Mineral Resources of the Sycamore Canyon Primitive Area Arizona

GEOLOGICAL SURVEY BULLETIN 1230-F

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By LYMAN C. HUFF *and* ELMER SANTOS, U.S. GEOLOGICAL SURVEY, *and*
R. G. RAABE, U.S. BUREAU OF MINES

STUDIES RELATED TO WILDERNESS

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An evaluation of the mineral potential of the area

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STUDIES RELATED TO WILDERNESS

The Wilderness Act (Public Law 88–577, Sept. 3, 1964) and the Conference Report on Senate bill 4, 88th Congress, direct to the U.S. Geological Survey and the U.S. Bureau of Mines to make mineral surveys of wilderness and primitive areas. Areas officially designated as "wilderness," "wild," and "canoe," when the act was passed, were incorporated into the National Wilderness Preservation System. Areas classed as "primitive" were not included in the Wilderness System, but the act provided that each primitive area should be studied for its suitability for incorporation into the Wilderness System. The mineral surveys constitute one aspect of the suitability studies. This bulletin reports the results of a mineral survey in the Sycamore Canyon Primitive Area, Ariz. The area discussed in the report corresponds to the area under consideration for wilderness status.

This bulletin is one of a series of similar reports on primitive areas.

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By LYMAN C. HUFF and ELMER SANTOS, U.S. Geological Survey, and R. G. RAABE, U.S. Bureau of Mines

SUMMARY

The Sycamore Canyon Primitive Area includes the canyons of Sycamore Creek and of its tributaries which are incised deeply into the south edge of the Colorado Plateau. The walls of these canyons are nearly flat-lying sedimentary Paleozoic and Mesozoic rocks—mostly sandstone, limestone, and siltstone. Depending upon their hardness and resistance to erosion, these sedimentary rocks form cliffs, steep slopes, or benches. The oldest formation exposed in the area is the Martin Limestone of Devonian age. It is overlain successively by the Redwall Limestone of Mississippian age, the Supai Formation of Pennsylvanian and Permian age, the Coconino Sandstone, Toroweap Formation, and Kaibab Limestone of Permian age, and the Moenkopi Formation of Triassic age. Overlying these sedimentary rocks unconformably and forming the rims of the canyons is a series of basaltic lava flows of Tertiary and Quaternary age. In general, the rock sequence is similar to that of Grand Canyon 60 miles to the north.

Rocks of the area are broken by northwest- and northeast-trending faults, most of which have displacements of less than 250 feet. Some faults do not displace the basalt on the canyon rims and are therefore older. Other faults displace both sedimentary rocks and basalt, and are therefore younger than the basalt. Dikes of basalt follow or parallel the northwest-trending faults. Two conspicuous sets of joints parallel the two fault trends.

No mineral production from the Sycamore Canyon Primitive Area has been recorded. No veins, or other kinds of mineral deposits offering any promise of economic return, were found in the geologic reconnaissance; and a geochemical reconnaissance revealed no anomalous concentrations of any ore-forming minerals. No geologic evidence was found that would justify wildcat exploration for mineral and petroleum deposits at greater depth than the canyon bottoms. Outside the primitive area, some of the rock formations present in the canyons contain oil and gas. However, erosion of the canyons themselves into these formations has released any oil or gas which may have been present within the primitive area. Rocks similar to those of the canyons are used for building stones and construction materials, but such rocks are widely available elsewhere.

The legendary Geronimo's gold mine, which has been explored by prospectors within the primitive area, is a cave or naturally formed solution cavity in limestone which has been partly filled with silt by geologic processes. No gold or other metal of economic importance was found in this prospect.

GEOLOGY AND MINERAL RESOURCES

By Lyman C. Huff and Elmer Santos
U.S. Geological Survey

INTRODUCTION

This report describes briefly the geology and mineral resources of the Sycamore Canyon Primitive Area, in north-central Arizona, an area of 73.8 square miles (47,230 acres) that includes parts of Coconino and Yavapai Counties and parts of the Coconino, Kaibab, and Prescott National Forests (fig. 1).

As indicated by its name, this primitive area consists chiefly of the rugged, rocky canyons of Sycamore Creek and its tributaries. The creek and its tributaries have eroded deep canyons into the Mogollon Rim, a great south-facing escarpment that forms the south limit of the Colorado Plateau. Nearly everywhere the boundary of the primitive area is on the upland close to the edge of Sycamore Canyon. The head of the canyon southwest of Flagstaff is at an altitude of about 6,700 feet above sea level; 18 miles to the south Sycamore Creek flows from the primitive area at an altitude of 3,650 feet. In much of the area the canyons are more than 1,700 feet deep.

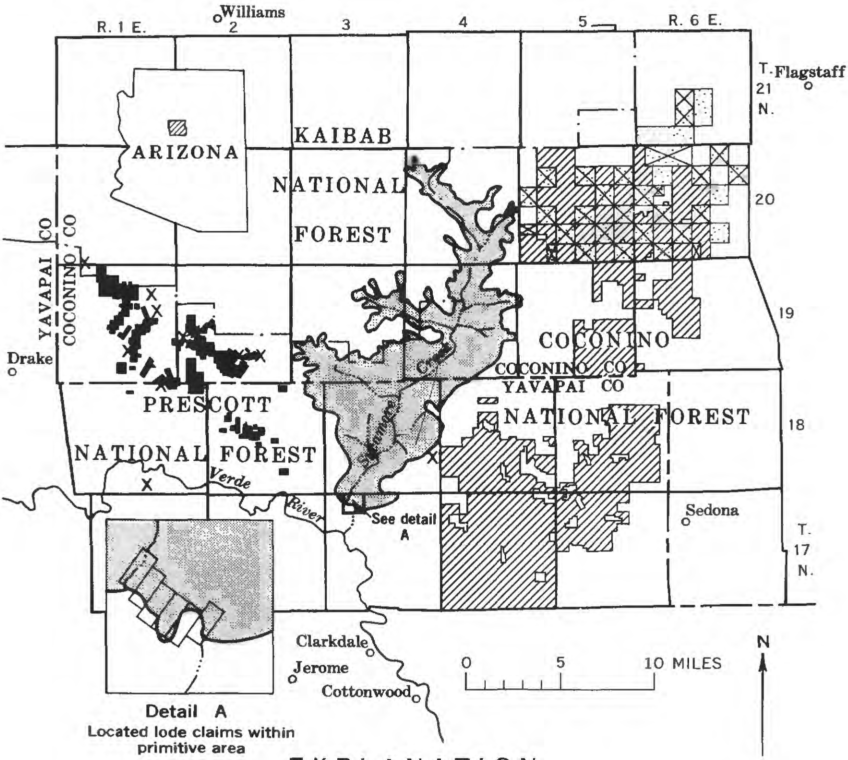
The area is easily reached from Clarkdale, Flagstaff, and Williams, Ariz., over secondary roads. Sycamore Point, at the edge of the area, can be reached by a road south from Williams. This vantage point affords an excellent view of Sycamore Canyon and its tributaries.

Access to the bottom of Sycamore Canyon is by trail from the rim. The best trails lead to Kelsey Spring, Geronimo Spring, Winter Cabin, and Taylor Cabin from the Flagstaff side of the canyon. Hiking except on these trails is difficult because of the numerous vertical cliffs. Along the bottom of the canyon, hiking is difficult because of the lack of trails and the presence of many large boulders.

The rim of Sycamore Canyon is in a Ponderosa pine forest. The trails down the sides of the canyon provide excellent vistas of rugged, rocky cliffs and an interesting botanical transition through the sycamore-tree flora of the canyon bottom to the desert flora near the mouth of the canyon.

The annual precipitation averages about 20 inches, of which about one-third is snow during the winter and one-third is late summer rain. Much of this precipitation sinks underground, and except near its mouth Sycamore Creek is ordinarily dry. Geronimo Spring affords a perennial supply of good drinking water at creek level near the head of the canyon. To the south, drinking water can be obtained seasonally from several deep rock basins along the bed of the creek, such as those at Taylor Cabin. These rock basins dry up completely during the summer.

The writers are indebted to R. G. Raabe, U.S. Bureau of Mines, for information on claims and prospects and to John Hart and other personnel of the U.S. Forest Service for information about trails, campsites, and springs in the area.



EXPLANATION

Boundary of Sycamore Canyon Primitive Area

Land covered by Federal oil and gas leases

Land covered by State oil and gas leases

Land partly covered by State oil and gas leases

Located claim groups covering rock quarries

X

Unplotted located claims covering rock quarries

National Forest boundary

FIGURE 1.—Location map, Sycamore Canyon Primitive Area and vicinity, Coconino and Yavapai Counties, Ariz.

INVESTIGATIONS

PREVIOUS STUDIES

The geology of the southern part of the Sycamore Canyon Primitive Area has been mapped and described in detail by Lehner (1958). The geology of the remainder of the area has never been mapped in detail but is shown at small scales on two county geologic maps (Moore and others, 1960; Arizona Bureau of Mines, 1958), on a map accompanying a study of the San Francisco volcanic field (Robinson, 1913, pl. 3), and on a map made in a study of gravels of Cenozoic age (Price, 1950a, fig. 2).

Some geologic formations in the area have received special study. Among these are the gravels of Cenozoic age (Price, 1950a), the Moenkopi Formation (Price, 1949), and the Toroweap and Kaibab Formations (McKee, 1938; Price, 1950b). Unpublished descriptions of stratigraphic sections of the Supai Formation and Redwall Limestone of Sycamore Canyon were given to the writers by E. D. McKee of the U.S. Geological Survey.

The Jerome mining district, which is about 10 miles south of the Sycamore Canyon Primitive Area, has received intensive geologic study. A report by Anderson and Creasey (1958) contains an excellent summary of this work. The springs and other water resources of the region have been studied by Feth (1954) and Feth and Hem (1963).

PRESENT STUDY

Investigations by the writers were conducted in the Sycamore Canyon Primitive Area from September–November 1965. A reconnaissance geologic map was prepared on which were plotted geologic features that might indicate the presence of mineralized areas. Faults, joints, formation contacts, and dikes were mapped, and the rocks were examined for stains and altered zones that might indicate mineralization. A scintillometer was used in the field to test the radioactivity of representative rocks of the area. Samples of various kinds were collected for geochemical analyses to detect the presence of anomalous quantities of metals which might indicate mineralization nearby. These included water samples from springs and streams, stream-sediment samples, soil samples, samples of rock that showed any evidence of hydrothermal alteration, and samples of fault breccia and iron gossan. In analyzing 48 samples, the writers used a colorimetric geochemical prospecting test for total heavy metals. Then semiquantitative spectrographic analyses capable of detecting minute amounts of 27 elements were made of these samples in a chemical laboratory by W. B. Crandell, D. J. Grimes, and J. L. Harris of the U.S. Geological Survey.

GEOLOGY

GEOLOGIC SETTING

Sycamore Canyon lies in a transition zone that separates the Colorado Plateaus province to the northeast from the Basin and Range province to the southwest. The Colorado Plateaus province is a flat upland having an altitude of about 7,000 feet in this area. The Basin and Range province is characterized by broad valleys with altitudes of about 3,000 feet and by narrow mountain ranges. The transition zone, known as the Mogollon Rim, is a rather abrupt southward-facing slope, or a gigantic topographic step, having a height of about 4,000 feet. Sycamore Canyon, one of several deep canyons that dissect the Mogollon Rim, is at the northwest end of the rim, which extends southeastward to the New Mexico border.

In the Basin and Range province southwest of Sycamore Canyon, the geologic structure is complex; many of the rocks have been tilted, faulted, and metamorphosed, and locally they have been hydrothermally altered and intruded by plutonic igneous rocks. By contrast, the structure of the Colorado Plateaus northeast of Sycamore Canyon is simple; the rocks are flat lying and consist principally of unaltered sedimentary rocks which locally are covered by basaltic lava flows near volcanic centers such as San Francisco Mountain.

The rocks in Sycamore Canyon are flat-lying unaltered sedimentary rocks like those of the Colorado Plateaus province. Much of the stratigraphic section exposed in the canyon consists of limestone, siltstone, and sandstone of Paleozoic age. Above these is a thin mudstone and sandstone formation of early Mesozoic age which is overlain by gravel and basalt flows of Tertiary and Quaternary age. Alluvial sand and gravel deposits along the flood plain of Sycamore Creek are also of Quaternary age.

The Paleozoic sedimentary rocks on the sides of Sycamore Canyon form an alternating series of steep cliffs and gentle benches, owing to differences in the hardness of the various formations and in their resistance to erosion. Narrow picturesque gorges have resulted where the Coconino Sandstone and other resistant formations were cut by Sycamore Creek and its tributaries.

Sycamore Canyon, though much smaller, is similar to the Grand Canyon in many respects. Many formations that crop out in Grand Canyon also crop out in Sycamore Canyon and form similar beautiful cliffs.

ROCKS

The geologic formations exposed in the Sycamore Canyon Primitive Area are listed in table 1. The oldest formation is the Martin Limestone of Devonian age. From geologic relations to the south (pl. 1), it is known that the full thickness of this limestone is about 480 feet and that only 50 feet of Tapeats Sandstone of Cambrian age separates the Martin Limestone from underlying metamorphic rocks of Precambrian age. The Martin Limestone is mainly a fine-grained thin-bedded dolomitic limestone with minor amounts of interbedded shaly siltstone and sandstone. It is gray, brownish gray, and pinkish gray. The formation crops out along Sycamore Creek at the south end of the primitive area.

The Redwall Limestone of Mississippian age, which overlies the Martin Limestone, consists of approximately 250 feet of very light gray to white coarse-grained massive limestone. It crops out as steep cliffs along the inner gorge of the canyon near the south end of the primitive area. Viewed from a distance, much of the Redwall appears to be red; the coloration results from a coating of reddish clay washed from the overlying formations.

TABLE 1.—*Generalized section of geologic formations in the Sycamore Canyon Primitive Area*

System	Stratigraphic unit	Thickness (feet)	Description
Quaternary	Alluvium	0–50	Unconsolidated sands and gravels. Contains large boulders in upper part of canyon.
——?——	Unconformity		
Tertiary	Basalt	50–500	Gray to black olivine basalt. Extensive volcanic flows over much of upland surface.
	Gravel	0–250	Interbedded sandstones and gravels, poorly consolidated.
	Unconformity		
Triassic	Moenkopi Formation	0–200	Alternate beds of red mudstone and red sandstone. Conglomerate bed at base.
	Unconformity		
Permian	Kaibab Limestone	250–360	Massive white to light-gray crystalline limestone containing a few beds of calcareous sandstone. Forms cliffs.
	Toroweap Formation	125	Interbedded white sandy limestone, red mudstone, and buff sandstone. Bedding thin and regular.

TABLE 1.—*Generalized section of geologic formations in the Sycamore Canyon Primitive Area*—Continued

System		Stratigraphic unit		Thickness (feet)	Description
Permian—Con.		Coconino Sandstone		400–500	Buff massive sandstone with conspicuous eolian-type crossbedding. Forms cliffs.
Permian—Con.		Supai Formation	upper member	760	Red sandstone with torrential-type fluviatile crossbedding. Forms cliffs.
Permian—Con.		Supai Formation	middle member	330	Interbedded red mudstone and red sandstone.
?					
Carboniferous	Pennsylvanian	Supai Formation	lower member	550	Red sandstone at top; interbedded sandstone and red mudstone below.
		Unconformity			
Carboniferous	Mississippian	Redwall Limestone		250	Coarse-grained crystalline white to light-gray massive limestone. Forms steep cliffs.
		Unconformity			
Devonian		Martin Limestone		[1] 480	Fine-grained gray limestone, dolomitic limestone, and argillaceous limestone. Bedding thin and regular.

[1] Near Packard Ranch, south of primitive area, where entire formation is exposed. Only about half the formation is exposed in primitive area.

The Supai Formation of Pennsylvanian and Permian age overlies the Redwall Limestone and is divided into three members. The lower member consists of about 550 feet of pale-brownish-red sandstone interbedded with red siltstone and mudstone. Sandstone predominates at the top of the member and crops out as rounded cliffs. The middle member is 330 feet of brownish-red and pale-brownish-red mudstone and siltstone interbedded with minor conglomerate, sandstone, and limestone. This member underlies broad, flat areas and gently rolling hills. The upper member is 760 feet of reddish-orange and pale-brownish-red sandstone interbedded with minor siltstone. The bedding is thin and regular, and the sandstone has fluviatile-type crossbedding. The sandstone weathers to cliffs, buttresses, and pinnacles.

The Coconino Sandstone of Permian age overlies the Supai Formation and consists of 400–500 feet of buff sandstone in thick massive beds with large-scale eolian-type crossbedding. In most places the color of the sandstone and the nature of the crossbedding serve in distinguishing the Coconino from the underlying Supai; in a few places the Coconino and Supai are difficult to distinguish. Along much of the canyon the Coconino Sandstone crops out as shear walls of the inner gorge of the canyon.

The overlying Toroweap Formation of Permian age consists of 125 feet of white sandy limestone interbedded with buff sandstone and red mudstone. It forms a sloping bench capping towering cliffs of the Coconino Sandstone.

Above the Toroweap is the Kaibab Limestone of Permian age which consists of 250–360 feet of white, yellowish-orange, and light-gray sandy limestone in thick massive beds interbedded with a few thin beds of calcareous sandstone. Much of the limestone is fossiliferous. This formation crops out as a steep slope composed of alternating cliffs and ledges. To simplify the geologic map, the Toroweap and the Kaibab Formations were mapped as one unit (pl. 1); they are easily distinguished in the field by their differing characteristics and appearance.

The Moenkopi Formation of Triassic age consists of 0–200 feet of interbedded dark-brownish-red mudstone, siltstone, and sandstone. The Moenkopi weathers to steep slopes and rounded hills.

Basalt flows of Tertiary age overlie the sedimentary rocks and form the rim of Sycamore Canyon. This series of flows ranges from 50 to 500 feet in thickness and forms nearly vertical cliffs along the canyon rim. Many flows have the polygonal jointing characteristic of basalt. These basalt flows are part of the San Francisco volcanic field which cover the upland and culminates in the San Francisco Mountain peaks north of Flagstaff.

Poorly consolidated sandstones and gravels also of Tertiary age are present locally between the basalt and the underlying sedimentary rocks. The basalt flows and the underlying sandstones and gravels were mapped as the Hickey Formation in the Clarkdale quadrangle (Lehner, 1958). In the Sycamore Canyon area these sandstones and gravels occur on Black Mountain and in a few places near Winter Cabin.

In the bottom of Sycamore Canyon, between Taylor Cabin and Packard Ranch, a basalt flow occurs just above creek level. This basalt was included by Lehner (1958) in the Verde Formation of Pleistocene or Pliocene(?) age. Because the basalt flowed down the canyon after its excavation, it is considered here to be of Pleistocene age. During geologic mapping the basalt flow was traced up the valley as far as the mouth of Tule Canyon, but the vent from which the basalt came was not identified. A possible source is the volcanic spatter cones and other young volcanic rocks near the head of Volunteer Canyon.

The youngest sedimentary materials in the area are the landslide deposits and the alluvial river gravels. The landslide deposits are a mixture of mud and unsorted rock fragments. They probably originated during a humid period in the Pleistocene when abundant ground water was available to lubricate the rocks and cause them to slide. Erosion of the slides has produced irregular, hummocky areas characterized by undrained depressions, such as Ott Lake near Winter Cabin, and by a lack of outcrops. There is no evidence of recent landsliding.

The alluvial river gravels consist mostly of sand, rounded pebbles, and boulders which have been deposited as a narrow belt along the flood plain of Sycamore Creek. Much of the present alluvium was probably deposited in 1965 during unusually large floods. Upstream from Sycamore Point the boulders are very large; many of them are more than 5 feet in diameter. The 1965 floods washed away much of the trail which followed the bed of Sycamore Creek.

STRUCTURE

The structure of the rocks in the Sycamore Canyon Primitive Area, like that of much of the Colorado Plateaus, is comparatively simple. The rocks appear to be horizontal, but the altitude of contacts (pl. 1) indicates that the rocks dip at less than 1° NE. Locally the rocks are cut by faults; from the relationship of the faults to basalt flows and erosion surfaces, several episodes of faulting can be demonstrated.

The faults in the area belong to two distinct sets. One set strikes northwest, and the other strikes northeast (pl. 1). Some faults define grabens—downdropped blocks lying between two parallel faults. Four conspicuous northwest-trending grabens transect Sycamore Canyon. One extends up the canyon from Geronimo Spring in sec. 26, T. 20 N., R. 4 E.; another lies just north of Sycamore Point; a third crosses the canyon about midway between Geronimo Spring and Sycamore Point; and a fourth extends up the canyon cut by Cedar Creek. All faults shown on the geologic map displace rocks more than 40 feet.

Some faulting, as noted by Lehner (1958), must have occurred before the oldest basalt was deposited because these faults do not offset the basalt. Two such faults are in Tule Canyon in sec. 12, T. 19 N., R. 3 E. Other faults—such as those that transect Little Lo Spring Canyon (sec. 23, T. 20 N., R. 4 E.)—offset, and must be later in origin than, the basalt. Exposures along some of the grabens show that the sequence of events was as follows: (1) Graben faulting of early basalt and older rocks, (2) erosion of a valley to a depth of about 400 feet along the graben, (3) extrusion of young basalt which filled the valley,

(4) faulting of young basalt, and (5) additional erosion along the graben valley.

Joints are numerous and are particularly widespread in Tule Canyon and to the south in Sycamore Canyon. The joints form two conspicuous sets paralleling the northwest- and northeast-trending fault sets. Many of the joints show some movement along the joint surfaces, and in many places it is difficult to distinguish between conspicuous joints and faults.

Basalt was intruded along some faults and joints to form dikes. The two dikes at the head of Volunteer Canyon (sec. 14, T. 20 N., R. 4 E.) evidently were feeder conduits for the basalt which was erupted along a line of spatter cones on the upland near the head of the canyon. The spatter cones form a line of low hills trending N. 80° W. in this area. Good exposures in the canyon provide an exceptionally clear example of the relationship between intrusions and volcanoes.

MINERAL RESOURCES

There is no recorded mineral production from the Sycamore Canyon Primtive Area, and except for stone, there is no record of production from the immediate vicinity. The primitive area, however, is in a region that contains mineral deposits. The important copper deposits of Jerome, Ariz., lie 10 miles south of the area. These deposits occur in Precambrian rocks which in the primitive area are 300–3,500 feet below the surface. Formations that contain uranium and copper at various places on the Colorado Plateaus occur in the primitive area, but the nearest productive deposits are near Cameron about 60 miles to the northeast. Oil and gas have been sought at many localities east and north of the area, but the nearest productive wells are 180 miles to the northeast.

No ore deposits nor mineralized rocks were found in the area. Hydrothermal and other forms of color alteration of the rocks are almost completely lacking. This and other geologic evidence indicate little likelihood of finding mineral deposits exposed at the surface. Several supplemental methods were used to check for the presence of concealed or undiscovered mineral deposits, but these studies revealed no indications of deposits of economic value.

METHODS OF INVESTIGATION

Surface indications of mineral deposits were sought by looking for ore minerals, and geochemical prospecting techniques were used to test soil, sediment, and water of the area for the ore metals. Gold and other valuable heavy minerals were sought by panning stream sediments.

Sediment samples were collected from Sycamore Creek and from all its larger tributaries. The silt fraction (less than 80 mesh) of these samples was collected for analysis. Representative samples of the two conglomeratic formations of the area—the gravels underlying the Tertiary basalt and the basal conglomerate of the Moenkopi Formation—were also collected. The natural waters of the area—which consist mostly of Dorsey, Geronimo, Summer's, and similar springs—were sampled, and water residues were obtained by evaporation. Rocks and soils from the very few places where there was evidence of hydrothermal alteration also were sampled. The location and results of colorimetric and spectrographic analyses of these samples are given in table 2.

Radioactivity of the rocks, which is used as a guide in searching for uranium deposits, was measured with a scintillometer along trails leading into Sycamore Canyon. Boulders along the bed of Sycamore Creek, which represent most of the rock types within the area, were also tested with the scintillometer.

RESULTS OF SAMPLING AND EVALUATION

In a few places the effects of hydrothermal alteration were recognized in rocks along faults and near the basalt dikes. A small iron-rich vein occurs on Buck Ridge (SW¼ sec. 23, T. 19 N., R. 4 E.) in the Kaibab Limestone. The vein seems to be 1–3 feet wide and about 300 feet long. Gossan from this vein (sample 34, table 2) contains anomalous amounts of molybdenum and arsenic as well as iron but little or no copper, lead, or zinc. Several shallow prospect pits were found here, but there was no evidence that any ore had been mined. On the basis of the examination and the chemical analyses, the prospect does not warrant further exploration. Along a fault in Railroad Draw (NE¼ sec. 24, T. 20 N., R. 4 E.) the Kaibab Limestone and Moenkopi siltstone are brecciated and altered. This breccia (sample 29) contains no significant amount of the ore metals. In several places, slightly altered reddish Coconino Sandstone occurs near basalt dikes. Analysis of this altered sandstone (sample 26) revealed no significant amounts of ore metals.

Samples of stream sediments and spring waters, which test the corresponding drainage basins upstream for ore deposits, all yielded analyses of the type which can be expected of unmineralized terrane. Samples 36 and 39, which contained 300 and 100 ppm (parts per million) copper according to the original analyses, were each found by supplemental colorimetric analysis to contain only 10 ppm. Some of the stream sediments contain 500–1,000 ppm chromium. The chromium probably comes from minerals very sparsely disseminated in the

Table 2.--Analyses of samples from

[M, major constituent (greater than 10 percent); 0, looked for but not detectabilities do not apply). Looked for but not detected in any Sb, Ta, Te, Tl, U, W, Zn. Analysts: W. B. Crandell, D. J. Grimes,

Sample	Semiquantitative spectrographic analyses																	
	Parts per million																	
	Ti	Mn	V	Zr	Ni	Cu	Pb	B	Y	Mo	Sn	Co	Ag	Be	Ga	As	Sc	Cr
1	1,500	100	20	500	0	30	5	30	30	0	0	0	0	0	7	0	3	50
2	1,500	150	30	500	0	20	5	30	20	0	0	0	0	0	7	0	3	30
3	1,000	100	50	500	30	20	5	30	20	10	0	0	1	0	7	0	3	50
4	1,000	200	30	300	30	20	5	30	10	0	0	0	0	0	7	0	3	50
5	1,000	300	30	500	0	10	5	50	10	0	0	0	0	0	7	0	3	20
6	1,000	70	20	500	0	10	0	<30	10	0	0	0	0	0	1	0	0	30
7	1,500	300	50	500	0	20	5	30	15	0	0	0	0	1	10	0	5	50
8	1,000	50	50	200	0	30	7	0	10	0	0	0	0	1	15	0	5	20
9	3,000	500	70	150	70	50	10	0	10	0	0	15	0	0	7	0	10	1,000
10	1,500	200	30	700	30	30	7	30	7	0	0	7	0	0	3	0	3	300
11	700	50	10	500	0	7	7	30	5	0	0	0	0	0	2	0	0	20
12	2,000	500	50	300	50	50	15	30	15	0	0	10	0	0	10	0	10	70
13	1,500	300	20	500	30	20	7	0	7	0	0	5	0	0	3	0	3	150
14	5,000	500	100	500	70	70	10	0	20	0	0	20	0	0	10	0	15	500
15	2,000	300	30	300	0	30	5	0	10	0	0	7	0	0	7	0	7	50
16	2,000	500	50	500	30	50	10	30	20	0	0	10	0	0	10	0	7	150
17	3,000	1,500	20	150	200	100	5	0	15	0	0	50	0	0	15	0	10	200
18	1,000	100	10	700	0	20	10	50	10	0	0	3	0	0	3	0	0	70
19	2,000	500	30	200	30	30	5	0	10	0	0	10	0	0	5	0	5	150
20	2,000	500	70	300	30	50	7	0	10	0	0	10	0	0	7	0	10	100
21	1,500	100	15	200	0	30	7	50	7	0	0	3	0	0	3	0	0	30
22	3,000	300	50	700	30	50	5	0	15	0	0	7	0	0	5	0	5	70
23	2,000	500	50	300	0	30	10	30	15	0	0	7	0	0	10	0	7	50
24	1,500	100	20	300	0	20	10	30	10	0	0	0	0	0	3	0	0	50
25	500	200	30	30	0	15	7	<30	5	0	0	0	0	0	7	0	0	15
26	300	15	5	50	0	10	0	30	0	0	0	0	0	0	0	0	0	7
27	100	50	5	15	0	70	15	0	0	0	0	0	0	0	0	1,000	0	10
28	500	200	7	50	30	150	10	0	5	3	0	3	0	0	0	0	3	50
29	1,000	70	50	100	0	30	3	50	10	0	0	0	0	0	10	0	5	70
30	300	700	30	7	0	50	5	0	5	0	0	5	0	0	0	3,000	7	10
31	3,000	500	50	50	70	100	5	0	7	0	0	15	0	0	10	0	10	150
32	500	70	150	70	0	10	15	50	10	7	10	3	0	0	7	0	5	70
33	3,000	20	100	100	0	10	5	100	7	3	7	0	0	1	15	0	10	200
34	700	100	100	200	50	15	7	0	5	300	0	0	0	0	0	3,000	3	50
35	200	200	15	0	0	7	0	0	0	0	0	0	0	0	0	0	0	30
36	3,000	200	30	700	20	300	50	30	20	0	0	0	0	1	0	0	0	50
37	2,000	70	20	100	10	70	10	20	10	0	0	0	0	1	0	0	0	20
38	3,000	70	30	150	15	50	15	20	7	0	0	0	0	1	0	0	0	20
39	3,000	150	30	300	20	100	30	20	10	0	0	5	0	1	10	0	5	150
41	150	10	20	0	0	50	10	<30	0	0	0	0	0	0	0	0	0	50
42	20	0	10	0	0	10	0	<30	0	0	0	0	0	0	0	0	0	7
43	20	0	15	0	0	10	0	30	0	0	0	0	0	0	0	0	0	15
44	10	0	10	0	0	2	0	<30	0	0	0	0	0	0	0	0	0	10
45	0	15	0	0	0	7	5	30	0	0	0	0	0	0	0	0	0	10
46	10	0	15	0	0	1	0	<30	0	0	0	0	0	0	0	0	0	15
47	0	0	0	0	0	1	5	150	0	0	0	0	0	0	0	0	0	10
48	0	0	10	0	0	2	20	100	0	0	0	0	0	0	0	0	0	20
49	10	0	10	0	0	50	0	70	0	0	0	0	0	0	0	0	0	10

the Sycamore Canyon Primitive Area

detected; --, not looked for; <, less than number shown (here usual sample: Au, Bi, Ce, Cd, Eu, Ge, Hf, Hg, In, Th, La, Li, P, Pd, Pt, Re, and J. L. Harris (spectrographic); L. C. Huff (chemical, total heavy metal)]

Sample	Semiquantitative spectrographic analyses--Con.									Total heavy metal (ppm)	Sample description
	Parts per million				Percent						
	Ba	Sr	Nb	Yb	Na	K	Fe	Mg	Ca		
1	200	100	10	3	0.15	1	0.7	1	2	40	Stream sediment.
2	200	70	10	2	.2	1.5	1	1	2	--	Do.
3	150	100	10	2	.15	.5	2	.2	.3	40	Soil.
4	150	100	10	1	.2	.5	1	.7	2	40	Stream sediment.
5	200	100	10	1	.1	1	1	.7	3	40	Gravel (Tertiary).
6	150	50	10	1	.03	0	.5	.2	1	40	Stream sediment.
7	300	100	10	1	.2	1	1.5	1	3	40	Do.
8	200	150	10	1	.2	.7	2	.7	.5	40	Gravel (Tertiary).
9	500	100	7	1	.3	.7	2	2	1.5	40	Stream sediment.
10	500	50	5	0	.1	0	1	.7	1	40	Do.
11	200	50	0	0	.05	0	.3	.7	1.5	40	Do.
12	500	70	7	2	.3	1	2	1.5	1.5	40	Do.
13	300	50	5	0	.1	.7	1	.7	.7	40	Do.
14	500	70	15	2	.2	.7	3	1	1	40	Do.
15	300	70	5	1	.2	.7	1	.5	.5	40	Gravel (Tertiary).
16	500	70	5	2	.3	1	2	.7	.7	40	Stream sediment.
17	500	150	7	2	.3	0	5	2	1.5	40	Do.
18	300	50	0	1	.1	1.5	.7	1.5	3	40	Do.
19	300	50	5	1	.15	.7	1	.7	1	40	Do.
20	300	100	5	1	.3	.7	2	1.5	1.5	40	Do.
21	300	50	0	0	.1	1	.7	1.5	3	40	Do.
22	300	70	10	2	.2	.7	2	1	1.5	40	Do.
23	500	70	5	2	.3	1	2	1.5	3	40	Do.
24	200	100	5	1	.1	.5	.7	1	1.5	40	Do.
25	1,500	100	0	0	.07	1	.7	2	M	40	Moenkopi Formation.
26	200	30	0	0	0	0	.15	.05	.07	40	Coconino Sandstone, altered.
27	150	1,500	0	0	.3	0	.3	.7	M	80	Travertine.
28	20	50	0	0	0	0	2	.5	M	40	Martin Limestone, base.
29	500	100	0	1	.05	1	.7	1.5	M	40	Moenkopi Formation, altered.
30	300	1,500	0	0	.15	0	1.5	.7	M	120	Travertine.
31	500	1,000	0	0	.5	.7	2	2	10	40	Sandstone above basalt.
32	500	700	0	1	.07	2	M	.05	1.5	40	Tapeats Sandstone.
33	300	70	0	0	.07	2	10	.3	.3	40	Do.
34	100	150	0	0	0	0	M	.1	.07	40	Iron gossan.
35	20	100	0	0	.01	0	.5	5	M	40	Fault breccia.
36	700	100	--	--	--	--	1.5	.3	.7	40	Stream sediment.
37	300	70	--	--	--	--	.5	.3	.5	40	Do.
38	300	70	--	--	--	--	.7	.3	.7	40	Do.
39	500	150	--	--	--	--	1	.5	2	40	Do.
41	30	1,000	0	0	2	0	.1	5	M	40	Water residue.
42	50	700	0	0	1	0	0	5	M	40	Do.
43	10	1,000	0	0	3	0	0	5	M	40	Do.
44	7	1,000	0	0	2	0	0	5	M	40	Do.
45	100	300	0	0	.7	.3	0	5	M	40	Do.
46	150	2,000	0	0	7	1	0	5	M	40	Do.
47	500	300	0	0	1	0	0	5	M	40	Do.
48	700	500	0	0	.7	0	0	5	M	40	Do.
49	500	500	0	0	1	0	0	5	M	40	Do.

basalt, and therefore the anomalous amounts do not indicate deposits of chromium ore.

The Jerome mining district, which is about 10 miles south of the primitive area, has produced substantial amounts of copper. These ore deposits are in Precambrian rock and are of Precambrian age. They are overlain by Cambrian and younger sedimentary rocks which are unaltered and unmineralized. The ore deposits were exposed by erosion which removed the cover of sedimentary rocks. The occurrence raises the question of whether ore deposits occur in Precambrian rocks beneath the primitive area.

The exposed Precambrian rock closest to the Sycamore Canyon Primitive Area—a small area near the Packard Ranch—is unmineralized; it was explored by a shallow shaft and by drilling about 1915, but no ore minerals were found. Hot artesian water which deposited travertine was found both in the shaft and in the drill holes. The travertine (samples 27, 30) contains traces of strontium, arsenic, and zinc. The basal beds of the Tapeats(?) Sandstone (samples 32, 33) nearby contain traces of vanadium but little or no copper, lead, and zinc. If important copper ore deposits were concealed beneath the Tapeats Sandstone nearby, the basal beds of the Tapeats probably would contain more than 80 ppm detrital copper, as at Jerome (Huff, 1955).

At the south edge of the primitive area, Precambrian rocks lie at a depth of about 300 feet, and they increase in depth to more than 3,500 feet near the north boundary. There are no surface indications of mineral deposits in the primitive area, and exploration for mineral deposits in Precambrian rocks buried beneath the thick cover of barren rocks would be very expensive.

The Colorado Plateaus province northeast of Sycamore Canyon contains uranium deposits and some copper prospects in sedimentary rocks, but all are more than 50 miles from Sycamore Canyon. The important uranium deposits of the province are in geologic formations not present in Sycamore Canyon. At the rim of the Grand Canyon, however, uranium ore has been found in the Supai and Coconino Formations. Copper mineralization also has been reported in the Supai, Redwall, and Kaibab Formations in the Grand Canyon area. Red rocks near uranium deposits of the Colorado Plateaus province are bleached or otherwise altered in color; such bleaching, which is easily recognized, is not present in the Sycamore Canyon area.

Near Cameron, Ariz., and in a few other places on the Colorado Plateaus, collapse structures containing uranium minerals have been found in areas of graben faults, but no evidence of uranium was found in the grabens of Sycamore Canyon.

GERONIMO'S MINE

The only known mining claims in the Sycamore Canyon Primitive Area are held by Mr. O. G. ("Jerry") Graves and associates. These claims covering Geronimo's mine or prospect are at the south edge of the primitive area, about 1.4 miles north of Mr. Graves' cabin at Packard Ranch.

The legend of Geronimo's mine is related in the "Mining Journal" of April 15th, 1946. In brief, the legend tells how a gold deposit was found and worked by Spanish explorers and later worked by Geronimo and other Apache Indians. According to the legend, much of the gold bullion recovered from the mine was buried in a secret place within the mine. Using several lines of evidence, Mr. Graves and a former partner (now deceased) located a cave in Sycamore Canyon, which they concluded was Geronimo's mine, and they staked claims that covered it. The prospect was examined on October 26, 1965, by the writers, accompanied by Mr. Graves and Robert Raabe (U.S. Bur. Mines). The mine is a cave in the Martin Limestone about 20 feet above Sycamore Creek. The cave is partly filled with clay and sand. During the 20 years that Mr. Graves and his partner worked at the mine, they excavated a T-shaped adit, aggregating about 200 feet in length, by removing fill from the cave. In this adit the cavern walls above the clay and sand fill are coated with a black powdery material which Mr. Graves interprets to be soot left from fires used by early miners for breaking the rock. Samples of this material were identified as black manganese oxide rather than soot. The undisturbed condition of the cave fill suggests that the cave is natural and has never been excavated before. No evidence of gold was found during the examination of the cave.

CONSTRUCTION MATERIALS

Some rocks of the Sycamore Canyon Primitive Area are suitable for construction materials and are similar to stone quarried elsewhere. Coconino Sandstone is quarried near Ashfork west of Sycamore Canyon and on the east side of Black Mountain east of Sycamore Canyon. The quarried sandstone is used widely throughout the southwest for flagstone and dimension stone. The Coconino Sandstone of Sycamore Canyon seems to be of similar quality; however, abundant supplies of sandstone are available for quarrying in easily accessible areas outside Sycamore Canyon.

WATER

Springs in the lower part of Sycamore Canyon maintain a perennial flow in lower Sycamore Creek within the primitive area. The discharge of Sycamore Creek during the dry months of July and August ranges from 4,550 to 5,125 gallons per minute (range of five measurements given by Feth, 1954, p. H34). About half this discharge comes from Summer's Spring.

Good drinking water supplies are not available in the Sycamore Canyon area except at the springs which are shown on the map. The abundant joints and faults in the rock permit water to seep underground quickly, and streambeds are dry except during flash floods caused by very severe storms.

PETROLEUM

No oil wells have been drilled in the Sycamore Canyon Primitive Area. The closest known well drilled for oil is about 5 miles east of the primitive-area boundary. This well—George Willett SDD–State 1—is in the SW¼NW¼ sec. 24, T. 20 N., R. 5 E. It was started in June 1965 and by November 1965 had been drilled to a depth of 2,500 feet. No geologic information about the well is available to the writers.

Geologic mapping has disclosed no structural features or stratigraphic traps within the primitive area favorable for the accumulation of petroleum.

ECONOMIC APPRAISAL

By R. G. Raabe, U.S. Bureau of Mines

INTRODUCTION

This report describes the work done by the U.S. Bureau of Mines to determine land status and mineral resources of the Sycamore Canyon Primitive Area (referred to on U.S. Forest Service maps as the Sycamore Canyon Wilderness Area), Coconino and Yavapai Counties, north-central Arizona.

Acknowledgment of assistance is made to the Arizona State office of the U.S. Bureau of Land Management, the U.S. Forest Service, the Arizona Bureau of Mines, the Arizona State Oil and Gas Conservation Commission, and personnel at the Iron King mine and other local residents.

INVESTIGATIONS

R. G. Raabe conducted the field investigation between October 14 and November 4, 1965. Some fieldwork was done with Geological

Survey personnel. Geological publications and records maintained by county, State, and Federal agencies were reviewed, and personnel of these agencies were interviewed. Inquiries were especially directed toward determining past mineral-location activity and exploration, if any, especially clues on possible activities not of record.

Records search and actual examination did not disclose any evidence of mineral or petroleum production within the Sycamore Canyon Primitive Area. The only evidence of past prospecting activity within the primitive area consists of a group of contiguous lode claims (Limestone, Redrock, Sagebrush, Cactus, Creek, and Spring) near the south boundary (fig. 1). The claims were located by Messrs. O. G. Graves and J. B. Dixon, recorded in the Yavapai County courthouse, Prescott, and held by annual assessment work after 1946. Mr. O. G. Graves refers to these claims as Geronimo's mine. The Limestone claim was examined by Forest Service mineral examiners on May 18–19, 1965, who "recommended that adverse proceedings be initiated by the Government against the Limestone lode mining claim under the following charges:

1. That a discovery of mineral in sufficient quantity and quality to constitute a valid discovery does not exist within the limits of the claim.
2. That the land within the claim is not chiefly valuable for mineral."

The Bureau of Mines found no evidence of the occurrence of valuable minerals on the six claims.

For more comprehensive coverage, the area of study was expanded to include the Verde mining district as well as a block of 30 townships (approx 1,080 sq mi) surrounding the Sycamore Canyon Primitive Area. The land status of this larger area is shown in figure 1; some of the area is covered by oil and gas leases and some by rock quarry claims.

VERDE MINING DISTRICT

The famous copper mines of the Verde mining district at Jerome, Ariz., are 10 miles south of Sycamore Canyon, and the Precambrian host rock of the district is presumably similar to the basement rock underlying the sedimentary formations in Sycamore Canyon. The area around the rich deposits of the United Verde and United Verde Extension mines was studied to identify any criteria of favorability for mineral occurrences that might be applicable in evaluating the mineral potential of Sycamore Canyon. Bureau of Mines' work at Sycamore Canyon did not disclose any evidence of similar alteration or of mineralization. This examination confirmed the Geological Survey's findings.

ROCK QUARRIES

Sandstone formations on plateaus near Sycamore Canyon but outside the primitive area boundaries are being quarried for flagstone (fig. 1). Presumably, sandstone within the primitive area could also be so utilized. However, the reserves outside the area are so extensive that all anticipated commercial demand for flagstone and building stone from these formations can probably be readily satisfied without using similar materials from the primitive area.

OIL AND GAS EXPLORATION

Records of the Arizona State Land Office and the Bureau of Land Management show no oil and gas or other mineral leases within the primitive area. Leasing and exploration drilling for oil and gas on both State and Federal lands have been carried on to the east of the Sycamore Canyon area, and two drilling operations were in progress a few miles east of the canyon at the time of the present investigation. One of these was on State land in sec. 24, T. 20 N., R. 5 E. The other was on Federal land in sec. 4, T. 17 N., R. 4 E. (fig. 1). To date, no discoveries have been made anywhere near Sycamore Canyon. The nearest producing wells are 180 miles away.

CONCLUSIONS

In a surface examination of the rocks in the area, the Bureau of Mines found no evidence of significant mineral reserves in the Sycamore Canyon Primitive Area or evidence of oil and gas potential. Sandstone suitable for building stone is so abundant in the general area that exploitation of the sandstone beds within the primitive area is not justified on the basis of foreseeable need.

LITERATURE CITED

Anderson, C. A., and Creasey, S. C., 1958, Geology and ore deposits of the Jerome area, Yavapai County, Arizona: U.S. Geol. Survey Prof. Paper 308, 185 p.

Arizona Bureau of Mines, 1958, Geologic map of Yavapai County, Arizona: Arizona Bur. Mines.

Feth, J. H., 1954, Preliminary report of investigations of springs in the Mogollon Rim region, Arizona: U.S. Geol. Survey open-file rept., 77 p.

Feth, J. H., and Hem, J. D., 1963, Reconnaissance of headwater springs in the Gila River drainage basin, Arizona: U.S. Geol. Survey Water-Supply Paper 1619–H, p. H1–H54.

Huff, L. C., 1955, A Paleozoic geochemical anomaly near Jerome, Arizona: U.S. Geol. Survey Bull. 1000–C, p. 105–118.

Lehner, R. E., 1958, Geology of the Clarkdale quadrangle, Arizona: U.S. Geol. Survey Bull. 1021–N, p. 511–592.

McKee, E. D., 1938, Environment and history of the Toroweap and Kaibab formations of northern Arizona and southern Utah: Carnegie Inst. Washington Pub. 492, 268 p.

Moore, R. T., Wilson, E. D., and O'Haire, R. T., 1960, Geologic map of Coconino County, Arizona: Arizona Bur. Mines.

Price, W. E., 1949, The Moenkopi formation at Sycamore Canyon, Arizona: Plateau, v. 21, no. 4, p. 49–54.

——— 1950a, Cenozoic gravels on the rim of Sycamore Canyon, Arizona: Geol. Soc. America Bull., v. 61, no. 5, p. 501–508.

——— 1950b, The Kaibab formation of Sycamore Canyon, Arizona: Plateau, v. 23, no. 1, p. 11–16.

Robinson, H. H., 1913, The San Franciscan volcanic field, Arizona: U.S. Geol. Survey Prof. Paper 76, 213 p.