

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Preliminary Report on the Mineral Resource Potential
of the Vermilion Cliffs-Paria Canyon Instant Study Area,
Coconino County, Arizona, and Kane County, Utah

By

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This report is preliminary and has not been
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Mineral Surveys
Related to Bureau of Land Management
Instant Study Areas

In accordance with the provisions of the Federal Land Policy and Management Act (Public Law 94-579, October 21, 1976), the Geological Survey and the Bureau of Mines have conducted mineral surveys on certain areas, which include those formally identified as "natural" and "primitive" areas prior to November 1, 1975. This report discusses the results of a mineral survey of the Vermilion Cliffs-Paria Canyon Instant Study Area, Coconino County, Arizona, and Kane County, Utah.

Contents

	Page
INTRODUCTION.....	1
GEOLOGY AND STRUCTURE by Alfred L. Bush, U.S. Geological Survey.....	3
MINING ACTIVITY by Michael E. Lane, U.S. Bureau of Mines.....	8
FACTORS AFFECTING MINERAL RESOURCE ASSESSMENT by Alfred L. Bush, U.S. Geological Survey.....	9
Uranium-copper-silver deposits.....	9
Gold and mercury deposits.....	11
Nonmetallic deposits.....	12
Organic fuels.....	14
Water.....	15
MINING DISTRICTS AND MINERALIZED AREAS by Michael E. Lane, U.S. Bureau of Mines.....	16
Mining districts and claims.....	16
Past and present mining activity and production.....	16
El Pequito mine.....	16
Sam prospect.....	17
Jasper mine.....	17
Sun Valley mine.....	18
Red Wing prospect.....	19
Unnamed prospect.....	20
Reserves.....	20
ASSESSMENT OF MINERAL RESOURCE POTENTIAL by Alfred L. Bush, U.S. Geological Survey, and Michael E. Lane, U.S. Bureau of Mines.....	21
SELECTED REFERENCES.....	24

Illustrations

Page

Figure 1. Sketch map of the Vermilion Cliffs-Paria Canyon Instant Study Area (ISA) showing the major folds and trends of faults, location of the uranium-copper-vanadium-silver occurrences, and the areas of restricted potential for the discovery of similar deposits.....	22
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Tables

Table 1. Columnar section of the sedimentary rocks underlying the Vermilion Cliffs-Paria Canyon Instant Study Area.....	4
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INTRODUCTION

The Vermilion Cliffs-Paria Canyon Instant Study Area lies mostly in Coconino County, Arizona, but extends into Kane County, Utah. The area studied in this report encompasses about 1,450 square kilometers (560 square miles); the area identified for possible Wilderness designation by the U.S. Bureau of Land Management consists of about 130,700 hectares (323,745 acres) of public land, about 90 percent of the area studied. The study area includes the established Paria Canyon Primitive and Vermilion Cliffs Natural Areas and lies between U.S. Highways 89 and 89A. The Vermilion Cliffs-Paria Canyon Instant Study Area has a low mineral resource potential.

The Paria Plateau is the dominant topographic feature in the area, ringed by the escarpment of the colorful, nearly vertical Vermilion Cliffs on the east, south, and west, and cut by the spectacular slots of Kaibab Gulch and the Paria River Canyon to the north. North of the Kaibab-Paria drainage, the Plateau loses its identity as its borders blur, and the upland surface consists of variously named benches (plate 1). At Lees Ferry, Arizona, where the west wall of the Glen Canyon of the Colorado River swings away from the river to become the Vermilion Cliffs, the sheer cliffs are about 370 m (1,200 ft) high; they increase to about 600 m (nearly 2,000 ft) near the southeast corner of the Paria Plateau. Westward the cliffs decrease to about 250 m (800 ft) along the south side of the Plateau and virtually disappear northward along House Rock Valley on the west side of the Plateau. A break in the cliffs occurs where Corral Valley joins House Rock Valley, and this affords the major road access to the Paria Plateau, a virtually unpopulated expanse of about 850 sq km (325 sq mi). Farther north the cliffs reappear as a ragged sequence of steep slopes and ledges as much as 275 m (900 ft) high that continues for 50 km (more than 30 mi) to the north as the east wall of

House Rock Valley and Coyote Valley. These narrow valleys follow the East Kaibab monocline and form the boundary between the Kaibab and Paria Plateaus, and are the western boundary of the study area.

The Paria Plateau and the flats north of the Kaibab-Paria canyons form a rolling upland, sloping gently northward at about 20 m per km (100 ft per mi). Bedrock is at or near the surface nearly everywhere, and soil, where present, is thin and sandy. Windblown sand is the common surficial material; in a very general way there is more sand at lower elevations, and so there is more in the northern part of the area. Sparse vegetation consists of pinyon, juniper, and desert shrubs and grasses, consistent with the arid to semi-arid climate, but is more abundant in the higher southern part of the Plateau, where a few small stands of ponderosa pine are present. The climate is arid to semi-arid, with summer temperatures in excess of 100°F and winter temperatures below freezing.

All the streams on the Plateau and the northern benches are ephemeral; Kaibab Gulch and some of the spring-fed streams that drain the Vermilion Cliffs are intermittent or perennial only in very short stretches. The only permanent stream is Paria River, and it occasionally has only a subsurface flow near its mouth.

Cattle raising is the only industry within the study area, but just outside the southeast boundary tourist trade supports motels at Marble Canyon and at Cliff Dwellers Lodge and centers on the float trips that run the rapids of the Colorado River downstream from Lees Ferry into Marble and Grand Canyons.

GEOLOGY AND STRUCTURE

By Alfred L. Bush, U.S. Geological Survey

The relatively flat-lying sedimentary rocks of the study area (pl. 1) range in age from Early Permian (upper part of the Kaibab Limestone) to Late Cretaceous (Dakota Sandstone) (Wells, 1960; Phoenix, 1963). The rocks represent a depositional sequence that changed from marine in the Paleozoic to continental, littoral, and marine again in the Mesozoic. Upper Cretaceous marine strata that once overlay the continental-littoral Dakota have been eroded from the study area, but are present only a few kilometers to the north. The estimated thickness of the rock units totals nearly 1,850 m (about 6,050 ft); 100 m or more of rock were removed during at least three periods of erosion during the Triassic and Jurassic. The lithologic and outcrop characteristics of the sedimentary rocks are described in the accompanying columnar section (table 1).

The uppermost Paleozoic rocks are exposed in many places just outside the western border of the study area, where the Kaibab Limestone forms the surface of the East Kaibab monocline, and in a few erosional windows and a fault block along House Rock and Coyote Valleys. The Kaibab is just below the surface along the east side of the area and crops out in a few places along the road that marks the boundary of the study area.

Mudstones and siltstones of the Moenkopi and Chinle Formations predominate in the lower two-thirds or so of the Triassic rock section, forming the foothills and lower slopes of the Vermilion Cliffs. Only the basal Shinarump Member of the Chinle forms a persistent and resistant unit that forms a marked bench that protects the underlying Moenkopi from erosion. The overlying Moenave and Kayenta Formations form the lower part of the steep to vertical cliffs and are the earliest units of the great sandpile

Table 1.--Columnar section of the sedimentary rocks underlying the Vermilion Cliffs-Paria instant study

area, Coconino County, Arizona, and Kane County, Utah

[Based on Phoenix (1963) and Green and others (1977)]

Holocene and Pleistocene(?)	No formal names		15+ <u>m</u>	Alluvial fan and terrace gravels, windblown and reworked sands, torva blocks and landslide debris, talus, stream gravels, and alluvium	Terraces, cones, dunes, hummocks, lobate tongues, valley bottoms
Pleistocene and Pliocene(?)	No formal name		1-2 m	High-level terrace gravels, containing exotic rocks	Terrace remnants
Late Cretaceous	Dakota Sandstone		30+ <u>m</u>	Conglomerate and coarse-grained sandstone below ripple-bedded sandstone and laminated siltstone, thin coaly seams	Ledges, short slopes, mesa tops
Middle Jurassic	San Rafael Group	Entrada Sandstone	200 m	Sandstone, massive, pale-gray, medium- to fine-grained, crossbedded	Bluffs
		Carmel Formation	125 m	Mudstone, red-brown to gray-green; silty limestone and siltstone, red, calcareous; red and red-brown sandstone and siltstone; crossbedded, pale-brown and white	Ledges, slopes
		Thousand Pockets Tongue 1/	0-70 m	Sandstone, massive, pale-yellow, medium- to fine-grained, crossbedded	Broad slopes
		Judd Hollow Tongue	0-10 m	Sandstone and siltstone, dark-brown to pale-gray, evenly bedded	Ledges
Early Jurassic and Late Triassic(?)	Glen Canyon Group	Navajo Sandstone	510-565 m	Sandstone, shades of gray to red-brown and orange, massive, sweepingly crossbedded in places, few lenses of dark-brown chert	Nipples, buttes, high sheer cliffs
		Kayenta Formation	35-90 m	Sandstone, pale-red-brown, massive, crossbedded and evenbedded, and alternating sandstone and siltstone, ripple marked	Benchs and ledges, cliffs
Late Triassic(?)	Moenave Formation	Springdale Sandstone Member	50-70 m	Sandstone, red, massive, darkly stained, broadly lenticular beds	Cliffs
		Dinosaur Canyon Sandstone Member	25-70 m	Sandstone, red-orange, flat-bedded, siltstone, varicolored, and mudstone, varicolored	Ledges, steep slopes
Late Triassic	Chinle Formation	Owl Rock Member	45-60 m	Limestones, cherty, conglomeratic, nodular; sandstone, siltstone, clayey mudstones, dark-red, nonbentonitic	Cliffs and slopes
		Petrified Forest Member	180-240 m	Mudstone and claystone, variegated yellow, pink, green, and blue, bentonitic; some siltstone, sandstone, and limestone pebble conglomerate	Smooth, rounded "popcorn" slopes
		Unnamed unit	0-50 m	Sandstone, arkosic, crossbedded, light-colored and silty mudstone, dark-red, gray, gray-green. Dies out westward. Fossil logs.	Ledges, steep slopes
		Shinerump Member	0-45 m	Conglomeratic sandstone and conglomerate, lenticular, crossbedded, light-gray to pale-brown, fills channels, organic trashy fossil logs, uraniferous, cupriferous	Prominent bench and ledges
Middle(?) and Early Triassic	Moenkopi Formation	Upper Red Member	20-35 m	Limy siltstone, mudstone, silty claystone, micaceous, thin limestone in east; sandstone, massive, pale-brown, makes "marker" bed near base	Cliffs and steep slopes
		Shnabkaib Member	0-5 m	Clayey siltstone, micaceous, gypsiferous, thin-bedded, uniform light-gray to light-gray-green, noncalcareous	Steep slopes
		Middle Red Member	95-200 m	Siltstone and mudstone, micaceous, gypsiferous, uniform pale-red-brown, noncalcareous, thin-bedded, ripple marked	Concave slopes
Early Permian	Kaibab Limestone		120+ <u>m</u>	Upper third: limestone, cherty, dolomitic; dolomite, siltstone; calcareous sandstone; tan and light-gray, fossiliferous. Lower two-thirds: dolomite, cherty; limestone, dolomitic; sandstone; alternating sequence, white to grayish-yellow, fossiliferous	Cliffs and benches
	Toroweap Formation		35+ <u>m</u>	Upper part interbedded, white and light-grayish-yellow, fine-grained, crossbedded sandstone, dark-red silty mudstone and siltstone, light-gray, cherty limestone; somewhat wavy bedding	Cliffs

1/ A member of the Page Sandstone which intertongues with the Carmel Formation.

that extends into and through the Jurassic sedimentary cycle in this part of the Colorado Plateau. The thickest single unit in the stratigraphic section is the Navajo Sandstone (more than 500 m--1,700 ft) which forms the massive, crossbedded upper part of the Vermilion Cliffs and which caps the Paria Plateau and large areas of the benches to the north.

Jurassic rocks (members of the Carmel Formation) are present only as remnants on small buttes on the Paria Plateau, but north of Kaibab Gulch and Paria River they include the Entrada Sandstone and occur in increasing thickness and area of coverage, extending north beyond the boundary of the study area. Basal Cretaceous rocks (Dakota Sandstone) crop out as remnants on small buttes only in the northeastern part of the study area--but younger units are abundant to the north of the boundary.

Quaternary sediments are widespread throughout the study area, but in a few places in the northwestern part of the area, west of Paria River, there are high-level consolidated gravels (Pliocene(?) conglomerate according to Olson, 1957), that may be of Late Tertiary or Early Quaternary age. Other high-level uncemented gravels are present in the northeastern part of the area; these appear to be younger than the cemented gravels, but still may be as old as Late Tertiary. The Quaternary deposits include alluvial fans, pediment gravels, talus, eolian sand dunes and sand blankets, stream gravels, and landslide debris, including classic examples of rotational slump (toreva) blocks (Reiche, 1937) and rockslides. Most of these deposits still are being formed--the pediment gravels are not.

The rocks of the study area are relatively undeformed; in the Paria Plateau they make a structural terrace that dips gently to the north and northeast, bordered on the west by the east-dipping East Kaibab monocline and on the east by the similarly east-dipping Echo Cliffs monocline (pl. 1). The

valleys of House Rock Wash and Coyote Wash bordering the Plateau follow the synclinal bend of the East Kaibab monocline and the chain of normal faults (mostly east side down) along the bend. Structural relief is more than 1,200 m (4,000 ft) between the crest of the monocline and the flat-lying rocks of the Plateau; at most, only about 100 m (325 ft or so) of the displacement is due to the fault system. At the eastern side of the study area the effects of the Echo Cliffs monocline can be seen only in the northeast corner, where the lower course of the Paria River approximately follows the up-structure side of the anticlinal bend of the monocline. This bend, too, is marked by steep normal faults, about equally east side down or up, with displacements of only a few meters. Structural relief across this part of the Echo Cliffs monocline is about 750 m (2,450 ft).

The rocks of the Plateau and the benches to the north are so gently warped and structural control is so sparse that the validity of the broad, ill-defined folds shown on the geologic map is quite low. There is reasonable certainty of the generally north-trending, north-plunging syncline in the east part of the Plateau, but it loses much of its definition north of Paria Canyon. The small anticline and syncline in the southwest quarter of the Plateau are less certainly identified, as the only valid control points are in a single line along the escarpment. No precise attitudes are available for the rock beneath most of the Plateau--and projection of attitudes and formation contact altitudes must be made over hundreds to thousands of meters horizontally and over hundreds of meters vertically. Even the areal variation in thickness of the Navajo Sandstone, the primary unit used for structural control, is known only poorly.

Steep, normal faults with lengths up to about 13 km (8 mi) and displacements of a few meters to less than 100 m (300 ft or so) occur in three

general areas: (1) the House Rock Wash-Coyote Wash belt; (2) a broad belt extending southeasterly from West Clark Bench through Bridger Point to Horse Ridge in the northeast corner of Paria Plateau; and (3) a band along the anticlinal bend of the Echo Cliffs monocline that broadens southwesterly between Lees Ferry and Marble Canyon.

The faults generally have little topographic effect on the Plateau and Bench surfaces, where most of the surface consists of the homogeneous Navajo Sandstone, masked by thin soils and extensive eolian sand. Along the walls of Paria Canyon, tributary drainages do follow the northwest-trending faults and a parallel joint system. In detail the course of Kaibab Gulch through "the Dive" and of Paria River below the Kaibab Gulch confluence is largely controlled by a set of easterly and north-northwesterly trending joints. On upland surfaces the faults can be identified mostly where remnants of the Carmel Formation are offset where it caps small buttes. Some fault segments may be part of a longer fault, but the continuity is masked by surficial deposits.

MINING ACTIVITY

By Michael E. Lane, U.S. Bureau of Mines

Most mining activity has taken place for uranium along the Vermilion Cliffs in the Chinle Formation. In this area there are a few old mines, the largest being the Sun Valley mine located southwest of Cliff Dwellers Lodge. There also are a few scattered prospects in Paria Canyon and in the northern portion of House Rock Valley (see descriptions below). The only known current activity is some sporadic exploration at the Sun Valley mine.

In addition to the uranium activity, prospecting and mineral resource investigations were conducted for gold and mercury occurrences in a mudstone unit of the Chinle formation (Phoenix, 1963). These investigations suggested that gold, and possibly mercury, occur in minute, but widespread, quantities in the Paria Canyon-Lees Ferry area.

Prior to 1913, attempts were made to recover gold at Lees Ferry which were evidently unsuccessful (Lawson, 1913). In 1957, attempts were made to recover gold about 10 km (6 mi) up Paria River (Phoenix, 1963). No evidence of recent prospecting was found during field investigation.

FACTORS AFFECTING MINERAL RESOURCE ASSESSMENT

By Alfred L. Bush, U.S. Geological Survey

The following sections are concerned almost entirely with geologic factors (lithologic and stratigraphic); geochemical associations are noted, but they do not have much effect on the resource assessment because the data points do not give a good geographic coverage of the rocks of the area. Pertinent sites (pl. 2) form a fence or necklace around the Paria Plateau and part of the northern benches--they give no clues as to what may lie under the Navajo Sandstone caprock. The sediment samples on the Plateau and on the benches represent mostly the upper part of the Navajo Sandstone, with a small contribution in some places from the members of the Carmel Formation. These are not the units that carry the uranium or gold occurrences, and except for one copper occurrence they appear to be barren in the area. In essence, the geochemical sampling program is of little value in assessing the mineral resource potential. Geophysical data is virtually lacking. No detailed surveys (scale 1:125,000 or larger) of any type have been made. The area has been covered in whole or in part at much smaller scale (1:250,000 to 1:2,500,000), but at these scales the data is not appropriate for this mineral resource assessment. (See Zietz and Kirby, 1967, 1968a, 1968b; Zietz, Shuey and King, 1976; LKB Resources, 1979; Geodata International, 1980.)

Uranium-copper-silver deposits

Thickness, porosity, permeability, and to some extent mineralogic composition are prime factors relating to favorability for ores of the metallic elements in the study area. Uranium, copper, small amounts of vanadium, and in some places silver characteristically occur together in channel-filling, coarse clastic sediments of the Shinarump Member (basal member) of the Chinle Formation. These sediments are commonly rich in organic

debris (for an example, see Petersen, 1960). Mineralized rock forms stratabound deposits most commonly localized in conglomeratic sandstone and medium- to coarse-grained sandstone at or near bends in channels cut in the underlying Moenkopi Formation. Thick channel sands and thicker parts of thin sands are usually favorable host rocks. Although channel sands in the middle and upper parts of the Shinarump Member are not devoid of uranium-copper mineralization, basal channel sands (filling channels cut in the Moenkopi) are far more likely to be productive. The channels served as conduits for the ore-bearing solutions, and the organic debris associated with the coarse sediments probably provided a reducing environment that triggered ore mineral deposition. Similar lithologic and hydrologic conditions are present in some lenticular sandstone and conglomeratic sandstone bodies in the unnamed unit and in the Petrified Forest Member of the Chinle; uranium and copper, usually without silver, occur locally in these units. Discrete channels are not as prevalent, as well defined, nor as well developed, and the uranium-copper occurrences are small.

Although relative permeability and porosity are among the controlling factors in determining the amount and rate of movement of ore solutions through the rocks, there are no absolute data comparing the capacities of ore-bearing rock and barren rock. In a general way, moderately well sorted rocks appear to be the most favorable hosts for uranium-copper-silver mineralization.

An exceptional occurrence is at the Sun Valley Mine, where rhenium is associated with uranium and molybdenum, in amounts ranging from 0.005 to 0.07 percent (Petersen, Hamilton, and Myers, 1959). No similar associations are known elsewhere on the Colorado Plateau. A single virtually uranium-free copper occurrence is in the upper part of the Navajo Sandstone on the Paria

Plateau, a few feet below the Judd Hollow Tongue of the Carmel Formation (at White Pocket, sec. 17, T. 41 N., R. 5 E. (Wells, 1960)). Molybdenum accompanies uranium and copper in some deposits (as at the Sun Valley Mine). It is more prevalent in deposits in the Petrified Forest Member than in the Shinarump Member.

Gold and mercury deposits

Small amounts of gold, ranging from barely detectable to about 40 ppb, occur in 42 of 46 widely distributed samples in the Petrified Forest Member (mostly below the middle) and in the underlying unnamed unit of the Chinle Formation. The other four samples may contain gold in amounts below the detection limit (a less sensitive technique was used than for most other samples). Mercury, first reported by Lausen (1936), occurs in 32 of these 46 samples, in similarly low concentrations (150 ppb or less, with one exception of 1.1 ppm). Mercury was absent in seven of the samples and was not looked for in seven other samples.

Small amounts of gold have also been found in the Shinarump Conglomerate Member; 19 samples taken to determine copper and uranium content showed measurable gold in 6 cases (2-6 ppb) and detectable gold in 5 other cases. Mercury was not sought in these samples. Gold also was found in one sample of the Moenkopi; mercury was not sought in this sample.

These gold occurrences in the Chinle and Moenkopi have been known since early in the 1900's. Lawson (1913) reported their values to range up to 12.5 cents per ton (gold was then \$20/oz) in three sampled sections near Paria, Utah, less than 20 km (12 mi) north of the study area. Of the 63 samples discussed by Lawson, 35 had measurable gold, 25 had a trace, and 3 were barren. Of the 58 samples analyzed in the present investigation, 26 had measurable gold (2 to 50 ppb), 28 had a trace, and 4 were barren. Lawson's

samples came from sections across the whole Petrified Forest Member, but at only three sites in an area of about $1\frac{1}{2}$ km² (1 sq mi). The present study's samples represent only a small part of the potentially gold-bearing rocks at any one site but are from 35 sites along a sample band about 95 km (60 mi) long. These diverse sampling procedures support the conclusion that this part of the Chinle Formation is gold bearing throughout a very large region. Lawson (1913) also reported gold in the "Permian shales" (Triassic Moenkopi Formation) below the Shinarump; of 14 samples, 7 showed measurable gold and 6 had trace values.

The gold of the Chinle occurs as "a very rare constituent of the heavy-mineral suite * * * as tiny flakes associated with magnetite, ilmenite, rutile, garnet, and zircon" (Phoenix, 1963). A number of attempts have been made to recover the gold in the Lees Ferry area, the most recent known effort being in 1957. The amalgamation methods used in the past have all been unsuccessful--or at least uneconomic; and even with the price of gold at \$700 per ounce, which would make 40 ppb gold worth \$0.80/ton, production probably would be uneconomical using present technology.

The mineralogic habit of the mercury has not been defined. It is present in most of the gold-bearing samples where looked for, and with a more sensitive analytical method might be found in those apparently barren at the 10 ppb lower limit of the Au-Hg film analytical technique.

Nonmetallic deposits

The rocks of the upper part of the Kaibab Limestone have been tested for suitability for cement, but are too siliceous and too high in MgCO₃ (McKee, 1938, p. 62-66; Kiersch, 1955, p. 15). They are suitable for use as agstone (Kiersch, 1955, p. xii) and road metal, but because of their substantial chert content may be too reactive to use as concrete aggregate. They may not be

sufficiently resistant to abrasion to use as top dressing in asphalt road mat. Large quantities are readily available as the Kaibab is at or close to the surface along both the east and west sides of the study area.

The Middle Red Member of the Moenkopi Formation (and to some extent the Upper Red Member) contain flagstone and blocky sandstone beds suitable for use in construction. Large quantities are available, and in general, access to the area is good, but suitable beds may be a few meters to several tens of meters above the general surface level, cropping out in steep cliffs. Gypsum in thin layers and crosscutting veinlets, and disseminated as gypsiferous mudstone, is common in the Moenkopi Formation, particularly on the east side of the Paria Plateau. It is particularly conspicuous in the upper part of the Middle Red Member in the vicinity of Cliff Dwellers Lodge and for some distance to the south and west. Nowhere, however, can it be considered a resource.

The Petrified Forest Member of the Chinle Formation is dominantly bentonitic and contains some nearly pure bentonite layers (Wilson and Keller, 1955). Overall, a large volume of bentonite is probably available, but the generally thin individual layers may be difficult to mine profitably. Access is somewhat difficult in most places, as the Petrified Forest Member's outcrop area in most of the study area is above steep cliffs and narrow benches of the Moenkopi Formation and the Shinarump Conglomerate.

Deposits of gravel suitable for construction purposes are found along some of the present stream courses, but in small amounts. Gravels weathered from the Shinarump Conglomerate Member of the Chinle Formation are common on the pronounced bench below the east side of the Paria Plateau, but the deposits are very thin. Old gravel deposits, related to earlier stream courses, are found on the Plateau and some of the benches north of Paria River. Most of them are relatively inaccessible, and the overall resource potential is low.

Organic fuels

There has been no oil or gas production from the study area, but within 75 kilometers (about 45 mi) rocks continuous or correlative with those present in the study area have either produced or had shows of live or dead oil. Oil has been produced from the Moenkopi and Kaibab at the Upper Valley field in Utah (Peterson, 1973), about 70 km (43 mi) to the north and from the Moenkopi Formation at the Virgin Field in Utah, about 50 km (30 mi) to the west (Campbell and Bacon, 1976). More than a dozen wells have been drilled to the west in the Arizona Strip; the Shnabkaib, Virgin Limestone, and Timpoweap Members of the Moenkopi, the Kaibab Limestone, Toroweap Formation, and Coconino Sandstone all have live or dead oil shows, and helium has been reported from several zones in one well (Heylmun, S. B., written commun., Dec. 11, 1979).

Eastward from the western Arizona Strip toward the Black Mesa Basin and the Four Corners area, stratigraphic facies changes are marked in the Triassic and Permian rocks, less so in the older Paleozoic rocks. Facies changes from marine to strandline and lagoonal conditions might result in stratigraphic traps in the Permian rocks in the study area (Kaibab, Toroweap, Coconino)--the Toroweap, for example, becomes much sandier eastward (Swapp, C. W., oral commun., Oct. 24, 1979; Heylmun, E. B., written commun., Dec. 11, 1979). Drill-hole data are scarce in the vicinity of the study area, and drilling depths are increased by several thousand feet under the Paria Plateau and the benches to the north. The possibility of oil and gas cannot be ruled out, but there is insufficient data for a reliable appraisal.

Although thin coal beds (0.5 m--1 to 2 ft) are present in the Dakota Sandstone, outcrop remnants are so small and thin that the coal is not a significant resource.

Water

From a local standpoint the most significant resource is water. Ground water below the Plateau and the northern benches occurs in the Navajo Sandstone and the Kayenta and Moenave Formations. Perennial springs of low to moderate flow occur at the contacts in many reentrants into the Vermilion Cliffs and in places along the lower reaches of Paria River (pl. 1). Although flow measurements are generally lacking, the volume is adequate to support a number of ranches, homes, and tourist accommodations. The water commonly is piped 5 to 8 miles.

In places on the Paria Plateau rainwater collects in limited quantity in deposits of loose sand and is protected from rapid evaporation. Ephemeral springs form at favorable low spots, or water can be gotten from shallow wells (a few meters deep). Ground water in the Navajo and lower rocks also can be recovered, but drill depths of 400 to 700 m would likely be needed, and the quantity available is uncertain.

MINING DISTRICTS AND MINERALIZED AREAS

By Michael E. Lane, U.S. Bureau of Mines

Mining districts and claims

No formal mining districts were established in the study area. Mineral resource literature and courthouse records of mining claims refer variously to Paria Canyon, Vermilion Cliffs, and Lees Ferry (see selected references).

One group of mining claims is currently within the study area (pl. 3). In the 1950's, a large number of claims were located on outcrops of the Chinle Formation in House Rock Valley, Vermilion Cliffs, and for about 16 km (10 mi) up Paria Canyon from Lees Ferry.

Past and present mining activity and production

Attempts were made about 1913 to recover gold at Lees Ferry but were unsuccessful. Additional attempts to recover gold were made about 1957 at a location about 9.6 km (6 mi) up Paria River from Lees Ferry. Several uranium mines operated in the 1950's and are described in the following paragraphs.

El Pequito mine

The El Pequito mine is about 3.2 km (2 mi) west of Lees Ferry in the NW1/4 section 14, T. 40 N., R. 7 E. (pl. 3, samples 3-16). It lies on the eastern edge of the study area at the base of the Vermilion Cliffs.

The El Pequito mine is in the Shinarump Member along the Moenkopi contact. Mineralization occurs in an old stream channel in the Shinarump. The channel is composed of poorly sorted conglomerate interbedded with sandstone and siltstone with local carbonaceous wood fragments.

Pebbles and sand grains in the channel are coated with ore minerals which also locally impregnate mudstone. The channel is spoon shaped and is most likely an offshoot of a larger channel. The Moenkopi is bleached below the Shinarump contact (Phoenix, 1963).

Phoenix reports the occurrence of pyrite, chalcopyrite, and uraninite in calcite veinlets, and also reports that several tons of ore were shipped. No pyrite or chalcopyrite was seen during the field investigation.

Attempts have been made to recover gold at Lees Ferry but were unsuccessful. Additional attempts to recover gold were made at a location about 9.6 km (6 mi) up Paria River from Lees Ferry. Several uranium mines operated in the 1950's and are described in the following paragraphs.

A map of the mine showing sample locations and assay results is shown in plate 3.

Sam prospect

The Sam prospect is in SE1/4 section 2, T. 39 N., R. 6 E. (pl. 3, samples 17-18), about 3.2 km (2 mi) northwest of Cliff Dwellers Lodge. The prospect is an adit 8.2 m (27 ft) long on the south side of Badger Canyon.

The adit is in the upper part of the Petrified Forest Member of the Chinle Formation. This unit is a slope-forming, gray to purple siltstone weathered to slopes and rounded knobs. At the prospect the rock is interbedded siltstone and mudstones. Two samples were taken at this location. One sample, a 0.8 m (2.5 ft) chip, contained 0.337 percent U_3O_8 , 0.14 percent vanadium, and 5.6 parts per million (ppm) mercury. The other sample, a 1.5 m (5.0 ft) chip, contained 0.026 percent U_3O_8 and 0.007 percent vanadium.

Jasper mine

The Jasper (Maggie) mine consists of a 12.2-m (40-ft) adit, situated in the SW1/4 section 27, T. 39 N., R. 6 E. (pl. 3, samples 19-23), about 91 m (300 ft) north of U.S. 89A about 0.4 km (1/4 mi) east of Cliff Dwellers Lodge.

The adit was driven at N. 6° E. in poorly sorted Shinarump Conglomerate composed of rounded quartzite pebbles and quartz sand. Siltstone is

interbedded with mudstone on the walls near the floor. This is most likely the Moenkopi Formation contact. There is minor copper staining at this location. The mudstone and siltstone comprise the lower 74 cm (29 in.) of the wall and conglomerate the upper 91 cm (36 in.). Sample 19, taken in the mudstone and siltstone, contains 0.018 percent U_3O_8 , but sample 20 taken directly above in the conglomerate contained no U_3O_8 . Two samples were taken 3.1 m (10 ft) from the portal on the east wall. Sample 21 contained 0.019 percent U_3O_8 and was taken in indurated conglomerate above the siltstone in the lower portion of the wall. Sample 22 was taken above 21 in poorly consolidated conglomerate and contained 0.135 percent U_3O_8 . Here, the conglomerate was composed of poorly sorted quartz and quartzite pebbles, small siltstone lenses, and some copper staining. Sample 23 was taken outside the adit adjacent to the portal, in the Moenkopi just below the contact. The sample assayed 0.085 percent U_3O_8 .

Sun Valley mine

The Sun Valley uranium mine is approximately 3.2 km (2 mi) southwest of Cliff Dwellers Lodge and about 1.6 km (1 mi) north of U.S. Highway 89A (pl. 3, samples 24-47). It lies near the southeastern boundary in the southernmost portion of the study area.

At the time of the study the mine was owned and operated by Intermountain Exploration Company. The immediate area is covered by the Jay Bird claim group; none of the claims are patented. There are also some millsites near Soap Creek (D. R. McGregor, 1977, unpublished report in the files of Intermountain Exploration Company).

The mine was started in 1954 during a period of intense uranium exploration in the area. An incline shaft was sunk on a Shinarump outcrop to develop a small ore deposit. Several hundred tons of uranium ore, averaging

0.28 percent U_3O_8 , was shipped before the shaft was filled with mud from a flash flood. Later, a vertical shaft was sunk and a drift was driven to connect with the old, sand-filled workings, but there was no further production (R. V. Wyman, 1970, unpublished report in the files of Intermountain Exploration Company).

The mine is situated on the Shinarump-Moenkopi contact where uranium mineralization occurs along a U-shaped Shinarump stream channel. The upstream and downstream portions are under the heavy cover of Vermilion Cliffs to the northwest.

Mineralized rock is irregularly distributed through the deposit. The highest U_3O_8 content of samples taken at the mine was 0.216 percent (sample 41 taken in the old workings). Uranium analyses of all samples taken at the mine are shown on plate 3. Four samples contained between 2 and 26 ppm rhenium. These quantities are not considered economically significant under present conditions.

Intermountain Exploration Company has done some drilling to determine possible extent of mineralization. Drilling has produced values as high as 1.6 percent U_3O_8 in one hole, and several holes showed more than 0.2 percent U_3O_8 .

A potential ore body exists in the Sun Valley mine area, but with the present data its relationship to the study area cannot be determined.

Red Wing prospect

The Red Wing prospect consists of two adits, 13 m (43 ft) and 17 m (55 ft) in length, in section 3, T. 40 N., R. 7 E. (pl. 3, samples 72-76). The property is in Paria Canyon about 6.4 km (4 mi) upstream from Lees Ferry.

The adits were driven in the lower Shinarump Member and upper Moenkopi Formation along the contact. The Shinarump is composed of trashy stream

channel material of sandstone, siltstone, and carbonaceous matter.

Radioactivity measurements ranged very widely. The Moenkopi at this location is typical maroon-colored siltstone with bleached areas.

Unnamed prospect

Two unnamed adits are located in SE1/4 section 2, T. 40 N., R. 7 E. These consist of a very short adit and a 9.8-m (32-ft) adit. The larger adit was the only one containing significant mineralization (0.033 percent U_3O_8). This adit contained some carbonaceous material which gave the highest geiger counter readings. The drift was in a thinly bedded siltstone over sandstone.

The short adit was in maroon and gray mudstone. The back appeared to be the bottom of a stream channel containing sandstone boulders. Very little mineralized rock was found.

Reserves

No reserves of uranium, gold, or mercury can be postulated for the study area with data presently available.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

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Overall, the Vermilion Cliffs-Paria Canyon Instant Study Area has a low mineral resource potential. A number of metallic mineral deposits (uranium-copper-vanadium-silver and gold-mercury) are present, and others of the same type undoubtedly can be found, but the prospect for discovery of other types of deposits is low. There is potential for uranium production in the area, but drilling would be needed to provide data for outlining ore and for reserve calculations. Probably all (certainly most) U-Cu-V-Ag deposits that crop out were discovered during a period of intensive prospecting during the early and mid-50's. Only two deposits have yielded ore, the larger several hundred tons. Similar deposits can be expected below the Paria Plateau, where they will be 600 m (2,000 ft) or more below the surface, but the density of distribution is likely to be lower as the Shinarump Conglomerate host rock, which thins and becomes discontinuous from east to west in outcrop around the Plateau, probably does so below the Plateau as well. Prospects for production from these deposits is virtually nil. The areas of restricted potential for additional deposits are shown on figure 1.

Gold-mercury potential is low, for although a large part of the Chinle Formation is gold bearing and has a small mercury content as well, the grade is very low, ranging up to about 40 ppb Au, and because of the minute size of the gold particles, recovery is difficult. Gold in the 40 ppb range is worth about \$0.80/ton at a \$700/oz price, making recovery uneconomical. There is virtually no potential for mercury resource at the very low concentrations indicated--generally below 150 ppb.

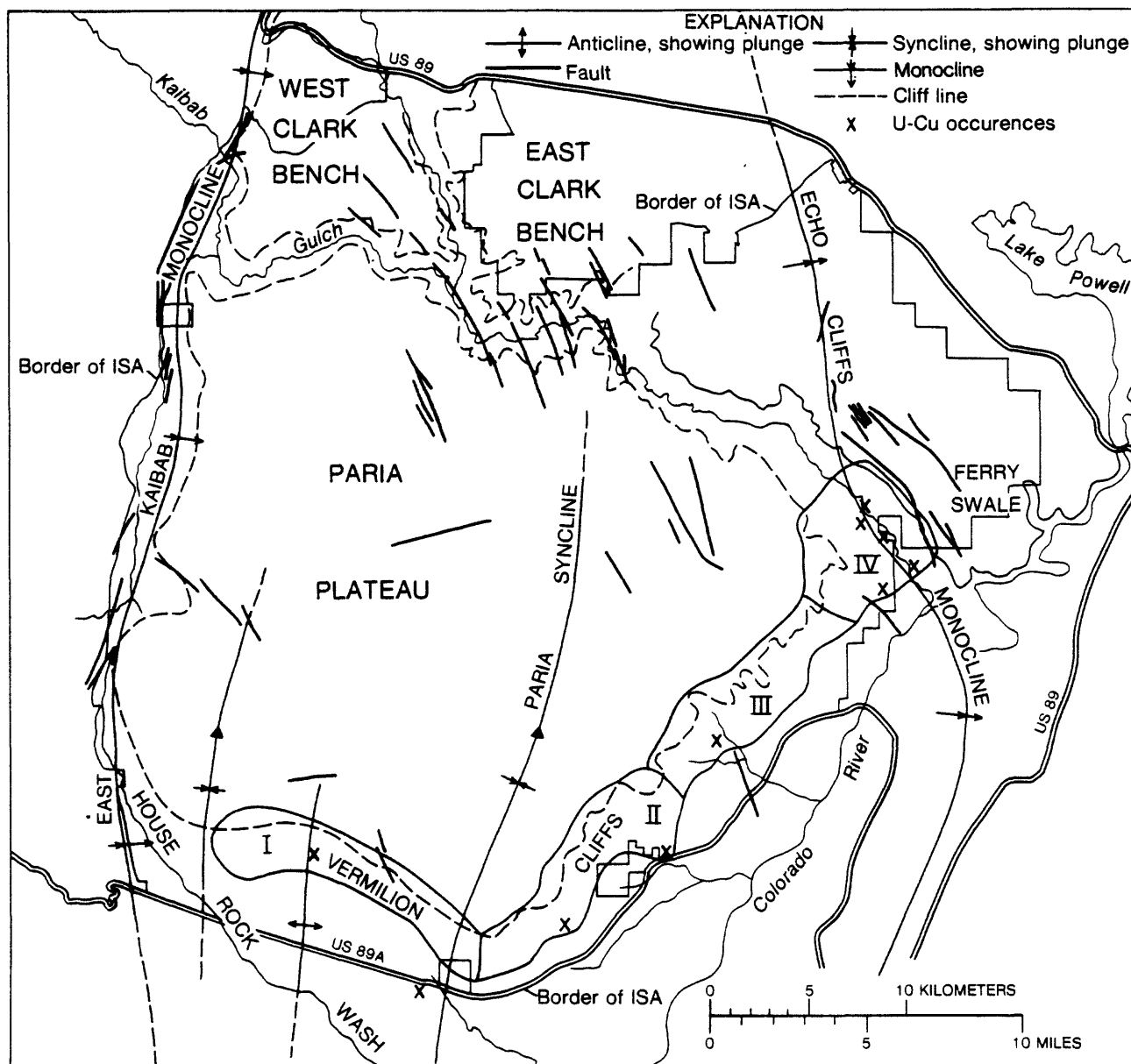


Figure 1.--Sketch map of the Vermilion Cliffs-Paria Canyon Instant Study Area (ISA) showing the major folds and trends of faults, location of the uranium-copper-vanadium-silver occurrences, and the areas of restricted potential for the discovery of similar deposits. I - Jacob Pools-Emmett Wash area; II - Sun Valley-Soap Creek area; III - Badger Creek-Cathedral Wash area; IV - Johnson Point-Paria River area.

There is a significant mineral resource in the limestone of the Kaibab Limestone for use as road metal and possibly as agstone. Large amounts are available, access is good, the rock is at or near the surface, but the market is local. Large amounts of suitable rock are available much nearer any of the marketing centers within 150 km of the study area. Flagstone and building stone in large quantities are available from the Middle Red Member (and to a lesser extent from the Upper Red Member) of the Moenkopi Formation. Again, the market is strictly local. The bentonite beds of the Petrified Forest Member of the Chinle Formation do not represent a significant resource--they tend to be thin and discontinuous and they are difficult of access, cropping out on the lower slopes of the Vermilion Cliffs. Gypsum occurring in the Moenkopi Formation has no resource potential.

Oil and gas prospects are difficult to assess with any assurance, but the most likely possibilities appear to be in stratigraphic traps, fairly deeply buried, in a low reservoir pressure province. The potential would have to be rated as low.

Water resources are locally very important. Ground water below the Paria Plateau (in the Navajo Sandstone and Kayenta and Moenave Formations) supports a number of springs of small to moderate flow along the Vermilion Cliffs. That water would be available to deep wells (400-700 m range) from the Plateau surface, but its quantity is uncertain. Perched water bodies, as in sand deposits on the Plateau, may supply water to shallow drilling, but are likely to be intermittent sources and of limited quantity.

SELECTED REFERENCES

- Babenroth, D. L., and Strahler, A. N., 1945, Geomorphology and structure of the East Kaibab monocline, Arizona and Utah: Geological Society of America Bulletin, v. 56, no 2, p. 107-150.
- Brown, S. C., and Lauth, R. E., 1963(?), Northeastern Arizona--its oil, gas, and helium prospects, in Oil, gas, and helium in Arizona--its occurrence and potential: Arizona Development Board for Arizona Oil and Gas Commission, p. 7-21.
- Bryan, Kirk, 1923, Wind erosion near Lees Ferry, Arizona: American Journal of Science, 5th ser., v. 6, p. 291-307.
- Campbell, J. A., and Bacon, R. S., 1976, Penetration chart of Utah oil and gas fields: Utah Geological and Mineralogical Survey, Oil and Gas Field Studies no. 14.
- Geodata International, Inc., 1980, Aerial radiometric and magnetic surveys, Escalante national topographic map, Arizona and Utah: Grand Junction, Colo., U.S. Department of Energy Open-File Report GJBX-15(80), 45 p.
- Green, M. W., Pierson, C. T., Bauer, D. P., and Umshler, D. B., 1977, A summary of the geology and mineral resources of the Paria Plateau-House Rock Valley area, Coconino County, Arizona: U.S. Geological Survey Open-File Report 77-737, 19 p.
- Gregory, H. E., 1948, Geology and geography of central Kane County, Utah: Geological Society of America Bulletin, v. 59, p. 211-247.
- Hackman, R. J., and Wyant, D. G., 1973, Geology, structural, and uranium deposits of the Escalante quadrangle, Utah and Arizona: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-744.

- Haynes, D. D., and Hackman, R. J., 1978, Geology, structure and uranium deposits of the Marble Canyon 1°x2° quadrangle, Arizona: U.S. Geological Survey Miscellaneous Investigations Map I-1003.
- Kiersch, G. A., 1955, Nonmetallic minerals--geology, evaluation, and uses, v. 2 of Mineral resources, Navajo-Hopi Indian Reservations, Arizona-Utah: Tucson, Arizona University Press, 105 p.
- LKB Resources, Inc., 1979 [1980], NURE aerial gamma-ray and magnetic reconnaissance survey, Colorado-Arizona area, Marble Canyon NJ 12-11 quadrangle; Grand Junction, Colo., U.S. Department of Energy Open-File Report GJBX-16(80), v. 1, 72 p.; v. 2, 75 p.
- Lausen, Carl, 1936, The occurrence of minute quantities of mercury in the Chinle shales at Lees Ferry, Arizona: Economic Geology, v. 31, p. 610-617.
- Lawson, A. C., 1913, The gold of the Shinarump at Paria: Economic Geology, v. 8, p. 434-448.
- Marshall, C. H., 1956, Photogeologic map of the Jacob Lake NE quadrangle, Coconino County, Arizona: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-194.
- McKee, E. D., 1938, The environment and history of the Toroweap and Kaibab Formations of northern Arizona and southern Utah: Carnegie Institute Washington, Publication 492, 268.
- McQueen, Kathleen, 1958, Photogeologic map of the Paria SE quadrangle, Kane County, Utah, and Coconino County, Arizona: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-265.
- Miller, V. C., 1950, Pediments and pediment-forming processes near House Rock, Arizona: Journal of Geology, v. 58, no. 6, p. 634-645.

- Minard, J. P., 1957, Photogeologic map of the Buckskin Gulch SE quadrangle, Kane County, Utah, and Coconino County, Arizona: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-260.
- Olson, A. B., 1957, Photogeologic map of the Paria SW quadrangle, Kane County, Utah, and Coconino County, Arizona: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-263.
- Patten, L. L., 1968, The occurrence of gold in the Chinle Formation of southern Utah and northern Arizona: U.S. Bureau of Mines Heavy Metals Program Situation Report (Interim)-41.
- Pierce, H. W., Keither, S. B., and Wilt, J. C., 1970, Coal, oil, natural gas, helium, and uranium in Arizona: Arizona Bureau of Mines Bulletin 182, p. 81-86, 119, 180-182, 194-195, 217-218.
- Petersen, R. G., 1959, Preliminary geologic map of the Emmett Wash NE quadrangle, Coconino County, Arizona: U.S. Geological Survey Mineral Investigations Field Studies Map MF-215.
- _____, 1960, Detrital-appearing uraninite grains in the Shinarump Member of the Chinle Formation in northern Arizona: Economic Geology, v. 55, no. 1, p. 138-149.
- _____, 1961, Preliminary geologic map of the Paria Plateau SE quadrangle, Coconino County, Arizona: U.S. Geological Survey Mineral Investigations Field Studies Map MF-196.
- Petersen, R. G., Hamilton, J. C., and Myers, A. T., 1959, An occurrence of rhenium associated with uraninite in Coconino County, Arizona: Economic Geology, v. 54, no. 2, p. 254-267.
- Petersen, F. G., and Phoenix, D. A., 1959, Preliminary geologic map of the Paria Plateau NE quadrangle, Coconino County, Arizona: U.S. Geological Survey Mineral Investigations Field Studies Map MF-214.

- Petersen, R. G., and Wells, J. D., 1961, Preliminary geologic map of the Emmett Wash NW quadrangle, Coconino County, Arizona: U.S. Geological Survey Mineral Investigations Field Studies Map MF-197.
- Peterson, P. R., 1973, Upper Valley field: Utah Geological and Mineralogical Survey, Oil and Gas Field Studies No. 7, 4 p.
- Phoenix, D. A., 1963, Geology of the Lees Ferry area, Coconino County, Arizona: U.S. Geological Survey Bulletin 1137, 86 p.
- Reiche, Parry, 1937, The Toreva-block--a distinctive landslide type: Journal Geology, v. 45, p. 538-548.
- Swapp, C. W., 1962(?), The geology and gas and oil possibilities of northwestern Arizona, in Oil, gas and helium, in Arizona--its occurrence and potential: Arizona Development Board for Arizona Oil and Gas Commission, p. 34-41.
- Strahler, A. N., 1940, Landslides of the Vermilion and Echo Cliffs, northern Arizona: Journal of Geomorphology, v. 3, no. 4, p. 285-300.
- Wells, J. D., 1960, Stratigraphy and structure of the House Rock Valley area, Coconino County, Arizona: U.S. Geological Survey Bull. 1081-D, p. 117-158.
- Wilson, R. L., and Keller, W. D., 1955, Clay minerals, in Kiersch, G. A., Mineral resources, Navajo-Hopi Indian Reservations, Arizona-Utah, v. 2, Non-metallic minerals--geology, evaluation, and uses: Tucson, University of Arizona Press, p. 22-41.
- Zietz, Isidore, and Kirby, J. R., 1967, Aeromagnetic and gravity profiles of the United States along the 37th parallel: U.S. Geological Survey Geophysical Investigations Map 597.

Zietz, Isidore, and Kirby, J. R., 1968a, Transcontinental geophysical survey (35°-39° N.)--Magnetic map from 100° to 112° W. longitude: U.S.

Geological Survey Miscellaneous Geological Investigations Map I-535A.

_____ 1968b, Transcontinental geophysical survey (35°-39° N.)--magnetic map from 112° W. longitude to the coast of California: U.S. Geological Survey Miscellaneous Geological Investigations Map I-532A.

Zietz, Isidore, Shuey, Ralph, and Kirby, J. R., Jr., 1976, Aeromagnetic map of Utah: U.S. Geological Survey Geophysical Investigations Map GP-907.