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MINERAL RESOURCE POTENTIAL OF THE PIGEON CANYON, NEVERSHINE MESA, AND SNAP POINT WILDERNESS STUDY AREAS, MOHAVE COUNTY, ARIZONA

By

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STUDIES RELATED TO WILDERNESS
Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94-579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report summarizes the results of a mineral survey of the Pigeon Canyon (AZ-010-109), Nevershine Mesa (AZ-010-105A), and Snap Point (AZ-010-105B) Wilderness Study Areas, Mohave County, Arizona.

MINERAL RESOURCE POTENTIAL SUMMARY STATEMENT

Field and laboratory investigations of the Pigeon Canyon, Nevershine Mesa, and Snap Point WSA's (Wilderness Study Areas) in Mohave County, Ariz., were conducted to determine the mineral resource potential of these lands. The investigations indicate that both the Savanic Mine collapse structure (which occupies parts of the Pigeon Canyon WSA and an area excluded from wilderness consideration) and the Cunningham Mine collapse structure (which occupies parts of the Nevershine Mesa WSA and an area excluded from wilderness consideration) have high potential for resources of uranium, copper, and other metals[1]. In addition, a small area within the Nevershine Mesa WSA that lies between the Savanic Mine and the Cunningham Mine collapse structures has moderate potential for resources of uranium, copper, and other metals because of its proximity to the two mineralized collapse structures and because joints between the two collapse structures can be hosts for uranium, copper, and other metal deposits.

Most collapse structures of the Grand Canyon region are not mineralized, but several collapse structures have yielded substantial quantities of uranium, copper, and other metals. For this reason four previously unknown collapse structures in the Pigeon Canyon WSA have moderate potential for resources of uranium, copper, and other metals.

The remainder of the Pigeon Canyon and the Nevershine Mesa WSA's has low potential for resources of uranium, copper, and other metals. The Snap Point WSA has no known mineralized zones or collapse structures that can be hosts for uranium, copper, and other metal deposits and therefore has low potential for resources of these commodities.

The potential for resources of oil and gas is low in exposed Paleozoic rocks east of the Grand Wash fault in all three WSA's. In those parts of the Pigeon Canyon and Nevershine Mesa WSA's west of the Grand Wash fault, the potential for resources of oil and gas is moderate in buried Paleozoic rocks. Gypsum occurrences west of the Grand Wash Cliffs in the Pigeon Canyon and Nevershine Mesa WSA's have a moderate resource potential for gypsum; however, this commodity is readily available and more accessible elsewhere in southern Utah and northern Arizona. Slightly anomalous amounts of syngenetic uranium and molybdenum occur in the gypsum deposits but represent a low resource potential at best for these elements. There are no gypsum deposits in the Snap Point WSA. No coal-bearing rocks were observed to cropout in the three WSA's and none are expected to be found in the subsurface of the three WSA's.

Industrial mineral resources (building stone, sand and gravel, and limestone) are present in all three WSA's. However, these commodities are more accessible and readily available elsewhere in northern Arizona and southern Utah.

[1]In this report, the term "other metals" refers to associated metals such as lead, zinc, silver, arsenic, nickel, molybdenum, cobalt, chromium, and antimony.

INTRODUCTION

From 1981 to 1983, the U.S. Geological Survey and the U.S. Bureau of Mines jointly conducted field investigations to evaluate the mineral resource potential of the Pigeon Canyon, Nevershine Mesa, and Snap Point WSA's, Mohave County, northwest Arizona (fig. 1). Field studies by the U.S. Geological Survey included geologic mapping by Ivo Lucchitta, L. S. Beard, and H. J. Rieck; geochemical sampling by J. C. Antweiler; and a reconnaissance survey for undiscovered collapse structures by G. H. Billingsley. M. E. Lane, of the U.S. Bureau of Mines, examined mines, prospects, and mineralized areas in and near the WSA's, and mapped and sampled all mine workings. In addition, the U.S. Bureau of Mines examined courthouse and Bureau of Land Management records for information concerning mining claim locations and oil and gas leases.

The areas of the Pigeon Canyon, Nevershine Mesa, and Snap Point WSA's measure 33,348, 19,457, and 9,380 acres, respectively, for a total of 62,185 acres. The nearest major town is St. George, Utah, about 50 mi north of the Pigeon Canyon WSA. Access to the three WSA's from the south is blocked by the Grand Canyon and Lake Mead; although access from the north is difficult, it is possible by means of the moderate-duty Wolf Hole-Shivwits Plateau dirt road, and then by the narrow, rough Pigeon Canyon dirt road. Driving distance from St. George is about 90 mi along these roads, which may become impassable in wet weather. The westernmost part of the Pigeon Canyon and Nevershine Mesa WSA's is accessible via the partly paved St. Thomas Gap road from Mesquite, Nev., and then by jeep trails in the Grand Wash trough country.

The three WSA's straddle the boundary between the Colorado Plateaus and the Basin and Range provinces. The boundary is defined here by the Grand Wash fault, whose fault-line scarp, trending approximately north, is composed of the west-facing lower Grand Wash Cliffs and Upper Grand Wash Cliffs. East of the Upper Grand Wash Cliffs is the Shivwits Plateau, the westernmost of the plateaus that collectively form the Colorado Plateaus province. Altitudes here typically range from 6,000 to 6,500 ft, attaining a maximum of 6,710 ft at Snap Point. The terrain west of the lower Grand Wash Cliffs is part of the Grand Wash trough, within the Basin and Range province. Altitudes here range from 2,000 to 3,000 ft. At an altitude of 4,400-4,600 ft, Grand Gulch Bench, also a part of the Colorado Plateaus province, separates the lower Grand Wash Cliffs from the Upper Grand Wash Cliffs.

Mining activity

Since 1873, copper and associated silver and lead have been mined intermittently at three localities that are mainly outside the Pigeon Canyon and Nevershine Mesa WSA's (fig. 2): (1) the Cunningham Mine, which occupies parts of the Nevershine Mesa WSA and an area excluded from wilderness consideration; (2) the Savanic Mine, which occupies parts of the Pigeon Canyon WSA and an area excluded from wilderness consideration; and (3) the Grand Gulch Mine, which is outside the Pigeon Canyon WSA by only 1/4 mi. A prospect in Snap Canyon in the Snap Point WSA, consisting of two short adits and a trench, is thought to be an exploration pit for water.

As of April 1983, no mining was taking place in the three WSA's, but two mining companies (5M Mining Corp., Hurricane, Utah, and Uranez, St. George, Utah) were planning a joint uranium-exploration project near the Savanic and Cunningham Mines.

Several companies have located large groups of claims in and near the three WSA's. Many oil and gas leases are also in and near the three WSA's.

Acknowledgments

The authors appreciate information concerning the Savanic and Grand Gulch Mines provided by the 5M Mining Corp., Hurricane, Utah, and information on collapse structures provided by Energy Fuels Nuclear, Inc., Denver, Colo.

GEOLOGY

That part of the three WSA's east of and including the lower Grand Wash Cliffs is underlain by well-exposed and little-deformed Paleozoic rocks and locally by small remnants of Tertiary basalt and Quaternary pediment and fan gravels (fig. 2).

That part of the three WSA's west of the lower Grand Wash Cliffs is underlain by Tertiary interior-basin deposits. Basalt is present locally within these deposits, and Quaternary pediment and fan gravels are widespread. Paleozoic rocks are not exposed west of the Grand Wash fault within the three WSA's but are inferred to be present beneath the Tertiary deposits because steeply tilted Paleozoic rocks occur nearby in isolated ridges (fig. 2).

Rock units

The three WSA's are within the transition zone from the shelf sequence of the Grand Canyon Paleozoic section to the geosynclinal sequence of this part of the Basin and Range province. From east to west, the transition zone is chiefly typified by a thickening of many units, as well as by an increase in limestone and dolomite at the expense of sandstone and shale. Of the 5,000-ft-thick section of exposed Paleozoic rocks (which include the upper part of the Middle Cambrian Muav Limestone to the Fossil Mountain Member of Sorauf (1963) of the Lower Permian Kaibab Limestone), the lower 2,700 ft or so is predominantly carbonate rocks and the upper 2,300 ft or so is mostly clastic rocks.

In this report, we use a composite nomenclature that reflects the lithologic similarity of the rocks in the area of the three WSA's to that of the rocks in either the Grand Canyon or the Basin and Range. For most of our stratigraphic section we have adopted the Grand Canyon terminology (McKee, 1937, 1938, 1940, 1945, 1975, 1982; Billingsley, 1978), but for Pennsylvanian and Lower Permian rocks we have used the Basin and Range terminology (Longwell, 1921, 1928; Longwell and Dunbar, 1936; McNair, 1951).

Cenozoic rocks occur mostly in the Grand Wash trough. The trough was formed by movement on the Grand Wash fault in late Tertiary time, and was filled chiefly by the Miocene Muddy Creek Formation, an interior-basin deposit. An overview of the age and environment of deposition of the Muddy Creek is given by Lucchitta (1966, 1979). The Muddy Creek was deposited between about 17 and 3.8 m.y. ago, and most likely between about 12 and 5 m.y. ago. At the axis of the Grand Wash trough, the Muddy Creek consists of sandstone, siltstone, gypsum, and fresh-water limestone. Small bodies of conglomerate derived from the lower Grand Wash Cliffs to the east and containing clasts of Paleozoic sedimentary rocks grade westward toward the axis into the sandstone, siltstone, gypsum, and fresh-water limestone. Intercalated within the sedimentary-clast conglomerate at the foot of the lower Grand Wash Cliffs is a flow of olivine basalt. Remnants of basalt are present on the face of the lower Grand Wash Cliffs and on Snap Point, suggesting that all are part of a single flow that cascaded down the face of the lower Grand Wash Cliffs. The flow at Snap Point has yielded a K/Ar age of 9.07 $\pm$ 0.8 m.y. (J. F. Haman, written commun., 1983).

Structural features

The dominant structural feature in the three WSA's is the north-trending Grand Wash fault, a high-angle dip-slip normal fault that has down-to-the-west displacement, and that is buried in the three WSA's by the Muddy Creek Formation. Lucchitta (1966) estimated the throw of this fault to be 10,000-20,000 ft in the Lake Mead area; displacement on the fault decreases northward to several hundred feet near the Virgin River in southwest Utah, about 60 mi north of Lake Mead.

Within the three WSA's, the upthrown block consists chiefly of Paleozoic rocks that dip 1°-2° NE; dips steepen to as much as 5° NE. near the lower Grand Wash Cliffs. High-angle, dip-slip normal faults are common in the upthrown block and trend roughly parallel to the Grand Wash fault. A few of these faults have dips of less than 60°, and some have reverse displacement. In a few instances, displacements are a few hundred feet; most are less than 100 ft. Within the three WSA's fault displacement directions are dominantly up-to-the west, a displacement direction opposite to that of the Grand Wash fault. However, east of the three WSA's on the Shivwits Plateau, faults gradually lose the systematic up-to-the-west displacement direction and form horst-and-graben structures.

On the downthrown block, the basin fill is nearly undeformed. Here, the Muddy Creek Formation is in depositional contact against Paleozoic rocks of the lower Grand Wash Cliffs and blankets the Grand Wash fault. Near the western edge of the Pigeon Canyon WSA, gypsum beds of the Muddy Creek are folded into a gentle asymmetrical anticline plunging gently to the north-northeast. This anticline is due to drag along the Wheeler fault. The Wheeler fault is a high-angle down-to-the-west normal fault with displacement measured in thousands of feet (Lucchitta, 1966). The fault trends northeast and intersects the Grand Wash fault several miles north of the Pigeon Canyon WSA. The Wheeler fault has been active both during and after deposition of the Muddy Creek. That part of the Grand Wash fault north of this intersection has also been active during this time interval, whereas the part of the Grand Wash fault south of the intersection has not. Evidently, the most recent movement south of this intersection has occurred along the Wheeler fault rather than along the Grand Wash fault.

No Paleozoic or Mesozoic rocks are exposed in the downthrown block within the three WSA's; however, these rocks are likely to be present beneath an unknown thickness of the Muddy Creek Formation because Paleozoic rocks are exposed as tilted blocks in Wheeler Ridge, about 4 mi west of the lower Grand Wash Cliffs. The strata dip steeply eastward beneath the basin fill and include the Kaibab Limestone.

Collapse structures

Small-scale structural features consist of collapse structures (Billingsley and others, 1983; Hoffman, 1977; Watkins, 1976; and Wenrich and Sutphin, 1983) that occur in the Pennsylvanian Callville Limestone and Lower Permian Pakoon Limestone of McNair (1951) and that resulted from solution in the underlying Mississippian Redwall Limestone. Studies related to the origin and significance of collapse structures have defined several distinctive features. The collapse structures are dominantly circular in plan, are cone shaped in section, and are characterized by inward-dipping strata. Collapse structures in which brecciated rock is visible at the surface are termed breccia pipes. Brecciated rock fragments are well cemented by siliceous or weakly calcareous, fine-grained, sandy matrix.

Many of the collapse structures throughout northern Arizona are known to contain uranium, copper, and other metals. The best concentrations of ore appear to be found in the outermost part of the collapse structures where beds begin to dip toward the center of collapse. Low-temperature hypogene solutions possibly introduced the primary pyrite, chalcocite, and uraninite that was probably upgraded by supergene enrichment. The structures are known to bottom in the Redwall Limestone of Mississippian age (Sutphin and others, 1983). Consequently, mineralization in these collapse structures is not likely to occur more than 800-900 ft below the contact between the Lower Permian Esplanade Sandstone and the Pakoon (Hoffman, 1977; Huntoon and others, 1981, 1982; Billingsley and Huntoon, 1983; Billingsley and others, 1983; and K. J. Wenrich, written commun.).

GEOCHEMISTRY

A reconnaissance geochemical survey of the Pigeon Canyon, Nevershine Mesa, and Snap Point WSA's was conducted during March 1981 and March 1982 to contribute to the mineral resource assessment. Geochemical samples were collected of stream sediments, rocks, and water. Two types of stream sediments were collected: (1) a fine-grained fraction that was sieved through an 80-mesh sieve to obtain clay- and silt-sized particles for analysis; and (2) panned concentrates of stream sediments to obtain a heavy-mineral fraction for analysis. In and near the Pigeon Canyon WSA, 93 samples were collected consisting of 56 fine-grained stream-sediment samples, 18 panned-concentrate samples, 18 rock samples, and 1 water sample. In the Nevershine Mesa WSA, 30 samples were collected consisting of 17 fine-grained stream-sediment samples, 5 panned-concentrate samples, and 8 rock samples. In the Snap Point WSA, 38 samples were collected consisting of 25 fine-grained stream-sediment samples, 5 panned-concentrate samples, 6 rock samples, and 2 water samples. Fine-grained stream-sediment samples were collected mainly from first-order (unbranched) drainages. Panned concentrates were collected mainly below the confluence of first-order streams so as to improve the chances of obtaining a sufficient quantity of heavy minerals for analysis; the content of heavy minerals in the source rocks is very small, and concentrations of heavy minerals in the drainages are therefore very low. Samples of the various rock types in the area were collected to obtain information on the background content and distribution of elements in the three WSA's. Mineralized rock samples were collected in the vicinity of the Grand Gulch, Cunningham, and Savanic Mines to show the contrast in concentration of various elements in mineralized rocks compared to non-mineralized rocks. Water samples from springs in arid environments such as that of these three WSA's are often excellent indicators of mineralized terrain. Unfortunately, only three sites were found in and near the WSA's where water samples could be collected.

All the samples except the water samples were analyzed by a six-step semiquantitative emission spectrographic procedure for 31 elements. Selected samples were analyzed by wet chemical methods for Au, Cu, Pb, U, and Zn, and by delayed-neutron-activation procedures for Th and U. The water samples were analyzed for Cu, Pb, Zn, U, sulfate, fluoride, chloride, pH, and conductivity. The geochemical data and pertinent geologic parameters are stored on magnetic disk, U.S. Geological Survey, Denver, Colo. Details of collection, preparation, and analyses of samples are presented by Hopkins and others (1984).

Determination of thresholds above which concentrations of elements are considered anomalous was based on plots of data sets for each sample type (J. C. Antweiler, unpub. data, 1983). Most of the thresholds were based on concentration contrasts of elements in samples collected in the vicinity of the mines compared to those collected from non-mineralized areas. Samples from around the mines showed considerable enrichment in Ag, As, Cu, Mo, Pb, Sb, U, and Sr; some of them were also somewhat enriched in Ba, Co, Ni, or Sr.

Nearly all the geochemical anomalies in the three WSA's are attributable to the mineralized collapse structures on which the three mines (the Grand Gulch, the Savanic, and the Cunningham) are located. Several fine-grained stream-sediment samples and panned-concentrate samples collected in drainages below the mines had anomalous amounts of silver, copper, uranium, and other metals. The intensity of concentration of metals in these drainages decreased rapidly downstream from the mines. Most of the drainages are dry all year, but erosion, particularly of mine dumps situated in the drainages, is rapid when violent thunderstorms occur. Bits of rock containing malachite and other copper minerals can be found for several miles downstream from the mines.

One other drainage, Grand Gulch Canyon north of the Grand Gulch Mine, had anomalous concentrations of copper, lead, and other metals in both fine-grained stream-sediment samples and panned-concentrate samples. These anomalies were traced to ore spills along a primitive wagon road down through the canyon.

Rock samples of the collapse structures at the three mines in or near the three WSA's contained as much as 0.07 weight percent uranium in some of the highly mineralized rock. Consequently, all other known collapse structures in the three WSA's were sampled for uranium, but none contained anomalous amounts of uranium or any other element (Hopkins and others, 1984). Because of the known uranium discoveries in similar collapse structures in the Grand Canyon area and because of the great interest in this commodity, special attention was given to the detection of possible uranium occurrences in the field by use of the scintillometer and in the laboratory by use of delayed-neutron-activation techniques and fluorometry methods. The only uranium anomalies found were those in previously mentioned samples that were taken near the mines.

Samples of gypsum from the Miocene Muddy Creek Formation near the western boundary of the Pigeon Canyon WSA contained as much as 5,000 ppm (parts per million) Sr, 10 ppm Mo, and 50 ppm Sn. Although these high concentrations are geochemically anomalous, the anomalies are syngenetic components of the sedimentary gypsum deposits and do not of themselves indicate metallic deposits in this area.

Analytical values for the three water samples were rated as non-anomalous on the basis of comparison with 15 other water samples collected from nearby areas.

The U.S. Bureau of Mines collected 221 samples from mine workings during this field investigation. The samples were analyzed for gold and silver by fire assay, and for uranium by fluorometric methods. In addition, selected samples were analyzed for specific elements by atomic absorption and for 42 other elements by semiquantitative spectrographic methods. Complete analyses can be inspected at the U.S. Bureau of Mines, Intermountain Field Operations Center, Denver Federal Center, Denver, Colorado 80225.

MINING DISTRICTS AND MINERALIZED AREAS

The Pigeon Canyon, Nevershine Mesa, and Snap Point WSA's are within the old Bentley Mining District. Mining has been limited to three mineralized areas that are mainly outside the Pigeon Canyon and Nevershine Mesa WSA's. The three mineralized areas are localized in collapse structures and have been mined for copper but not uranium. A prospect in Snap Canyon in the Snap Point WSA is thought to have been a pit dug chiefly to explore for water in a nearby seep spring (Cox and Russell, 1973) (fig. 2).

Grand Gulch Mine

The Grand Gulch Mine is about 1/4 mi from the Pigeon Canyon WSA in SE 1/4 sec. 21 and SW 1/4 sec. 22, T. 34 N., R. 14 W. (fig. 2).

Copper was first discovered here in June 1853. The Grand Gulch Mine was the first mine within the old Bentley Mining District. From 1906 to 1958, the mine produced copper ore intermittently. By 1951, production totalled 15,701 tons of ore containing 24,349 oz silver, 6,651 lb copper, and 715 lb lead (Lane, 1984).

Mineralized rock is mostly found along the periphery of the collapse structure. The ore bodies are in brecciated rocks and along joints in the Pakoon Limestone, and are vertically limited to an interval of less than 250 ft below the surface (Hill, 1915). Hill (1915) reported that the ore bodies are lens-like, form irregular pods, and are composed of malachite, azurite, brochantite, and chalcocite. Baillicul and Zollinger (1980) stated that the degree of brecciation decreases and finally ends some 230 ft below the surface.

It was not possible to determine whether the ore at the Grand Gulch Mine has been depleted because the lower levels of the mine were not accessible during our investigation. A few of the surface samples collected are ore-grade material, but the sample sites are so erratically distributed that calculation of reserves is not practical. Nevertheless, the collapse structure at the Grand Gulch Mine may still contain copper and other metal resources.

The highest copper content found in the mine is 12.2 percent in a 36-in.-long chip sample, the highest silver is 2.4 oz/ton in a 36-in.-long chip sample, and the highest U_3O_8 is 13 ppm in a 24-in.-long chip sample (Lane, 1984).

Savanic Mine

The Savanic Mine is in the SW 1/4 sec. 9, T. 33 N., R. 14 W., about 400 ft below the rim of an unnamed side canyon in the Pigeon Canyon WSA (fig. 2). The mine workings are outside the boundaries of the WSA but the subsurface mine shafts extend into a collapse structure that is within the Pigeon Canyon WSA.

At present, the Savanic Mine has the highest grade and most extensive copper occurrences of any collapse structure investigated near the three WSA's, mainly because much of the high-grade ore at the Grand Gulch mine probably has been mined. Copper minerals, which include azurite, malachite, chalcopyrite, bornite, and chalcocite, occur as disseminated stains, fillings in solution cavities, and fracture fillings forming an ore-mineral matrix to the breccia. Hematite is frequently associated with the copper minerals, especially in large cavities wholly or partially filled by these minerals.

The highest copper content in samples taken from the Savanic Mine is 18 percent in a 14-in.-long chip sample, and the highest uranium content is 19 ppm in an 18-in.-long chip sample (Lane, 1984). Elsing and Heineman (1936, p. 96) credited the Savanic with $300,000 production of copper and silver from 1906 to 1919. There is no record of any metals produced since 1919.

Cunningham Mine

The Cunningham Mine is located in a collapse structure partly within the Nevershine Mesa WSA and about 3/4 mi south of the Savanic Mine in NW 1/4 sec. 16, T. 33 N., R. 14 W. (fig. 2). Inward-dipping strata of the collapse structure cover a circular area 600-800 ft in diameter. Brecciated rock is exposed in two adits. Copper minerals occur as malachite crusts and specks. Production figures of copper and other metals from the Cunningham Mine are unknown.

Of the 30 samples taken at the Cunningham Mine, 9 contained more than 1 percent copper; a 28-in.-long chip sample had the highest concentration, 4.2 percent. The highest uranium content of 48 ppm was in a grab sample taken on a 4-ft grid. Barite was found as small white pods in one adit and in several pits. The highest barium content was 6.1 percent (Lane, 1984).

Prospect in Snap Canyon

A trench and two short adits in upper Snap Canyon in NW 1/4 sec. 13, T. 32 N., R. 14 W. form the only prospect found within the Snap Point WSA. The adits are in alluvium at the portals and end in what appears to be fractured and altered Lower Permian Hermit Shale. One adit ends in saprolite and may have been developed to collect spring water (Lane, 1984).

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

General Statement

Discoveries of uranium ore on the Colorado Plateaus province in about the last 6 years have rekindled interest in reactivating old copper mines for production of uranium ore. Studies of copper and uranium ore deposits on the Colorado Plateaus province have shown that many are in collapse structures, even though there is no agreement on how this mineralization occurred (Bowles, 1965, 1977; Hoffman, 1977; Miller, 1954; Watkins, 1976; Wenrich and Sutphin, 1983). Known mineral occurrences in the Pigeon Canyon, Nevershine Mesa, and Snap Point WSA's appear to be confined to collapse structures. Therefore, any undiscovered mineral occurrences would likely be closely associated with these structures. Many collapse structures of the Grand Canyon region are not mineralized, but those that are have yielded substantial quantities of uranium, copper, and other metals (Hill, 1915; Miller, 1954; Gornitz and Kerr, 1970). For these reasons, all collapse structures within the three WSA's are considered to have at least a moderate potential for resources of copper, uranium, and other metals. Classification of resource potential follows the definitions of Goudarzi (1984).

Pigeon Canyon Wilderness Study Area

The mineral resource potential for uranium, copper, and other metals is high in the area of the collapse structure associated with the Savanic Mine. Although the Savanic Mine workings are outside the Pigeon Canyon WSA, the associated collapse structure extends into the WSA. Minerals at the mine occur on joints in the Callville Limestone (Wescogame Formation of the Supai Group of McKee, 1982) that are associated with the collapse structure. Four other previously unknown collapse structures within the WSA (fig. 2) have moderate potential for the resources of uranium, copper, and other metals. The remainder of the Pigeon Canyon WSA has low potential for resources of uranium, copper, and other metals.

Because silty gypsum deposits occur in the Muddy Creek Formation in the western half of the WSA, this part of the WSA has a moderate potential for resources of gypsum; however, this commodity is readily available and more accessible elsewhere in southern Utah and northern Arizona. The slightly anomalous amounts of syngenetic uranium and molybdenum in the Muddy Creek gypsum deposits represent low potential at best for these elements.

That part of the WSA west of the Grand Wash fault has moderate potential for oil and gas resources, and that part east of the fault has low potential (Ryder, 1983). Paleozoic reservoir rocks are buried west of the fault, but on the eastern side of the fault they are visibly faulted, exposed, and susceptible to freshwater flushing as well as updip migration to the surface.

No coal-bearing rocks were observed in the Pigeon Canyon WSA, and none are expected to be present in the subsurface.

Industrial mineral resources are abundant in the Pigeon Canyon WSA; they include building stone, sand and gravel, and limestone. However, these resources are more accessible and readily available elsewhere in northern Arizona and southern Utah.

Nevershine Mesa Wilderness Study Area

With the exception of that part of the Nevershine Mesa WSA that is occupied by the Cunningham Mine, this WSA has low potential for resources of uranium, copper, and other metals. High potential for resources of uranium, copper, and other metals exists in the area of the Cunningham Mine, which is within a large collapse structure that has visible breccia containing copper and iron minerals at the surface. In addition, moderate potential exists for uranium, copper, and other metals in that part of the Nevershine Mesa WSA between the Savanic and Cunningham Mines because this area (1) lies between two known mineralized collapse structures that are only 3/4 mi apart and (2) may contain mineralized joints similar to those at the Savanic Mine.

Ryder (1983) rated the potential for resources of oil and gas in the Nevershine Mesa WSA as moderate west of the Grand Wash fault and as low east of the fault. Paleozoic reservoir rocks are buried west of the fault, whereas Paleozoic rocks on the eastern side of the fault are visibly faulted, exposed, and susceptible to freshwater flushing as well as updip migration to the surface.

No coal-bearing rocks were observed in the Nevershine Mesa WSA and none are expected to be present in the subsurface.

No gypsum deposits occur in the Nevershine Mesa WSA, but they may exist in the subsurface. However, this commodity is readily available and more accessible elsewhere in southern Utah and northern Arizona.

Industrial mineral resources such as building stone, sand and gravel, and limestone are abundant in the Nevershine Mesa WSA. However, these resources are more accessible and readily available elsewhere in northern Arizona and southern Utah.

Snap Point Wilderness Study Area

The Snap Point WSA has low potential for resources of uranium, copper, and other metals. No collapse structures were found within this WSA. One small prospect in the area presumably was dug to develop a spring (Cox and Russell, 1973; Lane, 1984). Ryder (1983) rated the potential for resources of oil and gas as low because the WSA lies entirely east of the Grand Wash fault where the Paleozoic reservoir rocks are visibly faulted, exposed, and susceptible to freshwater flushing as well as updip migration to the surface. No gypsum deposits are known to occur in the Snap Point WSA.

No coal-bearing rocks were observed in the Snap Point WSA, and none are expected to be present in the subsurface.

Industrial mineral resources such as building stone and limestone are abundant in the Snap Point WSA. However, these resources are more accessible and readily available elsewhere in northern Arizona and southern Utah. Sand and gravel occur in only minor amounts within the Snap Point WSA.

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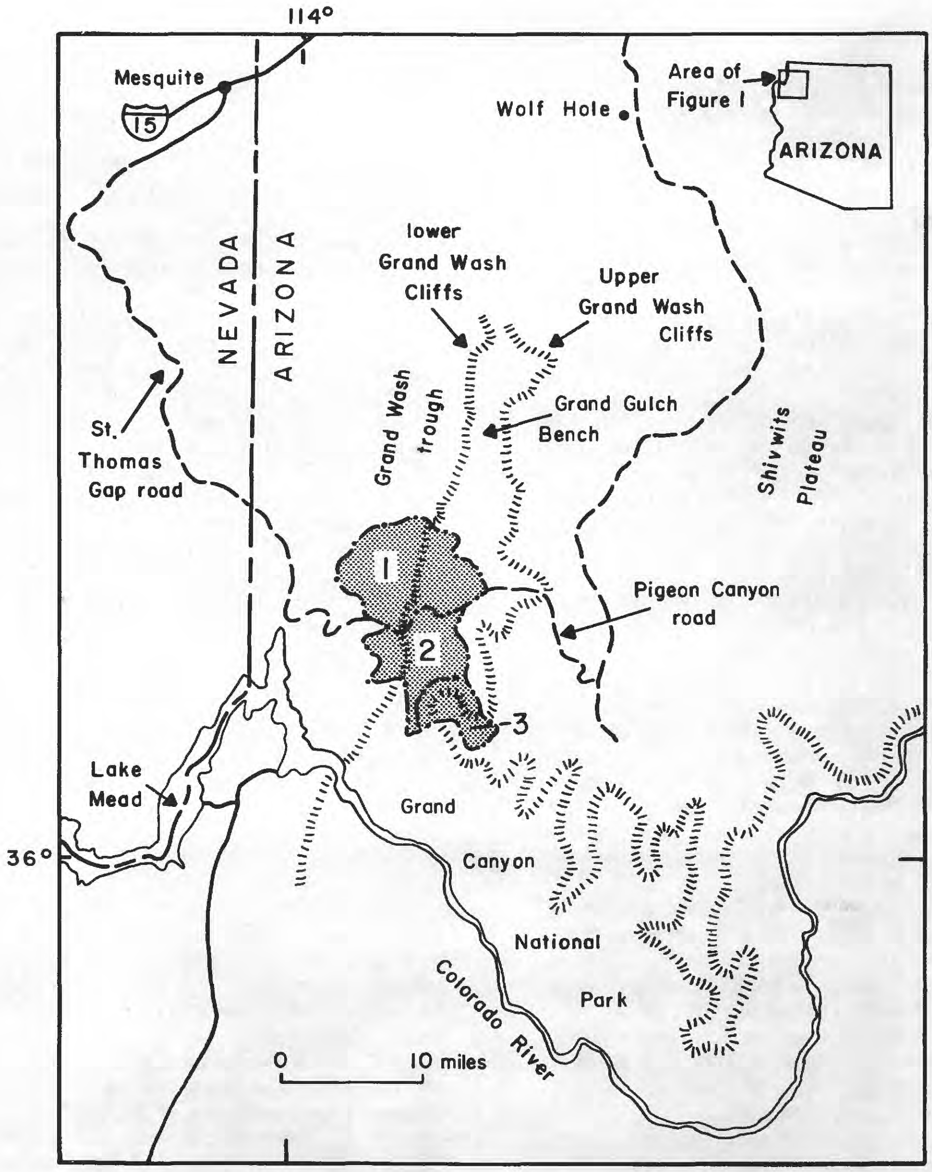

FIGURE 1.--Index map showing the location of the Pigeon Canyon (1), Nevershine Mesa (2), and Snap Point (3) Wilderness Study Areas, Mohave County, Arizona.

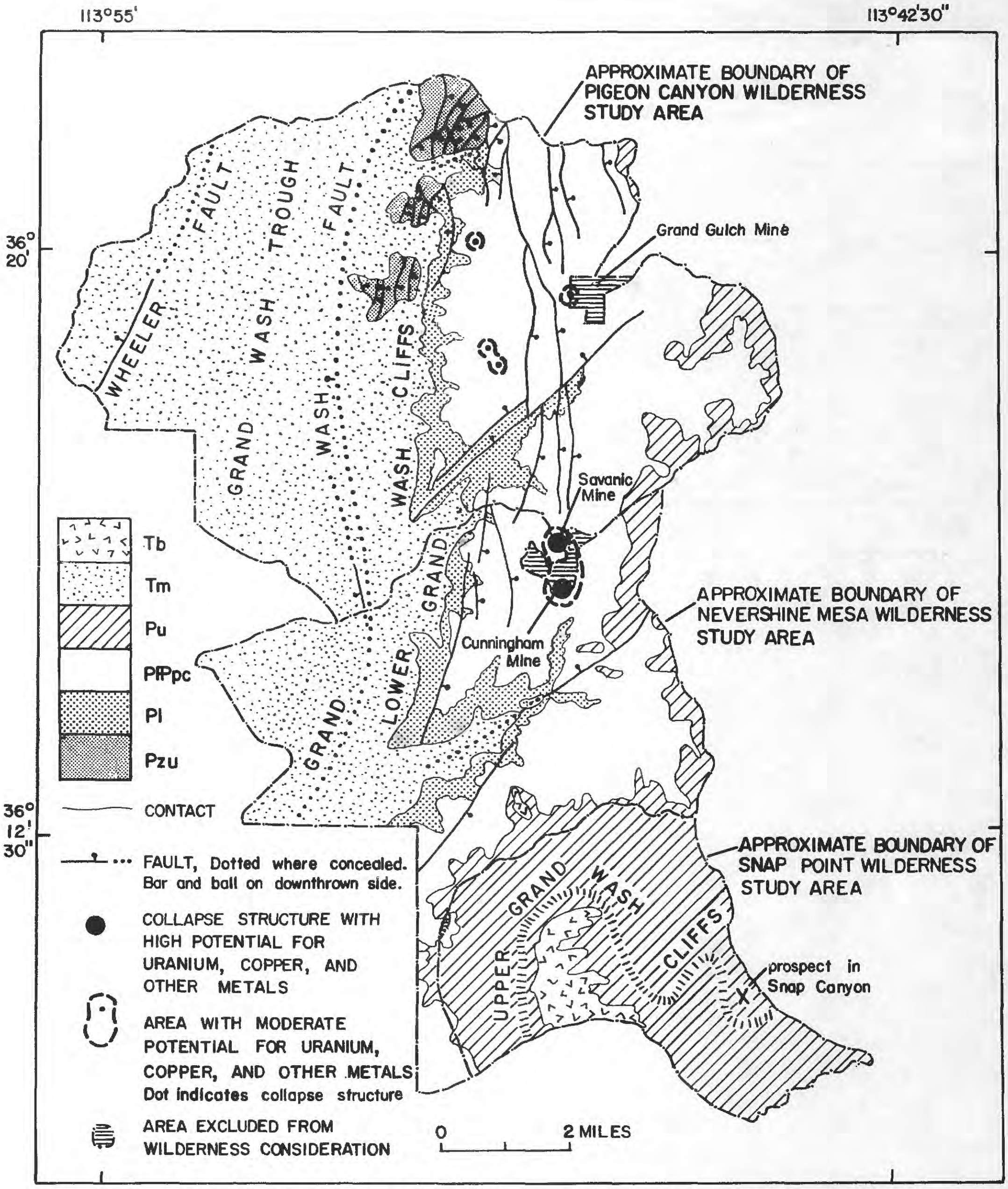

FIGURE 2.--Map showing simplified geology and mineral resource potential for uranium, copper, and other metals (associated metals such as lead, zinc, silver, arsenic, nickel, molybdenum, cobalt, chromium, and antimony) of the Pigeon Canyon, Nevershine Mesa, and Snap Point WSA's. The areas of high or moderate potental for uranium, copper, and other metals are shown; the remainder of the three WSA's has low potential for resources of uranium, copper, and other metals. Tb, basalt; Tm, Muddy Creek Formation, undivided; Pu, Permian rocks, undivided, includes Fossil Mountain Member of Sorauf (1963) of Kaibab Limestone, Toroweap Formation, Coconino Sandstone, Hermit Shale, and Esplanade Sandstone; P pc, Pakoon Limestone of McNair (1951) and Callville Limestone, undivided; Pl, lower Paleozoic rocks, includes Redwall Limestone, Temple Butte Limestone, and Muav Limestone; Pzu, Paleozoic rocks, undivided.

Mineral resource potential for oil and gas, gypsum, and coal in the Pigeon Canyon, Nevershine Mesa, and Snap Point Wilderness Study Areas

	Pigeon Canyon Wilderness Study Area	Nevershine Mesa Wilderness Study Area	Snap Point Wilderness Study Area
Oil and gas	Moderate potential west of Grand Wash fault Low potential east of Grand Wash fault	Moderate potential west of Grand Wash fault Low potential east of Grand Wash fault	Low
Gypsum	Moderate potential west of Grand Wash Cliffs No deposits known east of Grand Wash Cliffs	Moderate potential west of Grand Wash Cliffs No deposits known east of Grand Wash Cliffs	No deposits known
Coal	None	None	None