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MINERAL RESOURCE POTENTIAL OF THE MAZATZAL WILDERNESS AND CONTIGUOUS ROADLESS AREA GILA, MARICOPA, AND YAVAPAI COUNTIES, ARIZONA

SUMMARY REPORT

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 Mazatzal Wilderness (NF3048) and Mazatzal Wilderness Contiguous Roadless Area (3-016) in the Tonto and Coconino National Forests, Gila, Maricopa, and Yavapai Counties, Arizona. Mazatzal Wilderness was established by Public Law 88-577, September 3, 1964. The contiguous roadless area was classified as a further planning area during the Second Roadless Area Review and Evaluation (RARE II) by the U.S. Forest Service, January 1979.

SUMMARY

Small quantities of gold, silver, and copper have been produced from the Mazatzal Wilderness. The wilderness has a high potential for gold, silver, and lead resources in veins in the vicinity of the Story mine, a high potential for silver and copper resources in vein deposits near Copper Mountain, a moderate potential for silver, gold, and copper in vein deposits in one area along the eastern border, and a high potential for copper in vein deposits at Mineral Creek. The Copper Mountain area, the area of silver, gold, and copper vein deposits along the eastern border, and the Mineral Creek area also have a low potential for copper in massive sulfide deposits. Two additional areas in the eastern and northern parts of the wilderness have a low potential for copper in vein and massive sulfide deposits. The wilderness has a high potential for copper in massive sulfide deposits and a moderate potential for copper in carbonate veins at Copper Camp Creek. An area east of the Mazatzal Wilderness has a high potential for gold resources in rocks that also occur in the wilderness, though no gold was found in these rocks in the wilderness. Three areas in the southern part of the wilderness have high, moderate, and low potential for mercury resources. A low potential for molybdenum exists west of the wilderness in three areas, two of which extend into the roadless area and the wilderness. The central part of the wilderness has occurrences of tin, but little evidence of a resource potential for tin. Two areas southwest of the wilderness have low and moderate potential for uranium, and one of these areas extends into the roadless area and the wilderness. No evidence of a potential for fossil fuels was identified in this study.

INTRODUCTION

The Mazatzal Wilderness and the contiguous roadless area are located in the Tonto and Coconino National Forests, west and southwest of Payson, and are almost exactly in the geographic center of Arizona (fig. 1). This is a region of relatively small mining districts and few mines, but occurrences of many different metals are widespread. This report documents the geology, mining activity, and mineral potential of the Mazatzal Wilderness and adjacent areas and discusses long-known, as well as newly discovered, mineral occurrences and the possibility of undiscovered mineral resources.

Investigations summarized in this report were conducted in the field by the U.S. Bureau of Mines and the U.S. Geological Survey, principally in 1979-1980. A few areas were studied briefly in 1981 and 1982. The Bureau of Mines examined mines, prospects, mineral claims, and mineralized areas and searched mining records. The Geological Survey conducted geologic mapping, geochemical sampling, remote-sensing studies, and geophysical examinations.

Physiography

The Mazatzal Mountains constitute the dominant physiographic feature of the wilderness. The eastern slopes of these mountains rise steeply from about 3,500 ft in altitude along the valley of Rye Creek east of the range to 7,903 ft at Mazatzal Peak. To the west, the range slopes steeply from the crest, then more gently along the lower flanks to the Verde River, one of the main drainage channels of Arizona. In the northern part of the wilderness, the East Verde River, a tributary of the Verde, occupies a deep canyon that separates the Mazatzal Mountains from mesas to the north. The lowest parts of the wilderness have altitudes of about 2,200 ft and are located near Bartlett Reservoir in the southwestern part of the area studied.

Geologic setting

The Mazatzal Mountains lie at the margin of the Basin and Range physiographic province in a region of Arizona where the mountain ranges are about as wide as or wider than

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the intervening basins. The Mogollon Rim, which defines the southern physiographic border of the Colorado Plateau, is about 5 mi north of the Mazatzal Wilderness. Paleozoic rocks, extensively exposed along the Mogollon Rim, have been largely eroded from the wilderness and roadless areas. The few remaining masses of Paleozoic rocks in the wilderness rest on thick sequences of mostly steeply tilted stratified Proterozoic rocks and on Proterozoic granitic rocks. These rocks are similar to Proterozoic layered and intrusive rocks exposed widely in central Arizona east and northwest of the wilderness. Tertiary volcanic rocks exposed within the wilderness are at the southern end of a large volcanic field that extends north and northwest for more than 100 mi in the western parts of the Colorado Plateau and adjacent areas of the Basin and Range province.

Mining activity

Prospecting has been conducted intermittently in the Payson area, including the Mazatzal Wilderness, since the discovery of gold near Payson in the 1870's. Within the wilderness and contiguous roadless area, gold and silver were the object of prospecting activity before World War II (Lausen and Wilson, 1925) and may have been mined in small quantities from several deposits. Few records are available for this period. Sporadic exploration for precious and base metals since World War II has resulted in the production of small amounts of copper, gold, and silver in the wilderness. Within a few miles of the southeast corner of the wilderness, mercury was produced at several mines from 1913 to the 1960's (Beckman and Kerns, 1965), and exploration continued at a low level of activity to 1979. Ore containing copper, gold, and silver was mined in areas immediately east of the wilderness in the period 1938-1956. Uranium occurrences near Bartlett Reservoir were revealed in drill cores in the 1970's. Exploration for gold was being conducted a few miles southwest of Payson in 1980.

GEOLOGY, GEOCHEMISTRY, AND GEOPHYSICS PERTAINING TO MINERAL RESOURCE ASSESSMENT

General Geology

The geology of the Mazatzal Wilderness and contiguous roadless area was mapped during this study and is shown on the accompanying 1:48,000-scale map and on figure 2. The only previous description of the geology in the wilderness (Wilson, 1939) is of the Proterozoic rocks in higher parts of the Mazatzal Mountains between Cactus Ridge and North Peak. Ludwig (1973) mapped the geology of the mercury district, which is mainly outside the wilderness south of Cactus Ridge. Part of this mapping is included in the geologic map that accompanies this report.

The oldest rocks of the Mazatzal Wilderness and the surrounding area consist of sequences of Early Proterozic sedimentary and volcanic stratified rocks intruded by gabbro, diorite, and alkali granite. These rocks in turn are overlain depositionally by Early Proterozoic sedimentary strata. The aggregate thickness of the Proterozoic stratified rocks is 61,000 ft. The Proterozoic rocks locally are capped by Paleozoic strata or they are partly buried by Tertiary volcanic flows and interstratified sedimentary rocks.

The oldest of the Early Proterozoic rocks in the wilderness may be the structurally fragmented stratified sequence of mafic volcanic flows, pillow basalts, volcaniclastic rocks, graywacke, minor rhyolite, jasper, and siltstone exposed on the east flank of the Mazatzal Mountains, along the East Verde River, and on the south rim of Buckhead Mesa. This stratigraphic section is about 26,000 ft thick and is informally referred to here as the East Verde River sequence. It is thought to be older than the Early Proterozoic Alder Formation[3] and has lithologic similarities to the older (1,740-1,760 m.y.) Yavapai Series in the Jerome-Prescott region (Anderson and others, 1971; L. T. Silver, oral commun., 1982). A correlation with the Yavapai Series is not clearly established.

Proterozoic rocks of two stratigraphic sequences, each about 3,300 ft thick, crop out near the confluence of the Verde River and East Verde River in the northwestern part of the wilderness. One sequence, consisting of siltstone overlain by rhyolite conglomerate, rhyolite, and andesite is exposed in the Limestone Hills and rests in apparent conformity on the East Verde River sequence described above. The second sequence occurs to the west in the vicinity of Squaw Butte and is composed of graywacke, quartzite, and rhyolite. A contact between the two sequences has not been found. Both of these sequences have rocks similar to the upper part of the Alder Formation and the overlying rhyolite, and to the rhyolite that is widespread in the eastern part of the wilderness beneath quartzite. Both sequences are weakly metamorphosed to the greenschist facies and are largely unfoliated.

Diorite, gabbro, and minor syenite of Early Proterozoic age occur as small intrusive masses in the Proterozoic stratified rocks in the Limestone Hills in the northwestern part of the wilderness, and as a large complex east of the wilderness between Buckhead Mesa and Rye Creek. These rocks contain a few large inclusions of metasedimentary rocks in the eastern part of the area outside the wilderness.

Sedimentary and volcanic rocks of the Alder Formation, including felsic porphyry sills, are exposed in a tightly appressed syncline along the southern margin of the area. The formation comprises weakly to strongly foliated sandstone, graywacke, shale, conglomerate, rhyodacite and rhyolite tuffs and flows, and subordinate mafic volcanic rocks. These rocks are metamorphosed to the greenschist facies of regional metamorphism. According to Ludwig (1973), the formation is entirely volcanic or volcanogenic in origin. He estimated the thickness of the formation to be about 18,000 ft. During the present study an additional 5,000 ft of strata were found in the wilderness beneath the rocks mapped by Ludwig. Ludwig (1973) described the Alder Formation as conformably overlain by the Red Rock Rhyolite of Wilson (1937, 1939), a thick (more than 3,000 ft) sequence of alkali rhyolite, predominantly ash-flow tuff. The Alder Formation is in contact with other Proterozoic rocks of the area only along the northeast-trending Sheep Mountain fault. Lithologically the Alder Formation is dissimilar to the East Verde River sequence, and regional relations suggest that the Alder Formation is younger.

The central part of the Mazatzal Wilderness is underlain by a large complex of alkali granite and granophyre that intruded the East Verde River sequence and the gabbro-diorite complex. Regional relations indicate that the granite also is younger than the Alder Formation. Granophyre is widespread in the wilderness and was emplaced as huge sheet-like bodies high in the alkali granite complex. The granite contact dips shallowly northward beneath stratified rocks of the East Verde River sequence, which are intruded by dikes of tourmaline-bearing rhyolite porphyry that probably are related to the alkali granite. The alkali granite is thought to correlate with granite for which an apparent age of 1,730±15 m.y. was obtained by L. T. Silver (Conway, 1976) from a sample collected 3.5 mi east-northeast of Payson.

A quartz monzonite porphyry crops out in a 2.5 mi^2 area at Tangle Creek on the west border of the area, just outside the wilderness and adjacent roadless area. This rock type appears to be more calcic than the associated alkali granite and differs in geochemical signature from the alkali

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[3]Anderson and others (1971) geographically restricted the Alder Group to its type locality in the Mazatzal Mountains. The unit is here reduced in rank to Alder Formation since it contains no formations. Furthermore, the age of the unit is here revised from Precambrian to Early Proterozoic based on Pb-U dates of 1,730±20 m.y. from metavolcanic rocks as reported by Ludwig (1973).

granite in having anomalous amounts of molybdenum, boron, tungsten, thorium, niobium, and yttrium, and in having distinctive gravity and aeromagnetic signatures. The quartz monzonite porphyry is thought to have intruded the alkali granite, but the relative ages of these intrusive rocks have not been established, and it is not known if the quartz monzonite is Proterozoic.

A sequence of Early Proterozoic rocks underlying the higher parts of the Mazatzal Mountains consists of alkali rhyolite ash-flow tuff overlain in turn by the Deadman Quartzite of Wilson (1939), the Maverick Shale of Wilson (1939), and the Mazatzal Quartzite (Wilson, 1939). The close spatial association of the rhyolite with the upper parts of the alkali granite complex and the apparent chemical affinities of the rhyolite and granite suggest that the rhyolite may be the extrusive roof-rock equivalent of the granite that intruded it. Similar thicknesses and lithologic and chemical similarities suggest that this rhyolite and the Red Rock Rhyolite, which crops out south of the Sheep Mountain fault, may be equivalent. This is compatible with the sequence in Tonto Basin (Conway, 1976), where a thick alkali rhyolite rests on the Alder Formation and is overlain by a great thickness of quartzite that is similar to the Deadman and Mazatzal Quartzites. An obstacle to this idea, however, is the fact that the Alder Formation, thousands of feet thick south of Sheep Mountain fault, is apparently missing beneath the rhyolite north of the fault. Conway (1976) and Wilson (1939) suggested that the Deadman Quartzite of Wilson (1939) and the Mazatzal Quartzite correlate with quartzite at Natural Bridge. Silver (1967; oral commun., 1976) dated a rhyolite flow within the quartzite at Natural Bridge as 1,715 ±15 m.y.

Porphyritic quartz monzonite and pegmatite crop out in the southwest corner of the area outside the wilderness and resemble granitic rocks of Middle Proterozoic (Ruin Granite) age that have been recognized in a wide area farther south in the Mazatzal Mountains.

Cambrian and Devonian sandstone and carbonate rocks once were more abundant throughout the wilderness, but they crop out today only in the Limestone Hills, along lower Pine Creek, and, together with Mississippian and Pennsylvanian strata, in upper Pine Creek. These rocks have a total thickness of about 800 ft and are regarded as having been deposited in shallow seas at the western edge of the North American craton.

Rocks of Tertiary age cover about one-half of the area and record an intricate history of volcanism and sedimentation from the middle of the Miocene to about the middle of the Pliocene. Rocks emplaced during this time interval include basalt flows and intertonguing sandstone, limestone, and gravel, forming a composite section as thick as 2,000 ft. Dacite flows and tuffs occur locally in the Tertiary strata, and dacite porphyry exists as intrusive rocks at Lion Mountain, Squaw Butte, and near the northwest corner of the area.

The youngest rocks in the area are poorly consolidated Quaternary sand and gravel in pediment alluvium, terrace gravels, and stream deposits. Quaternary travertine accumulated at a locality in lower Pine Creek, and landslide masses are found in many parts of the area.

The rocks of the Mazatzal Wilderness record a long and complex structural history (Wilson, 1939; Conway and others, 1982). The oldest deformation that affected rocks in the area was the northwestward to northward tilting of the Proterozoic stratified rocks of the East Verde River sequence. The Alder Formation may have been deformed at this time, although the relative ages of the deformation experienced by these rocks and the stratified sequences along the East Verde River are unknown. The next recorded event was the emplacement of the alkali granite and associated granophyre into the roof rhyolite. After deposition of the Deadman Quartzite, Maverick Shale, and Mazatzal Quartzite, this sedimentary sequence and, locally, the underlying rocks were folded into a northeast-trending syncline and broken by thrust faults along which movement was to the northwest. Prominent northeast- to north-trending faults, including the arcuate Deadman and Sheep Mountain faults, formed subsequently, as did some northwest-trending faults. These faults are the youngest Proterozoic structural features in the area studied. Many north- and northwest-trending faults are of Tertiary age, and some of them merged with Proterozoic faults and reactivated them. The Tertiary faults appear to have been active as early as middle Miocene and to have contributed to the development of Basin and Range topography and structures.

Geology related to mineralization

Many of the mineral occurrences in the Mazatzal Wilderness appear to be related directly or indirectly to the alkali granite. The granite and associated granophyre are tin bearing. Cassiterite has been found in modern stream sediments in areas of greisen zones in the granitic terrane, although it has not been identified in bedrock samples. The greisen zones are composed of highly sericitized quartz-rich granitic rocks containing abundant quartz veins and locally tourmaline and hematite. The presence of cassiterite and tourmaline and high values of tungsten, beryllium, boron, fluorine, and rare-earth elements in stream sediments in areas of greisen in the granitic terrane are indicative of mineralization late in the crystallization history of the granite. This mineralization was followed by deposition of tin, silver, copper, gold, arsenic, antimony, mercury, bismuth, lead, and zinc in northeast-trending veins. The genetic relationship of this mineralization to the alkali granite is based on the presence of tin and mercurian, auriferous, and argentiferous sulfosalts in veins in both the granite and its host metamorphic rocks and on the existence of the same suite of trace elements (tin, boron, and niobium) in these veins as in the greisen zones in the alkali granite. Tourmaline and fluorite locally are abundant in the vein systems. The sulfide minerals contain silver, bismuth, arsenic, and other elements found in well-known tin mineralization systems in the world (Taylor, 1979). The northeast-trending faults that contain the veins displace rocks as young as the Mazatzal Quartzite and could have been active earlier. These relationships indicate that a significant time interval may have occurred between emplacement of the granite and the development of related vein mineralization, as has been described for tin granites elsewhere (Sainsbury and Reed, 1973; Jones and others, 1977).

Gold occurrences in diorite east of the Mazatzal Wilderness may be related to the alkali granite, but this association has not been firmly established. The gold deposits occur on northwest-trending faults that have had movement—presumably of Tertiary age—since the gold mineralization. It is not known if these faults existed in Proterozoic time, but Proterozoic faults of northwest trend occur in the area.

Secondary copper minerals occur in mafic volcanic rocks of the East Verde River sequence in the Eisenhauer Canyon area immediately east of the wilderness boundary. This copper may have been derived from syngenetic copper in the volcanic host.

The mafic volcanic rocks in the East Verde River sequence accumulated in a marine environment favorable for stratabound massive sulfide-type mineral deposits. Massive sulfide deposits occur in Proterozoic marine volcanic rocks at Jerome, Arizona (Anderson and Nash, 1972). Although no deposits of this type have been discovered in the area, the favorable rocks and the widespread copper vein deposits suggest that massive sulfide bodies may exist in the East Verde River sequence and could be the source of the secondary copper in Eisenhauer Canyon and elsewhere along the east and north sides of the Mazatzal Mountains as far northwest as Copper Mountain.

Copper occurrences in the same mafic volcanic unit from the Casterson mine to the House mine are spatially associated with apophyses of granitic rocks and include significant amounts of gold, silver, arsenic, mercury, and antimony, suggestive of a genetic relation to the hydrothermal system in the alkali granite. However, some of this copper may have come from the mafic volcanic host. These deposits were mined for their precious metal content with copper as a byproduct.

Primary and secondary copper minerals occur in mafic volcanic rocks in the Mineral Creek area near intrusive rhyolite related to the alkali granite. These minerals appear to be concentrated along faults that form a complicated pattern at the intersection of the Proterozoic Deadman and Tertiary East Verde fault zones. There is a weak expression in this area of the suite of elements related to the mineralization associated with the alkali granite. However, the location of copper minerals on or near Tertiary faults argues for remobilization.

Primary and secondary copper minerals with small amounts of gold, silver, and mercury occur at mines and prospects in the Copper Mountain area. These occurrences may represent extensions of vein systems in the granite. Widespread copper minerals in the mafic volcanic rocks and gossan interpreted as clasts in the graywacke are suggestive of earlier, syngenetic copper.

Abundant veinlets of secondary malachite are associated with stratiform lenses of gossan and chert at Copper Camp Creek in the wilderness south of Sheep Mountain fault. Primary sedimentary structures in the gossan and clasts of gossan in associated conglomerate attest to a syngenetic origin of the primary minerals and suggest that a massive sulfide body may occur in the Copper Camp Creek area. Extensive well-developed chlorite beneath the chert and gossan lenses is indicative of hydrothermal alteration and venting in the immediate vicinity. But here, as in copper deposits associated with mafic volcanic rocks immediately east of the wilderness, elements such as arsenic, antimony, bismuth, gold, silver, and mercury, typical of the hydrothermal system related to the alkali granite, are present and suggest an epigenetic overprint.

Mercury deposits of the Sunflower district east of the southern part of the Mazatzal Wilderness are in steeply dipping highly foliated strata of the Alder Formation and contain cinnabar near the surface and mercurian tennantite, tourmaline, and cinnabar at depth (Lausen and Gardner, 1927; Faick, 1958; Ransome, 1915). The mercurian sulfides and tourmaline suggest an affinity to the sulfide mineralization in the Proterozoic alkali granite. The cinnabar may have evolved from the breakdown of preexisting sulfides probably during Tertiary volcanism. Cenozoic basalt, apparently intrusive into the Alder Formation, occurs near Highway 87 immediately south of the Sunflower district, and Miocene volcanic rocks occur to the west in the wilderness. Aeromagnetic data suggest a possible buried intrusive body in the vicinity of the mercury district.

The quartz monzonite porphyry at Tangle Creek, immediately west of the Mazatzal Wilderness and contiguous roadless areas, was identified during this study as mineralized, although no prospects or mines were found. Unusual concentrations of molybdenum, bismuth, tungsten, uranium, thorium, and scandium were found in a narrow zone from the west side of Tangle Creek outside the wilderness and roadless area, north into the roadless area. Anomalous molybdenum and uranium concentrations in stream waters from the quartz monzonite porphyry at Tangle Creek were the highest found in the area. The geochemical suite and data from water analyses are suggestive of porphyry molybdenum mineralization.

Uranium in Tertiary tuffs and sedimentary rocks along the Verde River could have been derived from the siliceous tuffaceous debris they contain or from nearby Proterozoic granitic rocks. The granites of the area contain anomalous concentrations of uranium and were exposed when the sedimentary rocks accumulated.

A small occurrence of copper-stained quartz, locally considered a gem stone because it resembles turquoise, occurs in freshwater limestone and siltstone low on the east flank of Chalk Mountain.

Geochemistry

Three sample media were selected as best for geochemical sampling in the arid high desert environment of the Mazatzal Wilderness: stream sediment, heavy-mineral concentrates from stream sediment, and rock. Sediments and concentrates were collected from first- and second-order stream drainages at 472 localities in the wilderness and contiguous roadless areas, each drainage representing an area of approximately 1 to 2 mi^2. Selected rock samples also were taken from areas of altered outcrops and from existing mining areas to determine mineral suites and trace-element signatures of mineralized systems.

The samples were screened and the minus-80-mesh fraction of the sediment and the nonmagnetic heavy (½2.6 specific gravity) fraction of the concentrate were analyzed for 31 elements by a semiquantitative emission spectrographic method (Grimes and Marranzino, 1968). Rock samples were pulverized and also analyzed by semiquantitative emission spectrographic methods. The resulting analyses along with statistical data for the Mazatzal Wilderness and contiguous roadless area are listed in two reports by Marsh and others (1983).

Semiquantitative spectrographic analyses of the nonmagnetic fraction of the heavy-mineral concentrates from stream sediments proved to be the most useful in evaluating the Mazatzal Wilderness and contiguous roadless area and have provided the principal evidence for mineral systems related to the Proterozoic alkali granite and the quartz monzonite prophyry in the Mazatzal Wilderness and surrounding areas. This sample medium contains the common ore-forming sulfide and oxide minerals as well as barite and other nonmagnetic minerals (zircon, apatite, fluorite, cassiterite, rutile, and some sphene and tourmaline). The concentrate medium also provides data that give a greatly enhanced anomaly pattern, as all of the more common (low specific gravity, less than 2.6) rock-forming minerals (quartz and feldspar) that tend to dilute the anomalies have been removed.

Several suites of geochemically associated elements found in samples collected during this study were discussed earlier as having formed during two or more episodes of mineralization. In addition, chromium and nickel were identified in stream sediments and in panned stream-sediment concentrates from of Tertiary basalts that have not been mineralized. The highest concentrations of these elements form sharply defined geochemical map patterns at the east edge of the wilderness from the East Verde River north and in the west-central part of the Mazatzal Wilderness northeast of Horseshoe Reservoir. The source of the elements is thought to be a chromian pyroxene that formed the bulk of the concentrate samples taken from areas draining the basalts.

In an evaluation of uranium resource potential in conglomerate of several Proterozoic formations in central Arizona, Anderson and Wirth (1981) obtained data on the concentration of uranium in the Deadman Quartzite of Wilson (1939) and the Mazatzal Quartzite. Except for local minor enrichments of uranium (as much as 33 ppm) in hematite-rich conglomerate near the base of the Deadman, no significant sedimentary concentration of uranium was found in these quartzites in the Mazatzal Wilderness. Anderson and Wirth (1981) identified no resource potential.

Remote sensing

As part of this study, limonitic materials were identified in images of the Mazatzal Wilderness area using a color-ratio-composite method (Rowan and others, 1974). This technique combined with field data was used to map areas of hydrothermal alteration associated with limonitic materials and to help define mineralized systems. The term limonite, as defined by Blanchard (1968), is used as a general term for hydrous iron oxides but is modified to include any material with the unique spectral reflectance properties of the ferric oxide minerals such as hematite and goethite as defined by Hunt (1980). The minerals pyrite and (or) hematite are almost universally associated with hydrothermal alteration potentially related to mineralization and these minerals weather to produce limonite, which is detected by this technique. Areas of hydrothermal alteration that are totally lacking limonitic materials will not be detected by this technique; however, such areas missed by this approach are believed to be insignificant in the Mazatzal area. A more significant problem in the Mazatzal area was the presence of greater than 40 percent vegetation cover, which severely hindered the ability to map the distribution of limonitic rocks and soils by this technique. This vegetation problem was signficant for much of the wilderness where small scattered areas of limonite surrounded by areas of high vegetation cover were observed. These small limonitic areas are generally not related to mineralization but to exposed portions of known limonitic lithologies.

This vegetation problem, however, does not appear to be significant for the alkali granite, which includes the largest limonite anomaly. This large anomaly is characterized in a 1:250,000-scale color-ratio-composite image as an area of pervasive limonite staining, as opposed to the other part of the alkali granite, which, as seen in the image, has small scattered limonitic areas. These small limonitic areas are apparently due to limonite after mafic minerals in the granite. The large limonite anomaly is spatially associated with the tin mineral suite and is believed to define the extent of iron oxidation metasomatism associated with the tin mineralization. Inspection on the Landsat images of this same granite surrounding the Mazatzal Wilderness indicates that the iron metasomatism is not a universal characteristic of the granite and that the single largest area of iron metasomatism, which is spatially related to tin greisen, is within a part of this granite.

Geophysics

Aeromagnetic maps and a gravity map were made for this study. The aeromagnetic maps contain data from a low-level survey, flown at 1,000-ft terrain clearance, and a high-level survey flown at a constant altitude of 9,000 ft (Sauck and Summer, 1970). In addition, electromagnetic data were gathered in the Copper Camp Creek area in the southern part of the Mazatzal Wilderness during this study.

The low-level and the high-level aeromagnetic data are complementary in this study in that data from the low-level survey show the effects of rocks at and near the surface, and data from the high-level survey reflect control by deeper seated bodies.

The complex patterns of the small aeromagnetic highs and lows in the low-level survey are caused principally by Tertiary basalt. Aeromagnetic highs in the Sunflower mining district in the southeastern corner of the area, where the basalt is absent, follow the grain of the Alder Formation, and several highs along the East Verde River in the north-central part of the wilderness probably reflect Proterozoic gabbro, which lies in part beneath the basalt. Wherever alkali granite and the overlying thick sections of rhyolite and quartzites are preserved, relatively low magnetic values occur.

The high-level aeromagnetic survey also shows low magnetic relief in areas of alkali granite and the overlying rhyolite-quartzite section. A prominent high, centered west of Tangle Creek at the center of the western margin of the area, projects southeastward into the Mazatzal Wilderness. This anomaly is thought to result from an intrusive body that is concealed by Tertiary basalt and sedimentary rocks in the wilderness and may be related to the quartz monzonite porphyry exposed at Tangle Creek. A high-level aeromagnetic anomaly at the southeast corner of the area, outside the wilderness, extends northwestward into the Sunflower mercury district and is not explained by any exposed rocks. This anomaly may be caused by a buried intrusive mass. The spatial distribution of mercury deposits in the Sunflower district suggests a possible genetic relationship between mineralization and the inferred intrusion. Aeromagnetic anomalies of high relief at the eastern edge of the area outside of the wilderness, and two high anomalies in the north-center of the wilderness are interpreted as resulting from Proterozoic gabbro and diorite. The aeromagnetic gradient reflected by southward-rising magnetic values in the southern part of the high-level map may be related to a large Proterozoic granitic pluton.

An electromagnetic survey was conducted at Copper Camp Creek across a small part of the mineralized zone using an instrument especially designed to detect massive sulfide bodies. No evidence of a massive sulfide body was found above the maximum search depth of about 400 ft.

The gravity data for most of the Mazatzal Wilderness show relatively low values indictive of the widespread distribution of the Proterozoic alkali granite at the surface and of its inferred probable distribution in the subsurface. In particular, low gravity readings suggest that the granite underlies the rhyolite and overlying quartzites and shale in the vicinity of Mazatzal Peak in the east-central part of the wilderness, and that it may underlie the Tertiary basalt cover north of the East Verde River. Relatively high gravity values are associated with the Alder Formation south of the gravity gradient that follows the Sheep Mountain fault. This association suggests that alkali granite, if present, is very deep. This gradient extends to the Verde River along the projection of the fault and suggests a westerly extension of the Alder Formation beneath Tertiary rocks. A positive gravity anomaly in the Tangle Creek area lies over exposures of the quartz monzonite porphyry and is partially coincident with the nose of the high-level aeromagnetic high that trends southeastward into the wilderness at the assumed projection of an extensive intrusive mass, which includes the porphyry. The fact that the gravity anomaly in the Tangle Creek area is not coincident with the highest part of the magnetic anomaly west of the nose further suggests different geophysical responses to various phases of the larger intrusive body. The gravity and aeromagnetic patterns north of Tangle Creek along the west border of the roadless area also may reflect different phases of the quartz monzonite and related rocks. A positive gravity anomaly outside the east edge of the wilderness is caused by a large diorite body and the metamorphic mafic volcanic rocks to the west.

MINING DISTRICTS AND MINES

The Mazatzal Wilderness and contiguous roadless area are located between the main parts of the Green Valley (Payson), Mazatzal Mountains, Sunflower, and Magazine mining districts (Wilson and others, 1961; Mardirosian, 1973). Most mines and prospects in the wilderness lie in or adjacent to the Green Valley (Payson) district. Mineral deposits at the southeast corner of the wilderness are in the Sunflower and Mazatzal Mountain districts. Claims at Horseshoe Dam and east of Chalk Mountain have been recorded as belonging to the Magazine mining district. At the time of this investigation, no mining or claim activities were observed in the wilderness or contiguous roadless area with the exception of the area around McFarland Canyon (Marsh, 1983).

Green Valley (Payson) district

Claims, prospects, and mines in the part of the Mazatzal Mountains that lies in the wilderness are thought to be outside of formal mining districts, but most are informally associated with the Green Valley, or Payson, district. The Blue Lode, Los Conquistadores, and Stingy Lady prospects west of the crest of the Mazatzal Mountains may be part of the district. Assay and geochemical data indicate that these properties were explored chiefly for silver. These properties almost certainly were first worked before World War II, perhaps long before then, as trails leading to them are obscure; there are no roads today. Numerous mines and prospects in the area between Copper Mountain and Red Metal Tank also are informally considered to be in the Green Valley (Payson) district. Claims located for silver in this area postdate World War II. Exploration for silver and copper 1 mi southwest of Copper Mountain during the period 1964 to 1967 resulted in an open cut about 110 ft by 60 ft and 100 ft deep. This property was mined in 1967. Several miles of bulldozer roads were made during the exploration and mining.

The Casterson, Collom, Crackerjack, House, and Gowan mines are in the Green Valley (Payson) district. These mines may date from the early days of mining in the area, but there are few records. A photograph in an early report (Lausen and Wilson, 1925) shows a stope that was dug at the Gowan mine in the 1880's. The House and Collom mines are 1 mi east of the wilderness boundary. Portals of two adits of the Casterson mine are east of the boundary, but the workings extend into the Mazatzal Wilderness and the block of claims at the mine straddle the wilderness boundary (Ellis, 1982). At the time of the study, workings of the Collom and

Casterson mines were accessible, but mineralized parts of the House mine could not be reached.

Numerous roads and bulldozer cuts at Mineral Creek, north of the Collom mine, are the result of exploration work by at least six mining companies during the period 1957 to 1977. This work was conducted chiefly on the ridge north of Mineral Creek on both sides of the wilderness boundary. Bulldozer roads also were made in Eisenhauer Canyon in 1957 in an area that has a few prospects and several short adits (Ellis, 1982) and now is inside the wilderness.

Sunflower and Mazatzal Mountains districts

Early reports described the Sunflower district as including the mercury deposits that now lie east of the southern part of the wilderness (Ransome, 1915; Lausen and Gardner, 1927). Subsequently, mines of the area have been considered to be in the Mazatzal Mountains mining district (Beckman and Kerns, 1965; Bailey, 1969). Informal usage would include the Sunflower district as part of a larger Mazatzal Mountains district. The Story mine and the deposits at Copper Camp Creek are located in the wilderness 0.75 mi and 3 mi, respectively, west of the nearest mercury mine and informally are associated with these districts.

The Story mine was developed in a gold-silver-lead deposit located east of Saddle Mountain and less than 1,000 ft inside the Mazatzal Wilderness boundary. A shaft and two adits on the property are caved.

A few adits, prospect pits, and a shaft are located in McFarland Canyon north and northeast of the Story mine in rocks that show evidence of gold-pyrite-arsenopyrite mineralization. The workings appear to be old, as no roads lead to them.

At Copper Camp Creek, more than a dozen pits and trenches, a shaft 60 ft deep, and an adit 390 ft long occur in a block of 22 claims known as the Copper Cliff group. These workings were dug to explore the occurrence of copper carbonate minerals that locally are abundant in surface exposures. The age of the workings is unknown.

Magazine district

The Magazine mining district is centered southwest of the map area, about 7 mi west of Horseshoe Reservoir, in an area of silver and copper deposits (Wilson and others, 1961; Moore and Roseveare, 1969). In the 1970's, two blocks of 150 claims each were located on the east side of the Verde River and were recorded as belonging to the Magazine district. The claims extend from southeast of Horseshoe Dam, outside of the Mazatzal Wilderness, north to the vicinity of Chalk Mountain, where some of the claims are in the roadless area. At least three holes have been drilled in the claims. Tertiary sedimentary rocks in the claimed area contain abundant volcanic detritus and are uraniferous.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

Geologic, geochemical, remote-sensing, and geophysical data acquired during this study and information obtained from the mining history, mineral exploration, and assays indicate that the Mazatzal Wilderness and contiguous roadless areas have mineral potential for a number of metals. Within the wilderness there is potential for gold, silver, copper, lead, uranium, mercury, molybdenum, and possibly tin. One roadless area has potential for uranium and molybdenum.

Areas of mineral resource potential are shown on the accompanying 1:48,000-scale map and on figure 3. The criteria used to define the 18 areas shown are listed on the accompanying 1:48,000-scale map and are discussed below.

The resource potential of mineralized areas in the Mazatzal Wilderness, the contiguous roadless areas, and adjacent areas is ranked <u>in this report</u> using the following criteria:

Low potential.—The available information defines a geologic environment that is permissive for mineral resources, but there is little evidence to indicate that geologic processes acted to produce a mineral resource.

Moderate potential.—The available information defines a geologic environment that is favorable for mineral resources, and there is evidence to support the interpretation that geologic processes could have resulted in a mineral resource.

High potential.—The available information defines a geologic environment that is favorable for mineral resources, and there is sufficient evidence to support the interpretation that geologic processes resulted in a mineral resource.

Available information used in evaluating mineral potential includes the results of geologic, geochemical, or geophysical studies and the results of investigations of mines, claims, and production records. Geologic environment refers to the rocks and the structural features of the rocks in a geographically restricted setting and includes any materials that may have been added during mineralizing events. Geologic processes are those naturally occurring systematic actions that result in the development of rocks and minerals or that cause changes in them. A mineral resource is a concentration of naturally occurring solid, liquid, or gaseous material in or on the Earth's surface in such form and amount that economic extraction of a commodity from the concentration is currently or potentially feasible (U.S. Bureau of Mines and U.S. Geological Survey, 1980).

Areas 1, 2, 3, 4, 5, 6, 7, and 8—silver, gold, and copper

Areas favorable for silver, gold, and copper resources occur in metamorphic rocks in or near the northern, eastern, and southern parts of the wilderness. At some localities in the northern and eastern parts of the area, precious metals occur with substantial amounts of copper, but at other localities copper alone is the principal metal. In the southern part of the wilderness, precious metals and copper, other than in trace amounts, occur in separate deposits. The silver, gold, and copper deposits are small, and collectively they appear to constitute only a small resource of these metals. Occurrences of silver at the Stingy Lady prospect northeast of Midnight Mesa and copper at the Blue Lode and Los Conquistadores prospects in the west-central part of the wilderness are not indicative of resource potential for silver and copper.

The different ratios of precious metals to copper in the mineral deposits of these areas suggest a dual origin of the copper and possibly of the precious metals as discussed earlier. Some of the gold, silver, and copper are interpreted as having been derived from the alkali granite, whereas part of the copper may have been mobilized from syngenetic copper concentrations, possibly including massive sulfide deposits, in Proterozoic volcanic and volcaniclastic rocks. Gold and silver (with subordinate lead) in the southern part of the area may have yet a different origin.

Area 1

One of the principal areas of mineral resource potential in the Mazatzal Wilderness is located near the southern border of the wilderness in metamorphic rocks of the Alder Formation and includes the Story mine and nearby parts of McFarland Canyon. The Story mine was developed in tuffaceous volcaniclastic rocks containing silver-gold-lead vein deposits. As stated earlier, all of the workings are caved, and the only existing records of mining activity date from after World War II. Lead arsenate minerals related to the mineralization are evident in surface exposures in and around the old workings, and a gossan vein can be followed discontinuously for several hundred feet, possibly crossing the strike of the host rocks at a low angle.

Much of the area around the Story mine appears to be weakly sericitized, and the rocks exhibit a bleached and altered aspect (Marsh, 1983). The area has been strongly silicified and contains abundant quartz-chlorite veins. In many places, the fine-grained tuffaceous host rocks have been silicified, but they retain much of their original character. In many of the quartz veins, included tuffaceous material appears to have been altered to chlorite, which in some areas is further altered to iron oxides. In some quartz veins, sites once occupied by altered bedrock inclusions are now only voids. The altered area extends for at least 0.5 mi radius around the Story mine, and the zone of silicification extends much farther.

Assay values and the old mining records from the Story mine show that the mine has about 78,000 tons of indicated resources containing 0.06 oz/ton gold, 1.9 oz/ton silver, and 3.9 percent lead. These estimates are for resources remaining after subtraction of recorded production but include any unrecorded production that may have occurred.

In McFarland Canyon, gold occurs with pyrite and arsenopyrite in intrusive rhyolite sheets and in phyllitic, partly tuffaceous shale and metasiltstone of the Alder Formation, from about 0.5 mi inside the Mazatzal Wilderness to about 0.5 mi east of the wilderness boundary (Marsh, 1983). The mineralized area is about 1,500 ft wide and is parallel to the trend of the host rocks. The greatest concentrations of mineralized rock found in this area are 3,000 ft north of the Story mine and in an area about 1,500 ft in diameter centered 4,000 ft northeast of the Story mine. Several short adits, a shaft, and a few prospect pits are located in the area, but there is no record of production.

Mineralization in the McFarland Canyon area resulted in disseminated pyrite and generally sparse, but locally abundant, disseminated arsenopyrite in the rhyolite, and as arsenopyrite veins in the rhyolite and more commonly in the host sedimentary rocks. Arsenopyrite occurs as 0.75-1.5 in.-wide veinlets either as selvages to quartz veins or alone. Veins are not abundant in the area. They can be followed 10 to 20 ft subparallel to bedding and appear to form parts of a vein system that can be traced with interruptions for several thousand feet along McFarland Canyon (D. M. Brown and J. L. White, Texasgulf Western, Inc., oral commun., 1982). As at the Story mine, weakly sericitized rock is widespread and is found in the rhyolite as well as the metasedimentary rocks. The rhyolite and metasedimentary rocks are locally silicified, and the metasedimentary rocks contain quartz veins.

The rhyolite sheets follow the strike of the adjacent sedimentary rocks but are clearly intrusive, as the sheets locally cross the lithologic layering and foliation of these rocks. The rhyolite is unfoliated and thus postdates the Proterozoic deformation.

Geochemical data show that arsenic, gold, silver, lead, and small amounts of copper occur in the mineralized area and that the highest values for gold are in places having high concentrations of arsenopyrite. This is the same suite of elements that was found at the Story mine.

The origin of the mineral deposits at the Story mine and in McFarland Canyon is uncertain. The spatial association of rhyolite to the mineralized rocks in McFarland Canyon indicates a genetic relationship and might also account for the mineralization at the Story mine, although no rhyolite is exposed in the immediate vicinity of the Story mine. An argument against a genetic tie between the rhyolite and the mineralization is that the rhyolite sheets and adjacent host rocks are barren outside of McFarland Canyon.

Genesis of the mineral deposits by volcanogenic processes in the Story mine-McFarland Canyon area is suggested by the apparent stratabound distribution of the mineralized rock, its association with tuffaceous volcaniclastic rocks, and the widespread effects of silicification and sericitization. The existence of a small tongue of basalt on strike with the Story mine shows that volcanism was closely contemporaneous with sedimentation in that area, and high concentrations of lead, abundant in many distal massive sulfide deposits (Anderson and Guilbert, 1979), occur in the mineralized zone at the Story mine and in McFarland Canyon. Evidence of volcanogenic sulfides has been found in the lower part of the Alder Formation in the Copper Camp Creek area, discussed later, and interbedded jasper and sulfide-barren, but iron-rich carbonate rocks are suggestive of an exhalative process in the stratigraphically higher part of the Alder Formation. However, the mineralization in McFarland Canyon postdates emplacement of the rhyolite sheets, which were intruded after development of foliation in the host rocks. The quartz veins are later still and are subparallel to layering of the strata. Had the quartz veins formed in fractures that channeled rising hot solutions during volcanism, some of the veins likely would extend through the altered zones at large angles to the host strata (Boyle, 1979, p. 301).

The mineral deposits in the Story mine-McFarland Canyon area may have developed from an igneous source at depth, possibly an intrusive body related to the aeromagnetic high discussed earlier as occurring in the mercury mining area east of the Story mine. Although mercury was detected in sulfides, no evidence of cinnabar was found at the Story mine or in McFarland Canyon, and there is no evidence at present indicating a connection between this mineralization and mineralization in the mercury district.

Area 1 has a high potential for the occurrence of gold-silver-lead resources. Considerable exploration would be required to determine the extent and grade of mineralized rocks in the area.

Area 2

Silver and copper veins occur in the vicinity of Copper Mountain in the north-central part of the wilderness. This area includes upper parts of the steep north-facing slope of the canyon of the East Verde River south from Copper Mountain and contains Bullfrog Ridge and the ridge that trends northeasterly from Red Metal Tank. The area has a large block of claims (Ellis, 1982) and many mines and prospects, reflecting widespread mineralization. The veins trend north-northeast and occur in a zone of intensely fractured rocks on both sides of a major fault of the same trend. This fault separates Early Proterozoic mafic volcanic rocks to the east from Early Proterozoic graywacke to the west and cuts the alkali granite to the south.

Mineral occurrences in the part of area 2 east of the fault are mainly along Bullfrog Ridge and consist of silver-bearing copper sulfide and oxide minerals in volcanic rocks. Geochemical samples collected from prospects in mineralized rocks on the ridge and assay values from old workings show that the veins and the adjacent altered country rock are rich in copper, silver, lead, and zinc, and that they contain trace amounts of bismuth, cadmium, antimony, arsenic, and mercury. This geochemical suite is typical of the hydrothermal mineralization related to the alkali granite, which crops out a short distance to the south and may underlie the area at relatively shallow depth. The hydrothermal mineralization greatly overwhelmed any copper that may reasonably have been contributed by the mafic volcanic host. It is possible that massive sulfide deposits exist in the volcanic rocks and could be the source of the copper in the vein deposits.

The graywacke west of the north-trending fault locally is intensely altered and has abundant quartz veins. Iron oxide is abundant, and yellow and green complex secondary minerals coat fracture surfaces. No sulfide minerals were found in these rocks. Geochemical data from the veins show high concentrations of copper, silver, lead, and zinc, and trace quantitites of antimony, arsenic, and tin. This suite of elements also is indicative of the hydrothermal mineralization that emanated from the alkali granite.

Silver and copper in quartz veins in the area occur at the open-cut mine located west of Bullfrog Canyon and 1 mi southwest of Copper Mountain. This is the only place in the Mazatzal Wilderness where copper and silver production has been recorded. According to records of the U.S. Forest Service, this mine produced 33.5 tons of ore containing 938 lb of copper and 485 oz of silver in 1967. Based on this production and the presence of spotty but locally high-grade rock in the mine area, the deposit has a high potential for additional resources of silver and copper. Geochemical analyses and assays showing high concentrations of these metals in altered rock outside the mine are indicative of a high potential for the occurrence of silver and cooper resources elsewhere in area 2. The silver and copper resources could be expected to occur in a few deposits containing hundreds to a few tens of thousands of tons of mineralized rock. The possibility for the recovery of copper in the area may depend on the tenor of associated silver. The potential for the presence of massive sulfide resources in area 2 is low.

Area 3

Veins containing silver, gold, and copper occur at the House, Collom, and Casterson mines, which are located east of the east border of the Mazatzal Wilderness in area 3.

Evidence from underground workings, surface exposures, and dump materials show that mineral deposits in area 3 consist of well-defined veins in mafic volcanic rocks of the Proterozoic East Verde River sequence. Veins mapped at the Collom and Casterson mines follow northerly and northwesterly trends (Ellis, 1982) and contain quartz and locally sulfide and oxide minerals. The deposits in area 3 resemble those mineralized parts of area 2 near Copper Mountain that are underlain by mafic volcanic rocks. Like the deposits of Copper Mountain, the alkali granite crops out near mineralized parts of area 3. These exposures are 1 mi northwest of the House mine and in the eastern part of the Casterson mine area.

Geochemical and assay data from samples collected at mines in area 3 reveal low to high concentrations of silver, gold, and copper. A geochemical sample containing secondary copper minerals collected from the dump at the House mine was found to contain >30 ppm silver, 13 ppm gold, >20,000 ppm copper, and high concentrations of arsenic, antimony, bismuth, cadmium, lead, and zinc. A sample of country rock from this dump was found to have the same elements in lower but still anomalous concentrations. Samples from the dump of the Collom mine contain the same suite of elements. The trace-element suite in these rocks therefore has the same geochemical signature as mineralized rocks formed during the hydrothermal phase of the alkali-granite. However, it is reasonable to assume that some of the copper in the mineral deposits of area 3, like the deposits at Copper Mountain, may have been supplied by the mafic volcanic host rocks, possibly massive sulfide deposits.

The Casterson and Collom mines produced a few ounces of gold, about 300 oz of silver, and a few pounds of copper in the early 1940's. Both mines probably had some production before these dates. There is no recorded production from the House mine. The probable total production from all three mines was small. Combined inferred reserves of the Casterson and Collom mines are estimated to be 52,000 tons of mineralized rock containing 0.7 oz/ton silver and 0.07 oz/ton gold (Ellis, 1982). There is a moderate potential for the presence of additional vein-type mineral resources in favorable geologic settings in other parts of area 3, especially near granitic rocks, either exposed or at shallow depths. If present they probably would occur in deposits of high grade and small size and would measure from hundreds of tons to a few tens of thousands of tons of mineralized rock. The area has a low potential for resources of copper in massive sulfide deposits.

Area 4

Copper minerals are widespread in area 4, which trends approximately east-west for a distance of about 1.25 mi in the vicinity of Mineral Creek, north of North Peak, at the eastern border of the Mazatzal Wilderness. Half of the area is inside the wilderness. A large block of claims centered east of the wilderness covers most of area 4 and extends into the wilderness (Ellis, 1982).

At least six mining companies conducted mineral exploration work in the area during the period 1957-1977. This work resulted in the construction of many roads and bulldozer cuts, chiefly on the ridge north of Mineral Creek, on both sides of the Mazatzal Wilderness boundary.

Mafic volcanic rocks in the Mineral Creek area have copper oxides on fracture surfaces and local concentrations of secondary potassium feldspar. The greatest concentration of copper minerals is near the junction of the Deadman and East Verde River faults. Rocks associated with the alkali granite intruded graywacke south of Mineral Creek, and it is likely that these intrusive rocks also underlie the mafic volcanic rocks in the Mineral Creek area. Geochemical data show a weak trace-element signature of hydrothermal mineralization related to the alkali granite. However, much of the copper here could have been derived from the mafic volcanic bedrock. Copper carbonate minerals in faults indicate some remobilization of copper as young as Tertiary.

The resource potential for copper in mineralized veins and fractures in area 4 is high in an area 800 ft by 3,000 ft astride the Mazatzal wilderness boundary on the north side of Mineral Creek. This locality has the highest concentration of copper in area 4. The concentration is spotty, and copper averages 0.09 percent (Ellis, 1982). There is a moderate potential for the occurrence of copper resources in veins in the mafic volcanic rocks outside the area of greatest exposed mineral concentrations. Area 4 also has a low potential for copper resources in massive sulfide deposits.

Area 5

Copper carbonate veins locally are abundant in area 5, which is located at Copper Camp Creek in the southern part of the Mazatzal Wilderness. A shallow shaft, a short adit, and numerous prospect pits and trenches have been developed in the area in a block of 22 mining claims (Ellis, 1982). There is no record of production, and the amount of copper ore that might have been shipped would have been small (Ellis, 1982). Rocks in one of the more intensely mineralized parts of the adit in this area averages 0.71 percent copper and 0.2 oz/ton silver (Ellis, 1982). As discussed earlier, an attempt during this study to determine the presence of massive sulfides by geophysical means showed that such deposits are not present above the maximum search depth of 400 ft.

Beds and lenses of impure gossan, locally about 6 ft thick and interlayered with chert in the Alder Formation in area 5 suggest an early mineralization of the stratabound massive sulfide type in which volcanogenic sulfides were deposited by sedimentary processes. Fragments of gossan in volcanic breccia interlayered with the chert resulted from breakup and transport of the gossan and provide additional evidence of an early mineralization. The abundant malachite veinlets occur in the volcanic breccia and record a late mineralizing event. Significant concentrations of arsenic, antimony, bismuth, gold, silver, and tungsten in geochemical samples of the malachite-bearing rocks suggest that the late mineralization may be an overprint by the hydrothermal system related to the alkali granite, but it also is possible that the veins formed from copper derived from massive sulfide mineralization.

There is moderate potential for the occurrence of copper resources in carbonate veins and high potential for the occurrence of copper in massive sulfide deposits in the Copper Camp Creek area.

Areas 6 and 7

Scattered and generally low concentrations of copper minerals occur in areas 6 and 7, located respectively in the eastern and northern parts of the area studied. Area 6 is situated partly inside and partly outside the Mazatzal Wilderness Wilderness at the eastern border, near North Peak. It includes all of the area underlain by mafic volcanic rocks outside of area 3. Area 7 is situated entirely in the wilderness northwest of area 6 and contains mafic volcanic rocks outside of area 2.

Eisenhauer Canyon is the only part of area 6 showing possibly significant mineral occurrences. Mineral exploration was conducted in the area in 1957. There is no record of production.

Mineral occurrences at Eisenhauer Canyon consist of secondary copper minerals, principally malachite, and quartz concentrated in faults and fractures. The host mafic volcanic rocks are propylitized and contain abundant epidote. Spectrographic and wet-chemical analyses of rocks and stream sediments collected in the area show small amounts of copper, and assay data (Ellis, 1982) indicate that silver is present locally in low concentrations. Chemical elements indicative of mineralization related to the alkali granite are not present. The copper is interpreted as having been mobilized from the mafic volcanic bedrock, possibly from stratabound sulfide deposits.

A few occurrences of secondary copper minerals exist in mafic volcanic rocks of area 6 outside of Eisenhauer Canyon and in area 7. They are small and widely separated, and only a few prospects have been found in them. The weak mineral occurrences in these areas are thought to be of copper that originally was syngenetic in the host volcanic rocks, which could contain massive sulfide deposits. No clear evidence of massive sulfide deposits was found in areas 6 or 7.

The scattered occurrences of secondary copper minerals in areas 6 and 7 suggest the mineral resources of these areas are small, but if massive sulfide bodies exist the copper resources could be large. Available data indicate that areas 6 and 7 have a low potential for copper resources in veins and a low potential for copper resources in massive sulfide deposits.

Area 8

Gold is the principal commodity of area 8, which is located in the east-central part of the area studied, east of the Mazatzal Wilderness and contiguous roadless areas. Copper locally is important. The area has numerous prospects and a few mines and forms part of the Green Valley (Payson) mining district. Geologically, area 8 is similar to parts of the Green Valley district to the east, where many gold deposits are known (Lausen and Wilson, 1925). Although entirely outside of the wilderness, the area was examined briefly because it is mineralized and has some of the same rocks as nearby parts of the wilderness.

Gold deposits in area 8 occur as quartz-bearing veins in Proterozoic diorite and included metasedimentary rocks. According to Lausen and Wilson (1925) the veins contain free gold and gold in pyrite. The veins are in fault zones of westerly and northwesterly trend. Some of the veins show evidence of movement that postdates the mineralization (Lausen and Wilson, 1925). In addition to gold, the veins contain silver and copper.

The two largest mines in area 8 were examined during this study (Ellis, 1982). The Gowan mine was first worked during the period 1880-1882, but no production data are available for those years (Lausen and Wilson, 1925). The Gowan mine also produced gold in 1938-1940. The Crackerjack mine produced gold, silver, and copper during the period 1942-1956. Most of the 17,596 lb of copper produced from the Casterson, Collom, Crackerjack, and Gowan mine came from the Crackerjack mine. Assay data from the Gowan and Crackerjack mines show significant values of gold and silver, and the data from the Crackerjack mine show high copper values (Ellis, 1982).

Our studies suggest that, considering the existence of mines that have had production, the large size of area 8, and the extensive soil and forest cover, it is reasonable to assume that the area has a high potential for gold, silver, and copper resources in deposits the size of those at the Gowan and Crackerjack mines. Geochemical sampling in the area (not conducted during this study) would be helpful in estimating the number and location of any additional deposits. Although no gold deposits have been found in the dioritic rocks in the wilderness, faults of westerly and northwesterly trend in these rocks may nevertheless have potential for gold resources.

Areas 9, 10, and 11—mercury

About 95 percent of the mercury that has been recovered in Arizona has come from the Sunflower mining district (Bailey, 1969), which is centered a few miles east of the southern part of the Mazatzal wilderness. Although production from the district has been significant for Arizona, it amounts to far less than one percent of the total production of mercury in the United States (Bailey, 1969), and there has been little production from the district since the 1960's. About half of the district, including two of the four most productive mines—the Pine Mountain and Sunflower mines—are in the area studied. A small part of the district extends into the wilderness (fig. 3).

Area 9

The major mercury mines in the northern part of the Sunflower mining district, and the strongest indications of mercury in the area studied, are in area 9. This area begins at the eastern border of the Mazatzal Wilderness and extends to the northeast in a belt about 5,000 ft wide. It includes many prospects as well as numerous mines (Ellis, 1982).

Mercury in area 9 occurs as cinnabar in shaly tuff and sandstone of the Alder Formation. The mercury occurs intermittently along strike for 5 mi within a stratigraphic interval of about 5,000 ft on the north limb of a major syncline. Mercury mines in this limb are coextensive with an irregular Proterozoic felsic sill of the Pine Mountain Porphyry of Wilson (1939). Most mines occur near the margin of the sill; only a few prospects occur within it. Cinnabar is disseminated in the host rocks and is concentrated along prominent foliation planes. The northwest-trending nose of an aeromagnetic high underlies the central part of area 9 and may represent an unexposed intrusive body related to the mercury mineralization.

Occurrences of mercury in area 9 extend beyond the Sunflower mine workings and have been explored intermittently in recent years. No quantitative estimates have been made of the mercury resources of this area, with the exception of the Sunflower mine at the southwest end of area 9, which is estimated in this study to have inferred resources of 26,000 tons of rock containing 0.14 percent mercury outside the wilderness and 3,600 tons of rock containing 0.21 percent mercury inside the wilderness. The potential for the presence of mercury resources in area 9 is high.

Area 10

Two areas containing mercury are designated as area 10 (fig. 3). One surrounds area 9 and extends 0.3 mi into the Mazatzal Wilderness. The other part of area 10 is at the southeast margin of the area studied and contains highly foliated rocks of approximately the same stratigraphic interval in the Alder Formation as in the northern area. The aeromagnetic anomaly mentioned as occurring in area 9 is centered close to the southern of the two areas labeled as 10 and extends into the northern area. Both parts of area 10 contain few prospects and have few mines (Ellis, 1982), all of which have had little or no production.

Mercury is sparsely distributed in area 10. Only rock samples from the Story mine showed highly anomalous concentrations of mercury. Area 10 has a moderate potential for the occurrence of mercury resources. However, the chances of a deposit the size of the old producing mines in area 9 are considered small.

Area 11

Area 11 contains all exposures of the Alder Formation outside of areas 9 and 10. Most of the area is in the southern part of the Mazatzal Wilderness, but the area extends to the west and east of the wilderness boundaries (fig. 3). The only indications of mercury in the area are widely scattered anomalous geochemical concentrations. The potential for mercury resources in the area is low.

Areas 12, 13, and 14—molybdenum

Indications of molybdenum mineralization found in stream sediment, heavy-mineral concentrates from stream sediment, rock, and water in the Tangle Creek area west of the Mazatzal Wilderness during this study suggest that the quartz monzonite porphyry exposed west of Tangle Creek may contain a porphyry molybdenum resource. Area 12 is the exposed part of the quartz monzonite porphyry. Gravity and aeromagnetic data indicate that the quartz monzonite porphyry pluton may be moderate in size and may extend eastward and northeastward into the roadless area and the wilderness beneath younger rocks. The outline of area 13 is based on the gravity and aeromagnetic highs that project southeastward from the vicinity of the outcropping quartz monzonite porphyry. The outline of area 14 is based on weak gravity and aeromagnetic highs suggestive of the quartz monzonite porphyry at depth and on high molybdenum concentrations in a few surface samples. Additional sampling will be required in area 12, and drilling will be necessary in areas 13 and 14 to determine the existence, distribution, and grade of any mineralized rocks. On the basis of the meager data from the geologic reconnaissance and the geochemical and geophysical surveys, the potential for the occurrence of molybdenum resources in areas 12, 13, and 14 is low.

Areas 15 and 16—tin

Evidence of tin mineralization was found during this study in the alkali granite in the central part of the Mazatzal Wilderness. Cassiterite identified in heavy-mineral concentrates of stream-sediment samples collected in this part of the area had to have been derived from the granitic rocks, although none was found in the granite. Moreover, greisen zones in the alkali granite appear to be the favored host for the tin mineralization. High concentrations of tin, tungsten, beryllium, boron, fluorine, and rare-earth elements in the cassiterite-bearing panned concentrates provide additional indications of hydrothermal tin mineralization. The greisen zones occur in area 15, which is located near the center of the wilderness. This is the most favorable area for tin identified during this study, but it is not certain if the abundance of tin is great enough to be indicative of a potential for tin resources. Geochemical evidence suggests that other parts of the alkali granite pluton, labeled as area 16, also may contain greisen zones. However, area 16, like area 15, may not have concentrations of tin great enough to be indicative of a potential for tin resources. Additional sampling will be required to identify areas of tin concentration and to evaluate more fully the tin resource potential of the alkali granite. The chances of any part of the alkali granite pluton containing recoverable cassiterite are extremely poor. No significant concentrations of placer cassiterite were found. Evidence of tin mineralization has not previously been reported as occurring in this rock type in Arizona.

Areas 17 and 18—uranium

Uranium exists in Tertiary tuffs and sedimentary rocks near Horseshoe Reservoir, west of the Mazatzal Wilderness. A large block of claims has been staked in this area outside the wilderness and partly inside one roadless area (Ellis, 1982). Concentrations of uranium occur in siliceous tuff and tuffaceous, carbonate-rich Tertiary sandstone northwest and southeast of Horseshoe Dam, and in tuffaceous siltstone on the east, west, and north sides of Horseshoe Reservoir to about 2 mi north of Chalk Mountain. The highest assay value obtained was 165 ppm uranium oxide from a sample taken across a 4-in-thick bed southeast of Horseshoe dam (Ellis, 1982). All other values obtained in the same area were 18 ppm uranium oxide or less. Area 17, which trends northwesterly on the south side of the reservoir, has a moderate potential for the occurence of uranium resources, based on the assay concentrations and a favorable host rock. Area 18 has a low potential for the presence of uranium resources. The proximity of Proterozoic granitic rocks, which are slightly uraniferous, could be a source for some of the uranium in areas 17 and 18.

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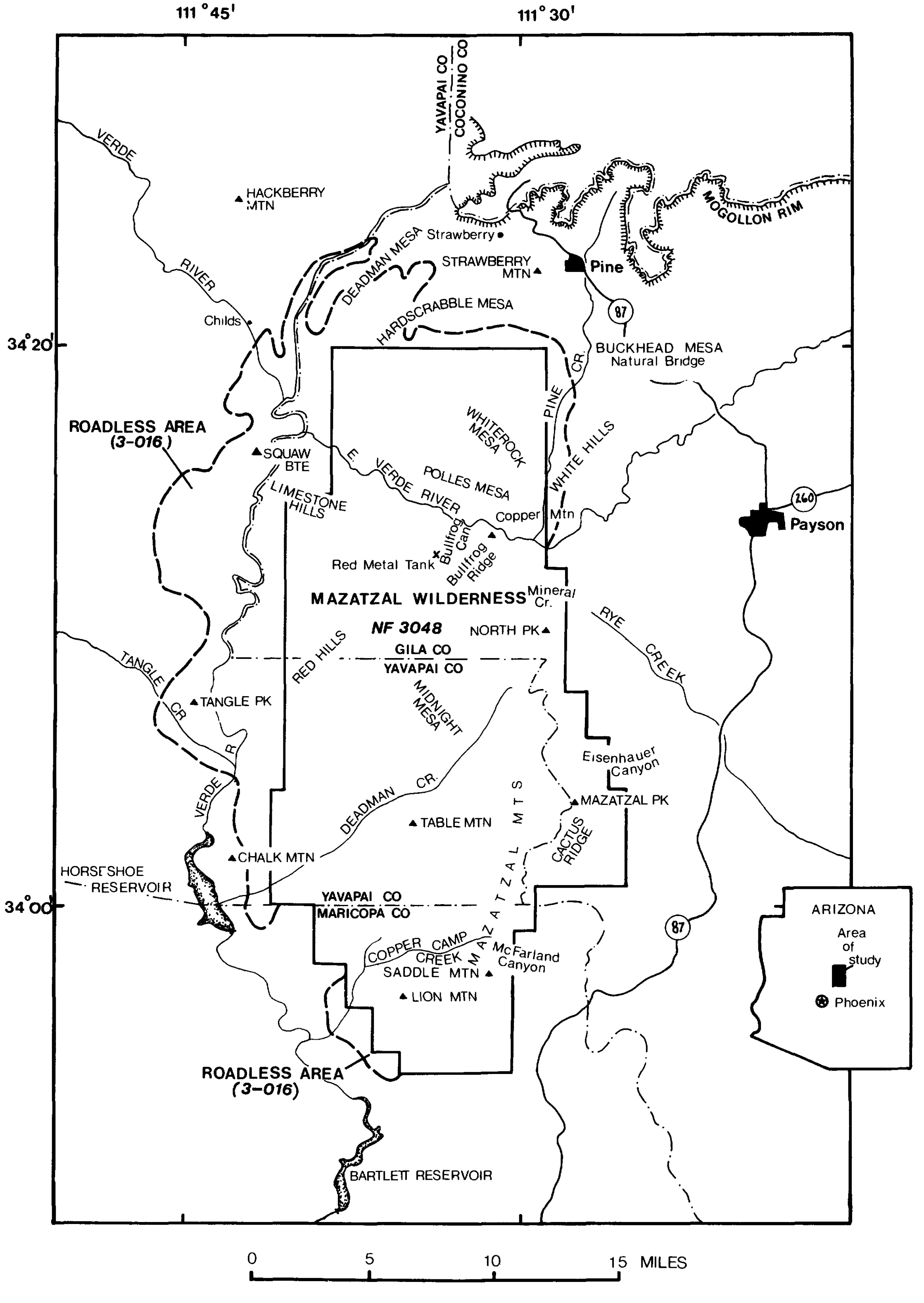

Figure 1.--Map showing location of the Mazatzal Wilderness and contiguous roadless area , central Arizona.

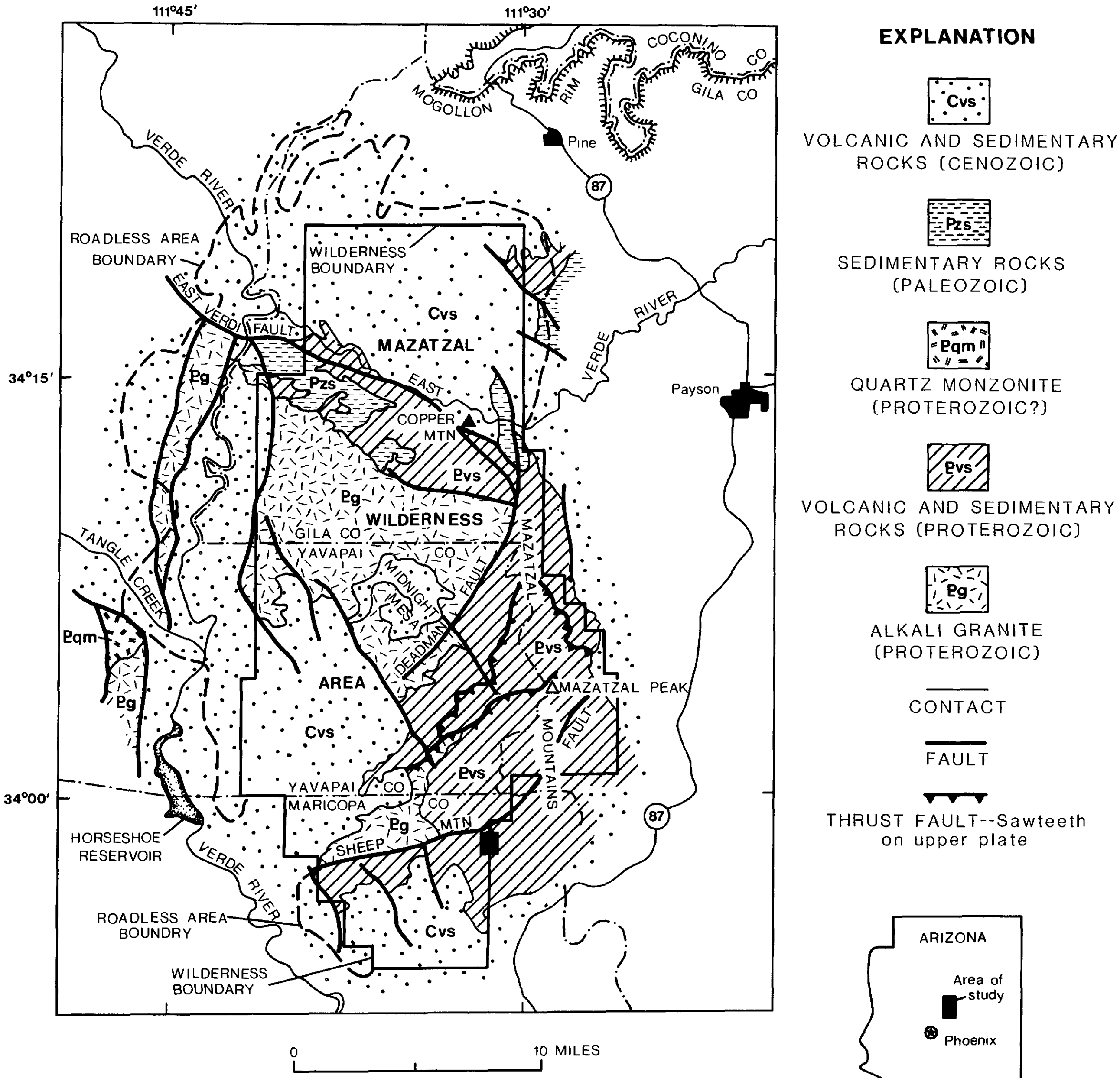

Figure 2.--Map showing generalized geology of the Mazatzal Wilderness and contiguous roadless area.

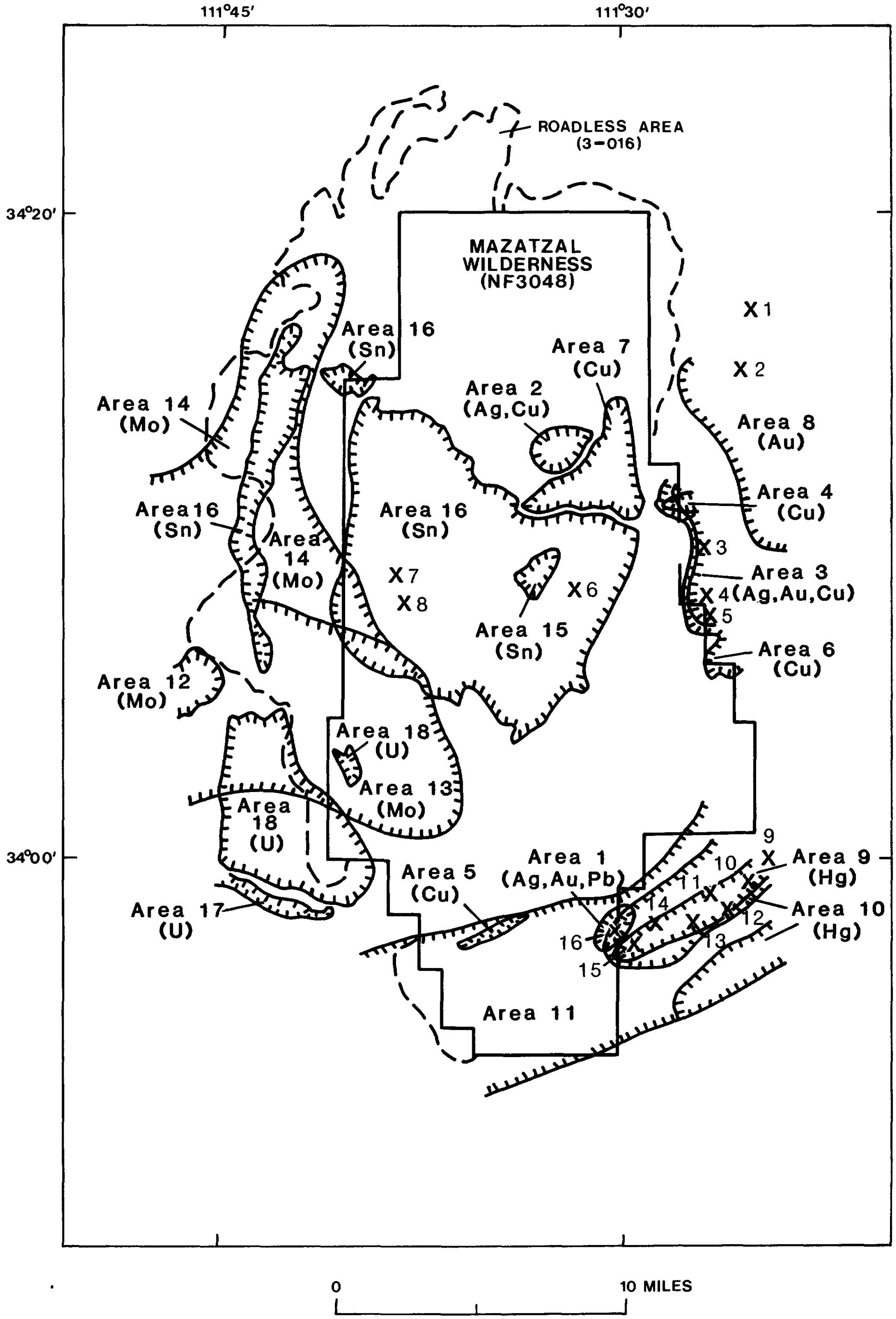

Figure 3.--Areas of mineral resource potential and locations of mines and prospects in the Mazatzal Wilderness and contiguous roadless area. See following page for explanation.

EXPLANATION

AREA OF MINERAL RESOURCE POTENTIAL--All hachures on mineralized side of line. Copper (Cu), gold (Au), lead (Pb), mercury (Hg), molybdenum (Mo), silver (Ag), tin (Sn), and uranium (U)

Area 1--High potential for silver, gold, and lead in vein deposits

Area 2--High potential for silver and copper in vein deposits. Low potential for copper in massive sulfide deposits

Area 3--Moderate potential for silver, gold, and copper in vein deposits. Low potential for copper in massive sulfide deposits

Area 4--High potential for copper where exposed copper veins are abundant. Moderate potential for copper where exposed copper veins are not abundant. Low potential for copper in massive sulfide deposits

Area 5--High potential for copper in massive sulfide deposit. Moderate potential for copper in vein deposits

Areas 6 and 7--Low potential for copper in vein deposits or massive sulfide deposits

Area 8--High potential for gold, silver, and copper in vein deposits

Area 9--High potential for mercury in vein deposits

Area 10--Moderate potential for mercury in vein deposits

Area 11--Low potential for mercury in vein deposits

Areas 12, 13, and 14--Low potential for molybdenum in porphyry deposits

Areas 15 and 16--Low(?) potential for tin in greisen zones

Area 17--Moderate potential for uranium in stratabound deposits

Area 18--Low potential for uranium in stratabound deposits

APPROXIMATE BOUNDARY OF WILDERNESS AREA

APPROXIMATE BOUNDARY OF ROADLESS AREA

X MINES AND PROSPECT

1. Crackerjack mine
2. Gowan mine
3. House mine
4. Collom mine
5. Casterson mine
6. Stingy Lady prospect
7. Los Conquistadores prospect
8. Blue Lode prospect
9. Gold Creek mine
10. Pine Butte mine
11. Pine Mountain mine
12. Mercuria mine
13. Oneida mine
14. Cornucopia mine
15. Sunflower mine
16. Story mine