a center of extrusion for the andesitic lavas that cap Outlaw Mountain, or a buried center for the rhyolite of Angel Roost.

The middle Tertiary volcanic rocks in the Lower San Francisco study area range from basaltic andesites to high-silica (>77 percent SiO_2) rhyolites. The rhyolites are chemically similar to those that are commonly associated with molybdenum, tin, and tungsten mineralization.

Analyses of stream-sediment concentrates and altered and mineralized rocks within the map area show no strong metal-anomaly patterns. However, samples of mineralized and altered rocks along individual quartz and calcite veins, and associated with some of the Potholes Country rhyolite breccia pipes and intrusions, and rhyolite dikes in the Goat Basin volcano, do have weak concentrations of some metals, including silver and gold, molybdenum, and copper. Such anomalous metal values are as much as >5000 ppm (parts per million) manganese, 1 ppm silver, 0.25 ppm gold, 70 ppm molybdenum, 200 ppm copper, 100 ppm lead, 100 ppm antimony, 70 ppm tungsten, 10 ppm beryllium, 20 ppm boron, 3000 ppm barium, and 50 ppm niobium. Stream-sediment concentrates show scattered weakly anomalous abundances of molybdenum, niobium, tin, fluorine and thorium adjacent to the rhyolite center at Harden Cienega, and weakly anomalous amounts of copper, molybdenum, fluorine, and barium occur in concentrates from Mineral Springs Canyon. Both areas are outside the boundaries of the study area. Analyses of equivalent uranium in rocks and stream sediments showed only normal low-level amounts of radioactive material.

Sample localities and complete results of the geochemical sampling will be presented in separate reports.

MINING DISTRICTS AND MINERALIZATION

There are no mining districts within the Lower San Francisco Wilderness Study Area and contiguous Roadless Area, and there were no active mining claims, either patented or unpatented, within the mapped area at the time of this study (1980-1981). Evidence of past prospecting activity in the form of claim posts, discovery papers, and prospect pits, was observed along quartz veins within the contiguous roadless area on the north side of the San Francisco River, just outside the wilderness study area boundary in sec. 30, T. 12 S., R. 20 W. Claims have been filed over much of Goat Basin since this survey was completed.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

The mineral resource potential of the Lower San Francisco Wilderness Study Area and contiguous Roadless Area is related to the following:

1) Possible base-metal deposits of Laramide age in rocks that are completely buried beneath younger rocks of upper Cenozoic age.
2) Base or precious metal deposits within the upper Cenozoic volcanic, volcaniclastic or sub-volcanic intrusive rocks that crop out in the mapped area.
3) Geothermal energy from deeply circulating meteoric water that surfaces in springs along the San Francisco River.

The probability of other mineral resources such as oil, gas, or uranium occurring within the study area is remote, but cannot be completely discounted.

The potential for vein or replacement deposits of base metals, or a porphyry copper of Laramide age, though largely unquantifiable, is present nearly everywhere beneath the upper Cenozoic volcanic rocks in this area. The only direct evidence by which to assess this potential is the presence of major copper deposits in Upper Cretaceous to lower Tertiary intrusive rocks less than 15 mi (25 km) southwest of the study area, and the presence of pre-Tertiary rocks in exploratory drill holes a few miles to the north. The geophysical data, which might provide a look through the upper Cenozoic volcanic cover, is equivocal, because most of the aeromagnetic and gravity anomalies can be related in part to the surface geology. Thus, anomalies that might signify buried Laramide intrusives could as well represent upper Cenozoic intrusives.

The potential for base and (or) precious-metal deposits in the upper Cenozoic rocks of the mapped area is associated with veins and altered rocks and geologic settings that are especially conducive to the formation of mineral deposits. Such indicators of mineralization occur at four places within the mapped area (fig. 2) as follows:

Goat Basin volcano (Area I, fig. 2)--This volcano, which is entirely within the contiguous roadless area, has a moderately high potential for base or precious metals in veins or replacement deposits, or a molybdenum-copper disseminated deposit. The stratified volcanic cone is 2-3 mi (3-5 km) in diameter and consists of lava flows and explosive breccia or agglomerate, and minor tuffs. Its flanks are largely buried by younger andesite lava flows, but its center is eroded to a depth of 1200-1400 ft (365-425 m) beneath the exhumed rim. A negative magnetic anomaly which is centered over the volcano, and the presence of small rhyolite dikes, and altered and weakly mineralized dacite and rhyolite in the center of the volcano indicate a probable subvolcanic silicic intrusive at shallow to moderate depths, which might be mineralized.

Potholes Country Graben (Area II, fig. 2)--A high-silica rhyolite intrusive and extrusive center that appears to be localized along the Potholes Country graben in the eastern part of the mapped area has a low to moderate potential for epithermal precious-metal or base-metal mineralization related to unexposed intrusives. The high-silica, high-potassium rhyolite has several of the chemical parameters, such as SiO_2 >74 percent; K_2O: $Na_2O + K_2O$ >1.25; Rb: Sr>2; Nb>20 ppm (F. E. Mutschler, Steve Lundington, and Mohammed Ikramuddin, written commun., 1980) that can be associated with molybdenum, tin and tungsten mineralization. The rhyolite of Potholes Country is altered locally, particularly near extrusive vents, where manganese and iron oxides coat fractures in rhyolite that is commonly bleached and silicified. Silver and gold mineralization occurs in quartz veins along the continuation of this belt of rhyolite east of the study area in at least one locality, where 5 samples contained 2, 7, 30, 50, and 100 ppm silver, and as much as 4 ppm gold, 500 ppm copper, and 15 ppm beryllium.

Rhyolite breccia pipes or diatremes, the upper tip of a rhyolite plug, and a northwest elongated magnetic low (Martin, 1982) mark the place where the graben crosses the San Francisco River, within the wilderness study area. The rocks exposed in this area mainly comprise a thick sequence of andesitic flows, but both the geology and the magnetic anomaly indicate a probable silicic intrusive at shallow to moderate depth beneath the surface in this part of the wilderness.

Quartz veins as much as 15-30 ft (5-10 m) wide occur within and peripheral to the graben, north of the river and are included within mineral resource Area II. Vein samples have weak but anomalous metal values of as much as 5000 ppm manganese; 1 ppm silver, 0.25 ppm gold, 200 ppm copper, 10 ppm beryllium, 70 ppm tungsten, 70 ppm lead, 100 ppm antimony, 3000 ppm barium, and 30 ppm boron. These metals could represent leakage from more intensely mineralized rocks at depth.

Dix Creek fault block (Area III, fig. 2)--A low potential for base or precious metal veins and replacement deposits, or disseminated mineralization in a possible unexposed intrusive is associated with the Dix Canyon fault block, a narrow north-northeast-trending scissored block that crosses the San Francisco River in the western part of the study area. This block is paralleled by a broad, elongate, magnetic low that has been interpreted as a possible large volume silicic intrusive at a considerable depth beneath the surface (Martin, 1982). In fact, there is a little rhyolite exposed at river level along the east side of the block, and the hornblende andesite that is exposed in the northern end of the block contrasts with the dominant pyroxene andesite flows in this area.

Quartz and carbonate veins, in zones as much as 30 ft (10 m) wide, occur along the faults on both sides of the Dix Creek block, and thermal springs along the San Francisco River on the east side of the block indicate deep circulation of ground water in this fault zone. Samples of the veins lack anomalous metal values except for manganese in calcite (as much as 700 and 1000 ppm), 1 ppm silver, 0.04 to 0.15 ppm gold, and 200 ppm copper in quartz at the north end of the fault block, just north of the wilderness study area boundary.

Rhyolite of Mule Creek-member of Harden Cienega (Tmr, Area IV, fig. 2)--A rhyolite extrusive center between Harden Cienega Creek and Antelope Creek, south of the study area boundaries in the New Mexico part of the mapped area, has a low potential for base- and precious-metal mineralization associated with highly differentiated silicic rocks. This 18 m.y. old Miocene silicic complex has the same high-silica, high potassium, and other chemical characteristics of rhyolitic rocks associated with molybdenum, tin and tungsten mineralization, as described for the slightly older rhyolite of Potholes Country. Molybdenum values in the nonmagnetic fraction of stream-sediment concentrates from drainage sites on the west side of this rhyolite volcanic center are as high as 100 ppm, but given a probable molybdenum content of 5-10 ppm for this rhyolite (radioisotope activation analyses by W. E. Brooks and Greg Green, written commun., 1980) these values are probably normal for concentrates in this particular lithologic environment. The rhyolite also contains large volumes of pumiceous, rhyolitic perlite, a possible future economic resource.

The Mule Creek rhyolite complex between Harden Cienega and Antelope Creeks is significant to the mineral resource potential of the Lower San Francisco Wilderness Study Area and contiguous Roadless Area mainly as it documents the surface expression of extensive rhyolitic magmatism, which has an unknown extent as subvolcanic intrusions in the subsurface in this area.

GEOTHERMAL RESOURCES

A potential for significant geothermal resources is present in the Lower San Francisco Wilderness Study Area according to a study made by the University of Arizona for the U.S. Department of Energy (Witcher, 1979). The wilderness study area encloses a stretch of the San Francisco River between two Known Geothermal Resource Areas (KGRA's), as classified by the U.S. Geological Survey (Muffler, 1979; Hatton, 1981). One of the KGRA's, the Lower San Francisco Hot Springs, New Mexico, is within a few hundred yards upstream from the east end of the wilderness study area; the other, the Clifton Hot Springs, Arizona is about 10 mi (15 km) downstream from the western end. A KGRA is defined by the U.S. Geological Survey as an area which has the necessary geothermal potential to justify spending money for development.

Data from Witcher (1979, tables 1, 2) show that a few of the springs along the river between the two KGRA's have surface temperatures that are above the average temperature of the other springs and the river water. Within the western part of the wilderness study area, spring No. 82 (fig. 2) has a surface temperature of 26^{o} C, significantly higher than the mean 20^{o} C temperature of the other springs and river water; and spring No. 83 has a slightly higher surface temperature than the average for the cold springs and river water. More important are the chemical composition of the water and the calculated reservoir temperature at depth. Spring No. 82 has sodium chloride water high in silica and lithium, containing 1500 mg/L (milligrams per liter) sodium, 3391 mg/L chlorine, 48 mg/L SiO_2 and 2.46 mg/L lithium, and a calculated reservoir temperature of 126^{o} C by the Na-K-Ca geothermometer, magnesium corrected. These characteristics make the water from spring No. 82 similar to that in the two adjacent KGRA's. By contrast, the other spring waters and San Francisco River water within the wilderness study area are magnesium-rich bicarbonate waters typical of those whose composition is derived from the dissolution of volcanic rocks (Witcher, 1979, p. 158; Garrels and MacKenzie, 1967).

Springs Nos. 82 and 83 occur along the eastern fault of the Dix Creek fault block, which is also cut by a west-northwest fault in this area. This setting for the thermal springs is consistent with an origin for the heated water by deep circulation of ground water through fractured rocks, the water rising to the surface again along a major fault zone.

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