STATUS OF MINERAL RESOURCE INFORMATION FOR THE HAVASUPAI INDIAN RESERVATION, ARIZONA

By

Edward A. duBray
U.S. Geological Survey

Mark H. Hibpschman
U.S. Bureau of Mines

Prepared by
U.S. Geological Survey and U.S. Bureau of Mines
for U.S. Bureau of Indian Affairs

Administrative report BIA-42
1978

CONTENTS

SUMMARY 1
INTRODUCTION 1
MAPS 2
GEOGRAPHY 2
PRESENT STUDY AND ACKNOWLEDGMENTS 2
GEOLOGY 2
Previous Geologic Investigations 2
Stratigraphy 3
Mississippian 3
Redwall Limestone 3
Pennsylvanian and Permian 3
Supai Group 3
Permian 4
Hermit Shale 4
Coconino Sandstone 4
Toroweap Formation 4
Kaibab Formation 4
Structure 4
Supai Monocline 4
Sinyala Fault 5
MINERAL RESOURCES 5
General 5
Energy Resources 5
Uranium 5
Petroleum, Coal, and Natural Gas 5
Metallic Minerals 6
Nonmetallic Mineral Resources 6
Travertine 6
Sand and Gravel 6
RECOMMENDATIONS FOR FURTHER WORK 6
REFERENCES 7

SUMMARY

Known mineral resources on the Havasupai Indian Reservation include lead, zinc, silver, vanadium, sand and gravel, travertine, and possibly uranium. Only travertine and sand and gravel are on the portion of the reservation that can be mined, and the travertine occurs near the scenic falls of Havasu Creek and thus could not be mined for aesthetic reasons. Sand and gravel probably will be used by the tribe on an as needed basis. The metallic ores are on the part of the reservation that is withdrawn from mining by law.

INTRODUCTION

This report was prepared for the U.S. Bureau of Indian Affairs by the U.S. Geological Survey and the U.S. Bureau of Mines under an agreement to compile and summarize available information on the geology, mineral resources, and potential for mineral development on certain Indian lands. Source material consisted of published and unpublished reports, and personal communication. There was no field work.

The Havasupai Indian Reservation is wholly within Coconino County, Arizona. Most of the reservation lies below the south rim of the Grand Canyon and is bounded on the east and north by Grand Canyon National Park. In 1944 the reservation was designated as an area of 3,058 acres in Havasu Canyon. Public Law 93-620 (88 Stat. 2089) of Jan. 3, 1976, increased the size of the reservation by 185,000 acres that surround the original 3,058-acre area. The same law granted the tribe an additional 95,300 acres of land for grazing and other traditional use (Figure 1). However, Section 10(b)5 of the law states:

> "no commercial timber production, no commercial mining or mineral production, and no commercial or industrial development shall be permitted on such lands."

The only known mineral deposit is located just north of the 3,058 acres and is described in this report.

The tribal council and chairman requested that this report be the only mineral resources report prepared on reservation lands and that no subsequent work be planned concerning mineral resources on the reservation.

The village of Supai, Havasupai tribal headquarters, is located in Havasu Canyon on the original 3,058 acres (Figure 1). According to the Bureau of Indian Affairs (1976), the tribal population, living on the reservation, is 302. The entire reservation is an area of outstanding scenic attraction, and tourism supplies a large part of both tribal and individual income.

The Supai village is about 75 road miles northeast of Peach Springs, Arizona. U.S. Highway 66 and the Santa Fe Railroad pass through Peach Springs. No road extends from the rim to the village so all access is by foot, horse or mule, or helicopter.

Principal population centers of the region are Flagstaff, about 150 miles southeast of the reservation (population 26,117), Kingman, about 115 miles southwest (population 7,312), and Peach Springs about 75 miles southwest (population approximately 600, BIA personal communication). Phoenix, with an area population of 863,357, is about 350 miles south of the reservation (Dept. of Commerce, 1973).

MAPS

The reservation is covered by 15' U.S. Geological Survey topographic maps: National Canyon, Supai, Havasupai, Powell Plateau, Kanab Point, Tuckup Canyon, and Black Tank Wash. The Grand Canyon and Williams 1:250,000 scale maps also include the reservation. The geologic map of Coconino County, by the Arizona Bureau of Mines and the University of Arizona, presents a general view of the regional geology. A more detailed geologic map of Grand Canyon geology is the one by Maxson (1969) and a colored geologic map was published in 1976 by the Grand Canyon Natural History Association and the Museum of Northern Arizona. The Bureau of Land Management areas of administrative responsibilities map indicates land ownership status and land use patterns. County road maps are available from the Arizona Department of Transportation.

Aerial photographs of the reservation area can be obtained from U.S. Geological Survey and the Army Map Service. Photos can be ordered from the EROS Data Center in Sioux Falls, South Dakota.

GEOGRAPHY

The reservation is on the Coconino Plateau at the southern edge of the Grand Canyon and is characterized by spectacular scenery (Figure 2). It includes one large side canyon to the Grand Canyon, Cataract-Havasu Canyon. Maximum relief on the reservation is 3,700 feet between Mooney Falls and the high point on the Coconino Plateau.

The elevation of the plateau ranges from 5,600 to 6,000 feet and is generally highest to the east. The many tributaries of Cataract Canyon cut into the plateau, and occasional knolls rise above it. All drainage in the area is into Cataract Canyon and thence into the Colorado River. Havasu Creek in Havasu Canyon south of Navajo Falls is the only perennial stream on the reservation.

PRESENT STUDY AND ACKNOWLEDGMENTS

The regional geology is summarized from the Coconino County, Arizona, geologic map and from Maxson's (1969) preliminary geologic map of the Grand Canyon west and central section. Mineral claim locations and descriptions are found in the CRIB (computerized resource information bank) file, references cited therein, and in other cited literature concerned with mineral deposits in Arizona. M. G. Johnson assisted with the CRIB file search.

GEOLOGY

Previous Geologic Investigations

Since its discovery by white men, the Grand Canyon and its environs has attracted many earth scientists. In 1861 J. S. Newberry of the Ives Expedition descended Peach Springs Canyon to the Colorado River and described the physiography and geology of this region 40 miles southwest of the Havasupai Reservation. In 1869 John Wesley Powell and his expedition passed very close to the reservation as they made a descent of the Colorado River in boats. The Paleozoic rocks of the Grand Canyon were studied by early geologists including G. K. Gilbert and C . E. Dutton in the late 1800's.

Walcott (1890, p. 584) measured a section at Nankoweap Valley, Darton (1915) measured one on the Bright Angel Trail, and Noble (1922) measured a section on Shinumo Creek in Bass Canyon.

Additional works on the Grand Canyon region include McKee (1933a, 1933b, 1938, 1969, 1974), McKee and Breed (1969), McKee and Gutschick (1969), McKee and McKee (1972), Maxson (1967), and Ragan and Sheridan (1970). Maxson's (1969) geologic map of the west and central sections is the most detailed map available.

Stratigraphy

The Paleozoic rocks exposed on the Havasupai Indian Reservation belong to the classic Grand Canyon section. The spectacular scenery and the excellent outcrops have drawn many geologists to study this section, hence the rocks are well known. More detailed descriptions and regional correlations are presented in McKee (1938b, 1938, 1969, 1974, 1975), McNair (1951), and McKee and Gutschick (1969). A generalized geologic map is presented on Figure 3 and a generalized geologic section is presented on Figure 4.

Mississippian

Redwall Limestone.--The Redwall Limestone crops out as a conspicuous cliff throughout the Grand Canyon region. The cliff, surficially stained reddish orange by wash from the overlying red rocks of the Supai Group, is 500 feet high and is locally cavernous. This formation unconformably overlies Devonian rocks. Typically light gray, the Redwall is an aphanitic to coarsely crystalline limestone, which contains thin beds and blebs of chert, substantial amounts of dolomite, and zones characterized by dense accumulations of crinoid debris. Four members have been distinguished by McKee and Gutschick (1969) on the basis of lithology. These various lithologies indicate that three transgressions and regressions of the sea occurred across the Grand Canyon region during Mississippian time.

Pennsylvanian and Permian

Supai Group.--Until recently the term Supai had formational status. McKee (1975) made it a group, split into four formations on the basis of lithology and contained fossils. Each of these, the Watahomigi Formation, the Manakacha Formation, the Wescogame Formation, and Esplanade Sandstone, in ascending order, is separated from the rocks above and below by channelized unconformities with up to 30 feet of relief on the unconformity surfaces. The Supai Group consists mostly of limy sandstone, sandy and silty limestone, and siltstone, all with reddish hues. The Watahomigi, which rests unconformably on the underlying Redwall Limestone, is a thin-bedded gray limestone with red-brown siltstone and is about 300 feet thick. The three overlying formations consist chiefly of red-brown siltstone, and the uppermost Esplanade Sandstone forms a conspicuous cliff. The whole group is about 1,000 feet thick and forms unimpressive slopes and benches due to its low resistance to erosion. Westward, limestone and dolomite become more prevalent, and the group forms more clifflike outcrops.

Permian

Hermit Shale.--On the east edge of the Coconino Plateau the Hermit Shale is 930 feet thick, and it thickens to the west. It is principally composed of nonresistant, thinly-bedded, silty and shaly sandstone. It has a gradational contact with the underlying Supai Group.

Coconino Sandstone.--Large crossbeds characterize this clean well-sorted sandstone. The sandstone is light tan and consists of moderately rounded quartz grains. The crossbeds indicate an eolian origin for the Coconino sandstone. Fossil footprints interpreted to be those of large reptiles are not uncommon.

Toroweap Formation.--The Toroweap Formation, like those described above, crops out only in Cataract Canyon and in its deeply incised tributaries. It represents transgression of a late Permian sea across the Grand Canyon area from the west. The formation has been divided into three units; α, β, and γ (Figure 4). The transgressing sea deposited primarily carbonate sediments, with a maximum thickness of 350 feet on the west side of Coconino Plateas. The α unit, deposited during marine regression, consists of redbeds, thin residual limestones, and beds of gypsum, and forms low cliffs. The β unit is predominantly carbonate sediments, deposited during the maximum advance of the sea; it forms high cliffs. The γ unit, deposited during transgression, is a thin slope-forming mudstone and shale deposit. The mudstone and shale beds are red and tend to stain the remainder of the formation and underlying rocks red as well.

Kaibab Formation.--This is the only formation exposed outside of Cataract Canyon. It forms the rim of the canyon and the surface of the Coconino Plateau in this region. Like the Toroweap Formation the Kaibab Limestone represents a transgression of a late Permian sea across the Grand Canyon region, and it also has been split into α, β, and γ units. Units α and γ are similar to their counterparts in the Toroweap Formation. Unit β grades from limestone to sandstone from west to east. The contact between the Kaibab and Toroweap Formations is an unconformity.

Structure

Like most Paleozoic and younger rocks in the Colorado Plateaus Province, those of the Havasupai Indian Reservation are very little deformed, although they have been uplifted many thousands of feet from their original site of deposition. The area is cut by several major high-angle faults and monoclines (Figure 2). In the Cataract Canyon area the major structural features are the Sinyala fault (trending northeast) and the Supai Monocline (trending north). These structures parallel major structural trends of the southern part of the Colorado Plateaus Province. Other small northeast-trending faults, and many slumps and landslides occur within the reservation as well.

Supai Monocline

The Supai Monocline trends north-northwest parallel to Cataract Canyon and crosses the Colorado River one-quarter mile upstream from the mouth of that canyon. It is an anomalous feature for the Grand Canyon region as it dips to the west;

most other monoclines dip to the east. The monocline is nowhere more than a mile in width and all strata in it dip less than 10°. Maximum displacement on the flexure is 200 feet. Where the monocline crosses the Colorado River, the Muav Limestone is tightly folded, and the fold is compressed to a width of several hundred feet. Huntoon (1974) notes that this is in agreement with the theory that the monoclines of the Grand Canyon region grade downward into reverse faults.

Sinyala Fault

The Sinyala Fault trends northeast and crosses Havasu Canyon between Beaver and Mooney Falls. This fault is a good example of the tendency for the faults of this region to die out upward. The Precambrian rocks along the Colorado River are offset a maximum of 12 feet, west side down. Two thousand feet higher in the section the maximum offset of the sedimentary rocks is 5 feet. This difference reflects the fact that deformation of the Paleozoic rocks of the region was minor as compared to the much stronger deformation of the older rocks in Precambrian time.

MINERAL RESOURCES

General

Prospectors roamed the Grand Canyon between the late 1860's and the middle 1900's. Much of their history and what they found has gone unrecorded.

The known mineral occurrences of the Havasupai Reservation are confined to Cataract Canyon and its tributaries, and they include lead, silver, zinc, uranium, vanadium, limestone, sandstone, travertine, and sand and gravel.

Energy Resources

Uranium has been found on and near the reservation. No coal, petroleum, natural gas, or helium have been found in this part of Arizona.

Uranium

Occurrences of uranium in the Colorado Plateaus Province are mostly confined to sedimentary rocks containing abundant organic detritus and silicified wood. Parts of the Supai Group and Hermit Shale contain organic-rich sedimentary rocks similar to those that elsewhere have uranium accumulations.

On the Havasupai Reservation a uranium occurrence is reported in sec. 2, T. 32 N., R. 4 W. (CRIB). Uranium is reported at several places in the adjacent Hualapai Reservation to the west, and at the Orphan Mine, just north of the South Rim headquarters of Grand Canyon National Park. No uranium ore has been produced from any of these occurrences on the reservation.

Petroleum, Coal, and Natural Gas

Pierce, Keith, and Wilt (1970) report that a test hole for petroleum near the Havasupai Reservation in T. 28 N., R. 1 W., penetrated the Cambrian Tapeats Sandstone and was classified as dry. All other test holes in northwestern Arizona have also been dry. The entire sedimentary section of the Havasupai Reservation is exposed in the Grand Canyon, and no hydrocarbons have been reported

in any of the formations. The outlook for production in this area is poor.

Metallic Minerals

The Bridal Veil or Johnson claims are situated between Havasu Falls and Mooney Falls about 2,000 feet north of the original 3,058-acre reservation, as shown on Figure 1. The deposit lies 50 to 250 feet above the floor of Havasu Canyon on a perpendicular cliff.

The deposit was discovered in 1885, and the last known development work was in 1924. According to Ferris and Busch (1924, p. 10, 23-24), several hundred tons of lead, silver, and zinc ore was produced. The same authors state that the vanadium was not recognized by the early miners and was discarded in the dump.

The deposit is described as being in collapsed solution cavities formed along the bedding planes of the Redwall Limestone. According to Ferris and Busch (p. 24), mineralization consists of galena, sphalerite, cerussite, anglesite, smithsonite, vanadinite, pyrite, calcite, barite, gypsum, and possibly calamine. Keith (1969), on his Map of Known Metallic Mineral Occurrences (excluding base and precious metal) in Arizona, shows uranium at the Bridal Veil mines location, but no other information is available concerning the mineral.

Development work has been done on the deposit, but collectively probably does not total more than a few hundred feet of underground workings on several claims.

The deposit is within that part of the reservation on which the law states that mining will not be allowed. Minor showings of uranium, lead, silver, and possibly platinum have been reported in other parts of the reservation but further investigations have not confirmed their presence. None are shown on Figure 1.

Nonmetallic Mineral Resources

Travertine

Travertine occurs in enormous quantities both on the original 3,058 acre reservation and in Havasu Canyon below it. However, the material within the original reservation is around the scenic falls of Havasu Creek and aesthetic considerations, inaccessibility, and lack of roads would preclude mining.

Sand and Gravel

Sand and gravel occurs along the course of Havasu Creek and has been and probably will continue to be used to a very limited extent by the tribe for concrete aggregate. It is unlikely that significant quantities of the material will ever be required.

RECOMMENDATIONS FOR FURTHER WORK

The law states that no mineral development can occur on the land recently given to the tribe, and the Chairman and Tribal Council requested that no further mineral investigations be undertaken. Therefore, there are no recommendations for further mineral related work on the Havasupai Indian Reservation.

REFERENCES

Allen, M. A., and Butler, G. M., 1921, Vanadium: Arizona Bureau of Mines Bulletin 115, 23 p.

Anthony, J. W., Wilson, E. D., and Moore, R. T., Bibliography of the geology and mineral resources of Arizona: Arizona Bureau of Mines Bulletin 161, 62 p.

Arizona Bureau of Mines and University of Arizona, 1960, Geologic map of Coconino County, Arizona: Arizona counties map series, scale 1:375,000.

Blake, W. P., 1900, Does platinum occur in Arizona: Engineering and Mining Journal, v. 69, p. 224.

Darton, N. H., 1915, A reconnaissance of parts of northwestern New Mexico and northern Arizona: U.S. Geological Survey Bulletin 435, p. 21. 1925, A resume of Arizona Geology: University of Arizona Bulletin, 298 p.

Darton, N. H., and others, 1915, Guidebook of the Western United States: U.S. Geological Survey Bulletin 613, p. 123-139.

Dutton, C. E., 1882, The physical geology of the Grand Canyon District: U.S. Geological Survey 2nd Annual Report XII-XVI, p. 49-161.

Ferris, H. A., and Busch, J. E., 1924, Bridal Veil mines in Cataract Canyon Arizona: Arizona Mining Journal, v. 8, no. 7, p. 9-10, 23-24.

Flagg, A. L., Mineralogical journeys in Arizona: Published by F. H. Bitner, Scottsdale, Arizona, 1958, 93 p.

Forrester, J. D., and Moore, R. T., 1962, Maps with special reference to geologic and mineral maps of Arizona: Arizona Bureau of Mines Bulletin 170.

Fowler, D. D., Euler, R. C., and Fowler, C. S., 1969, John Wesley Powell and the anthropology of the Grand Canyon: U.S. Geological Survey Professional Paper 670, 30 p.

Galbraith, F. W., 1941, Minerals of Arizona: Arizona Bureau of Mines Bulletin 149, 82 p.

Hughes, J. D., 1967, The story of man at the Grand Canyon: Grand Canyon Natural History Association, 195 p.

Hunt, C. B., 1969, Geologic history of the Colorado River: U.S. Geological Professional Paper 669C, p. 59-130.

Huntoon, P. W., 1974, The post-Paleozoic structural geology of the eastern Grand Canyon, Arizona, in Geology of the Grand Canyon: Museum of Northern Arizona and Grand Canyon Natural History Association, p. 82-115.

Huntoon, P. W., Billingsley, G. H., Jr., Breed, W. J., Sears, J. W., Ford, T. D., Clark, M. D., Babcock, R. S., and Brown, E. H., 1976, Geologic map of the Grand Canyon National Park, Arizona: Grand Canyon, Arizona, Grand Canyon Natural History Association, and Flagstaff, Arizona, Museum of Northern Arizona, scale 1:62,500.

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

Keith, S. B., 1969a, Map of known nonferrous base and precious metal mineral occurrences in Arizona: Tucson, Arizona Bureau of Mines scale 1:1,000,000.

Koons, D. E., 1945, Geology of the Uinkaret Plateau, Northern Arizona: Geological Society of America Bulletin, v. 56, February 1945, p. 151-180.

_____,1948a, Geology of Eastern Hualapai Reservation: Plateau Quarterly, v. 20, no. 4, April 1948, p. 53-60.

_____,1948b, High level gravels of Western Grand Canyon: Science, v. 107, May 7, 1948, p. 475-476.

Lucchitta, Ivo, 1975, Applications of ERTS images and image processing to regional geologic problems and geologic mapping in northern Arizona: California Institute of Technology Jet Propulsion Laboratory, National Aeronautics and Space Administrative Technical Report 32-1597, p. 97-106.

Maxson, J. H., 1967, Preliminary geologic map of the Grand Canyon-Eastern Section: Grand Canyon Natural History Association Publication.

Maxson, J. H., 1969, Preliminary geologic map of the Grand Canyon-Central and Western Section: Grand Canyon Natural History Association Publication.

McKee, E. D., 1933a, Landslides and their part in widening the Grand Canyon: Grand Canyon Nature Notes, v. 8, p. 158-161.

_____,1933b, The Coconino Sandstone--its history and origin, in Contributions to Paleontology: Carnegie Institute of Washington Publication 440, p. 78-115.

_____,1938, Environment and history of the Toroweap and Kaibab Formations of northern Arizona and southern Utah: Carnegie Institute of Washington Publication 942, 268 p.

_____,1969, Stratified rocks at the Grand Canyon, in The Colorado River region and John Wesley Powell: U.S. Geological Survey Professional Paper 669-B, p. 23-58.

_____,1974, Paleozoic rocks of the Grand Canyon, in Geology of the Grand Canyon: Museum of Northern Arizona and Grand Canyon Natural History Association, 183 p.

_____,1975, The Supai Group--subdivision and nomenclature: U.S. Geological Survey Bulletin 1395-J, 13 p.

McKee, E. D., and Breed, W. J., 1969, The Toroweap Formation and Kaibab Limestone, in San Andreas Limestone and its correlatives: New Mexico Geological Society Symposium, p. 12-26.

McKee, E. D., and Gutschick, R. C., 1969, History of the Redwall Limestone of northern Arizona: Geological Society of America Memoir 114, 726 p.

McKee, E. D., and McKee, E. H., 1972, Pliocene uplift of the Grand Canyon region, time of drainage adjustment: Geological Society of America Bulletin, v. 83, p. 1923-1932.

McKee, E. H., Gomez, P. M., and Hibpshman, M. H., 1977, Status of mineral resource information for the Hualapai Indian Reservation, Arizona: U.S. Bureau of Indian Affairs, Administrative report BIA-31, 38 p.

McNair, A. H., 1951, Paleozoic stratigraphy of part of northwestern Arizona: American Association Petroleum Geologists Bulletin, v. 35, no. 3, p. 503-541.

Moore, R. T., 1955, One hundred Arizona minerals: Arizona Bureau of Mines Bulletin 165, 30 p.

Noble, L. F., 1914, The Shinumo quadrangle, Grand Canyon district Arizona: U.S. Geological Survey Bulletin 549, p. 93-96.

_____,1922, A section of the Paleozoic formations of the Grand Canyon at the Bass Trail: U.S. Geological Survey Professional Paper 131, p. 23-73.

Noble, L. F., and Hunter, J. R., 1917, A reconnaissance of the Archean Complex of the Granite Gorge, Grand Canyon, Arizona: U.S. Geological Survey Professional Paper 98, p. 95-113.

Pierce, G. W., Keith, S. B., and Wilt, J. C., 1970, Coal, oil, natural gas, helium, and uranium in Arizona: Arizona Bureau of Mines Bulletin 182, 239 p.

Quiring, H., 1962, Platinmettelae in Die Metallischen Rohstoffe, 16 Band: Stuttgart, Ferdinund Euke Verlag, 288 p.

Ragan, D. M., and Sheridan, M. F., 1970, The Archean rocks of the Grand Canyon, Arizona: Geological Society of America, Abstracts with Programs, v. 2, no. 2, p. 132-133.

Ransome, F. L., 1917, Some Paleozoic sections in Arizona and their correlation. Chapter in shorter contributions to general geology, 1916: U.S. Geological Survey Professional Paper 98, p. 162-163.

Stipp, T. F., Haigler, L. B., Alto, B. B., and Sutherland, H. L., 1967, Reported occurrences of selected minerals in Arizona: U.S. Geological Survey Map MR 46.

Swapp, C. W., 1956, Arizona, boom or bust: World Oil, v. 143, no. 1, p. 81-91.

Townsend, R. C., 1961, Stone in Arizona: Arizona Development Board, 50 p.

U.S. Atomic Energy Commission and U.S. Geological Survey, 1970, Preliminary reconnaissance for uranium in Coconino County, Arizona: U.S. Atomic Energy Commission, and U.S. Geological Survey, 1951-1955, RME-155, 119 p.

U. S. Bureau of Competition, 1975, Report to the Federal Trade Commission on mineral leasing on Indian lands, 226 p.

U.S. Bureau of Indian Affairs, 1976, Information profiles of Indian reservations in Arizona, Nevada, and Utah: p. 39-41.

U.S. Bureau of Land Management, 1964, Areas of administrative responsibility of federal lands map, scale 1:500,000.

U.S. Department of Commerce, 1970, U.S. Census of population for Arizona: p. 4-10.

_____,1974, Federal and State Indian reservation and Indian trust areas: p. 59-60.

U.S. Geological Survey, Utah Geological and Mineralogical Survey and Arizona Bureau of Mines, 1969, Mineral and water resources of Arizona: Prepared for U.S. Senate Committee on Interior and Insular Affairs, Washington, D.C., 638 p.

Walcott, C. D., 1890, The fauna of the Lower Cambrian or Olenellus zinc: U.S. Geological Survey Tenth Annual Report, pt. 1, p. 509-760.

Wilson, E. D., 1939, Bibliography of the geology and mineral resources of Arizona: Arizona Bureau of Mines Bulletin 13, 164 p.

_____,1950, Arizona zinc and lead deposits: Arizona Bureau of Mines Geological Series 18, Bulletin 156, 144 p.

Wilson, E. D., and Roseveare, G. H., 1949, Arizona nonmetallics: 2nd Edition, Arizona Bureau of Mines, Mineral Technology Bulletin 42, 23 p.

Click back button (<<) on toolbar to return to text

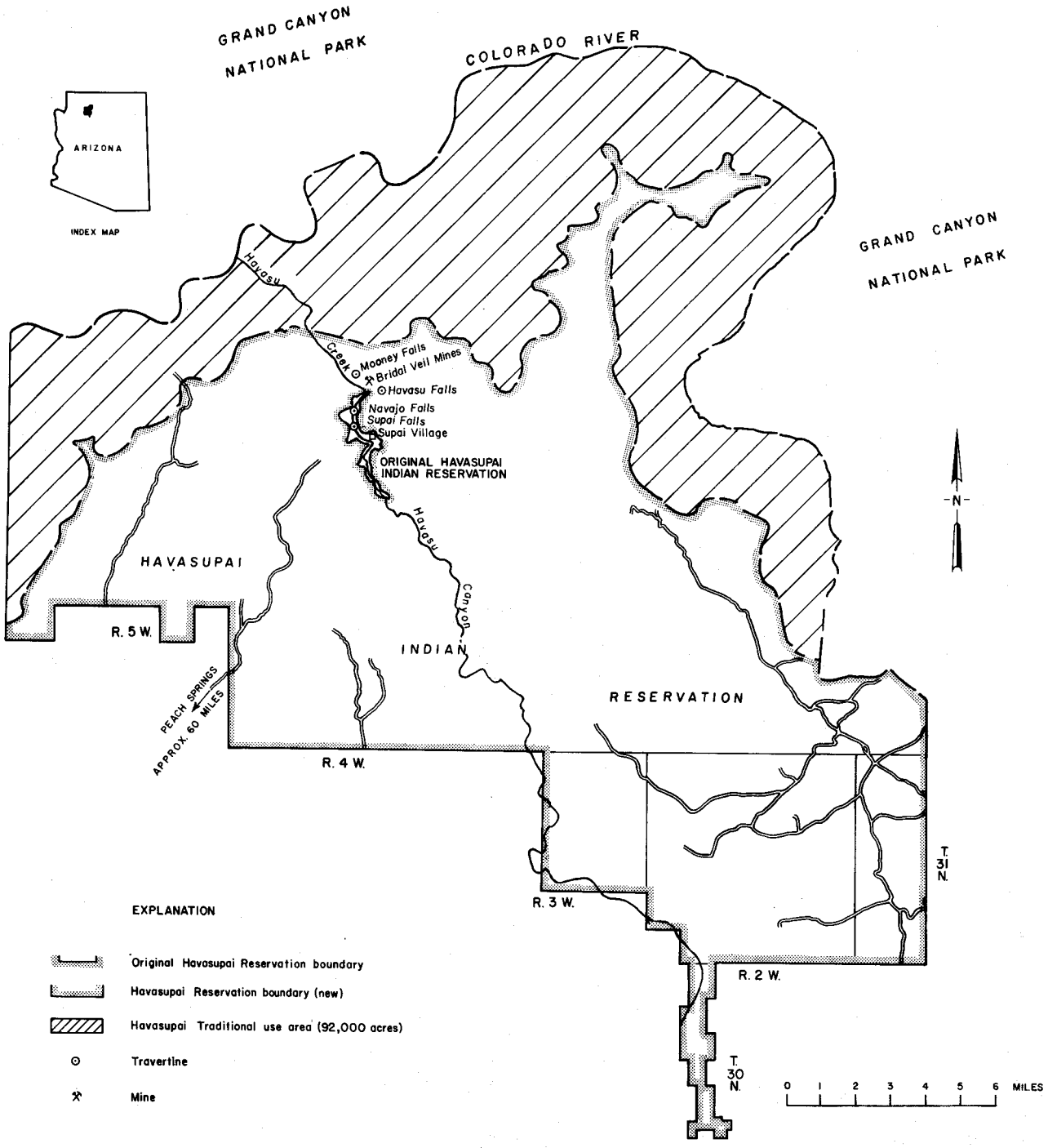

Figure 1. Map showing roads and mineral occurrences on Havasupai Indian Reservation, Arizona.

Click back button (<<) on toolbar to return to text

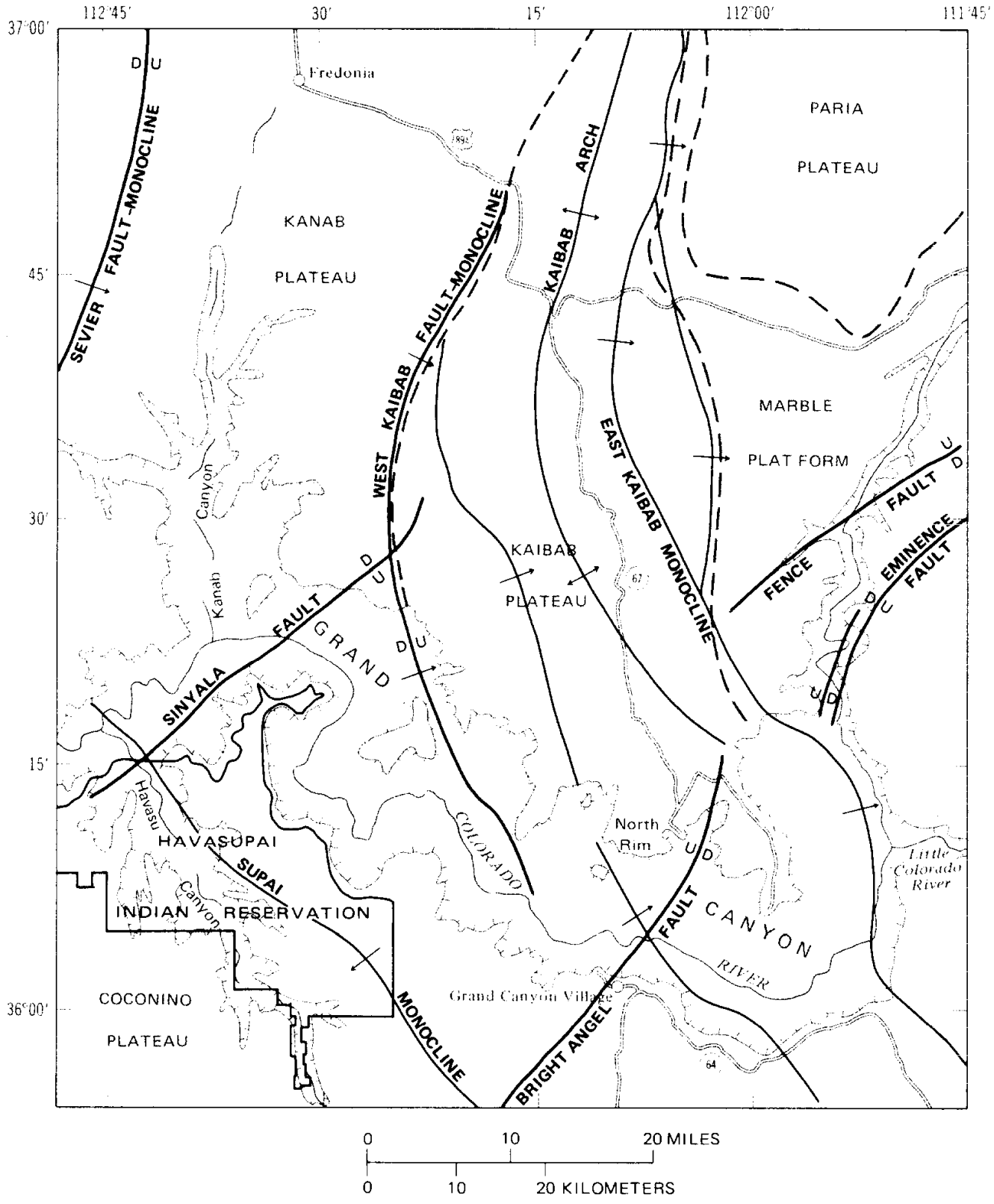

Figure 2. Physiographic features, major faults, and monoclines (showing dip) in and near the Havasupai Indian Reservation. Heavy dashed lines mark boundaries of physiographic subdivisions; relative movement on faults shown by D, down, and U, up. (Modified from Huntoon, 1974).

Click back button (<<) on toolbar to return to text

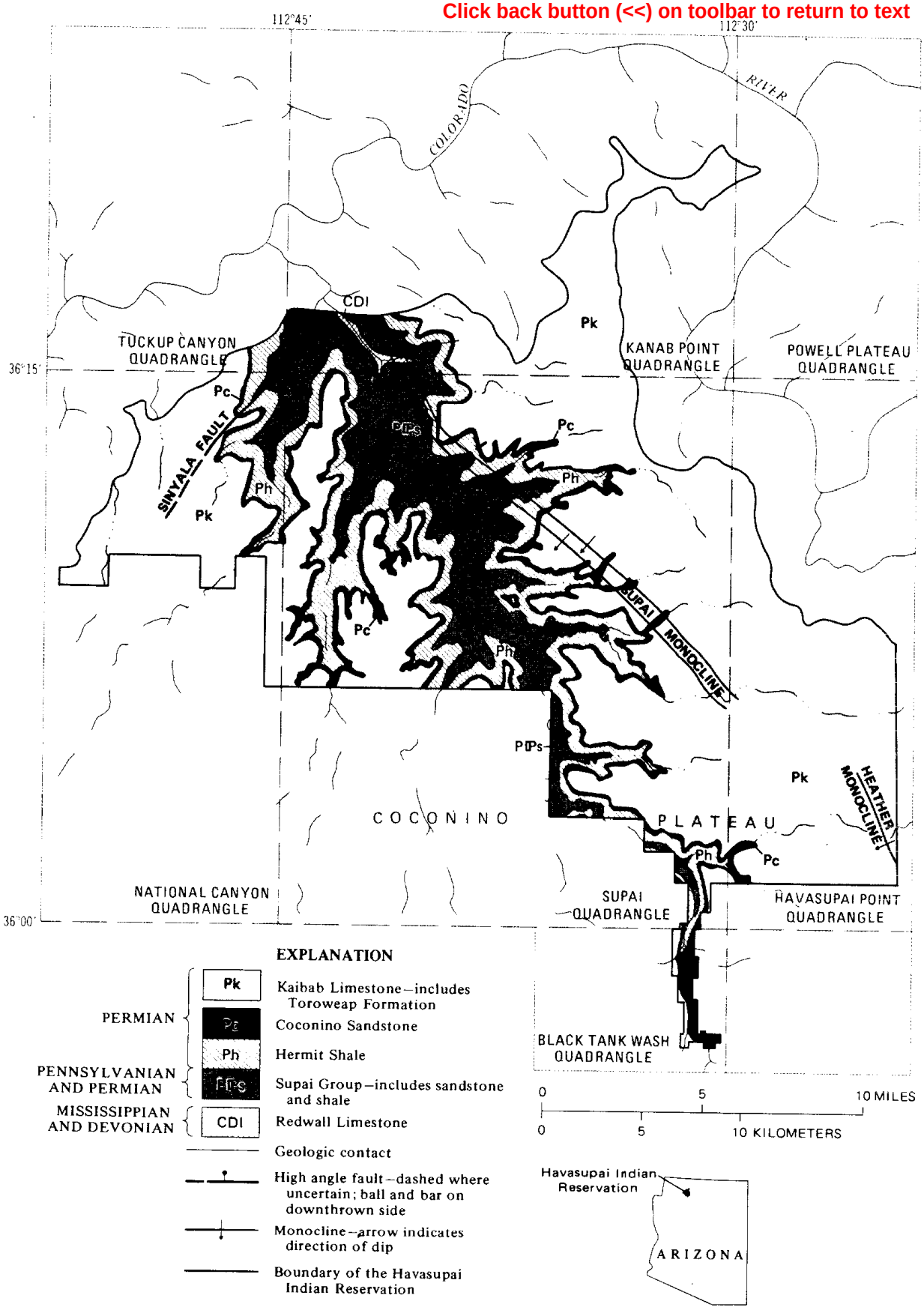

Figure 3. Geologic map of the Havasupai Indian Reservation. (Modified from Maxson, 1969).

Click back button (<<) on toolbar to return to text

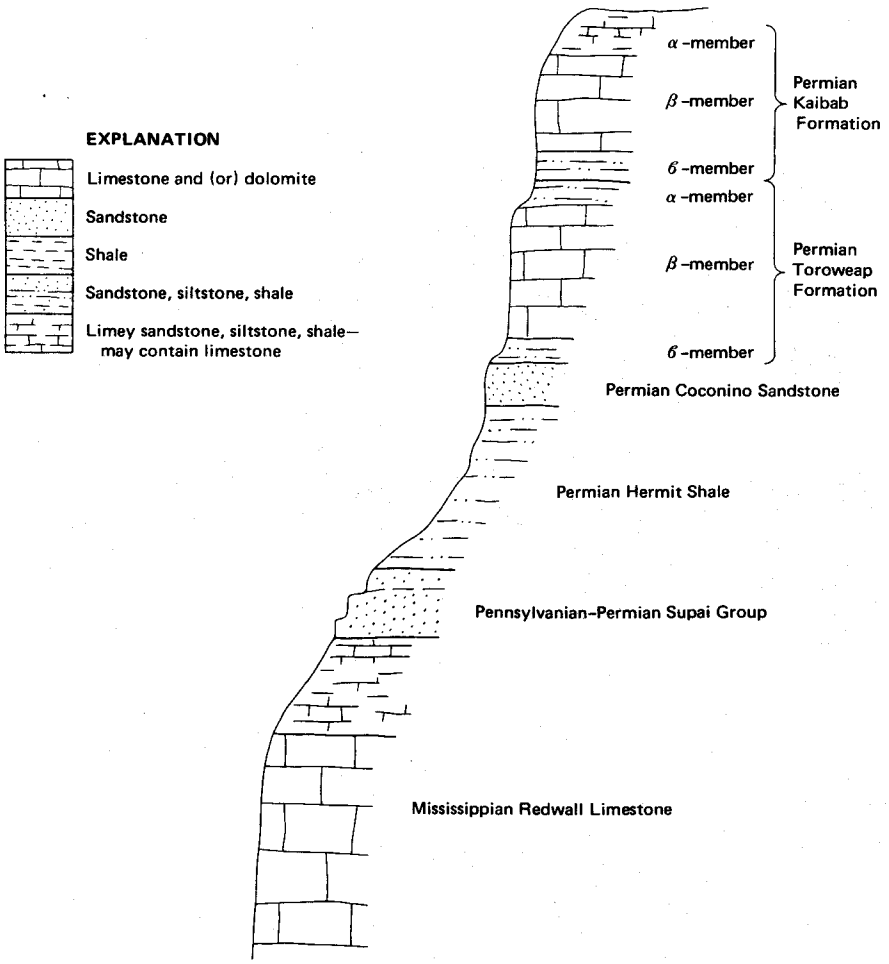

Figure 4. Stratigraphic section of the Grand Canyon section rocks that are exposed on the Havasupai Indian Reservation. Not drawn to scale (modified from Lucchitta, 1975).