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PAMPHLET

MINERAL RESOURCE POTENTIAL AND GEOLOGY OF THE RATTLESNAKE ROADLESS AREA, COCONINO AND YAVAPAI COUNTIES, ARIZONA

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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 geological and mineral survey of the Rattlesnake Roadless Area (03054), Coconino National Forest, Coconino and Yavapai Counties, Ariz. The Rattlesnake Roadless Area was classified as a further planning area during the Second Roadless Area Review and Evaluation (RARE II) by the U.S. Forest Service, January 1979.

MINERAL RESOURCE POTENTIAL SUMMARY STATEMENT

The mineral resource potential of the Rattlesnake Roadless Area, Ariz., is evaluated as low based on field studies performed by the U.S. Bureau of Mines and the U.S. Geological Survey during 1982. No anomalous concentrations of minerals are indicated by geochemical sampling within the boundary of the roadless area. Evaporite deposits, basaltic cinders, and building stone have been mined or quarried near the roadless area. Cinders, sand and gravel, and sandstone crop out in the roadless area but are readily available and more accessible outside its precipitous canyon system.

INTRODUCTION

Geographic setting

The Rattlesnake Roadless area covers 32,870 acres between long 111°37'30" and long 111°47'30" W. and between lat 34°40' and lat 34°52'30" N., Coconino and Yavapai Counties, in central Arizona (fig. 1). Sedona and Oak Creek, the nearest population centers, are located respectively at the northwest corner and on the west margin of the roadless area.

The roadless area boundary follows the rims of steep-walled canyons cut by Dry Beaver Creek and its main tributaries in Jacks, Pine Tank, and Rattlesnake Canyons. The streams head in the plateau uplands beyond the north, east, and south margins; the plateau is traversed by Interstate Highway I-17. The west and south margins of the roadless area are east and north of Arizona Highway 179, which connects with I-17 at the southwest corner of the roadless area. Bear Wallow Canyon, a west-draining tributary canyon of Oak Creek, is traversed by Schnebly Hill Road and marks the northwesternmost boundary of the roadless area. The mouths of Woods (Dry Beaver Creek), Jacks, and Bias Canyons mark the west and south margins of the Colorado Plateau. Here the plateau surface falls off abruptly to the Verde Valley, drained by the Verde River, the master stream of the region.

The maximum elevation in the roadless area is 6,834 ft at the basalt cap at the north end of Munds Mountain. The lowest elevation, about 3,480 ft, is on Dry Beaver Creek near the southwest corner of the roadless area. Maximum relief in the roadless area is more than 2,000 ft between the Munds-Lee Mountains divide and the valley floors of the bordering Oak Creek and Jacks Canyons. Relief between floor and upper canyon rims along the steep-walled and narrower Woods Canyon is 900 to more than 1,400 ft; the highest canyon walls are on the east side of the canyon. Jacks Canyon drops 2,400 ft over a distance of 13 mi from its head near the northern margin of the roadless area to its confluence with Dry Beaver Creek. Dry Beaver Creek drops 1,800 ft over a distance of 11.8 mi from where it enters the roadless area to its confluence with Jacks Canyon. The gradients of the main tributaries of Woods Canyon are somewhat steeper; from where they enter the roadless area to their confluences with Dry Beaver Creek, Pine Tank Canyon

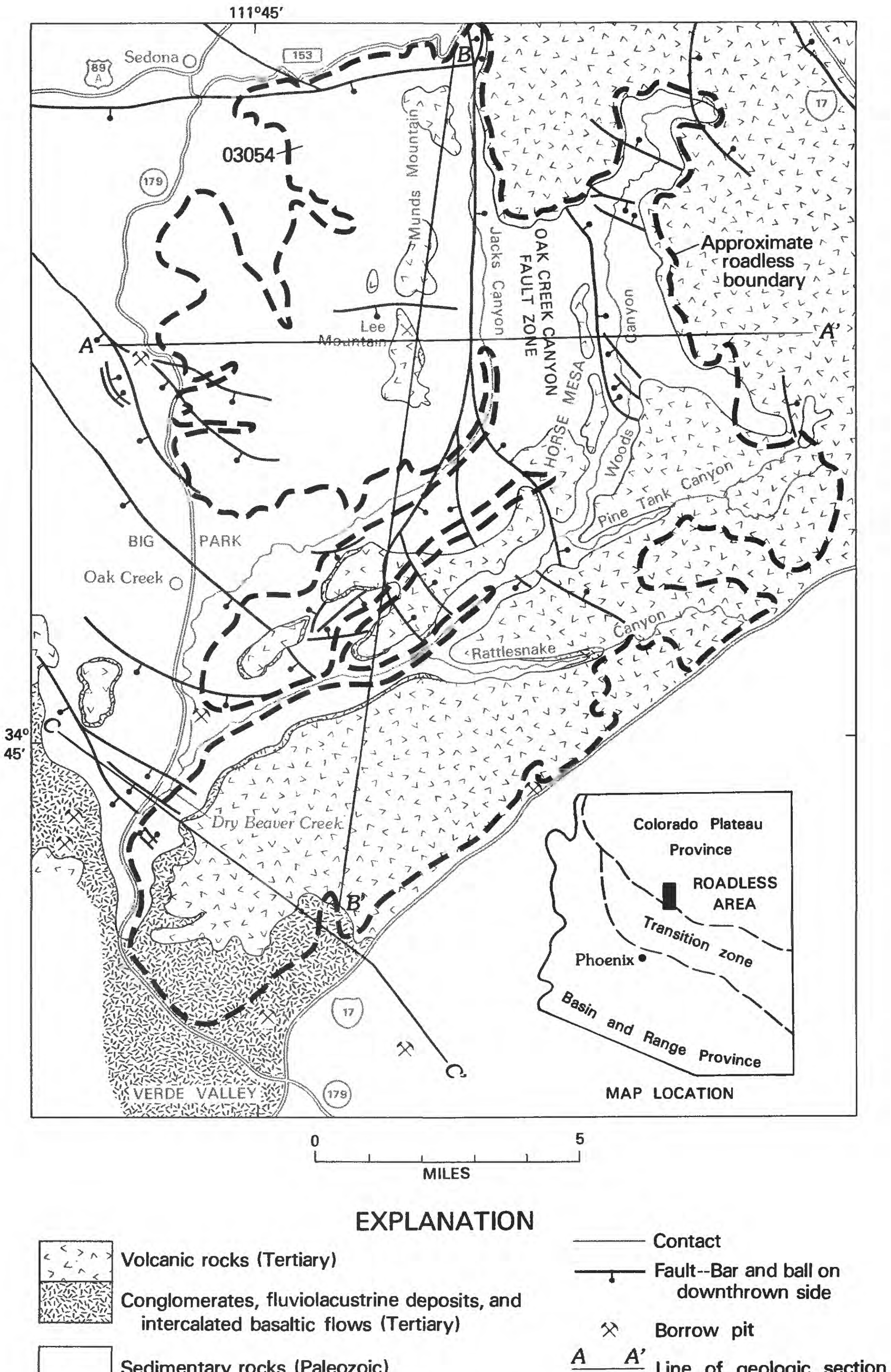


Figure 1.—Map showing location and simplified geology of the Rattlesnake Roadless Area (03054), Coconino and Yavapai Counties, Ariz. The entire roadless area has low mineral resource potential.

drops 1,200 ft over a distance of 3.3 mi, and Rattlesnake Canyon drops 1,280 ft over a distance of 4.3 mi. Dry Beaver Creek and its tributaries drain an area of about 142 sq mi.

Canyon rims in the roadless area are accessible by several four-wheel-drive trails across the plateau surface from points along Schnebly Hill road and Highway I-17. Access to Jacks Canyon is by road and four-wheel-drive trail to Jacks Canyon Tank, about 4 mi up the canyon from Highway 179. Access to the head of Jacks Canyon is by foot or horse along a well-maintained pack trail. Access to the bottom of Woods Canyon is by four-wheel-drive vehicle for about 2 mi from Highway 179 and by pack trail for about 5 mi more.

Geologic setting

The Rattlesnake Roadless Area includes the deeply embayed Mogollon Rim margin of the Colorado Plateau Province and part of the Verde Valley. The Verde Valley is a deeply dissected lacustrine basin, one of several tectonic basins in the Arizona transition zone that separates the Basin and Range and Colorado Plateau Provinces (fig. 1). Deep dissection of the rim by headward erosion of canyons draining the Colorado Plateau has created steep-walled interfluve ridges, mesas, and buttes wherein are exposed flat-lying, multicolored sedimentary rocks ranging in age from Pennsylvanian to Early Permian. These sedimentary rocks are overlain by variably thick Tertiary basaltic flows, eruptive materials, and associated sediments. Remnants of old erosion surfaces at progressively lower elevations are preserved locally beneath the flows. These surfaces define successive stages in the erosional and volcanic history of the rim. Intercalation of southwestward-dipping basalt flows with marginal fluviolacustrine sediments below 5,000 ft indicates that late phases of Colorado Plateau volcanism were contemporaneous with late phases of Verde Lake deposition during Pliocene time (Nations and others, 1981). Following regression of Lake Verde from the region, cyclical deposition and dissection along drainage lines took place in Pleistocene and Holocene time.

The structural setting is one of flat-lying to gently westward dipping sedimentary rocks cut by nearly vertical faults that trend primarily north-south, east-west, and northwest-southeast. Significant faulting occurred either prior to or concurrent with early volcanism of middle Miocene or earlier age and continued through late Miocene time.

Mining and drilling activity

There has been no mining and little, if any, prospecting within the roadless area. Three claims found in a review of the Yavapai County records were described as being near the roadless area boundary in Jacks Canyon, 4 mi south of the town of Sedona. The most recent of the three is more than 20 years old, however, and field work in the vicinity produced no evidence of claims or mine workings. All other Yavapai County claims reviewed were clearly outside the roadless area.

Of more than 70 mining claims located near Sedona in Coconino County, 12 have descriptions placing them in or partly in the roadless area (McColly, 1982). Nearly all 12 claims are just east of Sedona near the northwest boundary of the roadless area. No evidence of mining could be found at any of these claim sites, and all had been filed by the mid-1950's or earlier.

More than 20 oil and helium test holes have been drilled in Coconino and Yavapai Counties outside the boundaries of the roadless area (Conley, 1974). Most of these test holes bottomed in Precambrian basement rocks; some showed minor signs of hydrocarbons in the overlying Paleozoic rocks, but none were productive.

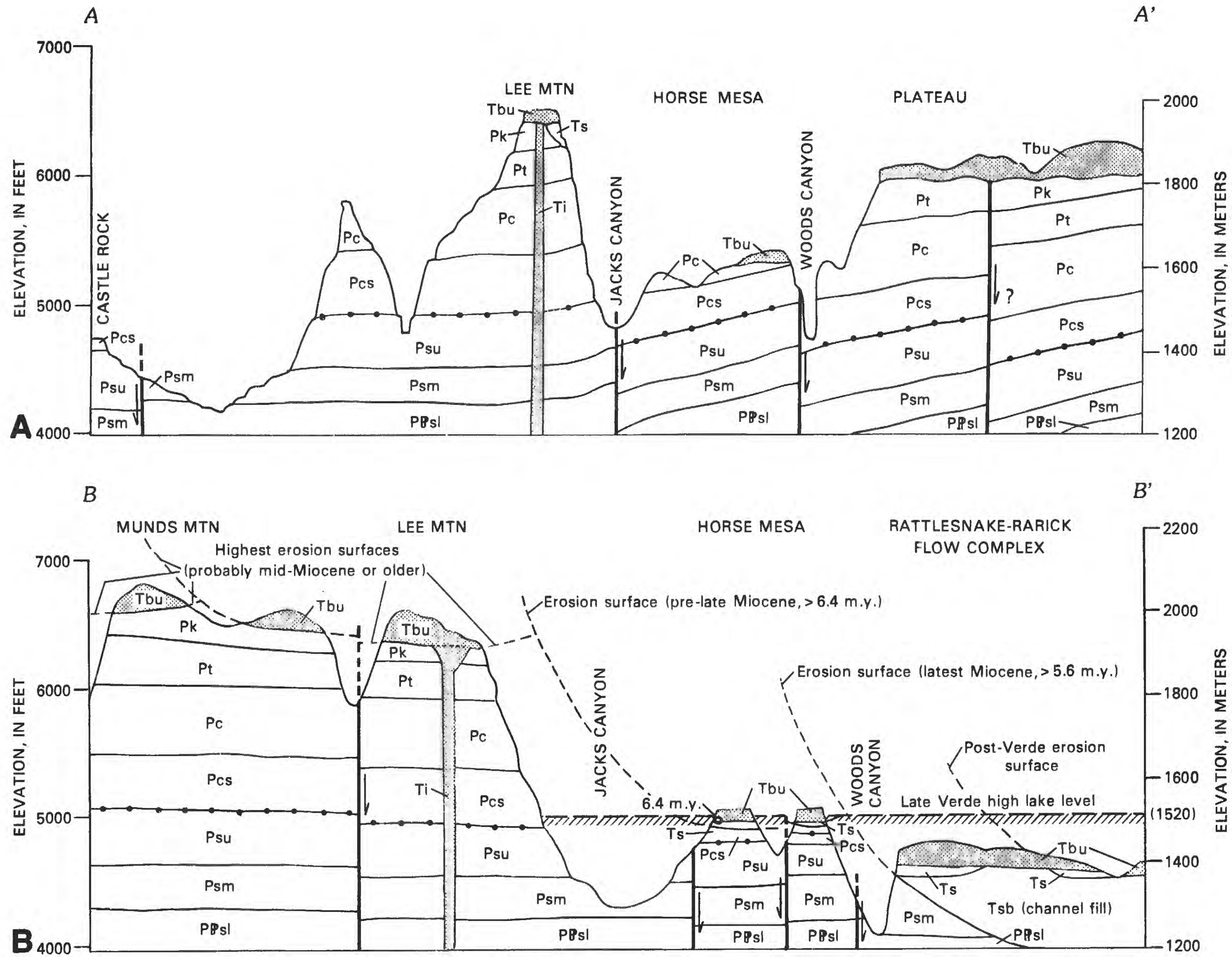
GEOLOGY

The exposed rocks in the Rattlesnake Roadless Area include as much as 2,500 ft of nearly flat lying and faulted sedimentary rocks ranging in age from Pennsylvanian to Early Permian. These rocks are locally covered by variably thick Tertiary volcanic rocks and sediments (fig. 1). Well records for the Sedona area indicate a subsurface sequence of older Paleozoic rocks (Cambrian to Mississippian in age), which averages more than 1,000 ft in thickness, and which unconformably overlies faulted, intruded, and metamorphosed granitic rocks of Precambrian age (Earl Huggins, oral commun., 1982).

The Paleozoic rocks in Verde Valley and the Sedona area have been variously correlated with formations exposed in the Grand Canyon (Huddle and Dobrovolny, 1945; McKee, 1945; Twenter and Metzger, 1963; Blakey, 1979; and Elston and DiPaolo, 1979). Because of rapid facies changes, gradational contacts, and possible structural complications, discrepancies persist among these proposed interregional correlations and in the resulting placement of formational boundaries within the area of Verde Valley and Sedona. For purposes of this local study the Paleozoic section was subdivided into eight readily mappable, laterally persistent, and environmentally diagnostic lithologic units (fig. 2A) that most closely follow subdivisions proposed by McKee (1945) and Blakey (1979).

The Paleozoic section is largely capped in the eastern and southern parts of the roadless area by variably thick Tertiary volcanic flows, intrusive rocks, pyroclastic materials, and fluviolacustrine sediments. The volcanic rocks are mainly alkali-olivine basalt flows and include one or two flows as much as 300 ft thick in the northwestern part of the roadless area, and five to nine or more flows as much as 500 ft thick in the headwaters of Woods Canyon and along the east and south margins of the roadless area. Mears (1949) has reported intrusive rocks of basaltic composition at Schnebly Hill. A large feeder dike or plug underlies the basalt cap of Lee Mountain. Smaller dikes intrude Paleozoic rocks in the Devils Dining Room area east of Sedona and at the top of Cathedral Rock south of Sedona, and they intrude the Tertiary sediments between Bias and Hog Canyons. Mineralized rock suggestive of potential ore bodies at depth was not observed along the exposed intrusive contacts of the roadless area. Potassium-argon-dated flows from the volcanic mantle of the Mogollon Rim, between Wet Beaver Creek to the south and Sycamore Canyon to the north, range in age from 14.6 to 4.5 m.y. (McKee and Anderson, 1971; Damon and others, 1974, Peirce and others, 1979); this age range suggests that much of the regional volcanic activity took place in middle

A



A
A'
B
B'
ELEVATION, IN FEET
ELEVATION, IN METERS
7000
6000
5000
4000
2200
2000
1800
1600
(1520)
1400
1200
CASTLE ROCK
MUNDS MTN
LEE MTN
JACKS CANYON
HORSE MESA
WOODS CANYON
PLATEAU
RATTLESNAKE-RARICK FLOW COMPLEX
Highest erosion surfaces (probably mid-Miocene or older)
Erosion surface (pre-late Miocene, > 6.4 m.y.)
Erosion surface (latest Miocene, > 5.6 m.y.)
Post-Verde erosion surface
Late Verde high lake level
6.4 m.y.
Tsb (channel fill)
Tbu
Ts
Ti
Pk
Pt
Pc
Pcs
Psu
Psm
PPsl

B

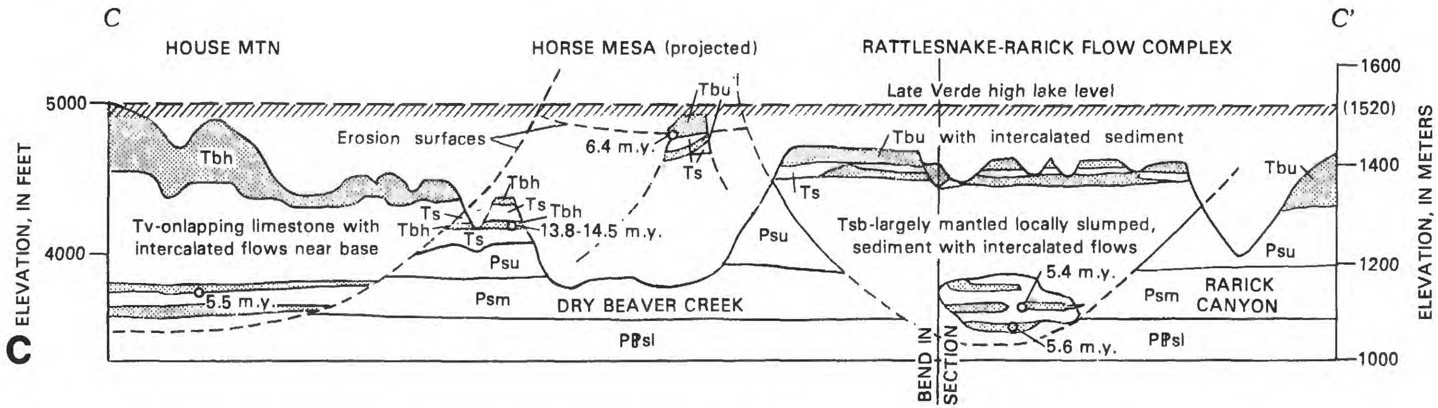


Figure 2.—Generalized sections of the Rattlesnake Roadless Area. For lines of section, see figure 1. Horizontal scale 1:100,000; vertical exaggeration 7x; o = potassium-argon ages in millions of years. Tbu, basalt flows and pyroclastic deposits; Ti, basalt intrusive; Tbh, House Mountain basalt flows; Tsb, sedimentary rocks and basalt; Tv, Verde Formation; Ts, mainly prevolcanic sediments; Pk, Kaibab Formation; Pt, Toroweap Formation; Pc, Coconino Sandstone; Pcs, transition zone between Coconino Sandstone and Supai Formation; Psu, upper Supai Formation; Psm, middle Supai Formation; PPsl, lower Supai Formation. Outcrop of Fort Apache (?) Member of Supai Formation shown by line and dots (—•—•—•—).

Miocene to Pliocene time. A basal flow on Horse Mesa in the roadless area is 6.4 m.y., late Miocene, in age (Peirce and others, 1979).

The volcanic flows in the roadless area directly overlie either eroded bedrock, Tertiary conglomerates, or interbedded conglomerates and finer grained lacustrine sediments that fill shallow to deep channels cut into underlying bedrock. The conglomerate beds vary appreciably in lithologic composition and range from monolithologic gravels of local provenance to gravels having mixed lithologies that reflect both local and more distant upstream sources. West-dipping conglomerate beds containing clasts of Precambrian rocks are associated with the faulted flows on Horse Mesa and with the unfaulted flows south of Woods Canyon. The conglomerates rich in Precambrian clasts are at various stratigraphic levels. They evidently record repeated westward recycling of gravel sources on the Mogollon Rim, now covered with volcanic rocks. The gravel sources could have been derived from Precambrian uplands west of the Colorado Plateau and deposited on the plateau prior to the structural subsidence of the Verde Valley in earlier Tertiary time (Peirce and others, 1979). Heavy-mineral concentrations suggestive of potential placer deposits or upstream mineral bodies were not observed in the exposed fluviolacustrine deposits of the roadless area.

Stages in the progressive dissection of the plateau margin following relative uplift during the Laramide Revolution (Peirce and others, 1979) are suggested by remnants of old erosion surfaces preserved at various elevations beneath lava flows of various ages (fig. 2B). The highest surfaces of probable mid-Miocene or older age are beneath flow remnants capping Munds and Lee Mountains and are cut in the Kaibab Limestone. An intermediate low-gradient surface truncates bedding and structures in the upper Supai Formation and in the Coconino Sandstone beneath faulted flow remnants on Horse Mesa having a potassium-argon date of 6.4 m.y. (late Miocene). The youngest buried erosional surface is a broad, deep paleochannel cut below the Horse Mesa surface and into the lower and middle members of the Supai Formation (fig. 2C). The paleochannel is buried beneath a largely mantled and slumped sequence of west-dipping fluviolacustrine deposits intercalated with and capped by conformable basalt flows. The lowest two basalt flows yielded potassium-argon dates of 5.6 m.y. and 5.4 m.y., near the Miocene-Pliocene transition. The record is of recurrent volcanism from plateau sources during the last post-Miocene phase of Lake Verde deposition in the region (Jenkins, 1923; Nations and others, 1981; Nations, oral commun., 1982). The mapped distribution of interbasalt fluviolacustrine sediment and of lacustrine limestone float and stromatolitic incrustations on surface flows indicate that Lake Verde rose to at least the present 5,000 ft contour before its final regression from the roadless area.

During and following lake regression, gravel and sand deposits at various elevations on valley slopes and butte tops record a multiple sequence of aggradational and erosional events primarily of Quaternary age. Locally as many as five aggradational epicycles are recorded by terrace gravels and alluvial fans graded to successively lower levels. The highest gravels, such as those capping Table Top Mountain south of Sedona, are just below the reconstructed high-level position of Lake Verde, and probably were deposited as fan deltas, fans, or marginal terraces either during or shortly after the lake had attained its maximum extent in late Pliocene or in early Pleistocene time. Heavy-mineral concentrations suggestive of potential placer deposits or upstream primary mineral bodies were not observed in the sand and gravel deposits exposed in the roadless area.

The structural setting is of nearly flat lying Paleozoic and Cenozoic rocks cut by a system of nearly vertical normal faults. The faults trend primarily northwest-southeast, north-south, and east-west. Faults having northeast trends are a minor component of the extensional fracture pattern. Main elements of the mapped fault system are colinear with major fault zones that similarly cut Paleozoic and Cenozoic rocks throughout northern Arizona. This regional system is interpreted as primarily reflecting major structures and fault displacements in the underlying Precambrian basement rocks (Huntoon, 1974; Lucchitta, 1974; Shoemaker and others, 1978).

The northwest-trending faults in the roadless area and in the adjoining Sedona area (see map by D. P. Elston and W. D. DiPaolo, Levings, 1980, pl. 1) are colinear with the Chino Valley fault system of northwestern Arizona. The north-south- to northwest-trending faults in Jacks and Woods Canyons are extensions of the Oak Creek fault mapped to the north in Oak Creek and Casner Canyons (Mears, 1949; Twenter and Metzger, 1963). The Oak Creek fault is traceable across the Coconino Plateau to the north as the Oak Creek Canyon system. Southward projections of the major northeast-trending fault zones mapped to the north (the Bright Angel, Mesa Butte, and Sinyala fault zones) pass west of the roadless area, which may explain the general absence of northeast-trending faults in the area.

Within the roadless area, the north-south- and northwest-southeast-trending faults tend to decrease southward in displacement and to split into a series of curving faults that define both horsts and grabens. The progressive decrease in displacement and bifurcation into secondary faults suggest that the roadless area is near the margin of a tectonic subprovince. The displacement of faults east of Munds and Lee Mountains is mainly down to the east, whereas the displacements on those to the west and south are mainly down to the southwest and south. The east-west-trending faults are similarly displaced down to the south. The fault pattern indicates that the Munds-Lee Mountain area may be underlain by a deep-seated, fault-defined crustal block that during displacement has controlled differential block subsidence about its east, west, and south margins. A magnetic high coincides with the postulated differentially uplifted crustal block, indicating that the block is probably intruded by Precambrian or younger igneous bodies of high magnetic susceptibility (see section on geophysics).

The regional tectonic history includes repeated episodes of faulting ranging in age from the Precambrian to the Holocene. Seismic data indicate that some fault zones are still active (Shoemaker and others, 1978). Most of the Cenozoic faulting in the region is related to the compressional Laramide Revolution (Late Cretaceous-early Tertiary) and to extensional faulting of post-middle Tertiary age

(Lucchitta, 1974). Peirce and others (1979) proposed that potassium-argon-dated stratigraphic and geomorphic relations along the Colorado Plateau margin may be the consequence of these tectonic episodes plus a previously unrecognized tectonic event that caused uplifting during Oligocene(?) time. They conclude that the latest movement along the Oak Creek fault took place around 13 m.y., during mid-Miocene time. Differential displacements of Paleozoic rocks and potassium-argon-dated volcanic rocks on Horse Mesa where crossed by the Jacks Canyon extension of the Oak Creek fault record movements both before and since 6.4 m.y. ago. These stratigraphic relations place latest movements along the fault in late Miocene or later time. The presence of unfaulted post-5.6 m.y. fluviolacustrine deposits and capping basalt flows immediately south of Horse Mesa indicates that faulting may have occurred between 6.4 and 5.6 m.y. ago, in late Miocene time. Mineralized areas suggestive of potential ore bodies at depth were not detected along the fault zones exposed in the roadless area.

On the basis of results of this and previous studies, none of the rocks within the roadless area boundary are known to be mineralized. Observations made along intrusive contacts and fault zones exposed in the roadless area did not detect mineralized areas suggestive of potential ore bodies at depth. Heavy-mineral concentrations suggestive of potential placer deposits or primary upstream mineral sources were not found in the fluviolacustrine and alluvial deposits examined in the field. Samples collected from intrusive contacts, fault zones, and fluviolacustrine and alluvial deposits show no anomalous concentrations of metallic minerals.

GEOCHEMISTRY

Sampling strategy and analytical techniques

The geochemical survey of the Rattlesnake Roadless Area included collection and analysis of 114 stream-sediment, 68 heavy-mineral-concentrate, 20 rock, and 4 water samples (see accompanying map). The density of stream-sediment sampling averaged about 1.5 samples/mi^2; most samples were taken from first-order channels. Heavy-mineral concentrates were collected at about 50 percent of these sites. Water samples were taken from local springs and ephemeral pools. The rock samples were taken to obtain background concentration of 31 elements in the various geologic units found in the roadless area. The Coconino Sandstone was sampled somewhat more extensively than other units because it is known to contain slightly anomalous amounts of silver (6-9 parts per million) in a location about 20 mi south of the Rattlesnake Roadless Area.

All stream-sediment, heavy-mineral-concentrate, and rock samples were analyzed for 31 elements by a six-step, semiquantitative emission spectrographic method. The rock and stream-sediment samples were further analyzed for zinc, cadmium, bismuth, antimony, and arsenic by atomic-absorption spectrophotometry techniques, and for uranium by fluorimetric procedures. Water samples were analyzed for SO_4, chlorine, fluorine, and NO_3 by ion chromatography; for calcium, manganese, sodium, potassium, lithium, and zinc by flame atomic-absorption spectrophotometry; for copper, molybdenum, arsenic, iron, manganese, and aluminum by flame atomic-absorption spectrometry; for uranium by laser-excited fluorescence; for specific conductance by conductivity bridge; and for alkalinity by Gran's plot potentiometric titration. A complete listing of major- and trace-element analyses for the roadless area is available as an open-file report (Gerstel and others, 1983).

Evaluation of geochemical results

The geochemical data do not indicate concentration of metallic minerals within the roadless area. The slight silver anomaly detected in Coconino Sandstone to the south did not clearly show up in the rock samples collected in the roadless area. Samples collected from fault zones, intrusive contacts, and from fluviolacustrine and alluvial deposits show no anomalies suggestive of mineral concentrations at depth or in upstream parts of the drainage basin. The barium anomaly detected in some samples appears to be related to the past fluviolacustrine environment of the roadless area.

GEOPHYSICS

Aeromagnetic data for the Rattlesnake Roadless Area show the geophysical expressions of the major geologic features but cannot be related directly to potential mineral deposits (Martin, in press). A dominating magnetic high centered near the Munds-Lee Mountain upland is probably caused by differentially uplifted Precambrian rocks intruded by an igneous body of high magnetic susceptibility. A steep magnetic gradient east of Munds Mountain, along Jacks Canyon, possibly marks the faulted edge of the postulated intrusive body, and an east-trending magnetic ridge across Munds Mountain and Woods Canyon may relate to displaced or younger intrusive rocks at depth.

MINING DISTRICTS AND MINERALIZED AREAS

The Rattlesnake Roadless Area is not included in any mining district, and no occurrences of metallic minerals are known within a 10 mi radius (Keith, 1969a, b).

Nonmetallic deposits are limited to borrow, cinders, gravel, sand, and stone used locally for building and road construction (McCrory and O'Haire, 1965). Pits from which borrow, cinders, gravel, and sand have been removed are found at several places along Interstate Highway I-17 and State Routes 89A and 179. Nearly all are inactive, most are small, and none are in the roadless area.

Near Sedona, several dozen mining claims were located during the early- and mid-1950's for building stone or flagstone, though none has a production history. Similar stone occurs in the roadless area where the Coconino Sandstone and the Supai Formation are exposed, but there is no evidence of past production.

U.S. Bureau of Land Management records showed no active mining claims and no leases or permits for oil, gas, or other leasable minerals in or near the roadless area.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

The mineral resource potential of the Rattlesnake Roadless Area, Ariz., is low on the basis of field studies and research performed by the U.S. Bureau of Mines and the U.S. Geological Survey during 1982. The available information indicates a low potential for the occurrence of metallic mineral deposits, energy resources, or nonmetallic mineral deposits other than borrow, cinders, gravel, sand, and stone in the Rattlesnake Roadless Area.

Observations made along intrusive contacts and fault zones did not detect mineralized areas suggestive of potential ore bodies at depth. Heavy-mineral concentrations suggestive of potential placer deposits or primary, upstream mineral sources were not found in the fluviolacustrine and alluvial deposits examined in the field. Geochemical samples collected from intrusive contacts, fault zones, and fluviolacustrine and alluvial deposits showed no anomalous concentrations of metallic minerals. Numerous oil and helium test holes drilled in nearby areas and in rocks similar to those mapped in the roadless area proved unproductive. Deposits of borrow, cinders, gravel, sand, and stone are exposed or can be inferred within the roadless area (fig. 1), but abundant similar deposits are more readily available outside the roadless area.

SELECTED REFERENCES

Blakey, R. C., 1979, Lower Permian stratigraphy of the southern Colorado Plateau, in Baars, D. L, ed., Permianland—a field symposium, Sept. 1979, Moab, Utah: Four Corners Geological Society Field Conference Guidebook, No. 9, p. 115-129.

Conley, J. N., 1974, Review of the development of oil and gas resources of northern Arizona, in Karlstrom, T. N. V., Swann, G. A., and Eastwood, R. L., eds., Geology of northern Arizona with notes on archaeology and paleoclimate: Geological Society of America Guidebook for Rocky Mountain Section Meeting, Flagstaff, Ariz., Part I, Regional Studies, p. 393-406.

Damon, P. E., Shafiqullah, Mohammed, and Leventhal, J. S., 1974, K/Ar chronology for the San Francisco volcanic field and rate of erosion of the Little Colorado River, in Karlstrom, T. N. V., Swann, G. A., and Eastwood, R. L., eds., Geology of northern Arizona with notes on archaeology and paleoclimate: Geological Society of America Guidebook for Rocky Mountain Section Meeting, Flagstaff, Ariz., Part I, Regional Studies, p. 221-235.

Elston, D. P., and DiPaolo, W. D., 1979, Pennylvanian-Permian stratigraphy of the Sedona area and environs, central and northern Arizona, in Baars, D. L., ed., Permianland—a field symposium, Sept. 1979, Moab, Utah: Four Corners Geological Society Field Conference Guidebook, No. 9, p. 131-141.

Gerstel, W. J., Day, G. W., and McDanal, S. K., 1983, Analytical results for 178 stream-sediment, 98 heavy-mineral concentrate, 27 rock, and 11 water samples from the Rattlesnake and Wet Beaver Roadless Areas, Coconino and Yavapai Counties, Arizona: U.S. Geological Survey Open-File Report 83-339, 156 p., 2 map sheets, scale 1:24,000.

Huddle, J. W., and Debrovolny, Ernest, 1945, Late Paleozoic stratigraphy and oil and gas possibilities of central and northeastern Arizona: U.S. Geological Survey Oil and Gas Investigations Preliminary Chart 10.

Huntoon, P. W., 1974, Synopsis of the Laramide and post-Laramide structural geology of the eastern Grand Canyon, Arizona, in Karlstrom, T. N. V., Swann, G. A., and Eastwood, R. L., eds., Geology of northern Arizona with notes on archaeology and paleoclimate: Geological Society of America Guidebook for Rocky Mountain Section Meeting, Flagstaff, Ariz., Part I, Regional Studies, p. 317-335.

Jenkins, O. P., 1923, Verde River lake beds near Clarkdale, Arizona: American Journal of Science, 5th ser., v. 25, p. 65-81.

Keith, S. B., 1969a, Map of known metallic mineral occurrences (excluding base and precious metals) in Arizona: Tucson, University of Arizona, Arizona Bureau of Mines, scale 1:1,000,000.

_____1969b, Map of known base and precious minerals occurrences in Arizona: Tucson, University of Arizona, Arizona Bureau of Mines, scale 1:1,000,000.

Levings, G. W., 1980, Water resources in the Sedona area, Yavapai and Coconino Counties, Arizona: Arizona Water Commission Bulletin 2, 37 p.

Lucchitta, Ivo, 1974, Structural evolution of northwest Arizona and its relation to adjacent Basin and Range province structures, in Karlstrom, T. N. V., Swann, G. A., and Eastwood, R. L., eds., Geology of northern Arizona with notes on archaeology and paleoclimate: Geological Society of America Guidebook for Rocky Mountain Section Meeting, Flagstaff, Ariz., Part I, Regional Studies, p. 336-354.

Martin, R. A., in press, Aeromagnetic map of the Rattlesnake Roadless Area, Coconino and Yavapai Counties, Arizona: U.S. Geological Survey Miscellaneous Field Studies Map.

McColly, R. A., 1982, Mineral investigation of the Rattlesnake Roadless Area, Coconino and Yavapai Counties, Arizona: U.S. Bureau of Mines Open-File Report MLA 133-82, 5 p.

McCrory, F. J., and O'Haire, R. T., 1965, Map of known nonmetallic mineral occurrences of Arizona: Tucson, University of Arizona, Arizona Bureau of Mines, scale 1:1,000,000.

McKee, E. D., 1945, Oak Creek Canyon: Flagstaff, Ariz., Plateau, v. 18, no. 2, p. 25-32.

McKee, E. H., and Anderson, C. A., 1971, Age and chemistry of Tertiary volcanic rocks in northcentral Arizona and relation of the rocks to the Colorado Plateaus: Geological Society of America Bulletin, v. 82, p. 2767-2782.

Mears, Brainard, Jr., 1949, Cenozoic faults, gravels and volcanics of Oak Creek Canyon, Arizona: New York, Columbia University, doctoral thesis, 84 p.

Nations, J. D., Hevly, R. H., Blinn, D. W., and Landye, J. J., 1981, Paleontology, paleoecology, and depositional history of the Miocene-Pliocene Verde Formation, Yavapai County, Arizona: Arizona Geological Society Digest, v. 13, p. 133-149.

Peirce, H. W., Damon, P. E., and Shafiqullah, Mohammed, 1979, An Oligocene(?) Colorado Plateau edge in Arizona: Tectonophysics, v. 61, p. 1-24.

Shoemaker, E. M., Squires, R. L., and Abrams, M. J., 1978, Bright Angel and Mesa Butte fault systems of northern Arizona: Geological Society of America Memoir 152, p. 341-367.

Twenter, F. R., and Metzger, D. G., 1963, Geology and ground water in Verde Valley--the Mogollon Rim Region, Arizona: U.S. Geological Survey Bulletin 117, 132 p.