UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Geology and mineral resource potential of the Narrows (AZ-010-135), Lime Hills (AZ-010-134), and Sand Cove (AZ-010-128) 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 their mineral resource potential. 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 Narrows (AZ-010-135), Lime Hills (AZ-010-134), and Sand Cove (AZ-010-128) Wilderness Study Areas, Mohave County, Arizona, as designated by the U.S. Bureau of Land Management.

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SUMMARY

The Narrows, Lime Hills, and Sand Cove Wilderness Study Areas (WSAs) are on lands administered by the U.S. Bureau of Land Management in northwestern Mohave County, Ariz. (fig. 1). They have areas with resource potential for gypsum, base and precious metals, uranium, limestone, sand and gravel, and oil and gas (fig. 3). An area along the northeast boundary of the Narrows WSA has identified resources of several hundred million tons of gypsum, and near the eastern and northern boundaries of the Lime Hills WSA there is a high resource potential for gypsum. An area southwest of the Lime Hills WSA and west of the Sand Cove WSA has a low resource potential for base and precious metals in vein and breccia-pipe deposits. An area along the eastern boundary of the Sand Cove WSA has a low resource potential for uranium and base metals in sedimentary rocks. Limestone and sand and gravel deposits are present in the WSAs but there are more readily accessible deposits nearer the probable markets. The Lime Hills, Sand Cove, and the eastern half of the Narrows WSAs have a low resource potential for oil and gas. The rocks exposed in these areas are known to be oil- and gas-bearing elsewhere in the region, but the source rocks and the types of structural and stratigraphic traps conducive to petroleum accumulation are not in evidence. The western half of the Narrows WSA cannot be clearly evaluated, due to thick Quaternary sediments and the lack of subsurface data, but this area is also assigned a low resource potential for oil and gas.

INTRODUCTION

During 1981 and 1982, the U.S. Bureau of Mines and the U.S. Geological Survey conducted field investigations to evaluate the mineral-resource potential of three areas administered by the U.S. Bureau of Land Management in the northwestern part of Mohave County, Arizona: The Narrows, Lime Hills, and Sand Cove Wilderness Study Areas (WSAs) (fig. 1). Field studies included a survey of known prospects and mineralized areas by the U.S. Bureau of Mines, and geologic mapping, reconnaissance studies, and geochemical sampling by the U.S. Geological Survey to define the extent of mineralization associated with mines and prospects and to determine if previously unknown resources exist in the areas.

The Narrows WSA encompasses a 7,700-acre tract and is bounded on the south by the Virgin River Canyon and Interstate Highway 15. On the north and west it is bounded by graded roads which also provide access. The community of St. George, Utah, lies 19 mi northeast, and Mesquite, Nevada, is 14 mi southwest of the area. The Lime Hills WSA is a 12,900-acre tract approximately 13 mi south of St. George. It adjoins the east side of the Paiute Primitive Area and is bounded on the north by Interstate Highway 15. Graded and unimproved dirt roads provide access to the southern and eastern parts of the area. The Sand Cove WSA comprises 40,100 acres, and adjoins the southeast part of the Paiute Primitive Area and the southern part of the Lime Hills WSA. The area is accessible by graded roads from Mesquite, 26 mi by road to the west, and from St. George, 47 mi by road to the north (fig. 1).

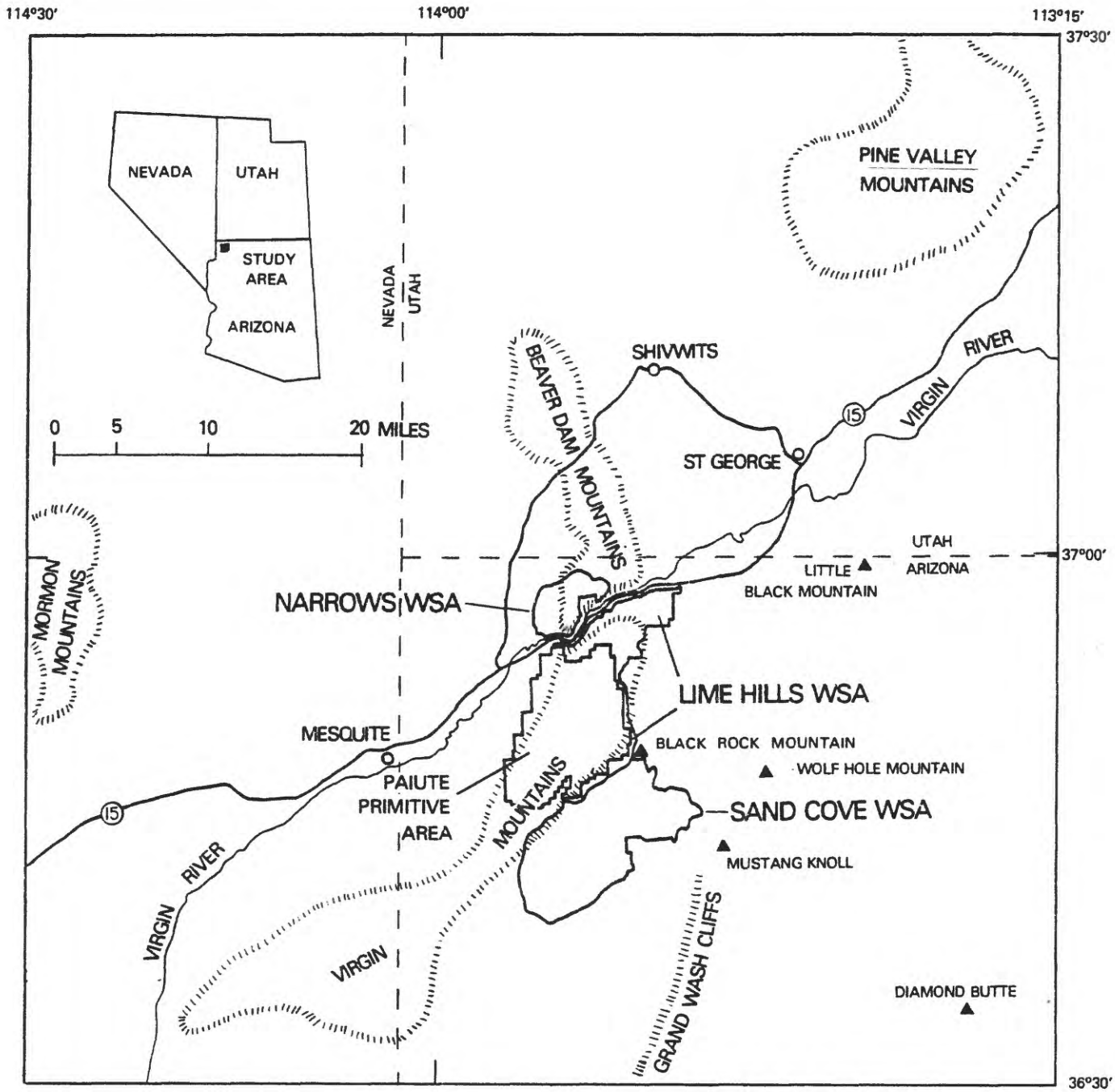

Figure 1.--Index map showing the location of the Narrows (AZ-010-135), Lime Hills (AZ-010-134), and Sand Cove (AZ-010-128) Wilderness Study Areas, Mohave County, Arizona.

GEOLOGY

Physiographic setting

The three WSAs are located in an area of very high relief. The southern and eastern edges of the Narrows WSA are the nearly vertical northern walls of the Virgin River Gorge. The bottom of the gorge is a little less than 2,000 ft in altitude, and the highest point in the WSA (only 3,500 ft horizontally from the bottom) is a little more than 4,300 ft. Overall, the Narrows WSA is a large, gently west-tilted structural block that includes west-facing, gently sloping alluvial fans of the Virgin River Valley in its westernmost part. The northern segment of the irregularly shaped Lime Hills WSA is chiefly in an area of rugged topography with cliffs on the southern walls of the Virgin River Gorge. The southern segment, a long, thin, northerly and northeasterly trending tract, is on the basalt-capped ridges and mesas east of the Virgin Mountains and south of the Virgin River Gorge. Black Rock Mountain (7,067 ft) is included in this segment, and Mount Bangs (8,012 ft), which is the highest peak locally, is about 1 1/2 mi from the western boundary of the Lime Hills WSA. The northern boundary of the Sand Cove WSA is on Black Rock Mountain, a high, basalt-capped mesa. The area slopes gently to the southeast and south from the base of the mesa; much of the southern part of the Sand Cove WSA is in flat, wooded country.

Stratigraphy

The rocks of the Wilderness Study Areas are described in some detail on the geologic map (plate 1); a generalized summary is given below, and a simplified geologic map is shown in figure 2.

No Precambrian crystalline rocks are exposed in the three WSAs, but they are widely exposed in the adjacent Paiute Primitive Area and they underlie all three areas, in places at only moderate depths. The crystalline rocks are chiefly Proterozoic X (2,500 to 1,600 m.y. old) gneiss and schist that are continuous with similar rocks exposed in the Virgin Mountains to the west (fig. 1) and correlative with those exposed in other parts of northern Arizona to the southeast. Some light-colored granitic rocks also exist within the WSAs and may be of Proterozoic Y age (1,600 to 800 m.y.); they are correlative with similar granites in parts of southern Nevada and western Arizona to the south.

The Paleozoic sedimentary rocks in the three WSAs were deposited in the transition zone between the stable cratonic platform to the east and the gently subsiding shelf or miogeocline to the west. The transition zone is characterized by intertongued rocks on both the shelf and platform facies; the nomenclature of either facies is applicable to the sequence and terms of both facies are used in this report. The basal Cambrian rocks are chiefly clastic marine strata that are overlain by a thick succession of Upper Cambrian shallow-water marine limestone and dolomite. Devonian through Permian marine carbonate rocks rest disconformably on the Upper Cambrian strata. A thick unit of Permian windblown sandstone overlies the marine sequence and is succeeded by Permian marine limestone and evaporitic rocks. Paleozoic rocks underlie all of the eastern part of the Narrows WSA and the northern part of the Lime Hills WSA.

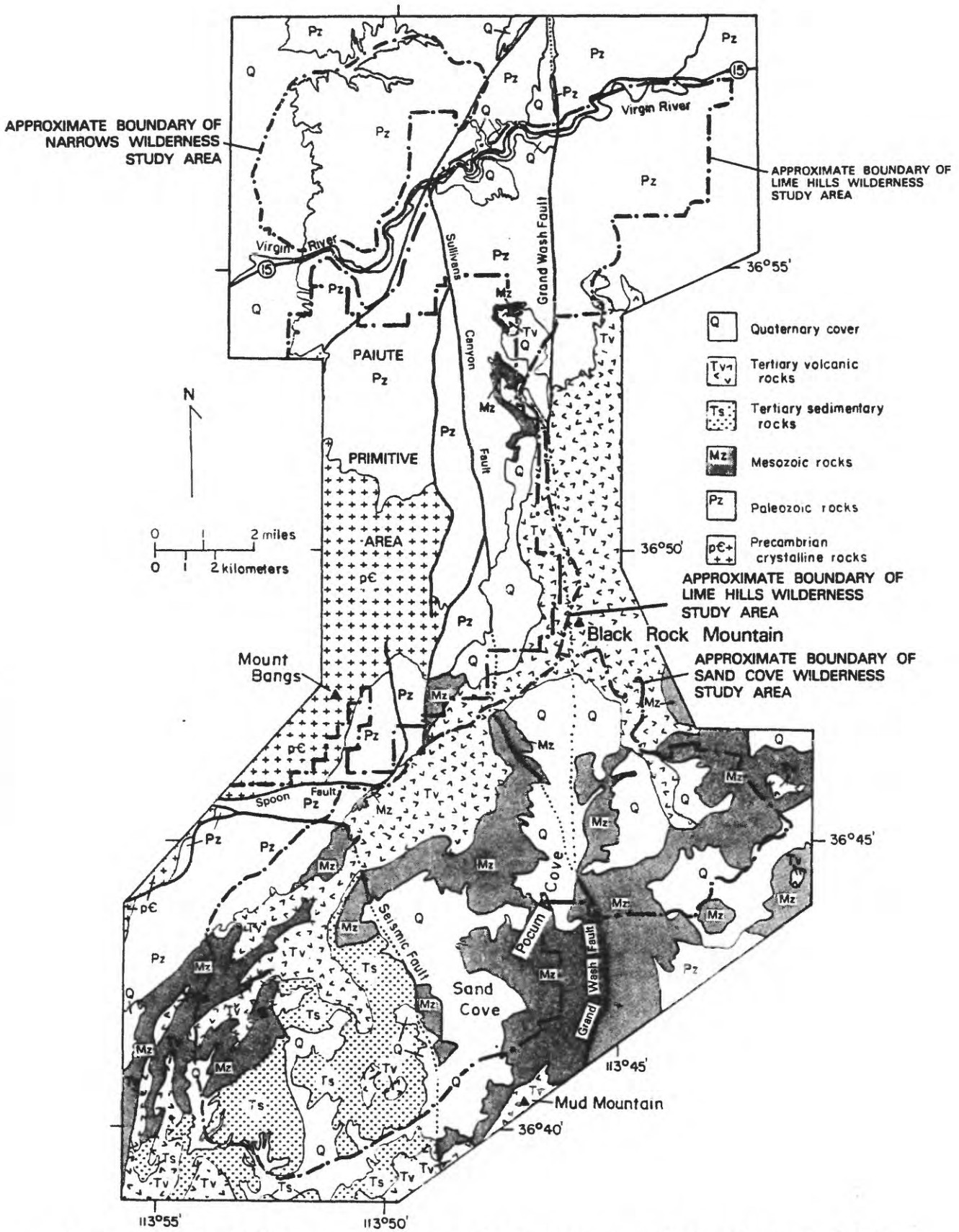

Figure 2.--Simplified geologic map of the area around the Narrows, Lime Hills, and Sand Cove Wilderness Study Areas, Mohave County, Arizona

The Mesozoic sequence is chiefly nonmarine clastic and evaporitic rocks, with the exception of one unit of nearshore marine carbonate strata near, or at the base of, Triassic rocks in the three WSAs. Above the nearshore marine rocks, Triassic tidal-flat and mud-flat deposits are overlain by Triassic fluvial conglomerate, sandstone, and claystone. Windblown Jurassic and Triassic(?) sandstone is abundant above the fluvial deposits and, just outside the WSAs, is, in turn, overlain by Cretaceous nonmarine claystone and fluvial to alluvial sandstone. Mesozoic rocks are present throughout the southern half of the Sand Cove WSA.

The Tertiary sequence is chiefly nonmarine clastic, lacustrine, fluvial, and alluvial rocks, but also includes thick subaerial basalt flows and lacustrine limestone and gypsum. The oldest Tertiary beds are Miocene lacustrine rocks that occupied part of a regionally extensive but shallow basin about 20-16 m.y. ago (Bohannon, in press). Unconformably overlying these units are thick clastic, fluvial, and alluvial beds that filled a deep, rapidly subsiding, west-facing half-graben about 12-10 m.y. ago (Bohannon, in press). Undeformed to little-deformed basalt flows and associated alluvial and fluvial gravels unconformably overlie the rocks of the half-graben. The oldest lacustrine rocks and those that filled the half-graben are exposed in the southwestern corner of the Sand Cove WSA. The basalt and associated gravels are exposed throughout Sand Cove and in the southern part of the Lime Hills WSA.

Thin Quaternary surficial deposits are widespread in all three WSAs. In the western part of the Narrows WSA, Quaternary alluvial fans reach an unknown thickness at the eastern edge of the Virgin River Valley, the easternmost local Basin and Range valley.

Structure

The three WSAs straddle the Grand Wash fault, which is a major physiographic boundary between the Colorado Plateau and Basin and Range Provinces (pl. 1 and fig. 2). East of the fault, in the Colorado Plateau Province, the rocks are only moderately deformed, and have a slight regional north to northeast tilt. Regionally, increasingly younger strata are exposed northward, but this regional trend is disrupted by local folding near the WSAs; dips are not greater than 10° and most are about 2°-5°. Faults are rare. West of the Grand Wash fault, in the Basin and Range Province, deformation is pronounced, and increases in intensity westward. Adjacent to the fault, strata dip as much as 15°, and their dip increases to the west to vertical or is overturned. Faults are much more closely spaced in the western parts of the WSAs and in the Paiute Primitive Area than they are near the Grand Wash fault.

Examined from east to west, across the width of the Lime Hills WSA and the Paiute Primitive Area, the Colorado Plateau-Basin and Range transition is very complex. Rocks in the Plateau Province are nearly flat lying, and Upper Permian strata are at altitudes of about 5,000-6,000 ft. In a narrow zone west of the Grand Wash fault and east of Sullivans Canyon, the Upper Permian strata were dropped to about 4,000 ft and have slightly steeper dips than on the plateau to the east. West of Sullivans Canyon, rocks of Precambrian through Permian age were greatly uplifted, and, at Mount Bangs in the Paiute

Primitive Area, Precambrian rocks are at altitudes in excess of 8,000 ft. West of the Paiute Primitive Area, along normal faults at the eastern margin of the Virgin River Valley, all of the above-described rocks have been dropped possibly several miles, according to proprietary oil-industry seismic information.

Several faults with large displacement occur in and near the WSAs. The Grand Wash fault is a north-trending, high-angle, normal-separation fault that has as much as 1,000-1,500 ft of down-to-the-west displacement of Paleozoic and Mesozoic rocks. The Grand Wash fault offsets slightly the oldest Tertiary basalt flows, but is overlapped by the youngest flows. The north-trending, vertical Sullivans Canyon fault separates gently north-dipping Permian strata to the east from highly deformed Mississippian, Pennsylvanian, and Permian rocks to the west. The precise type, age, and amount of displacement on the Sullivans Canyon fault are not known, but horizontal-motion indicators preserved on some fault surfaces suggest a large component of lateral slip. Vertical stratigraphic separation is slight at the northern termination of the Sullivans Canyon fault, where it abuts a large, northeast-trending, southeast-dipping normal fault in the Lime Hills WSA, but the displacement is about 3,500 ft, 10 mi to the south. Several northeast-trending, southeast-dipping normal faults splay from the west side of the Sullivans Canyon fault and form a zone of faults across which Mississippian rocks in places are downfaulted to rest against Precambrian rocks; the offset represents thousands of feet of primarily lower Paleozoic strata that have been eroded. West of Black Rock Mountain this zone narrows into one north-northeast-trending fault, the Spoon fault (Moore, 1972), that abruptly bends to a westerly trend southwest of the mountain. Another fault, herein called the Seismic fault, in the southwestern part of the Sand Cove WSA, is a large, north-trending west-dipping normal fault that separates young Tertiary clastic rocks to the west from Mesozoic rocks to the east. Although the fault is not well exposed, it appears spectacularly on proprietary petroleum-industry seismic profiles; these records indicate that the fault bounds the east side of a large west-thinning wedge of young Tertiary sedimentary rocks. Near Black Rock Mountain the Seismic fault apparently bends to the west and parallels the westerly trace of the Spoon fault. Both faults join a group of northeast-trending, southeast-dipping, low-angle, younger-on-older faults west of Black Rock Mountain. Much of the lower Paleozoic rock sequence has been removed along this group of faults.

GEOCHEMISTRY

The results of analyses of 78 stream-sediment samples, 22 pan concentrates of stream-sediment samples, 20 water samples, and 78 whole-rock samples taken in the Narrows, Lime Hills, and Sand Cove WSAs are reported by J. C. Antweiler (unpublished U.S. Geological Survey manuscript, 1983). Evaluation of these data indicates geochemical anomalies in the upper reaches of Cottonwood Wash (Area G-1, fig. 3) and in Triassic rocks near Ide Spring (Area G-2, fig. 3). Cottonwood Wash lies along the southwest boundary of the Lime Hills WSA, and along the western boundary of the Sand Cove WSA. Samples from Cottonwood Wash contained anomalously high silver, copper, lead, zinc, manganese, and barium. The anomalies are related to local mineral deposits that were prospected at the South End breccia pipe and at the Goddess claim (Hamm, 1980), and are supported by data on samples of possible ore grade

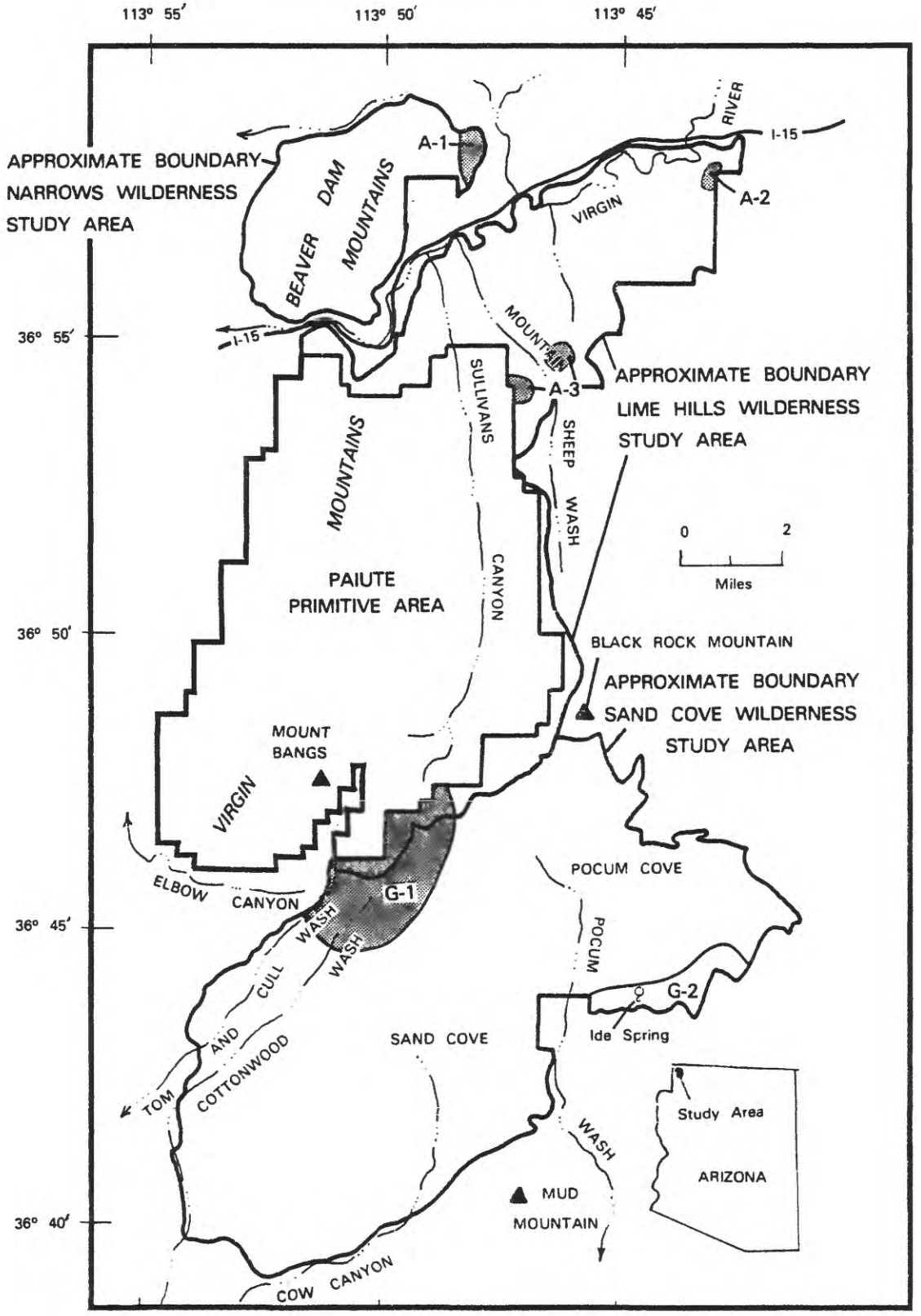

Figure 3.--Map showing the areas of mineral resource potential in the Narrows, Lime Hills, and Sand Cove Wilderness Study Areas, Mohave County, Arizona. Areas A-1, A-2, A-3: Gypsum, high Potential; G-1: Ag, Pb, Zn, Cu, low potential; G-2: U, Cu, low potential.

analyzed by the U.S. Bureau of Mines. No significant geochemical anomalies were determined in the Narrows WSA.

MINERAL RESOURCE POTENTIAL

In the Narrows WSA, claim staking and prospecting have been centered on a gypsum deposit at Cedar Wash (Area A-1, fig. 3) and are the only mineral exploration-related activities known in the WSA. At Cedar Wash, along the northeast boundary, a unit about 300 ft thick of gypsum with interbedded limestone and sandstone occurs near the top of the Bird Spring Formation of Permian-Pennsylvanian age. The unit crops out over an area of about 480 acres and contains several hundred million tons of gypsum. However, other sources of gypsum are more readily available closer to market.

The Lime Hills WSA also has gypsum deposits in the Permian Kaibab Formation in Purgatory Canyon (Area A-2, fig. 3), and in the Triassic Moenkopi Formation in Mountain Sheep Wash (Area A-3, fig. 3). The identified resources of gypsum are large, but the deposits are accessible only with difficulty.

Near the south end of the Lime Hills WSA, in the drainage basin of Cottonwood Wash (Area G-1, fig. 3), base and precious metals have been sought at the Goddess workings and at the South End breccia pipe (Hamm, 1980; Villalobos and Hamm, 1980). Reportedly (Paul Lamoreaux, written commun., 1982), the Goddess produced 10 tons of ore containing silver, lead, and zinc. Analyses of samples taken from the shaft indicate 0.5-2.9 oz Ag per ton, 1.5-2.2 percent Pb, and 2.7-7.2 percent Zn; samples taken from a pit contained 0-1.1 oz Ag per ton, 0.1-0.53 percent Pb, and 0.19-3.7 percent Zn (Hamm, 1980). Production from the South End breccia pipe is unknown, but was probably small; a stockpile at the workings contains about 1 yd^3 of mineralized material. A sample from the stockpile contained 5.4 percent Cu and 1.15 percent As (Hamm, 1980). Geochemical samples from Cottonwood Wash showed anomalously high contents of silver and base metals. Area G-1 (fig. 3) is considered to have a low resource potential for base and precious metals in vein and breccia-pipe deposits.

Evidence of mining activity in the Sand Cove WSA is restricted to one prospect pit in the Shinarump Conglomerate Member of the Chinle Formation, which is a known host rock for uranium in other parts of the Colorado Plateau. Samples collected from and around the pit had only low contents of uranium and thorium common to other rocks in the area. Geophysical exploration by private companies for oil and gas was also being conducted during the time of fieldwork for this study.

Water from Ide Spring on the eastern boundary of the Sand Cove WSA (Area G-2, fig. 3) is anomalously high in uranium and copper. The area is underlain by the Triassic Moenkopi and Chinle Formations which are probably the source of the metals. Triassic shale beds have 2-10 times the radioactivity of other rocks in the area, as indicated by a scintillometer, but the highest value obtained by delayed neutron activation analyses for uranium was 59 ppm, compared to 5-10 ppm for most samples. Based on sample data, copper, lead, and zinc are also enriched in some of the Triassic rocks at a level of 2-5 times that of other common rocks. The area is rated as having a low resource potential for uranium and base metals.

PETROLEUM RESOURCE POTENTIAL

The Sand Cove WSA was, as of 1981, entirely under lease for oil and gas, and geophysical exploration crews have been active along the southern border of the area. The nearest producing oil field is the Virgin Field, about 30 mi northeast of the WSA. Although the formations exposed in the WSA and in the Virgin Field are the same, the primary producing structure, the Virgin Anticline, does not extend into nor is near the WSA. Our mapping and proprietary petroleum-industry seismic data suggest that the Sand Cove WSA does not contain a similar, large-scale fold or other suitable structural or stratigraphic trap for oil or gas. Some drill holes testing the Mesozoic rocks in nearby parts of Utah have had oil shows (Cook, 1963), and oil seeps are known in Triassic rocks in other parts of southwest Utah (Ritzma, 1973), but such evidence for oil and gas is rare, as is evidence for widespread source rocks in the WSA. Therefore we consider the resource potential for oil and gas in the Sand Cove WSA to be low.

Parts of the Lime Hills WSA are under lease for oil and gas, but none of the Narrows WSA is similarly leased. No active geophysical exploration is known to be underway in either study area. Geologic mapping of the Lime Hills WSA suggests that the possibility for petroleum traps and accumulations is low because of the large number and close spacing of major faults. Comments regarding the source rock potential of the Sand Cove WSA also apply to the Lime Hills WSA. In general, the east half of the Narrows WSA is a tilted block with Pennsylvanian rocks exposed at the surface, and the possibilities for source beds and structural and stratigraphic traps are apparently very small. Because the western part of the Narrows WSA is covered by thick Quaternary deposits, a similar evaluation for oil and gas in that area is not possible without drilling and geophysical studies, which are beyond the scope of this report. The eastern part of the Narrows WSA and the entire Lime Hills WSA are regarded as having a low resource potential for oil and gas, and although it cannot be fully evaluated the western part of the Narrows WSA also is considered as having a low resource potential for oil and gas.

REFERENCES CITED

Bohannon, R. G., in press, Nonmarine sedimentary rocks of Tertiary age in the Lake Mead region, southeastern Nevada and northwestern Arizona: U.S. Geological Survey Professional Paper 1259.

Cook, E. F., 1963, Geology and oil possibilities of Washington County, in Crawford, A. L., ed., Oil and gas possibilities of Utah, re-evaluated: Utah Geological and Mineralogical Survey Bulletin 54, p. 303-318.

Hamm, L. W., 1980, Mines and prospects map of the Paiute Primitive Area, Mohave County, Arizona: U.S. Geological Survey Miscellaneous Field Studies Map MF-1160-B, scale 1:24,000.

Ritzma, H. R., 1973, Oil-impregnated rock deposits of Utah: Utah Geological and Mineralogical Survey Map 33, scale 1:1,014,000 (1 in. = approx. 16 mi), 2 sheets.

Villalobos, H. A., and Hamm, L. W., 1980, Summary report of the mineral resource appraisal of the Paiute Instant (Primitive) Study Area, Mohave County, Arizona: U.S. Geological Survey Open-File Report 80-984, 11 p.