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MINERAL RESOURCE POTENTIAL OF THE WHETSTONE ROADLESS AREA COCHISE AND PIMA COUNTIES, ARIZONA

SUMMARY REPORT

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STUDIES RELATED TO WILDERNESS

Under the provisions of the Wilderness Act (Public Law 88-577, September 3, 1964) and related acts, 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 Whetstone Roadless Area, Coronado National Forest, Cochise and Pima Counties, Arizona. The Whetstone Roadless Area (3-120) 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

Several areas in the Whetstone Roadless Area have metallic and non-metallic resource potential: a moderate potential for resources of copper, silver, gold, and lead in vein deposits in the Mine Canyon area, and a high potential for a deeply buried porphyry-type copper deposit, beyond the limits of the known porphyry copper occurrence, on both sides of the roadless area boundary; a low potential for copper resources in the Copper Plate mine area; a moderate potential for tungsten resources in the area along the contact zone of alaskite and schist in the Guindani Canyon-Middle Canyon area, and a low potential in the area south of Middle Canyon; a low potential for fluorite resources in the vicinity of the Lone Star mine and within the roadless area; a low potential for gold resources along the fault between Bolsa Quartzite and the Abrigo Limestone at the Gold Crystal prospect in the Guindani Canyon-Middle Canyon area; a moderate potential for uranium resources associated with the mafic dikes, and additional vein-type uranium deposits in the Cottonwood Canyon area; a low potential for mercury resources in the area around Middle Canyon inside the roadless area and in the Montosa Canyon-Willow Canyon area; a high potential for gypsum resources in several localities where the Epitaph Formation is exposed. No evidence of a potential for resources of fossil fuels was found during this study.

INTRODUCTION

This report presents the results of field examinations conducted by the U.S. Bureau of Mines in the spring and fall of 1980 and the U.S. Geological Survey in the spring of 1981 to determine the mineral resource potential of the Whetstone Roadless Area. The Bureau of Mines determined assay values, searched mining records, and investigated mines, prospects, mineral claims, and mineralized areas. The Geological Survey conducted geologic studies, geochemical sampling, and geophysical surveys.

The Whetstone Roadless Area occupies 36,610 acres in the higher parts of the Whetstone Mountains, Coronado National Forest, southeastern Arizona. The area is about 40 mi southeast of Tucson and 25 mi north of the international border with Mexico. Benson, 6 mi northeast of the roadless area, is the nearest town (fig 1).

Access to the perimeter of the area is provided by unimproved dirt roads and jeep trails from paved highways to the north, east, and south, and from unimproved roads to the west. The interior of the area is rugged, brush covered, and has few trails.

The Whetstone Mountains are located in the Basin and Range physiographic province, about 100 mi south of the mountainous region of central Arizona. In this part of the Basin and Range province, the mountains generally trend northwesterly or northerly, and the intermontane basins are as broad or broader than the mountains on either side. The principal physiographic feature of the Whetstone Mountains is a prominent ridge about 9 mi long that trends north-northeast and culminates in several peaks 7,100 to 7,700 ft in elevation, none of which stands out significantly compared to the others. Lowlands slope gently away from the mountain base, which lies at an elevation of about 4,800 ft. To the east is San Pedro Valley, a wide basin along whose unusually straight north-trending axis flows the San Pedro River, one of the few perennial streams in southern Arizona. On the west is the valley of Cienega Wash. The Whetstone Mountains terminate abruptly on the north at a wide, low pass; to the south they descend to low hills that end at Rain Valley, which separates the range from the mountains to the south (fig. 1).

Mining activity

The Whetstone Roadless Area has been prospected since about 1870, when small copper-gold-silver-lead deposits were discovered in Mine Canyon just outside of the roadless area. Mining, prospecting, and exploration have continued intermittently since that time.

Mineral production from the roadless area has been limited to copper, silver, and quartz sandstone at the Copper Plate mine, and tungsten at the James mine (fig. 2). Mining outside, but near the roadless area boundary has been conducted for copper, gold, silver, and lead in the Mine

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Canyon area, and for fluorite, quartz, tungsten, and uranium in the Guindani Canyon-Middle Canyon area, mostly during the 1950's and earlier.

Exploration for uranium took place in the Cottonwood Canyon area and in the Guindani Canyon-Middle Canyon area in the 1950's and in the middle-1970's through 1981. Only two properties have produced ore, and both are outside of the roadless area.

In 1982, leases for oil and gas had been issued by the Bureau of Land Management for all public land in the Whetstone Roadless Area. No drilling has taken place.

GEOLOGY, GEOCHEMISTRY, AND GEOPHYSICS PERTAINING TO MINERAL RESOURCE ASSESSMENT

General geology

The Whetstone Mountains are underlain by Proterozoic metamorphic and igneous rocks, Paleozoic and Mesozoic sedimentary rocks, and late Mesozoic intrusive bodies (fig. 3). North of latitude 31°45' these rocks have been mapped by Creasey (1967) and Tyrrell (1957); south of that latitude the rocks have been mapped by Hayes and Raup (1968). Additional small areas have been mapped by Burnette (1957), DeRuyter (1979), and Graybeal (1962). Creasey (1967) and Tyrrell (1957) measured stratigraphic sections of the Paleozoic and Mesozoic strata.

The oldest rocks in the Whetstone Mountains belong to the Pinal Schist of Early Proterozoic age. The Pinal crops out on the east side of the range and consists of muscovite-biotite-quartz schists that locally contain chlorite, cordierite, and andalusite. These schists are interpreted as regionally metamorphosed shales and silty shales. They were contact metamorphosed by adjacent unfoliated masses of alaskite and a porphyritic quartz monzonite exposed, respectively, on the northeastern and northern flanks of the mountains. Silver (1978) reported that the Pinal in the Johnny Lyons Hills, about 13 mi northeast of Benson, formed from sediments that were deposited 1,680 to 1,700 m.y. ago and metamorphosed 1,625 to 1,680 m.y. ago. Silver (1978) also reported that the quartz monzonite in the Whetstone Moutains is in the 1,400 to 1,450 m.y. range.

Sedimentary rocks from all periods of the Paleozoic Era except the Ordovician and Silurian crop out in a belt that crosses the Whetstone Mountains from northwest to southeast and forms the high peaks along the crest of the range. Cambrian sandstone and quartzite record the beginning of Paleozoic sedimentation and represent onlap by advancing seas. The overlying limestones and dolomites of Cambrian to Permian age are shelf carbonate deposits that accumulated on the North American craton. Carbonate deposition from the Late Cambrian into the Late Pennsylvanian was mostly in open marine to intertidal environments, whereas deposition from the Late Pennsylvanian to the Late Permian resulted from oscillations between tidal, supratidal, and open marine conditions. Gypsum beds of Late Permian age record supratidal deposition in an arid environment. In a general way the Paleozoic carbonate rocks reflect increasingly shallower-water depositional environments and increasing rates of deposition with time. The Paleozoic formations aggregate about 8,000 ft in thickness.

Sedimentary and volcanic rocks of Jurassic and Triassic age crop out in a small area near the southern end of the Whetstone Mountains.

Sedimentary rocks of Early Cretaceous age are exposed in the western part of the Whetstone Mountains. These strata rest unconformably on Lower Permian and younger rocks on which considerable local relief was carved prior to deposition of the Cretaceous beds. The Cretaceous sediments accumulated in a prograding deltaic environment near the margin of a shallow sea that advanced northwestward into southeastern Arizona from Mexico. Terrigenous material shed from highlands to the north was deposited in marine and nonmarine environments (Hayes, 1970). Cretaceous strata total about 8,800 ft in thickness.

A number of intrusive bodies were emplaced in the Paleozoic and Mesozoic strata of the area during the Late Cretaceous. These consist of a small granodiorite pluton, several irregular granodiorite bodies and sills, and intrusive rhyodacite in vaguely sill-like masses (Creasey, 1967). Petrographic similarities suggest that all of these rocks may be related genetically. DeRuyter (1979) showed that the granodiorite pluton has a border phase of quartz gabbro and that the pluton is cut by dikes of basalt and silicic rocks all thought to be comagmatic with the granodiorite. Geophysical data suggest that the main mass of the pluton underlies the surface exposures and that a sill-like projection in the subsurface may extend eastward. The pluton has been dated as 76±4 m.y. old (Marvin and others, 1978), approximately correlative with extensive silicic volcanism in the region (Hayes, 1970), and with an episode of porphyry copper mineralization in southeastern Arizona (Creasey, 1980). Mineralized granodiorite in the central part of the pluton contains sericite and secondary potassium feldspar.

Cenozoic rocks in the roadless area include a Tertiary alkali diorite dike in the low hills at the south end of the mountains, and extensive accumulations of gravel, mostly around the base of the range.

The structure of the Whetstone Mountains is generally simple, and is dominated by a homocline of the Paleozoic and Mesozoic strata that dips about 25° southwest. Steeply dipping normal faults and several southwesterly dipping thrust faults have traces of only a few miles. All have maximum offsets of only a few hundred feet and do not significantly disturb the simple homoclinal pattern of the strata. Drewes (1980) mapped thrust faults in two west-northwest-trending synclines near the north end of the Whetstone Mountains. He also concluded (Drewes, 1981) that the range rests on a deeply buried subhorizontal thrust fault. Basin and range faults that may flank the mountains presumably are buried beneath the Tertiary and Quaternary gravels.

The tilting, folding, and thrust faulting in the Whetstone Mountains took place after deposition of the Cretaceous strata, probably during the Laramide orogeny of the latest Cretaceous and early Tertiary. Drewes (1980) interpreted the thrust that he believes exists beneath the range as being of regional extent and that the upper plate was transported toward the interior of the continent during the Laramide orogeny. Dickinson (1981) doubts the existence of major regional thrust plates in southern Arizona. Interpretations by Dickinson (1981) and Davis (1979) suggest that thrust sheets in southern Arizona were on the flanks of uplifted masses containing basement rocks and may have different directions of transport on opposite sides of the uplifts. The presence of a largely undisturbed stratigraphic section resting depositionally on an unbroken Proterozoic basement is suggestive that large-scale thrust faulting may not have occurred in the Whetstone Mountains area.

Geology related to mineralization

Most metallic and nonmetallic mineral deposits in the Whetstone Mountains were formed by hydrothermal processes that can be related to emplacement of igneous bodies. Mineral deposits include uranium, fluorite, and tungsten in areas underlain by Proterozoic quartz monzonite and alaskite on the northern and northeastern flanks of the mountains and copper deposits concentrated in and around Cretaceous granodiorite near the southern end of the range.

Uranium occurs as vein deposits in the quartz monzonite, and tungsten and fluorite occur in veins in the alaskite. A genetic relationship between these deposits and the two Proterozoic igneous rock types is suggested by their close geographic association. The alaskite appears to be younger than the quartz monzonite, and the close spatial relationships and similar mineralogy of the two rock types suggests that the alaskite is a more silicic phase of the quartz monzonite. The presence of a suite of trace-elements consisting of uranium, tungsten, fluorine, niobium, yttrium, and beryllium in the mineral deposits and the affinity of this suite for silicic igneous rocks suggests deposition in the postmagmatic phase of an igneous cycle, presumably of the quartz monzonite-alaskite system. The abundance of fluorine accounts for the association of beryllium with the mineral deposits, because fluorine in a magma can cause beryllium (and other metals) to become concentrated in residual solutions instead of entering silicate latices (Griffitts, 1972). The abundance of beryllium was insufficient to form beryllium deposits.

The origin of the large mass of quartz located between the quartz monzonite and alaskite is uncertain. This uncertainty is reflected in the geologic map of the Benson quadrangle (Creasey, 1967) in which the quartz is not assigned an age. The spatial association of the massive quartz with Proterozoic igneous and metamorphic rocks is the only clue suggesting a Proterozoic(?) age for the quartz body in the Whetstone Mountains.

The copper deposits in the southern part of the Whetstone Mountains are in the Cretaceous granodiorite pluton and in skarns developed from Cretaceous and Permian carbonate strata adjacent to the pluton; they are undoubtedly Cretaceous in age. Deposits of sulfides in Mine Canyon are the largest mineralized bodies associated with the Cretaceous igneous rocks. A few small copper deposits, and geochemical data discussed later, indicate that weak hydrothermal mineralization related to granodiorite and rhyodacite intrusions also occurred throughout the area of Cretaceous sedimentary rocks.

Concentrations of mercury in Middle Canyon and in the Montosa Canyon-Willow Canyon area (fig. 2) are not clearly associated with any known igneous event. The mercury could be as old as the Cretaceous intrusive bodies, some of which are adjacent to the Montosa Canyon-Willow Canyon area.

Geochemistry

A reconnaissance geochemical study of the Whetstone Roadless Area was conducted using four sample media—stream sediment, heavy-mineral concentrates from stream sediment, rock, and water. Stream sediments were collected from 63 first- and second-order drainage basins approximately 2.5 mi^2 in size. Heavy-mineral concentrates (>2.6 specific gravity) were collected at 62 sample sites to provide enhanced geochemical anomalies and information on mineral species such as metallic sulfides and oxides. Information on background values and mineral suites were obtained from rock samples selected at 19 sites. Water samples were collected from 21 localities throughout the roadless area.

The stream-sediment and heavy-mineral concentrate samples were screened, and the minus-80-mesh fraction of the sediment and the minus-30-mesh fraction of the nonmagnetic heavy fraction ($\geq$2.6 specific gravity) of the concentrate were analyzed for 29 elements by semiquantitative emission spectrographic methods (Grimes and Marranzino, 1968). Rock samples were pulverized and analyzed spectrographically for the same 29 elements. Stream-sediment samples also were analyzed for seven elements by wet chemical methods. Water samples were collected in acid-rinsed polyethylene bottles and were filtered and acidified at the sample site. An untreated water sample also was taken from each site. The analyses, description of the analytical methods used, and statistical data derived from the analyses are given by Werschky and others (1983).

The lower limit of background concentrations was taken as the mean value plus two standard deviations, equal to the 95 percentile value or the break in slope of cummulative frequency plots for • most elements. For antimony, arsenic, bismuth, cadmium, gold, molybdenum, silver, thorium, tin, tungsten, and zinc, any concentration detected by emission spectrographic techniques was considered anomalous.

The geochemical data, principally from the nonmagnetic fraction of panned concentrates, show that samples from the Proterozoic rocks contain anomalous concentrations of uranium, beryllium, yttrium, niobium, tin, tungsten, and molybdenum. Fluorite in a few panned concentrates and relatively high fluorine values in water samples suggest that fluorine belongs to this suite. Uranium values of 2 to 14 parts per million are common in samples from the area underlain by quartz monzonite and alaskite. High beryllium values are found throughout the area of Proterozoic rocks, whereas high molybdenum values are spotty, and tin and tungsten concentrations are high primarily in areas dominated by alaskite.

Small amounts of copper near the upper limit of background in stream-sediment samples from the Proterozoic quartz monzonite suggest that copper may occur in the rock-forming silicate minerals, possibly biotite. Similar widespread values of lead and zinc may have come from feldspars. Copper and lead were found only in very low concentrations in panned concentrates in the area of quartz monzonite.

Anomalous mercury values (0.13-2.5 ppm) were found in stream-sediment samples in Middle Canyon on the east side of the range and (about 0.1 ppm) in the Montosa Canyon-Willow Canyon area on the west side. Cinnabar was found in 8 panned concentrates from these areas.

Copper, lead, molybdenum, tin, tungsten, silver, and gold form a geochemical suite associated with copper deposits in and adjacent to the small Cretaceous granodiorite pluton near the south end of the range. Relatively few high copper values were found in heavy-mineral concentrates from the area around the pluton, especially considering the existence of copper sulfide deposits in skarns adjacent to the pluton. These low copper values indicate that copper was greatly diluted in the streams that drain the mineralized areas. Similarly, copper was found only in very low concentrations in a heavy-mineral concentrate from the Copper Plate mine west of the granodiorite pluton, although copper minerals are evident in the mine workings. In arid regions, copper is so mobile in the surface environment that it commonly has a weak geochemical signature in areas of copper occurrences. Low but possibly significant values of antimony and arsenic were found by wet chemical analysis of stream sediments collected around the granodiorite pluton.

Stream-sediment samples collected in the area of Cretaceous strata on the west side of the Whetstone Mountains have slightly high, but less than anomalous, concentrations of antimony, arsenic, and zinc, as determined by wet chemical analyses, and of copper and lead as determined by spectrographic analyses. A few heavy-mineral concentrates from the area have high values of molybdenum and tin. This is the same trace-element suite found around the granodiorite pluton, but in the area of Cretaceous sedimentary rocks is weak and spotty. This geochemical expression may indicate that the granodiorite is more extensive in the subsurface in the west side of the roadless area.

Geophysics

A complete Bouguer gravity map was made for this study from readings made at 112 field stations (Bankey and Kleinkopf, 1982), and an aeromagnetic map was made from data obtained from aircraft flown at 1,000 ft terrane clearance.

Most of the conspicuous anomalies on the aeromagnetic map are associated with intrusive bodies. The most prominent aeromagnetic high is located over the Cretaceous granodiorite pluton at Mine Canyon (figs. 2 and 3). Magnetic values around this pluton drop off sharply to the north, less sharply to the west and south, and they define a nose that extends to the east-southeast. A modeled magnetic profile indicates that the nose may be a sill-like projection of the granodiorite. Two negative anomalies and a positive anomaly over a sill of Cretaceous granodiorite that crops out in French Joe Canyon may result from altered and unaltered parts of the sill. Mafic minerals may have been destroyed in at least part of the sill. The positive values may be from a buried intrusive mass in the Proterozoic basement. The only negative aeromagnetic anomaly over the intrusive rhyodacite mapped by Creasey (1967) in the western part of the area is at the head of Shellenberger Canyon (see accompanying 1:48,000-scale map). Because the anomaly is broad and does not correlate with a specific exposure of this rock type, it enforces geologic observations that the fine-grained granodiorite in the western part of the area is altered and forms thin bodies. High aeromagnetic values are associated with the Proterozoic quartz monzonite. The abrupt termination of these values a few miles north of the study area support the interpretation of Creasey (1967) that the quartz monzonite is dropped down along a north-northwest trending fault. A north-south aeromagnetic high at French Joe Camp could be from a prong of the quartz monzonite extending south beneath the Pinal Schist.

The gravity map shows high values associated with the Cretaceous granodiorite pluton, the Cretaceous fine-grained granodiorite bodies, and the Paleozoic carbonate rocks, and generally low values associated with the Proterozoic intrusive rocks. A prominent pattern of low gravity readings southwest of Guindani Canyon may be due to a projection of the Proterozoic quartz monzonite beneath Paleozoic cover.

MINING DISTRICTS AND MINERALIZED AREAS

The Whetstone mining district encompasses the Whetstone Mountains and includes the entire Whetstone Roadless Area. On the basis of the distribution of mines and prospects, the district can be divided into four mineralized areas—the Mine Canyon area, the Copper Plate Mine area, the Guindani Canyon-Middle Canyon area, and the Cottonwood Canyon area (fig. 2). Geochemical data indicate a fifth mineralized area near Montosa and Willow Canyons. A summary of the location and other information about the principal mines of the area is given in table 1.

Mine Canyon Area

Numerous adits, shafts, open cuts, and shallow pits occur near Mine Canyon in parts of unsurveyed secs. 20 and 21, T. 19 S., R. 19 E., that are outside the southern part of the Whetstone Roadless Area but are nearly surrounded by it. Mineral deposits in the Mine Canyon area contain copper, lead, gold, and silver in quartz veins and shear zones, as disseminations along seams and fractures in Cretaceous granodiorite, and as disseminations and massive replacements in skarn deposits in limestones of the Cretaceous Bisbee Group and of Permian formations. The granodiorite associated with these deposits has been described by DeRuyter (1979) as the host for a small porphyry copper deposit.

Copper Plate mine area and vicinity

The Copper Plate mine, in the central part of sec. 24, T. 19 S., R. 18 E., consists of an irregular open pit 70 ft long, approximately 30 to 50 ft wide, and 15 to 30 ft deep, which exposes a fault zone 6 to 9 ft wide. The fault, which cannot be traced beyond the limits of the pit, cuts sandstone, shale, and marl of the Bisbee Group. The mine exposes copper carbonate minerals disseminated in the host sandstone and coated and filled along fractures and bedding planes. On the north side of the pit, copper-stained sandstone has a width of about 50 ft and an exposed thickness of 8 to 10 ft. The fault zone occurs in the middle of this mineralized zone. Mineralized rocks are present behind talus and waste-rock at the base of the exposure.

Copper carbonate minerals in the Bisbee Group also occur at a prospect west of the Whetstone Roadless Area and 2.5 mi northwest of the Copper Plate mine. In the main working, a 3-ft-wide copper-stained zone, striking southwest and dipping 45° southeast, was explored down-dip in a 30-ft-deep inclined shaft.

Guindani Canyon-Middle Canyon area

Tungsten, quartz, and fluorite mines, and gold and uranium prospects occur in the Guindani Canyon-Middle Canyon area on the east side of the Whetstone Mountains. Several tungsten properties are known, but the only one with recorded production within the Whetstone Roadless Area is the James mine. Each of the other mineral commodities is found in a single deposit outside the roadless area—quartz at the Ricketts mine, fluorite at the Lone Star mine, gold at the Gold Crystal prospect, and uranium at the Star No. 1 (Bluestone) prospect (fig. 2).

Workings at the various tungsten mines consist of short adits, open cuts, and scattered prospect pits that explore quartz veins in alaskite near an alaskite-schist contact. Disseminated scheelite and wolframite occur in the quartz veins and in the alaskite along the contact.

The Ricketts mine consists of open cuts near the eastern end of a massive deposit of bull quartz of Proterozoic(?) age. The quartz is more than a mile in length and extends about 800 ft into the roadless area. The part of the quartz body exposed in the roadless area is approximately 100 ft wide.

The Lone Star fluorite mine consists of an inclined shaft that connected levels at 60, 90, 190, 250, and 300 ft below the surface. In 1957 the 60- and 90-ft-levels were caved, and the 300-ft-level was flooded (Burnette, 1957). In 1980, the headframe had been demolished and the shaft opening filled. The only accessible parts of the vein were a few remnants in an open trench (or caved stope) north of the shaft. Burnette (1957, p. 25-26) stated that the vein, which is in Pinal Schist, averages 2-ft wide in the Lone Star mine, but pinches out 50 ft south of the shaft, and that at the lower levels of the mine the vein may be close to Proterzoic granite rocks. The exposed granitic rocks near the mine were mapped by Creasey (1967) as alaskite.

The Gold Crystal prospect, 2 mi west of the Lone Star mine, and about 200 ft east of the roadless area, consists of a trench dug on a fault that separates the Cambrian Bolsa Quartzite and Abrigo Limestone (Creasey, 1967). The fault strikes N. 20° E., and dips 47° SW. Iron-stained fault breccia and gouge form the 2-ft-wide gold-bearing zone exposed in a trench 15 ft wide and 200 ft long. The trench varies in depth from 15 to 25 ft. The vein is not known to extend into the roadless area.

The Star No. 1 (Bluestone) uranium prospect consists of four short adits and scattered prospect pits along the contacts between mafic dikes and alaskite. Two northwest-trending dikes about 15 ft apart are exposed, the westernmost is about 4 ft wide and can be traced for 55 ft; the other is about 2 ft wide and can be followed for 80 ft. Uranium minerals occur irregularly along the two dikes, and are concentrated in areas of shearing and alteration. Keith (1973, p. 91) stated that autunite, tyuyamunite, and possibly other secondary uranium minerals are present. These minerals also were found during this study. There is no evidence that the dikes extend into the Whetstone Roadless Area.

Anomalous concentrations of mercury were found in stream-sediment and panned-concentrate geochemical samples in Middle Canyon, but no mercury deposits are known.

Cottonwood Canyon area

The Cottonwood Canyon area contains uranium in fractures, shear zones, and faults, and along quartz veins and dikes in quartz monzonite. The structural features lack continuity. The most extensively developed property in the Cottonwood Canyon area is the Windmill No. 1 mine. Workings consist of a 107-ft inclined shaft, 90 ft of drifts at the bottom of the shaft, a 20-ft raise, and a 38-ft adit. The shaft is now caved. Uranium minerals at the Windmill No. 1 mine are distributed erratically along a N. 55° W. shear zone that pinches and swells. Erratic distribution is typical of uranium concentrations in the Cottonwood Canyon area.

Montosa Canyon-Willow Canyon Area

Indications of mercury minerals in the Montosa Canyon-Willow Canyon area consist of anomalous concentrations of mercury found in stream sediments and cinnabar identified in heavy-mineral concentrates. The cinnabar was probably deposited in faults and fractures in Permian and Cretaceous bedrock units.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

Information from geological, geochemical, and geophysical studies, and from examinations of mines, mineralized areas, mining records, and assays indicate that the Whetstone Roadless Area has potential for resources of copper, gold, silver, lead, molybdenum, quartz, gypsum, tungsten, uranium, and mercury. The resource potential is found in five areas—the Mine Canyon area, the Copper Plate mine area, the Guindani Canyon-Middle Canyon area, the Cottonwood Canyon area, and the Montosa Canyon-Willow Canyon area. In addition, gypsum deposits are known in seven parts of the roadless area and at two localities south of the roadless area. The areas of mineral resource potential are shown on figure 2 and on the accompanying 1:48,000 scale map. The resource potential of mineralized areas in the Whetstone Mountains is ranked in this report using the following classification:

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 geological, 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 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).

Mine Canyon area

An indicated resource of about 32 million tons of 0.28 percent copper and 0.01 percent molybdenum has been calculated by DeRuyter (1979) for a porphyry-type deposit in the granodiorite pluton in Mine Canyon. These data were obtained from 5,600 ft of core from five holes drilled to a maximum depth of about 1,800 ft, 1,000 to 1,500 ft south of the Nevada and Mascot workings. The copper-molybdenum resource estimated by DeRuyter (1979) and copper-silver-gold-lead in vein deposits in the granodiorite and replacement deposits in the adjacent skarn deposits are outside the Whetstone Roadless Area. Geophysical data, however, indicate that the granodiorite pluton projects into the roadless area at depth. Mineralized rocks are less likely to be associated with the postulated sill-like projection of the granodiorite under the southeastern part of the roadless area because the sill-like body likely would have been too far from the mineralizing fluids that rose from the central part of the pluton in Mine Canyon. Deep drilling would be required to test this possibility, but the main target area for mineralized rock, as well as the known mineral occurrences, is outside the Whetstone Roadless Area. The potential for resources of copper, silver, gold, and lead in undiscovered vein deposits of the type known in Mine Canyon is moderate for the Mine Canyon area inside and outside of the roadless area. The potential for a porphyry-type copper resource beyond the limits of known porphyry copper occurrences is high on both sides of the roadless area boundary in the Mine Canyon area. A porphyry copper deposit in the roadless area is likely to be deeply buried.

Copper Plate mine area

A copper resource exists in the sandstone of the Bisbee Group at the Copper Plate open-pit mine. The quartz-rich sandstone was used as smelter flux in the 1950's. A sample representative of the strongest copper showings remaining in the pit contained 0.68 percent copper and 0.6 oz silver (McColly and Scott, 1982), or about half of the mine-run value reported by Keith (1974, p. 145). The copper content across the entire mineralized zone probably averages significantly less. A resource of 2,000 to 4,000 tons of copper is possible, assuming an average cross section equal to that exposed on the north wall of the pit, and northward projection of 50 to 100 ft.

Another copper deposit occurs in the Bisbee Group west of the Whetstone Roadless Area 2.5 mi northwest of the Copper Plate mine. Small shipments may have been made from this property, but most of the extracted material remains on the dump. Few indications of copper were found in the Copper Plate mine area outside the Copper Plate mine and the property northwest of the mine. For this reason, the Copper Plate mine area has low potential for copper resources.

Guindani Canyon-Middle Canyon area

Tungsten, quartz, fluorite, gold, and uranium resources are known in the Guindani Canyon-Middle Canyon area. Mercury also may be present. Of these commodities, the Whetstone Roadless Area has potential for tungsten, quartz, and possibly fluorite and mercury resources.

Most of the tungsten production from the Guindani Canyon-Middle Canyon area came from the Chadwick property east of the roadless area. All of the exposed ore-grade deposits at this property and at other mines in the area were exhausted prior to 1960, and there are no strong clues to the presence of additional tungsten deposits. Nevertheless, for the area along the contact zone of the alaskite and schist, there is a moderate potential for tungsten resources.

An anomalous concentration of tungsten in a geochemical sample from French Joe Camp, near the south end of the Guindani Canyon-Middle Canyon area, and an aeromagnetic high suggestive of a buried granitic mass indicate that the area south of Middle Canyon has a low potential for tungsten resources.

Quartz resources in the roadless area in the vicinity of the Ricketts mine amount to 5,000 to 6,000 tons for each vertical foot beneath the outcrop area. The maximum depth of the deposit is not known. About 800 ft of the outcrop extends into the roadless area, but over 90 percent of the quartz is east of the roadless area. Samples assayed by the U.S. Bureau of Mines showed no metallic mineral values in the quartz (McColly and Scott, 1982). The Guindani Canyon-Middle Canyon area has a low potential for concealed quartz resources outside of the known deposit.

Due to inaccessibility of the mine workings at the Lone Star mine, we were unable to determine if fluorite resources are present. The vein trends northwestward toward the contact between the alaskite and the Pinal Schist in the Whetstone Roadless Area, and is 2 ft wide at one exposure near the roadless area. No additional occurrences of fluorite veins are known in the Whetstone Mountains. The potential for fluorite resources in the vicinity of the Lone Star mine and within the roadless area is low.

Gold found along the fault between Bolsa Quartzite and the Abrigo Limestone at the Gold Crystal prospect is the only occurrence of its type known in the Whetstone Mountains. No production is recorded. One grab sample contained 0.02 oz/ton of gold (McColly and Scott, 1982). The extent of the gold-bearing rock is not known. The Guindani Canyon-Middle Canyon area has a low potential for gold resources of this type.

The existence of uranium resources at the Star No. 1 (Bluestone) prospect is suggested by radioactivity counts and by assay values of 0.020 and 0.024 percent uranium oxide (McColly and Scott, 1982) from samples collected at the workings. Radioactivity of the western mafic dike at the mine, as measured with a scintillation counter during this survey, ranged from 600 to 9,500 counts per second. A sample of the most radioactive rock found in this dike contained 0.094 percent uranium. Radioactivity of the eastern dike ranged from 400 to 4,000 counts per second. A sample of the most radioactive rock in this dike yielded 0.082 percent uranium. These were the richest samples found. The Guindani Canyon-Middle Canyon area, outside Whetstone Roadless Area has a moderate potential for uranium resources associated with the mafic dikes.

The source of the mercury in geochemical samples of stream sediments in Middle Canyon was not found. The area around Middle Canyon inside the roadless area has a low potential for mercury resources.

Cottonwood Canyon area

High scintillometer readings and chemical analyses indicate potential uranium resources in the Cottonwood Canyon area. The Windmill No. 1 mine, located north of the Whetstone Roadless Area, has been estimated to have 110 lb of uranium in rocks containing 0.11 percent uranium (W. L. Emerick and T. M. Romslo, written commun., 1957). The most radioactive sample from the dump at the Windmill No. 1 claim contained only 0.038 percent uranium. Samples from other radioactive areas of the Cottonwood Canyon area were found to contain 32 to 281 ppm uranium. By comparison samples of unaltered quartz monzonite and alaskite host rocks were found to have 2 to 4.5 ppm uranium. The Cottonwood Canyon area has a moderate potential for additional vein-type uranium deposits.

Montosa Canyon-Willow Canyon area

Mercury concentrations in stream-sediment samples, and cinnabar identified in panned concentrates suggest the presence of mercury deposits in this area. At present this area is considered as having a low potential for the occurrence of mercury resources.

Areas of gypsum resources

Gypsum beds are known in the middle member of the Epitaph Formation of Permian age in the Whetstone Mountains. The best exposure of gypsum is of a bed about 33 ft thick, located south of the roadless area boundary and 1.0 mi west of Sands Ranch. Gypsum is rarely exposed at the other eight localities where the middle member of the Epitaph Formation has been mapped, and the thickness and areal extent of gypsum beds has not been determined. These areas have a high potential for gypsum resources. However, gypsum resources found within the Whetstone Roadless Area would have little promise for the recovery of gypsum because of the rugged terrain and the availability of other deposits closer to markets.

The Whetstone Mountains lie above a postulated thrust fault of regional extent, which, according to one concept, may conceal accumulations of oil and gas (Keith, 1979). In 1982, leases for oil and gas had been issued by the Bureau of Land Management for all public lands in the Whetstone Mountains. However, no drilling for oil and gas has taken place in the Whetstone Mountains, and the existence of the thrust fault has not been proved. No potential for resources of fossil fuels was identified during this study.

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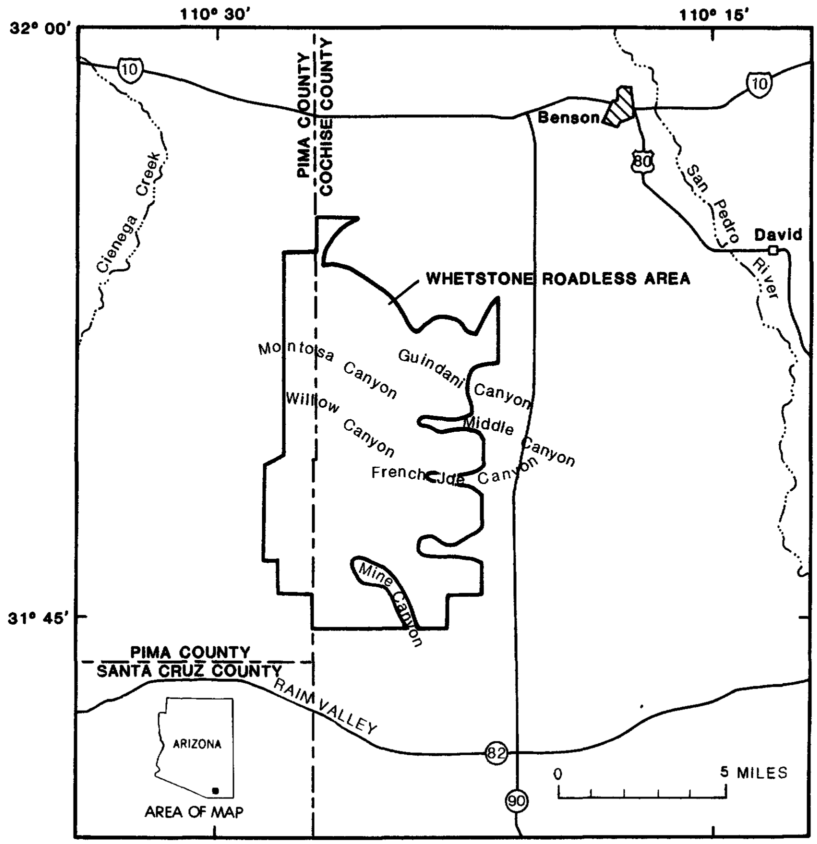


Figure 1.--Map showing location of Whetstone Roadless Area (3-120), Arizona.

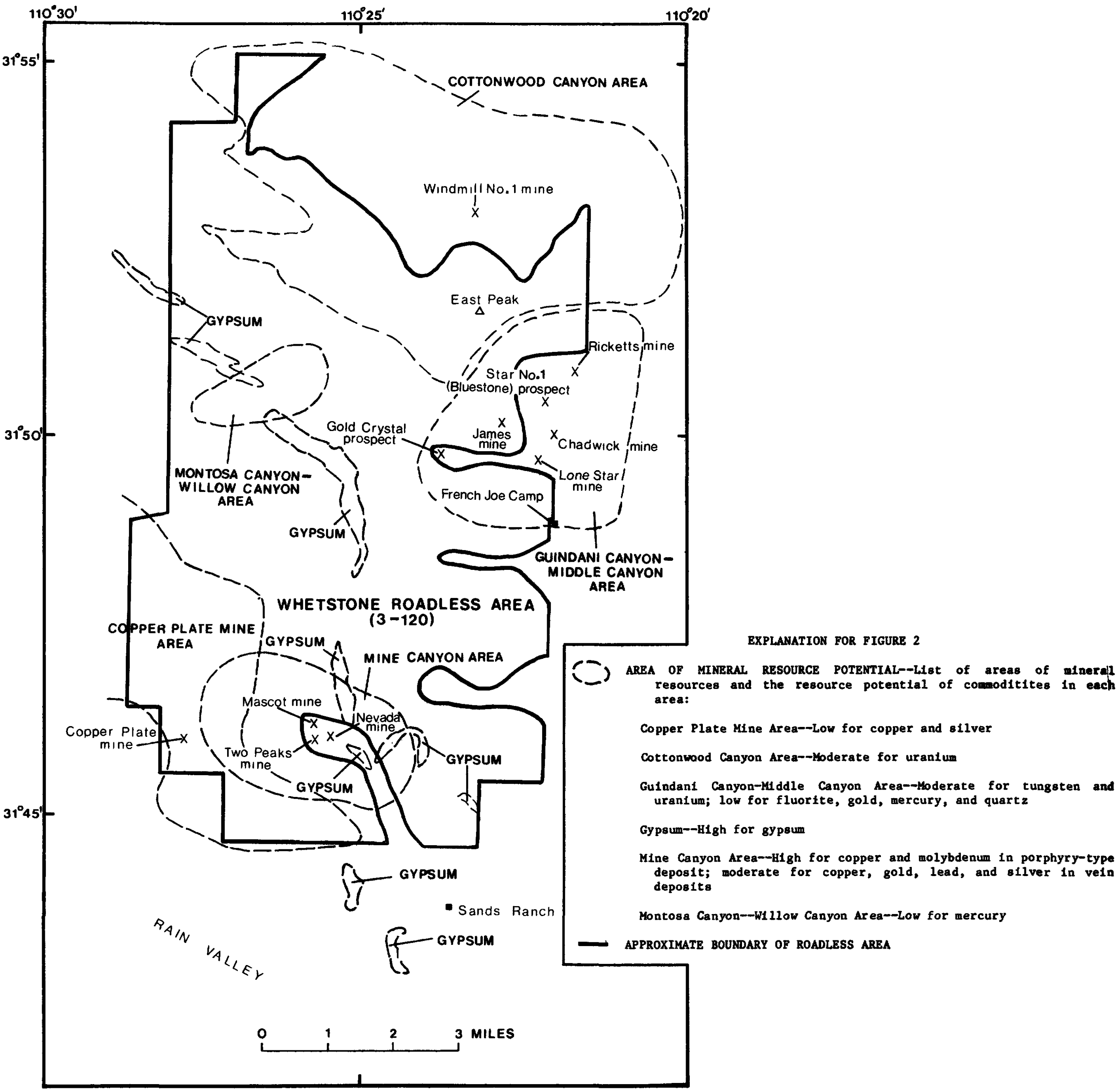
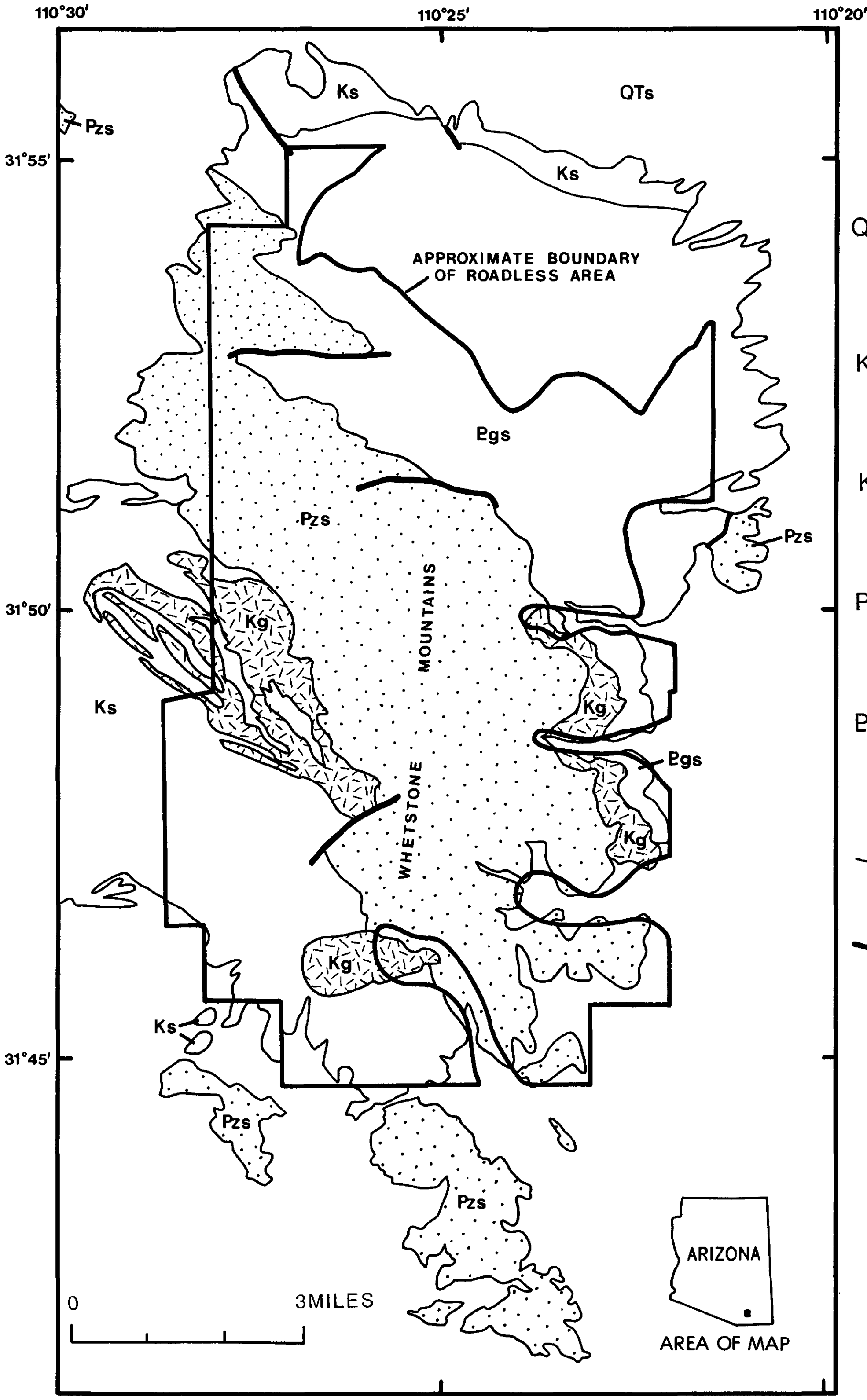


Figure 2.--Map showing areas of mineral potential in the Whetstone Roadless Area and vicinity, Arizona.



EXPLANATION

QTs SEDIMENTARY ROCKS (QUATERNARY AND TERTIARY)

Kg GRANITIC ROCKS (CRETACEOUS)

Ks SEDIMENTARY ROCKS (CRETACEOUS)

Pzs SEDIMENTARY ROCKS (PALEOZOIC)

Ꝑgs GRANITIC ROCKS AND SCHIST (PROTEROZOIC)

CONTACT

FAULT

Figure 3.-- Generalized geologic map of the Whetstone Roadless Area.

Table 1.--Summary of information derived from U.S. Bureau of Mines examination of known mineral deposits in and near the Whetstone Roadless Area, Cochise and Pima Counties, Arizona

Deposit	Location	Commodity	Geologic control	Production and development
Nevada-Mascot mines	Mine Canyon area	Copper, gold, silver	Sulfide minerals are disseminated in fault zones and quartz veins in a granodiorite stock.	Total production unknown (refer to text). Mascot adit 500 ft long, Nevada adit 250 ft long, shallow shafts, several prospect pits.
Two Peaks mine	Mine Canyon area	Copper, gold, silver	Sulfide minerals are disseminated in fault zones and quartz veins in a granodiorite stock.	Production unknown. Adit 250 ft long, adit 40 ft long, shaft 40 ft deep, and several prospect pits.
Copper Plate mine	Copper Plate mine area	Copper, silver	Copper carbonates localized in fault zone cutting sandstone	1,600 tons of ore averaging 1.2 percent copper, 0.6 oz silver per ton produced in 1957-58 (Keith, 1974, p. 145). 70-ft-long, 30-ft-deep open pit.
Gold Crystal prospect	Guindani Canyon-Middle Canyon area	Gold	Gold occurs in gouge and breccia along a fault contact between limestone and quartzite.	Production unknown. Trench 200 ft long; caved adit.
James mine	Guindani Canyon-Middle Canyon area	Tungsten	Scheelite and wolframite occur disseminated in quartz veins in alaskite.	Several hundred pounds of concentrates produced from sorted ore assaying more than 2.0 percent tungsten trioxide (Dale and others, 1960, p. 55-56. Trench 75 ft long, several prospect pits.
Lone Star mine	Guindani Canyon-Middle Canyon area	Fluorite	Fluorite occurs in a vein in schist	20,000 tons of fluorite produced from 1946 to 1967 (Keith, 1973, p. 91). Caved shaft and several trenches on strike with vein, several prospect pits.
Star No. 1 (Bluestone) prospect	Guindani Canyon-Middle Canyon area	Uranium	Uranium occurs along mafic dikes in alaskite.	About 47 tons of low-grade uranium ore produced in 1958-60 (Keith, 1973, p. 91). Four short adits, scattered prospects pits.
Chadwick mine	Guindani Canyon-Middle Canyon area	Tungsten	Scheelite and wolframite occur disseminated in quartz veins in alaskite.	60-80 units (1,200-1,600 lbs.) of tungsten trioxide were produced (Wilson, 1950, p. 9-10). Trench 100 ft long; several prospect pits.
Ricketts mine	Guindani Canyon-Middle Canyon area	Silica	Quartz vein along contact between alaskite and quartz monzonite.	Several tens of thousands of tons of quartz mined from 1955 to 1959 (Keith, 1973). Several open pits, prosepcts.
Windmill No. 1 mine	Cottonwood Canyon area	Uranium	Uranium occurs in fault zones in quartz monzonite pluton.	Approximately 16 tons of ore averaging 0.11 percent uranium produced in the 1950's. Inclined shaft 107 ft deep, 90 ft of drifts, a 20-ft-deep raise, and a 38-ft-long adit.