UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

A SUMMARY OF THE GEOLOGY AND MINERAL RESOURCES OF THE PARIA PLATEAU-HOUSE ROCK VALLEY AREA, COCONINO COUNTY, ARIZONA

By

Morris W. Green, Charles T. Pierson, Douglas P. Bauer, and Dennis B. Umshler

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This report is preliminary and has not been edited or reviewed for conformity with U.S. Geological Survey standards.

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ABSTRACT

The Paria Plateau-House Rock Valley area of north-central Arizona is located on the southwestern edge of the Colorado Plateau physiographic province in an area underlain by about 5,000 meters of fossiliferous marine and continental sedimentary rock ranging in age from Precambrian through Quaternary. The area, which lies north of the Grand and Marble Canyons, is bounded on the west by the East Kaibab monocline and on the east by the Echo monocline. The Paria Plateau, bounded on the south by the scenic Vermilion Cliffs, is composed of continental red-beds of Triassic and Jurassic age, which dip gently northward at 2° to 3° away from the north end of the Marble Platform upon which the Paria Plateau sits.

With the exception of a relatively small quantity of uranium mined from sedimentary rocks of Late Triassic age (Shinarump Member of the Chinle Formation) near Lee's Ferry on the east side of the Paria Plateau, mineral resources have not been found in the report area, even though oil, gas, helium, and coal have been produced from similar strata in adjacent areas to the north in the Kaiparowits Basin and to the east in the Black Mesa Basin.

INTRODUCTION

The following report is a summary description compiled from existing literature on the geology and mineral resources of the Paria Plateau-House Rock Valley area, Coconino County, Arizona. The information in this report has been submitted for use in preparation of the Navajo Land Selection Environmental Impact Statement, which is under preparation by the Bureau of Indian Affairs of the Department of the Interior.

GEOLOGIC SETTING

The Paria Plateau-House Rock Valley area of northern Arizona and southern Utah (Fig. 1) lies

Figure 1—NEAR HERE

within the southwestern part of the Colorado Plateau physiographic province. The province, which comprises an area of approximately 390,000 square kilometers, lies within the states of Arizona, Colorado, New Mexico, and Utah.

Underlying the province are generally flat-lying sedimentary rocks of younger Precambrian, Paleozoic, Mesozoic, and Tertiary age. These rest on an older Precambrian basement comprised mainly of igneous and metamorphic rocks, and they are intruded by a variety of Tertiary igneous rocks. Uplifts and related downwarps and platforms, as well as faults and monoclinal folds, are locally present. Thin alluvial and eolian deposits of Holocene age cover much of the surface of the Colorado Plateau.

STRATIGRAPHY

The Paria Plateau-House Rock Valley area is underlain by over 5,000 m of sedimentary, igneous, and metamorphic rocks which range in geologic age from the Precambrian era to the Quaternary period (Table 1).

Table 1.—NEAR HERE.

Spectacular exposures of the sequence are present a short distance south of the report area in the Grand and Marble Canyons of the Colorado River and in the Vermilion Cliffs, which bound the southern edge of the Paria Plateau.

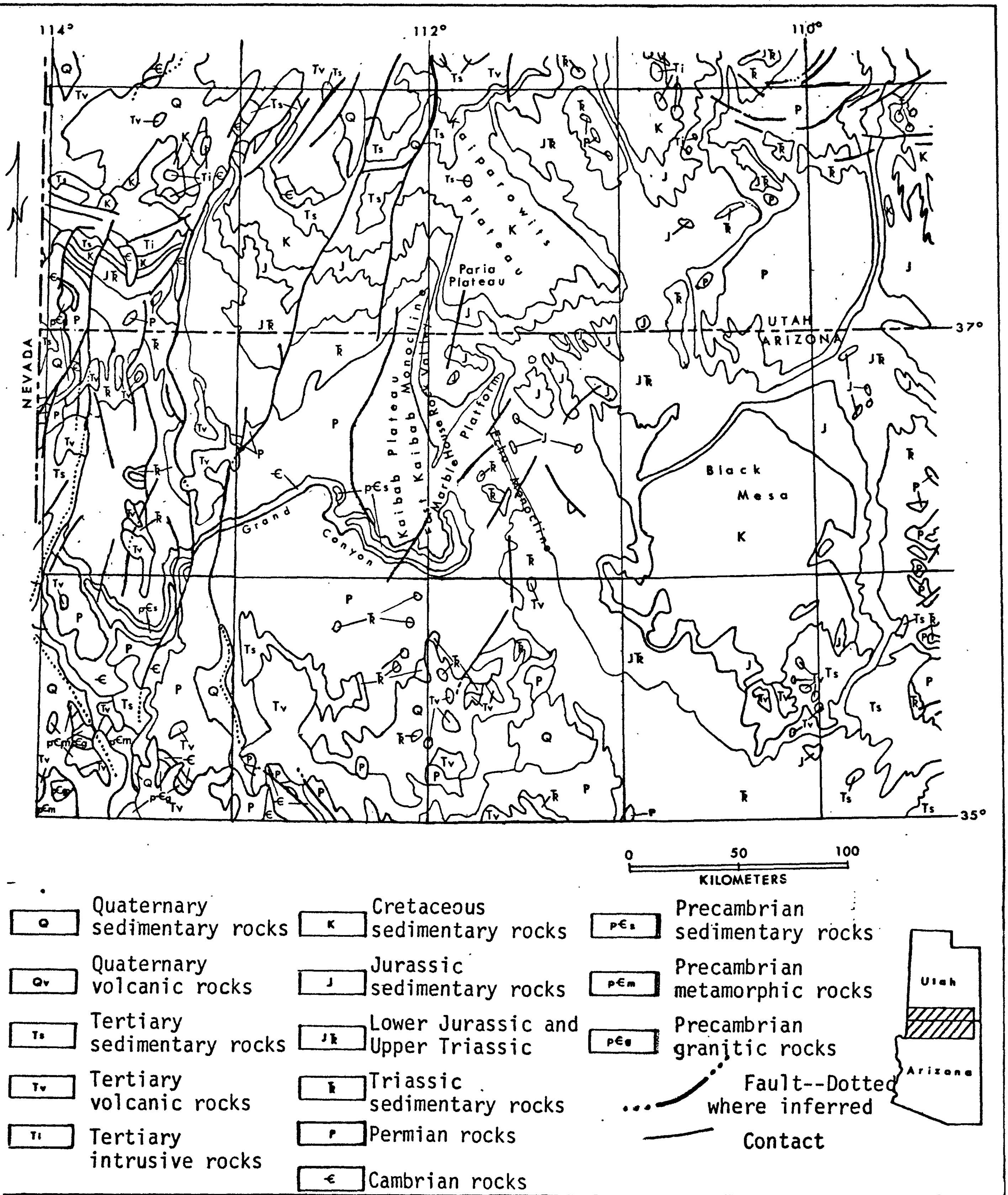

Figure 1.--Generalized geologic map of part of northern Arizona and southern Utah showing the geologic setting of the Paria Plateau-House Rock Valley area, Arizona. Modified from the Geologic Map of the United States (King and Beikman, 1974); scale 1:2,500,000.

Table 1--Columnar stratigraphic section of rocks underlying the Paria Plateau-House Rock Valley area, Coconino County, Arizona.

Age	Group	Formation	Member	Thickness	Description	Land forms	
Quaternary				15± m	Terrace-gravel, landslide, alluvial-fan, and talus debris; windblown sand and stream gravel	Benches, lobate tongues, cones, dunes, valley bottoms	
Late Cretaceous		Dakota Sandstone		30± m	Ripple-bedded sandstone and laminated siltstone underlain by conglomerate and coarse-grained sandstone	Ledges and short slopes	
Late Jurassic	San Rafael Group	Entrada Sandstone		200 m	Sandstone, pale-gray, medium- to fine-grained, cross-bedded	Bluffs	
Late and Middle Jurassic	San Rafael Group	Carmel Formation		0-120 m	Siltstone, silty limestone, and interbedded sandstone; siltstone, red, calcareous; sandstone, red, white, and brown	Ledges and slopes	
Jurassic and Late Triassic (?)	Glen Canyon Group	Navajo Sandstone		510-560 m	Sandstone, white to reddish-brown and orange, massive, cross-bedded; contains a few lenses of dark-brown chert	Nipples, buttes and sheer cliffs	Formations outcropping in the Vermilion Cliffs
Late Triassic (?)	Glen Canyon Group	Kayenta Formation		35-90 m	Sandstone and alternating sandstone and siltstones; red to pale reddish-brown; sandstone, massive; locally is cross stratified and ripple marked	Benches and ledges	
Late Triassic(?)	Glen Canyon Group	Moenave Formation	Springdale Ss Member	50-70 m	Sandstone; red and massive	Cliffs	
	Glen Canyon Group	Moenave Formation	...nosaur Canyon Ss Member	40-70 m	Sandstone and siltstone; sandstone reddish-orange and flat-bedded; siltstone varicolored	Ledges and steep slopes	
Late Triassic	Glen Canyon Group	Wingate (?) Sandstone		12-20 m	Sandstone, light brown to reddish-orange, crossbedded and planar bedded, fine-grained	Ledges	
		Chinle Formation	Owl Rock Member	15-60 m	Siltstone, clayey siltstone, limestone, cherty limestone, limestone conglomerate, and sandstone; siltstone, dark red and nonbentonitic; limestones, nodular	Smooth rounded slopes	
		Chinle Formation	Petrified Forest Member	180-240 m	Siltstone, claystone, silty sandstone, sandstone, and limestone pebble conglomerate; siltstone, varicolored, mainly reds, green, and blue, and bentonitic	Smooth rounded slopes	
		Chinle Formation	Shinarump Member	0-45 m	Conglomeratic sandstone, pale brown, white, to light gray	Benches and ledges	
Middle (?) and Early Triassic		Moenkopi Formation		100-220 m	Gypsiferous siltstone, clayey siltstone, and silty limestone, pale to dark reddish-brown and grayish-green, thin-bedded; pale-brown sandstone marker bed at top of formation	Concave slopes	
Permian	Aubrey Group	Kaibab Limestone	Upper part	40± m	Cherty dolomitic limestone, dolomite, siltstone, and calcareous sandstone, tan and light gray, fossiliferous		Outcrops in northern part of Marble Canyon
	Aubrey Group	Kaibab Limestone	Lower part	80± m	Cherty dolomite, dolomitic limestone, and sandstone, fossiliferous, alternating sequence, white to grayish yellow; sandstone generally white		
	Aubrey Group	Toroweap Formation		35-70 m	Dolomitic limestone, cherty limestone, gypsum, anhydrite, siltstone, and white to yellowish-white sandstone		
	Aubrey Group	Coconino Sandstone		0-20 m	Sandstone, light yellowish-gray, massive		
	Aubrey Group	Hermit Shale		150± m	Siltstone and shale, reddish-brown and grayish-green, massive		
	Supai Group	Esplanade Sandstone		140+ m	Sandstone, fine-grained; and interbedded siltstone and gypsum; mainly reddish-orange		
Pennsylvanian	Supai Group	Wescogame Formation[1]		60± m	Sandstone, reddish-brown, fine-grained, calcareous, and cross-stratified, moderate reddish-orange, fossiliferous		
	Supai Group	Manakacha Formation[1]		75± m	Sandstone, limy, cross-bedded, and sandy limestone, reddish-orange to reddish-gray, fossiliferous		
	Supai Group	Watahomigi Formation[1]		60± m	Limestone and mudstone, conglomeratic at base, multicolored, fossiliferous		
Mississippian		Redwall Limestone	Mooney Falls Member	60-105 m	Limestone and dolomitic limestone; thick bedded, medium gray, fossiliferous		Formations present in the subsurface within the Paria Plateau-House Rock Valley area (not exposed)
		Redwall Limestone	Thunder Springs Member	25± m	Dolomite, limestone and interbedded chert; medium-gray and white chert; fossiliferous		
		Redwall Limestone	Whitmore Wash Member	25-30 m	Dolomite and limestone, thick bedded, medium gray, fossiliferous		
Late and Middle (?)		Temple Butte Limestone		0-30 m	Limestone, purplish-gray to pinkish-gray, medium bedded, conglomeratic at base, fills channels at top of Muav Limestone; fossiliferous		
Cambrian	Tonto Group	Muav Limestone		45-240 m	Limestone, gray, and siltstone, greenish-gray, calcareous; fossiliferous		
	Tonto Group	Bright Angel Shale		105-120	Shale, silty, greenish-gray, thin bedded, fossiliferous		
	Tonto Group	Tapeats Sandstone		60-90 m	Sandstone, coarse-grained, quartzose, light brown, horizontally bedded; small-scale internal cross-stratification; fossiliferous		
Younger Precambrian	Grand Canyon Supergroup; Chuar Group	Sixtymile Formation[2]		35± m	Breccia and coarse pebbly sandstone and minor amounts of cherty siltstone		Outcrop in the Grand Canyon of the Colorado River
	Grand Canyon Supergroup; Chuar Group	Kwagunt Formation[2]	Walcott Member[2]	240± m	Shale, dolomite, and limestone and interbeds of silicified cherty pisolite; micro-fossiliferous		
	Grand Canyon Supergroup; Chuar Group	Kwagunt Formation[2]	Awatubi Member[2]	335± m	Shale and mudstone with interbeds of ferruginous siltstone, multicolored; contains bioherms and stromatolites composed of crystalline dolomite		
	Grand Canyon Supergroup; Chuar Group	Kwagunt Formation[2]	Carbon Butte Member[2]	75± m	Mudstone and sandstone, red to purple, micaceous; ripple marks; mudcracks		
	Grand Canyon Supergroup; Chuar Group	Galeros Formation[2]	Duppa Member[2]	160± m	Mudstone, siltstone, and shale with interbedded limestone and sandstone locally		
	Grand Canyon Supergroup; Chuar Group	Galeros Formation[2]	Carbon Canyon Member[2]	470± m	Limestone, shale, sandstone, interbedded; limestone is dolomitic micrite; grades into calcareous siltstone; shales blue to black, micaceous; sandstone green-gray; stromatolites		
	Grand Canyon Supergroup; Chuar Group	Galeros Formation[2]	Jupiter Member[2]	470± m	Mudstone, siltstone, and shale in upper part; stromatolitic limestone in lower part; multicolored; abundant ripple marks, rain-drop impressions, and mudcrack in argillaceous sediments		
	Grand Canyon Supergroup; Chuar Group	Galeros Formation[2]	Tanner Member[2]	200± m	Dolomite and shale; dolomite in lower part and shale in upper part; sparsely fossiliferous		
	Grand Canyon Supergroup	Nankoweap Formation		?	Sandstone and interbedded siltstone, purple and white; sandstone cross stratified; mildly metamorphosed		
	Grand Canyon Supergroup; Unkar Group	Cardenas Lavas		300± m	Basaltic lavas and interbedded sandstones		
	Grand Canyon Supergroup; Unkar Group	Dox Sandstone	Upper member	50-90 m	Mudstone, micaceous, and sandstone, silty and quartzose; mudcracks, small-scale crossbeds, and ripple marks		
	Grand Canyon Supergroup; Unkar Group	Dox Sandstone	Upper middle member	120-180 m	Siltstone, mudstone, and interbedded quartz sandstone, red, leached intervals (white); stromatolites, salt crystal casts; irregular beddings; and abundant ripple marks and mudcracks		
	Grand Canyon Supergroup; Unkar Group	Dox Sandstone	Lower middle member	60-275 m	Mudstone, siltstone, and sandstone in alternating sequence, red to reddish-brown, fine-grained; wide variety of sedimentary structures; sandstones are arkosic		
	Grand Canyon Supergroup; Unkar Group	Dox Sandstone	Lower member	290-670 m	Sandstone, light-tan to greenish-brown, quartzose and siliceous, and sandstone, calcareous, lithic, and arkosic; 244 m thick Shale and mudstone, dark brown to green; 122 m		
	Grand Canyon Supergroup; Unkar Group	Shinumo Quartzite		340-410 m	Sandstone, red or purple; quartz, and subarkosic, siliceous cement; conglomeratic at base to fine grained higher in unit; abundant sedimentary structures including cross-bedding, ripple marks, channel and-fill, deformation structures, and rare mudcracks		
	Grand Canyon Supergroup; Unkar Group	Hakatai Shale		170-290 m	Shale, bright orange to purple; sandstone, coarse-grained and thin-bedded; mudstone, red and conglomeratic; sandstones are arkosic and conglomerates are composed of clasts of metamorphic and volcanic rocks		
	Grand Canyon Supergroup; Unkar Group	Bass Limestone[3]		60-100 m	Dolomite, arkosic sandstone, sandy dolomite, shale, argillite, and intraformational breccias or conglomerates, red to brown; ripple marks, mudcracks, and graded bedding. Includes a basal conglomerate recognized as the Hotauta Conglomerate Member		
Older Precambrian		Includes the Vishnu Schist, Zcroaster Plutonic Complex[4], and the Trinity and Elves Chasm Gneisses[4]. Rocks are of predominantly metasedimentary and intrusive igneous origin					

1. McKee (1975)
2. Ford (1972)
3. Beus (1974)
4. Brown (1974)

Although most formations in the stratigraphic sequence are of sedimentary origin, intrusive and extrusive igneous and metamorphic (meta-sedimentary) rocks form a thick part of the Precambrian in the lower part of the sequence exposed only in the deepest parts of the Grand Canyon. Thick accumulations of sedimentary rocks indicate that the report area and surrounding regions of the Colorado Plateau were the site of depositional basins for a long period of geologic time. Sedimentary rocks are composed of conglomerates, sandstones, siltstones, claystones, shales, limestones, dolomites, gypsum, and anhydrite. The lithology, sedimentary structures, lithofacies, and fossil content of the formations indicate that deposition occurred in a wide variety of ancient depositional environments including arid desert, high- and low-energy stream, lake, coastal plain, delta, and shallow and deep submarine. The formations are characteristically thick, horizontally bedded or crossbedded, and brightly colored dark- to light-reddish-brown and reddish-orange. The brilliant colors and the strong cliff-forming character of the rocks combine to form one of the most scenic areas in the Southwest.

The most recent detailed geologic studies of the areas are reports by Wells (1960) and Phoenix (1963). Intense geologic study of the nearby Grand and Marble Canyons is continuing. Aside from the latest geologic map of the Grand Canyon (1976) published by the Grand Canyon Natural History Association and the Museum of Northern Arizona, two additional reports containing several papers on the Grand Canyon and adjacent region are available. These reports include a two-part guidebook completed in 1974 by the Geological Society of America and a guidebook completed by the Four Corners Geological Society in 1969. Table 1 of this report has been compiled largely from these two reports.

No specific study has dealt exclusively with the paleontology in the Paria Plateau-House Rock Valley area; however, it is well known from the many paleontological and geologic reports written on the nearby region, as well as on the Colorado Plateau in general, that several of the formations underlying the report area contain fossils representative of both faunal and floral assemblages that flourished during past geologic episodes. Notable among the many workers who have studied and listed these fossil assemblages are W. J. Breed (1968), C. L. Camp (1920), E. H. Colbert (1972), G. E. Lewis and others (1961), E. D. McKee (1938, 1951, and 1954), and S. P. Welles (1947).

The most important fossil-bearing formations in the report area include the Toroweap and Kaibab Formations of Permian age, and the Moenkopi and Chinle Formations of Triassic age. The Kaibab and Toroweap are marine in origin and contain the following invertebrate fossil remains: worms (burrows), corals, sponges, crinoids, echinoderms, brachiopods, pelecypods (clams), scaphopods, gastropods (snails), cephalopods, crustaceans, and fish. The Moenkopi is considered to be both shallow marine and continental in origin, because it contains fossils diagnostic of both environments; namely, worms (burrows and borings), brachiopods, clams, snails, cephalopods, scaphopods, arthropods, echinoderms, crinoids, fish, amphibians, reptiles, and plants. The Chinle Formation is considered to be of continental origin.

Fossils from the Chinle are abundant and include a variety of invertebrate as well as vertebrate animal remains. Pelecypod, gastropod, arthropod, fish, amphibian, reptile, and plant fossils have been found in the formation over the entire Colorado Plateau.

For a listing of the scientific names of the fossils mentioned above, reference is made to the cited publications.

STRUCTURE

Prominent tectonic features near the Paria Plateau-House Rock Valley area are typical of those found elsewhere on the Colorado Plateau. Three main structural features, the East Kaibab monocline, the Echo monocline, and the Marble Platform (fig. 1), are present in or near the area.

The East Kaibab monocline (Kelley, 1955) lies immediately west of the Paria Plateau and has a vertical displacement of about 1,070 m. The structure extends for approximately 210 km along a trend of about N. 10° E. This structure forms the eastern boundary of the Kaibab Plateau, which lies west of the report area.

The Echo monocline as defined by Phoenix (1963, p. 44) lies to the east of the area. This structure extends for approximately 100 km semiparallel to, and about 40 km east from, the East Kaibab monocline. The Marble Platform lies between the two monoclines and extends from the Grand Canyon area on the south to the Paria Plateau on the north.

The Paria Plateau stands about 700 m higher than the Marble Platform. Sedimentary beds in the Paria Plateau area dip gently (about 2°) to the north.

The Colorado River is incised into the Marble Platform between the Echo and East Kaibab monoclines to form the Marble Canyon. River incision is the result of the superposition of a meandering, low-gradient stream upon the more resistant Kaibab Limestone of Permian age (Phoenix, 1963, p. 56), which forms the caprock over much of the Marble Platform and adjacent Kaibab Plateau.

High-angle faults having offsets of as much as 200 m parallel the regional monoclinal trend. Such a fault extends from the Utah state line north-northeastward for about 25 km on the East Kaibab monocline, immediately to the northwest of the report area.

Joints and other small faults, both parallel to and oblique to the monoclinal trends, are also present in the area. Joint systems are best developed in the sandstone formations.

SEISMICITY

According to the seismic risk map of the western United States (fig. 2), the area

Figure 2—NEAR HERE.

lies within a zone of expected moderate earthquake damage. According to Shoemaker and others (1974, p. 386), a total of 27 earthquakes have occurred in the northern part of Arizona between 1938 and 1973. These earthquakes have ranged from a minimum of 2.2 to a maximum of 5.1 on the Richter scale. The nearest earthquake to the Paria Plateau-House Rock Valley area occurred on December 15, 1971, and registered 3.0 on the Richter scale.

MINERAL RESOURCES

Oil, gas, and helium

Pierce, Keith, and Wilt (1970) discuss the oil, gas, and helium resources of Arizona. No oil, gas, or helium has been produced from the Paria Plateau-House Rock Valley area. The nearest production comes from the Black Mesa Basin to the east. Oil and gas are produced from rocks of Pennsylvanian and Mississippian age while helium is produced from rocks of Triassic, Permian, and Mississippian age.

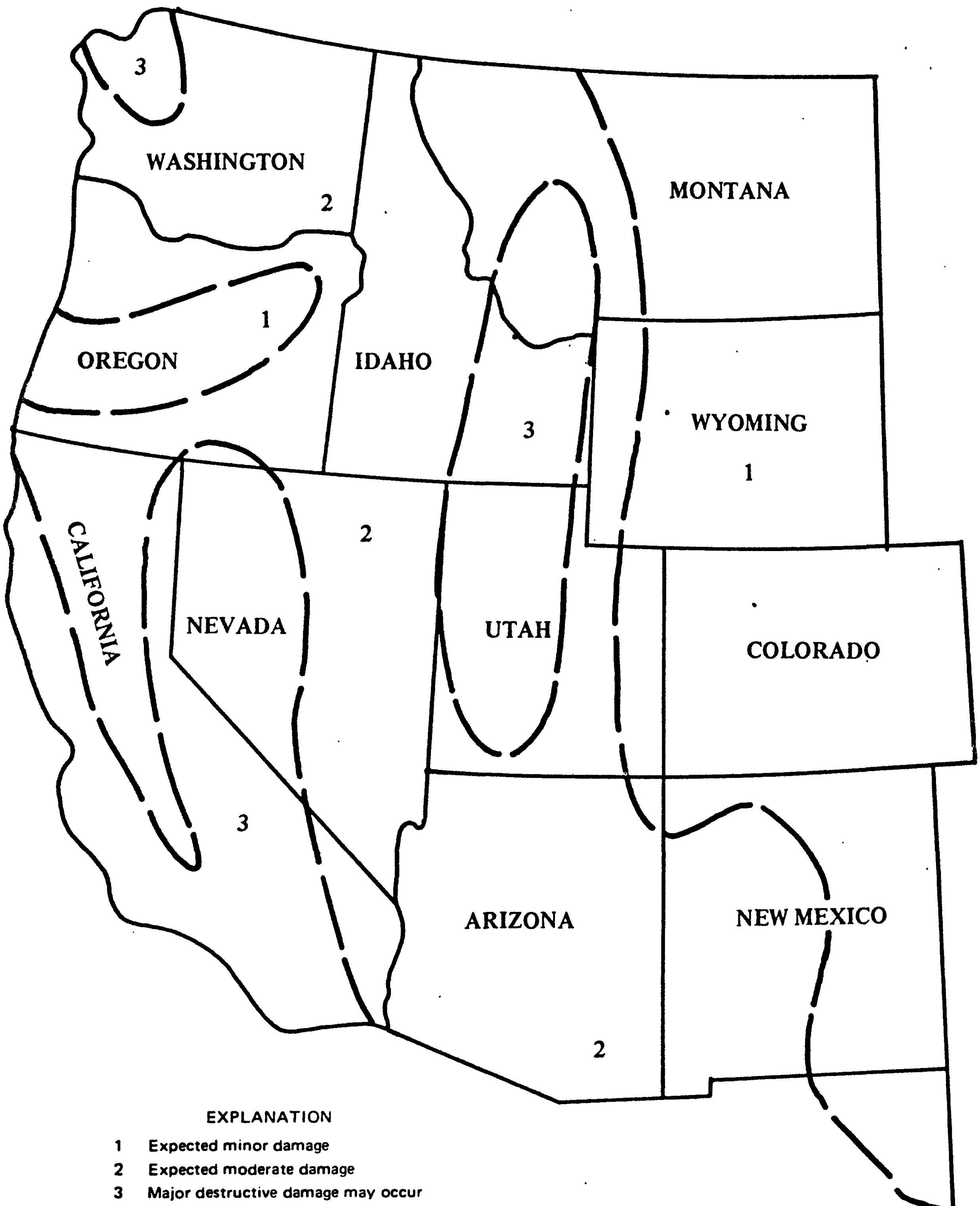

Figure 2.--Seismic risk map of the western United States. Provided by ESSA/Coast and Geodetic Survey.

No exploratory wells for oil and gas have been drilled in the report area. Only sparse drilling has occurred in surrounding areas, but some of these wells have reported shows of oil and gas. The breaching of the Paleozoic rocks by the Colorado River coupled with poorly developed Devonian and Pennsylvanian marine sections have not been encouraging to exploration in the area. The part of the Kaibab Plateau north of the Colorado River apparently has a well-developed subsurface water-bearing fracture system that supplies springs issuing from Cambrian rocks in the Grand Canyon.

Brown and Lauth (1958) stated that all the formations underlying the area except the middle and upper members of the Chinle Formation are thought to be potential producers. The hydrocarbon potential of the report area cannot be adequately determined until exploration wells are drilled in the area.

Coal

No coal resources occur in the Paria Plateau-House Rock Valley area. The nearest area where coal production occurs is at Black Mesa east of the area. Coal-bearing rocks in the western United States are typically of Cretaceous and Tertiary age. Only in the extreme northern part of the report area are rocks of this age present. The potential for coal resources in the areas is essentially nonexistent.

Uranium

According to Wells (1960, p. 138) in his geologic report on the House Rock Valley area, "The Shinarump member of the Chinle Formation, which is the most important ore-bearing unit in the region, is absent in much of the House Rock Valley area, and where the Shinarump is present no mineralization is known."

In the report on the Lee's Ferry area, Phoenix (1963, p. 59-60) stated that beneath the Paria Plateau, uranium deposits would have to be mined at depths greater than 2,000 feet, if they were present in the Shinarump Member. Phoenix considered the aspect of the Shinarump Member favorable to the localization of uranium ore minerals and stated that "it seems reasonable to suppose that there are favorable places to explore."

From study of these two reports, the subsurface of the western part of the Paria Plateau area seems to have little or no uranium potential, whereas the eastern part may have modest potential. According to Phoenix (1963, p. 59) "Exploration for uranium has not been highly successful in the Lee's Ferry area. Ore has been shipped from only one mine, the El Pequito...."

Figure 3 shows the location of uranium mines and prospects in the

Figure 3—NEAR HERE.

vicinity of the Paria Plateau-House Rock Valley area. These mines lie within what Peirce and others (1970, p. 119) have described as the Vermilion and Echo Cliffs District.

Other minerals

No other major mineral commodities are known to occur in the report area. Sandstone, small amounts of gravel, and impure dolomitic limestone are present in the area and have been used for road metal and building stone in small-scale building projects.

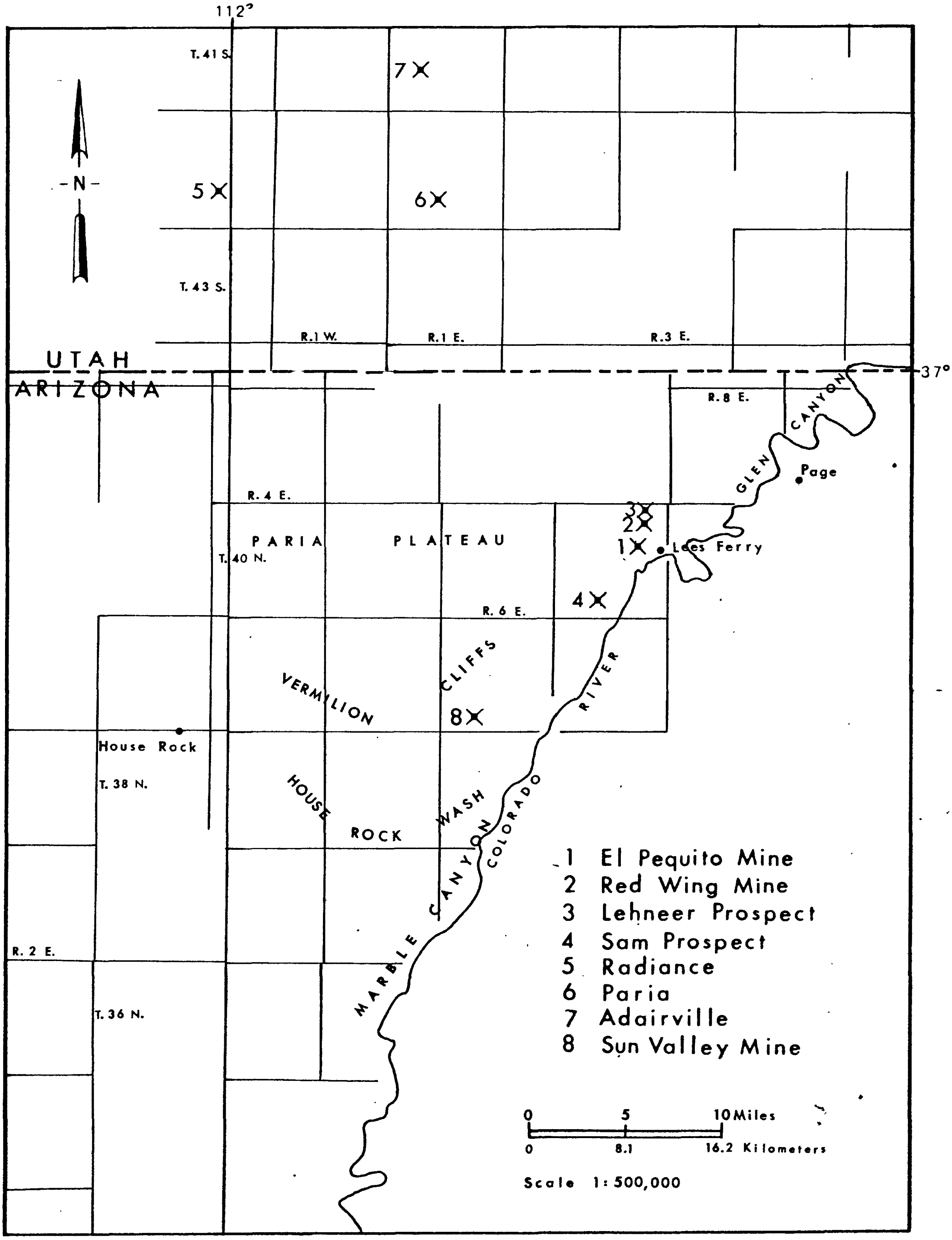

Figure 3.--Uranium mines and prospects in the vicinity of the Paria Plateau-House Rock Valley area.

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