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MINERAL RESOURCE POTENTIAL OF THE VERMILION CLIFFS-PARIA CANYON INSTANT STUDY AREA, COCONINO COUNTY, ARIZONA, AND KANE COUNTY, UTAH

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Studies Related to Wilderness
Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94-579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine their mineral resource potential. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral survey of the Vermilion Cliffs-Paria Canyon Instant Study Area, Coconino County, Arizona, and Kane County, Utah.

MINERAL RESOURCE POTENTIAL SUMMARY STATEMENT

In general, the mineral potential of the study area is low; in the past the area has yielded only several hundred tons of uranium ore, and there have been a number of unsuccessful efforts to produce gold.

The generally small uraniferous deposits are in the Chinle Formation, mostly in the basal Shinarump Member, and mostly on the east side of the Paria Plateau. To the south and west, around the plateau, the Shinarump host rock pinches out or is present in only a few places, and the same relationships are likely below the plateau, where the host rocks are deeply buried, from 1,500 to 3,000 ft below the surface. These factors suggest the total uranium-copper-vanadium-silver potential to be very low.

Gold and mercury occur in very low concentrations in the clayey units of the Petrified Forest Member of the Chinle. Gold concentrations are 40 ppb and less, and the gold is present in very fine particles; recovery is very difficult. Overall, the mercury concentrations are so low that no realistic mineral resource potential can be estimated.

Nonmetallic mineral materials of possible value include limestone, flagstone, clay, and gravel, but they are of only local interest. No oil or gas resources are known in the study area. Coal resources within the area are nonexistent, but the Dakota Sandstone does contain coaly beds a few miles to the north.

Water is perhaps the most significant resource needed in the study area. A number of perennial springs support the few local ranchers and tourist facilities. Some ground water would be available below the plateau, but drilling depths would be more than 2,000 ft (600-700 m).

INTRODUCTION

The Vermilion Cliffs-Paria Canyon Instant Study Area is mostly in Coconino County, Ariz., but extends into Kane County, Utah (fig. 1). The area studied in this report encompasses about 560 mi^2 (1,450 km^2); the area identified for possible wilderness designation by the U.S. Bureau of Land Management consists of 323,745 acres (about 130,700 hectares) of public land, about 90 percent of the area studied. The studied area includes the established Paria Canyon Primitive and Vermilion Cliffs Natural Areas and lies between U.S. Highways 89 and 89A.

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 (see map). At Lees Ferry, Ariz., the west wall of the Glen Canyon of the Colorado River swings away from the river to become the sheer Vermilion Cliffs, 1,200 ft (about 370 m) high; they increase to nearly 2,000 ft (about 600 m) near the southeast corner of the Paria Plateau. Westward the cliffs decrease to 800 ft (about 250 m) along the south side of the plateau and virtually disappear northward along House Rock Valley on the west side of the plateau (see map). A break in the cliffs occurs where Corral Valley joins House Rock Valley, and this break affords the major road access to the Paria Plateau, a virtually unpopulated expanse of 325 mi^2 (about 850 km^2). Farther north the cliffs reappear as a ragged sequence of steep slopes and ledges as much as 900 ft (275 m) high that continues for more than 30 mi (50 km) to the north as the east wall of House Rock Valley and Coyote Valley. These narrow valleys follow the East Kaibab monocline, 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 that slopes gently northward at 100 ft/mi (about 20 m/km). Bedrock is at or near the surface nearly everywhere, and soil 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 semiarid climate, but is more abundant in the higher southern part of the plateau, where a few small stands of ponderosa pine are present. Summer temperatures reach more than 100,F, and winter temperatures drop 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 are 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 in the study area, but just outside the southeast boundary tourist trade supports motels at Marble Canyon and at Cliff Dwellers Lodge. At Lees Ferry, river runners begin float trips that run the rapids of the Colorado River downstream into Marble and Grand Canyons.

GEOLOGY, GEOCHEMISTRY, AND GEOPHYSICS

Geology

The relatively flat lying sedimentary rocks exposed in the study area (see map) 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. The estimated thickness of the exposed rock units totals about 6,050 ft (nearly 1,850 m); more than 300 ft (100 m or more) of rock was removed during at least three periods of erosion in the Triassic and Jurassic. Upper Cretaceous marine strata that once overlay the continental-littoral Dakota have been eroded from the study area, but are present only a few miles to the north. During the Cenozoic, more than 3,000 ft (1,000 m or more) of rock were removed. 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. The basal Shinarump Member of the Chinle is a persistent and resistant unit that makes 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 oldest units of the great sandpile 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 Triassic(?) and Jurassic Navajo Sandstone (1,700 ft--more than 500 m), 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.

Other Jurassic rocks (mostly the Judd Hollow Tongue of the Carmel Formation) are present only as remnants on small buttes on the Paria Plateau, but north of Kaibab Gulch and Paria River the rocks include the Thousand Pockets Tongue of the Page Sandstone (Peterson and Pipiringos, 1979), the Carmel Formation, and the Entrada Sandstone, and they occur in increased thickness and area of coverage, extending north beyond the boundary of the study area. Basal rocks of the upper Cretaceous Dakota Sandstone crop out as remnants on small buttes only in the northeastern part of the study area, but younger units are abundant 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 (see map; also Bush, 1982). The valleys of House Rock Wash and Coyote Wash bordering the plateau on the west 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 4,000 ft (more than 1,200 m) between the crest of the monocline and the flat-lying rocks of the plateau; at most, only 325 ft or so (about 100 m) 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 2,450 ft (about 750 m).

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 (Bush, 1982) 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 feet horizontally and over hundreds of feet 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 as long as 8 mi (about 13 km) and having displacements of a few feet to 300 ft or so (a few meters to less than 100 m) occur in three general areas (see map): (1) the House Rock Valley-Coyote Valley belt; (2) a broad belt extending southeast from West Clark Bench through Bridger Point to Horse Ridge in the northeast corner of the Paria Plateau; and (3) a band along the anticlinal bend of the Echo Cliffs monocline that broadens to the southwest 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 its confluence with Kaibab Gulch 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 the Carmel caps small buttes. Some fault segments may be part of a longer fault, but the continuity is masked by surficial deposits.

Geochemistry and geophysics

Geochemical associations do not have much effect on the resource assessment because the accessible data points cannot give a good, geographic coverage of the rocks of the area. Pertinent sample sites (Bush and Lane, 1982) form a fence or necklace pattern around the Paria Plateau and part of the northern benches; the samples give no clues as to what may lie under the Navajo Sandstone caprock. The sediment samples from the plateau and 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 studied in whole or in part at much smaller scale (1:250,000 to 1:2,500,000), but data at these scales are 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-vanadium-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 in the study area) 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 Petrified Forest Member and in the unnamed unit of the Chinle; uranium and copper, usually without silver, occur locally in these units. Discrete channels are not as prevalent, as well defined, or 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.

Data are insufficient to characterize accurately the average content of metals in the uranium-copper-vanadium-silver deposits. Analytical data for the samples collected in this study, and data published elsewhere, show a range in content from a few thousandths percent to more than 1 percent U_3O_8, from a few thousandths to several percent copper, from a few thousandths to several tenths percent vanadium, and from less than 0.01 oz/ton to 1 or 2 oz/ton silver. Molybdenum accompanies uranium and copper in some deposits, as at the Sun Valley mine (see below). Generally the content is very low, a few hundredths percent or less, and the occurrences are more prevalent in deposits in the Petrified Forest Member than in the Shinarump Member.

An exceptional occurrence is at the Sun Valley mine, where rhenium in amounts ranging from 0.005 to 0.07 percent is associated with uranium (as much as several percent) and molybdenum (as much as 1.5 percent) (Petersen and others, 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)).

Gold and mercury deposits

Small amounts of gold, ranging from barely detectable (2 ppb) to about 40 ppb, occur in 42 of 46 widely distributed samples from 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 5-ppb detection limit of a less sensitive technique that was used. 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 Member; 19 samples taken to determine copper and uranium content showed measurable gold in 6 samples (2-6 ppb) and detectable gold in 5 other samples. 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 be as much as $0.125/ton at $20.67/oz (about 180 ppb) in three sampled sections near Paria, Utah, less than 12 mi (20 km) 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 the sections were close together, in an area of 1 mi^2 (about 1 1/2 km^2). 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 60 mi (95 km) 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 if the price of gold were $700/oz, 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 gold-mercury film analytical technique.

Nonmetallic deposits

The rocks of the upper part of the Kaibab Limestone have been tested for suitability for cement, but they are too siliceous and too high in $MgCO_3$ (McKee, 1938, p. 62-66; Kiersch, 1955, p. 15). They are suitable for use as "agstone" (agricultural limestone) (Kiersch, 1955, p. xii) and road metal, but because of their substantial chert content, they 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) contains 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 feet to several tens of feet 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 conglomerate of the Shinarump 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

No oil or gas has been produced from the study area, but within about 45 mi (75 km), rocks continuous with 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), 43 mi (about 70 km) to the north, and from the Moenkopi Formation at the Virgin Field in Utah, 30 mi (about 50 km) 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 (E. B. Heylmun, consultant, 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 (C. W. Swapp, U.S. Bureau of Land Management, oral commun., Oct. 24, 1979; E. B. Heylmun, consultant, 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 data are insufficient for a reliable appraisal.

Although thin coal beds (1-2 ft--0.5 m) 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 (see map). 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 5-8 mi (8-13 km).

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 obtained from shallow wells (several feet deep). Ground water in the Navajo and lower rocks also can be recovered, but drill depths of 1,300 to 2,300 ft (400 to 700 m) would likely be needed, and the quantity available is uncertain.

MINING DISTRICTS AND MINERALIZATION

Most mining activity along the Vermilion Cliffs has taken place for uranium in the Chinle Formation. In this area there are a few old mines that were operated in the 1950's; the largest is the Sun Valley mine, southwest of Cliff Dwellers Lodge. There also are a few scattered prospects in Paria Canyon and in the northern part of House Rock Valley. 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 6 mi (about 10 km) up Paria River (Phoenix, 1963). No evidence of recent prospecting was found during the field investigation.

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. 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 10 mi (about 16 km) up Paria Canyon from Lees Ferry.

El Pequito mine

The El Pequito mine is about 2 mi (3.2 km) west of Lees Ferry in the NW 1/4 sec. 14, T. 40 N., R. 7 E. (see map). 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 reported the occurrence of pyrite, chalcopyrite, and uraninite in calcite veinlets, and also reported that several tons of ore were shipped. No pyrite or chalcopyrite was seen during the field investigation.

A map of the mine showing sample locations and assay results has been published (Lane, 1982, samples 3-16).

Sam Prospect

The Sam prospect is in the SE 1/4 sec. 2, T. 39 N., R. 6 E. (see map) about 2 mi (3.2 km) northwest of Cliff Dwellers Lodge. The prospect is an adit 27 ft (8.2 m) 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 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 (Lane, 1982, samples 17-18). One sample, a 2.5-ft (0.8-m) chip, contained 0.337 percent U_3O_8, 0.14 percent vanadium, and 5.6 ppm mercury. The other sample, a 5.0-ft (1.5-m) chip, contained 0.026 percent U_3O_8 and 0.007 percent vanadium.

Jasper mine or prospect

The Jasper (Maggie) mine consists of a 40-ft (12.2 m) adit, in the SW 1/4 sec. 27, T. 39 N., R. 6 E. (see map), 300 ft (about 91 m) north of U.S. Highway 89A, 0.25 mi (about 0.4 km) east of Cliff Dwellers Lodge.

The adit was driven N. 6, E. in the Shinarump Member, here a poorly sorted 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 make up the lower 29 in. (74 cm) of the wall and conglomerate the upper 36 in. (91 cm). Sample 19 (Lane, 1982, samples 19-23), 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 10 ft (3.1 m) 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 part 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 mi (4.8 km) southwest of Cliff Dwellers Lodge and about 1 mi (1.6 km) north of U.S. Highway 89A (see map). It lies near the southeastern boundary in the southernmost part of of the study area.

At the time of the study the mine was owned and operated by Intermountain Exploration Co. 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, Intermountain Exploration Co., unpub. report, 1977).

The mine was started in 1954 during a period of intense uranium exploration in the area. An inclined 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, Intermountain Exploration Co., unpub. report, 1970).

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

Mineralized rock is irregularly distributed through the deposit. Uranium analyses of all samples taken at the mine have been published (Lane, 1982, samples 24-47). The highest U_3O_8 content of samples taken at the mine was 0.216 percent (sample 41 taken in the old workings). Four samples contained between 2- and 26-ppm rhenium. These quantities are not considered economically significant under present conditions.

Intermountain Exploration Co. has done some drilling to determine the 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 its relationship to the study area cannot be determined from existing data.

Red Wing mine

The Red Wing mine consists of two adits, 43 ft (13 m) and 55 ft (17 m) in length, in sec. 3, T. 40 N., R. 7 E. (see map). The property is in Paria Canyon 4 mi (about 6.4 km) 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. Analytical data for the five samples taken have been published (Lane, 1982, samples 72-76). The Moenkopi at this location is typical maroon siltstone with bleached areas.

Unnamed prospect--Two unnamed adits are in the SE 1/4 sec. 2, T. 40 N., R. 7 E. (see map). These consist of a very short adit and a 32-ft (9.8 m) adit. The longer adit is the only one containing significant mineralization (0.033 percent U_3O_8). This adit contains some carbonaceous material, which gave the highest Geiger counter readings. The drift is in a thinly bedded siltstone over sandstone.

The short adit is 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, copper, gold, or mercury can be postulated for the study area from data presently available.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

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 more of the same type undoubtedly can be found, but the prospect for discovery of other types of deposits is low. The area has potential for uranium production, but drilling would be needed to provide data for outlining ore and for reserve calculations. Probably all (certainly most) uranium-copper-vanadium-silver deposits that crop out were discovered during a period of intensive prospecting in the early and mid-1950'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 2,000 ft (600 m) or more below the surface, but the density of distribution is likely to be lower, as the Shinarump Member 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 2: A, Jacob Pools-Emmett Hill area; B, Sun Valley mine-Soap Creek area; C, Badger Canyon-Cathedral Wash area; D, Johnson Point-Paria River area.

Gold-mercury potential is low, for although a large part of the Chinle Formation is gold bearing and has a small mercury content, the grade is very low, as much as about 40-ppb gold, and because of the minute size of the gold particles, recovery would be 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 resources at the very low concentrations indicated, generally below 150 ppb.

The Kaibab Limestone is a significant mineral resource for use as road metal and possibly as agstone. Large amounts are available, access is good, and 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 100 mi (160 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 are not 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 (1,300-2,300 ft range (400-700 m)) from the plateau surface, but its quantity is uncertain. Perched water bodies, as in sand deposits on the plateau, might supply water to shallow drilling but are likely to be intermittent sources and of limited quantity.

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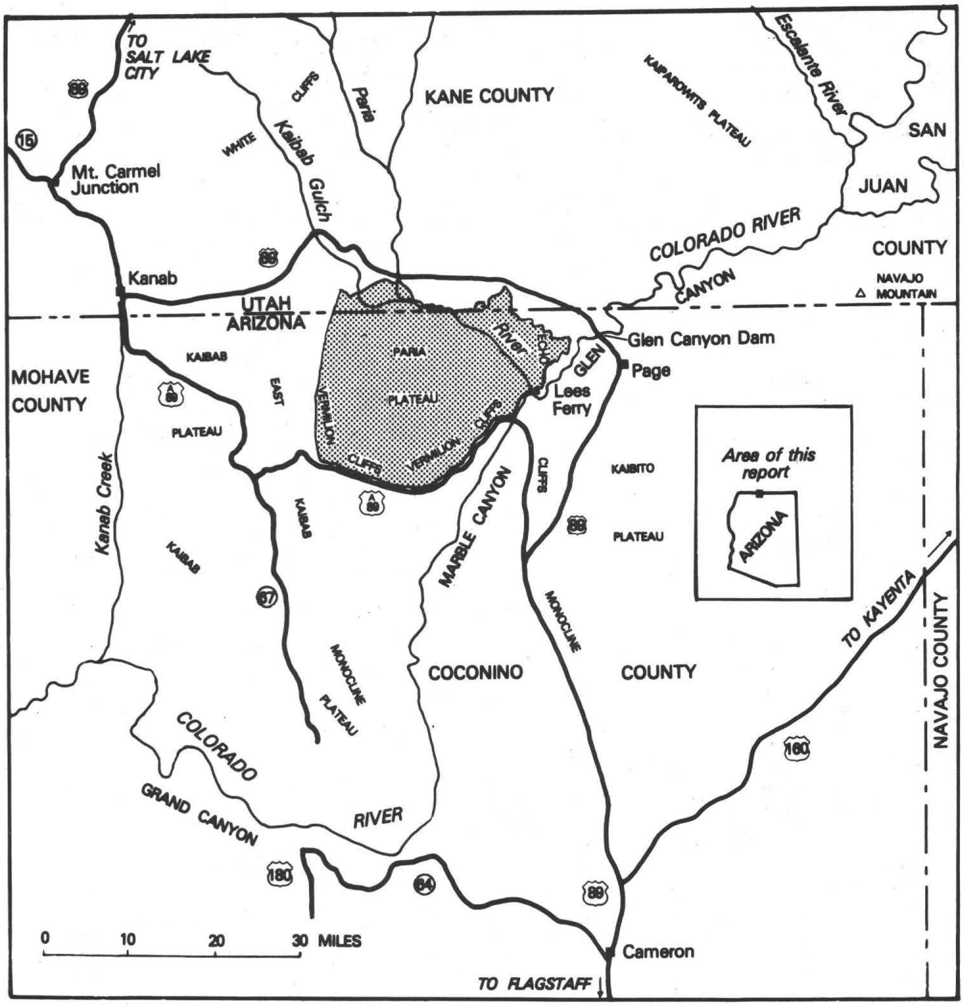

Figure 1.--Index map showing the location of the Vermilion Cliffs-Paria Canyon Instant Study Area.

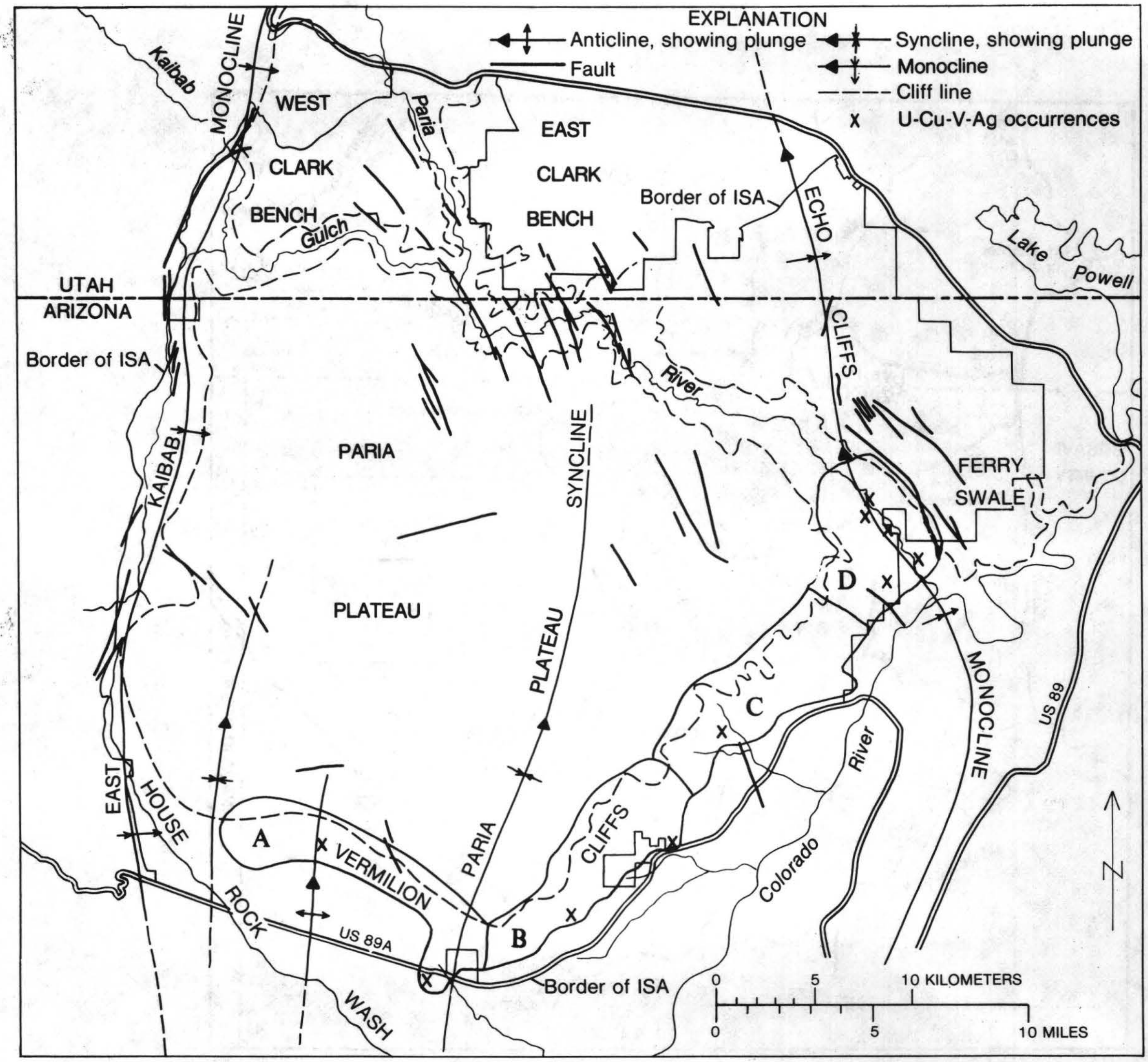

Figure 2.--Sketch map of the Vermilion Cliffs-Paria Canyon Instant Study Area (ISA) showing the major folds and trends of faults, location of the uranium-copper-vanadium-silver occurrences, and the areas of restricted potential for the discovery of similar deposits. A, Jacob Pools-Emmett Hill area; B, Sun Valley mine-Soap Creek area; C, Badger Canyon-Cathedral Wash area; D, Johnson Point-Paria River area.

Table 1.--Columnar section of the sedimentary rocks exposed in the Vermilion Cliffs-Paria Canyon Instant Study Area, Coconino County, Arizona, and Kane County, Utah

[Based on Phoenix (1963), Wells (1960) and Green and others (1977)]

Age	Name			Thickness	Description	Weathering form
Holocene and Pleistocene(?)	No formal names			50± ft, 15± m	Alluvial fan and terrace gravels, windblown and reworked sands, toreva blocks and landslide debris, talus, stream gravels, and alluvium.	Terraces, cones, dunes, hummocks, lobate tongues, valley bottoms.
Pleistocene and Pliocene(?)	No formal name			3-6 ft, 1-2 m	High-level terrace gravels, containing exotic rocks.	Terrace remnants.
Late Cretaceous	Dakota Sandstone			100± ft, 30± m	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		650 ft, 200 m	Sandstone, massive, pale-gray, medium- to fine-grained, crossbedded.	Bluffs.
		Carmel Formation		400 ft, 120 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.
		Page Sandstone	Thousand Pockets Tongue	0-230 ft, 0-70 m	Sandstone, massive, pale-yellow, medium- to fine-grained, crossbedded.	Broad slopes.
		Carmel Formation	Judd Hollow Tongue	0-35 ft, 0-10 m	Sandstone and siltstone, dark-brown to pale-gray, evenly bedded.	Ledges.
Jurassic and Triassic(?)	Glen Canyon Group	Navajo Sandstone		1675-1855 ft, 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.
Late Triassic(?)		Kayenta Formation		120-310 ft, 35-95 m	Sandstone, pale-red-brown, massive, crossbedded and evenbedded; and alternating sandstone and siltstone, ripple marked.	Benches and ledges, cliffs.
		Moenave Formation	Springdale Member	180-220 ft, 55-65 m	Sandstone, red, massive, darkly stained; broadly lenticular beds.	Cliffs.
			Dinosaur Canyon Member	90-220 ft, 25-65 m	Sandstone, red-orange, flat-bedded; siltstone, varicolored; and mudstone, varicolored.	Ledges, steep slopes.
Late Triassic	Chinle Formation		Owl Rock Member	150-200 ft, 45-60 m	Limestones, cherty, conglomeratic, nodular; sandstone, siltstone, clayey mudstones, dark-red, nonbentonitic.	Cliffs and slopes.
			Petrified Forest Member	625-810 ft, 190-245 m	Mudstone and claystone, variegated yellow, pink, green, and blue, bentonitic; some siltstone, sandstone, and limestone pebble conglomerate.	Smooth, rounded "popcorn" slopes.
			Unnamed unit	0-175 ft, 0-50 m	Sandstone, arkosic, crossbedded, light-colored; and silty mudstone, dark-red, gray, gray-green. Pinches out westward. Fossil logs.	Ledges, steep slopes.
			Shinarump Member	0-150 ft, 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	15-120 ft, 5-35 m	Limey siltstone, mudstone, silty claystone, micaceous, thin limestone in east; sandstone, massive, pale-brown, makes marker bed near base.	Cliffs and steep slopes.
			Shnabkaib Member	0-15 ft, 0-5 m	Clayey siltstone, micaceous, gypsiferous, thin-bedded, uniform light-gray to light-gray-green, noncalcareous.	Steep slopes.
			Middle red member	310-650 ft, 95-200 m	Siltstone and mudstone, micaceous, gypsiferous, uniform pale-red-brown, noncalcareous, thin-bedded, ripple marked.	Concave slopes.
Early Permian	Kaibab Limestone			325± ft, 100+ m	Upper one-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			120 ft, 35 m	Sandstone, white and light-grayish-yellow, fine-grained, crossbedded, dark-red silty mudstone and siltstone, light-gray, cherty, limestone; upper part interbedded; somewhat wavy bedding.	Cliffs.