GJBX-64(78)

PRELIMINARY EVALUATION OF THE URANIUM FAVORABILITY IN THE KAIPAROWITS PLATEAU REGION, GARFIELD AND KANE COUNTIES, UTAH

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Grand Junction, Colorado 81501

May 1978

MASTER

PREPARED FOR THE U.S. DEPARTMENT OF ENERGY
GRAND JUNCTION OFFICE
UNDER CONTRACT NO. EY-76-C-13-1664

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CONTENTS

ILLUSTRATIONS

TABLES

SUMMARY

The basal sandstone of the Chinle Formation (Upper Triassic) and the Salt Wash Member of the Morrison Formation (Upper Jurassic) in the Kaiparowits Plateau, south-central Utah, were evaluated in terms of uranium potential. Both surface and subsurface data were utilized.

Favorability of the basal Chinle sandstone was based on (1) presence of intermediate-size sandstone-filled channels cut into the Moenkopi, (2) presence of carbonaceous material, (3) an adequate source of uranium, and (4) gamma-ray anomalies from test-hole logs. Favorability of the Salt Wash Member of the Morrison Formation was based on (1) sandstone-mudstone ratios that approach equality, and (2) presence of thick sandstone lenses, carbonaceous material, and halos of light-tan to brown limonite staining.

Although the basal Chinle sandstone and the Salt Wash Member of the Morrison contain sizable uranium deposits throughout much of the Colorado Plateau, both units lack characteristics that are favorable for significant uranium deposits in the Kaiparowits Plateau.

INTRODUCTION

This report is a preliminary evaluation of the uranium potential of the basal sandstone of the Chinle Formation (Triassic) and of the Salt Wash Member of the Morrison Formation (Jurassic) in the Kaiparowits Plateau, south-central Utah. The project was begun in October 1976, and was completed in March 1977. The study was conducted by the Bendix Field Engineering Corporation (BFEC) on behalf of the Grand Junction Office of the U.S. Energy Research and Development Administration (ERDA).

PURPOSE

The purpose of this study was to define areas favorable for uranium deposits in the project area. Both surface and subsurface data were utilized. Emphasis was on the basal sandstone of the Chinle Formation and on the Salt Wash Member of the Morrison Formation.

LOCATION

The Kaiparowits Plateau, south-central Utah, is part of the Colorado Plateau province (Fig. 1). The Circle Cliffs Upwarp lies to the northeast, the Aquarius Plateau to the north, and the Pansaugant Plateau to the southwest. The project area covers approximately 4,800 sq mi in Garfield and Kane Counties, Utah.

PREVIOUS WORK

The first extensive study of the Kaiparowits Plateau was completed by Gregory and Moore (1931). In 1953, an airborne radiometric survey of the Morrison Formation was flown by the U.S. Atomic Energy Commission; no areas of anomalous radioactivity were found (Klosterman, 1954).

Stratigraphic information pertaining to the Morrison Formation can be found in Craig and others (1955), Harshbarger and others (1957), and Peterson and Waldrop (1965). Stratigraphy and the origin of the Chinle Formation are discussed in detail by Stewart and others (1972). Information on the geology, mineral resources, and uranium deposits in Garfield County, including specific references to the Morrison and Chinle Formations, is given by Doelling (1967, 1975).

PROCEDURES

An extensive search of published and unpublished literature was conducted to obtain geologic information and to locate known uranium occurrences. All available gamma-ray logs from the area were used for stratigraphic correlation and for identification of anomalies. These logs are listed in Appendix A. Due to limited outcrops, the Chinle Formation was studied principally by subsurface methods.

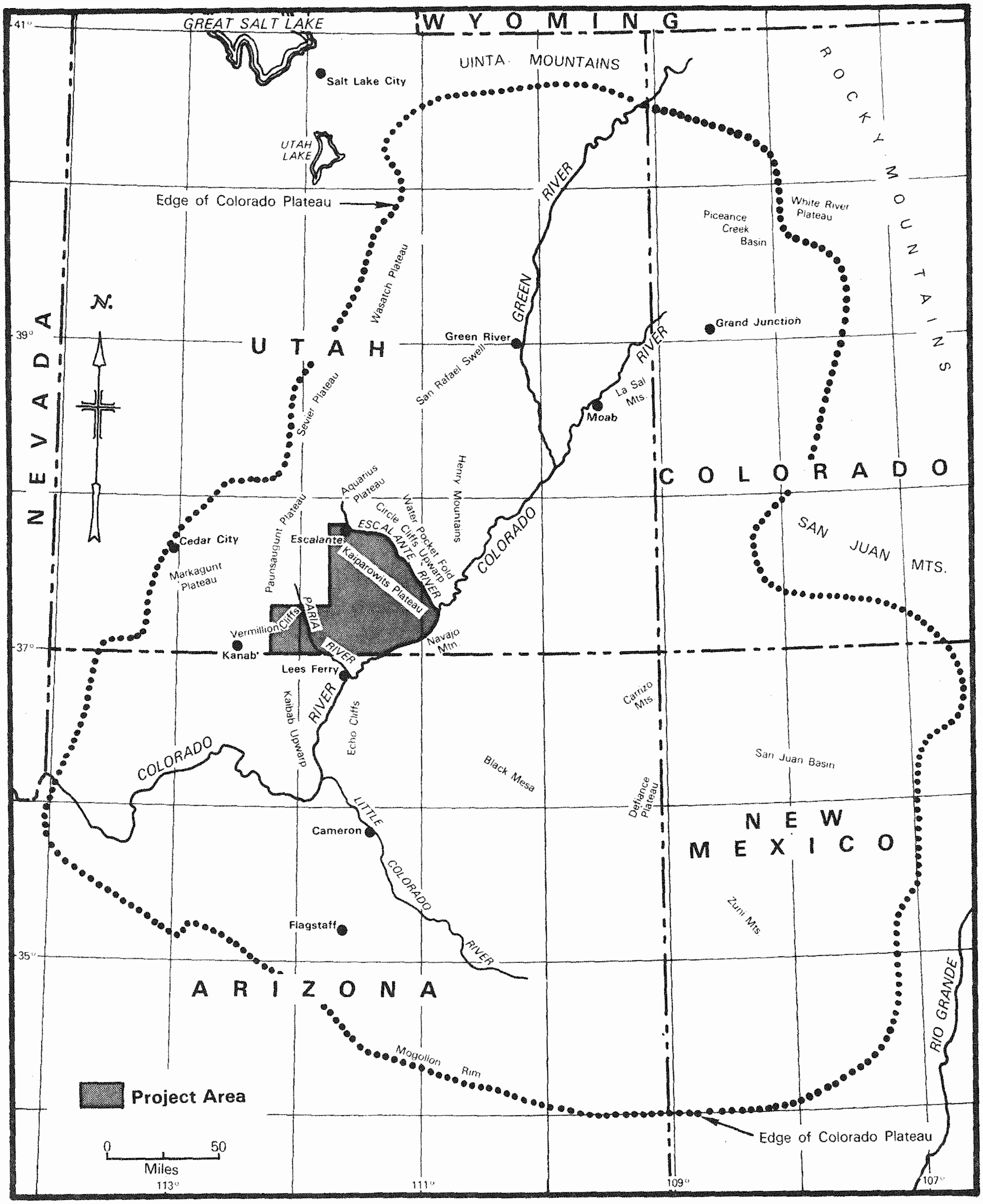

Figure 1. Location map of the Kaiparowits Plateau, south-central Utah.

Five surface samples were collected from the Morrison Formation throughout the project area. Equivalent uranium (eU), thorium (eTh), and potassium (eK) were determined by gamma-ray spectroscopy for all rock samples. Precision of this method is ±5 percent. Vanadium, molybdenum, selenium, copper, iron, and lead were analyzed by atomic absorption spectroscopy; results are precise to ±5 percent. Petrographic studies included clay analyses and mineral identification.

A helicopter-borne radiometric reconnaissance, using a portable scintillometer, was flown over Morrison and Dakota-Tropic outcrops. No anomalous areas were found in the Morrison Formation. Values from the carbonaceous shales and lignites are about 2X background values.

GEOLOGY

The geologic structure of south-central Utah is relatively simple; the surface of the Kaiparowits Plateau has been warped into a series of north-south aligned anticlines and synclines. The Straight Cliffs are a prominent erosional escarpment that mark the eastern boundary of the plateau. The northern and western parts contain erosional remnants and foothills of the High Plateaus. Figure 2 is a generalized geologic map of the area.

During Mesozoic time, major orogenic movements to the south, southwest, and west of the Kaiparowits region initiated sediment transport into and across the area. The lower boundary of the Mesozoic is an erosional unconformity that marks a pronounced change in sedimentation from Permian marine carbonates to Triassic redbeds (Lessentine, 1965). During Middle Triassic time, an interior basin was created and persisted until late in the Jurassic; this basin was a site of mostly continental sedimentation during this time. During latest Jurassic and Early Cretaceous time, south-central Utah remained stable or was gently uplifted (Stokes and Heylmun, 1965). Thin deposits of sandstone and conglomerate spread uniformly over the area. Rocks of Late Cretaceous age in the Kaiparowits Plateau consist of intertonguing continental and marine beds.

The major rock units under consideration in this report are the basal sandstone of the Triassic Chinle Formation and the Salt Wash Member of the Jurassic Morrison Formation. Figure 3 is a generalized stratigraphic column of the Kaiparowits region.

CHINLE FORMATION

The Chinle Formation (Upper Triassic) extends over most of the Colorado Plateau and into adjacent areas. Stewart and others (1972) have used the name Shinarump Member to denote a widespread, but discontinuous sandstone and conglomerate unit at the base of the Chinle throughout much of the southern part of the Colorado Plateau. The Shinarump Member is a sandstone and conglomerate unit deposited by complex stream systems in which the time of deposition and the provenance of the deposits varied (Stewart and others, 1972). The Shinarump is yellowish-gray, fine- to coarse-grained sandstone with

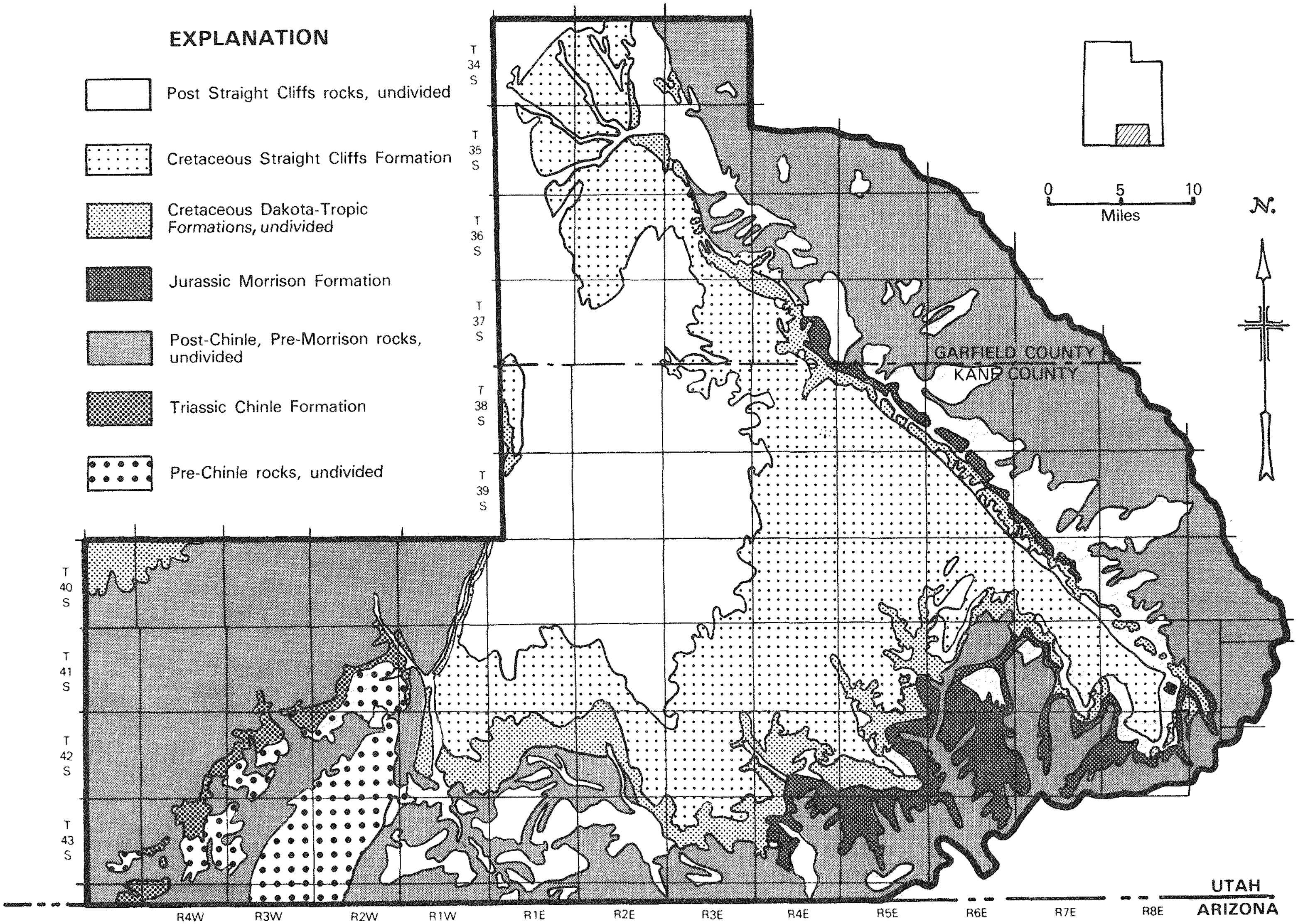

Figure 2. Generalized geologic map of the Kaiparowits Plateau (modified from Hackman and Wyant, 1973, and Hintze, 1963).

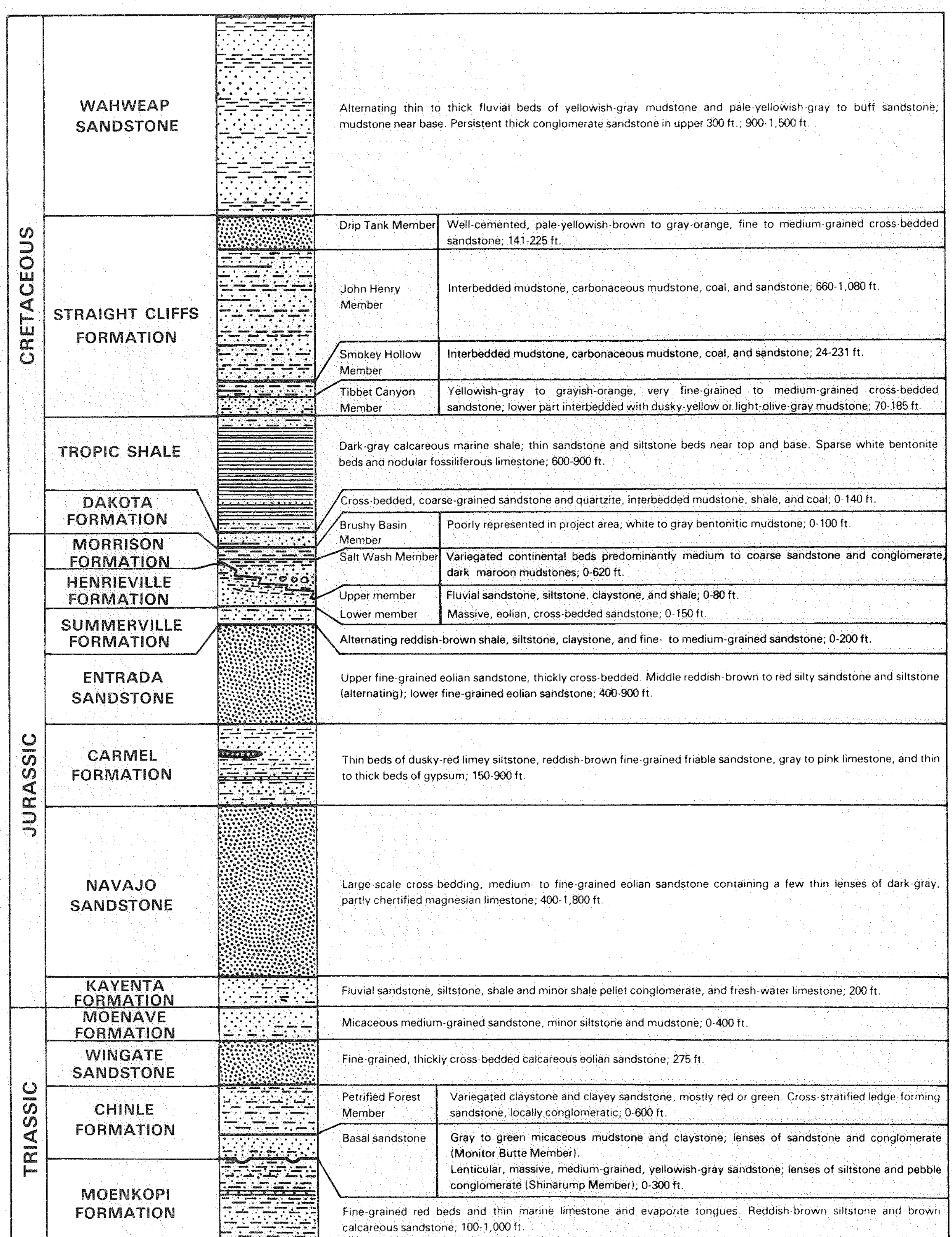

Figure 3. Generalized stratigraphic column, Kaiparowits Plateau (from Doelling, 1975; Hackman and Wyant, 1973; and Stewart and others, 1972).

subordinate lenses of siltstone and pebble conglomerate. Logs and fragments of carbonized and silicified wood are locally abundant. This unit is resistant and forms vertical cliffs. The Shinarump unconformably overlies the Moenkopi Formation. In places, the contact is marked by conspicuous channels scoured into the Moenkopi and filled with sandstone of the Shinarump. Thin accumulations of plant fragments at the bottom and sides of some of the channels are silicified, coalified, or mineralized with uranium and copper (Doelling, 1975).

The basal sandstone of the Chinle Formation is discontinuous in the area of the Circle Cliffs; but in the subsurface to the west, including the Kaiparowits region, the basal sandstone becomes a blanket deposit (Doelling, 1975). This blanket deposit is probably in part the Monitor Butte Member of the Chinle Formation with a few remnants of Shinarump at the base (R. G. Young, 1977, personal commun.). In a study of the White Canyon and Monument Valley areas of Utah and Arizona, Young (1964) concluded that the basal sandstone is composed of two distinct units separated by an unconformity. The lower unit, which is essentially confined to the deeper scours, is the Shinarump Member, and sandstone resting disconformably on the Shinarump is the basal sandstone of the Monitor Butte Member. In the White Canyon and Monument Valley areas, the Monitor Butte consists of gray to green micaceous mudstone and claystone with a few lenses of fine- to coarse-grained sandstone and conglomerate. The basal sandstones of the Monitor Butte appear to be channel-fill deposits much like those of the Shinarump; they are lenticular and contain lenses of siltstone, mudstone, and claystone. The fine-grained lenses are more numerous in the Monitor Butte than in the Shinarump, are light gray to green, and are very micaceous.

The Petrified Forest Member overlies the basal sandstone of the Chinle in the project area (Fig. 3). This member is bentonitic claystone or mudstone and clayey sandstone with minor siltstone, conglomerate, and thin seams of gypsum. Much of the claystone is believed to have been formed by alteration of volcanic debris (Stewart and others, 1972). One of the most characteristic features of the Petrified Forest is the varied coloration; the rocks are predominantly red or green, but some are shades of purple, blue, orange, yellow, or gray. Silicified wood associated with the sandstone facies is abundant in some areas.

MORRISON FORMATION

The Morrison Formation (Upper Jurassic) is well exposed throughout the project area. It consists of two members: the lower Salt Wash Member and the upper Brushy Basin Member. The Salt Wash unconformably overlies the Summerville Formation (Middle Jurassic). The Summerville consists of thinly bedded sandstone and claystone. Southeast of Escalante, the typical thin-bedded facies of the Summerville is gradually replaced by light-colored, irregular eolian sandstone beds, making the contact between the Summerville and Salt Wash difficult to distinguish.

The Salt Wash is pale-pink to buff, arkosic, medium- to very coarse-grained sandstone with subordinate layers of maroon mudstone and siltstone. Current and festoon cross-bedding predominate, although laminar bedding is more common in outcrops north of Escalante. Limonite speckling is common; some sandstone beds contain limonite nodules with cores of pyrite. Carbonaceous material was not seen in outcrop. Silicified wood is also uncommon. The sandstones fill shallow scours in underlying mudstones, and the mudstones display compaction features. Dark-red mudstone has been bleached to pale gray-green immediately beneath thick sandstone beds. The complex interfingering relationships at channel edges in Morrison outcrops farther east in the Henry Mountains are not developed because of the continuity of the Salt Wash sands.

The upper mudstone unit of the Morrison Formation, the Brushy Basin Member, is poorly represented in the Kaiparowits region and is absent in the southern part of the project area due to pre-Dakota erosion. Where present, the Brushy Basin is difficult to differentiate from the mudstones of the overlying Dakota Formation.

The Morrison Formation reaches its maximum thickness of 620 ft at Navajo Point (T. 42 S., R. 8 E.). It thins to the south and southeast of the project area; at Cummings Mesa (T. 43 S., R. 8 E.), it is 350 to 400 ft thick, although the section is incomplete here. The formation thins to the southwest and is beveled by pre-Dakota erosion a few miles west of Wahweap Creek (T. 42 S., R. 1 E.). To the northwest, the Morrison intertongues with the predominantly eolian Henrieville Sandstone and its fluvial characteristics become less distinguishable. To the northeast the formation has been eroded but is exposed again 20 mi away in the Waterpocket Fold. The Morrison pinches out toward Escalante.

Although the Morrison Formation is well exposed on the eastern and southern flanks of the Kaiparowits Plateau, facies changes beneath the plateau are poorly understood. However, it is generally agreed that, during Salt Wash time, the Kaiparowits area was near the apex of a large fanlike alluvial deposit that spread toward the northeast (Craig and others, 1955; Mullens and Freeman, 1957; Thompson and Stokes, 1970).

CRETACEOUS STRATA

The Dakota Formation unconformably overlies the Morrison in the eastern part of the project area, but farther west, near Glen Canyon City, it rests unconformably on either the Henrieville or Entrada Sandstone. The Dakota consists of buff to light-gray, coarse-grained, cross-bedded sandstone, which is typically fossiliferous. The sandstone is interbedded with shaly sandstone, mudstone, shale, carbonaceous shale, and coal. The Dakota is a transgressive littoral deposit with fluvial, paludal, tidal flat, and nearshore marine environments represented (Doelling, 1975).

Conformably overlying the Dakota Formation is the Tropic Shale. It is generally dark-colored, slope-forming, marine mudstone and clayey shale, with interspersed beds of fine-grained sandy shale. The base and top are commonly more sandy than the middle, and beds of fossiliferous fine-grained sandstone are present locally. The contact of the Tropic Shale with the overlying Straight Cliffs Formation represents a transitional regressive period from a marine to nonmarine environment. The contact is usually defined as the bottom of the first thick littoral marine sandstone unit within this transitional sequence.

The Straight Cliffs Formation is composed predominantly of thick beds of light-colored, cliff-forming, cross-bedded sandstone, with shale, mudstone, and coal. It has been subdivided into four members in the Kaiparowits area by Peterson (1969); these are, in ascending order: Tibbet Canyon, Smokey Hollow, John Henry, and Drip Tank.

The contact between the Straight Cliffs Formation and overlying Wahweap Sandstone is often difficult to place. However, the lower Wahweap sandstones are generally thinner-bedded and less resistant than those of the Straight Cliffs Formation.

URANIUM FAVORABILITY

URANIUM OCCURRENCES

The basal Chinle sandstone members, such as the Shinarump and Moss Back, and the Salt Wash Member of the Morrison Formation contain significant deposits of uranium in many parts of the Colorado Plateau. Sixteen uranium prospects are reported in the Kaiparowits area (Table 1). Information concerning these occurrences is taken from the U.S. Atomic Energy Commission Preliminary Reconnaissance Reports and may be incomplete.

In the Circle Cliffs area, northeast of the Kaiparowits Plateau, most of the uranium in the Chinle Formation is confined to the base of the Shinarump Member. The most significant mineralization is found in, at, or adjacent to sandstone-filled channels cut into the Moenkopi. Clay galls, siltstones, mudstones, and carbonaceous material have been incorporated into the sandstone along the edges and bottoms of the channels, producing a sandstone-to-mudstone ratio suitable for localization of ore (Doelling, 1975). Mineralization probably occurred because uranium-bearing solutions were impeded along zones of low porosity and permeablility. In the basal Chinle, the deposits are either of the uranium or copper-uranium type.

In the Lees Ferry area south of Kaiparowits Plateau, the most productive deposits of uranium have been found in the two lower, more permeable units of the Chinle Formation: the Shinarump Member, and the overlying sandstone and mudstone unit. The upper part of the Chinle also is mineralized locally (Phoenix, 1963). In the Shinarump Member, oxidized uranium and copper minerals are commonly localized in the lower part or on the sides of channels.

Within the study area, a radiometric anomaly in the Petrified Forest Member was sampled and analyzed for uranium content (MAF 130, App. B). This sample contained 0.51 percent U_3O_8; the uranium mineral was identified as arsenuranylite [$Ca(UO_2)_4 (AsO_4) (OH)_4 \cdot 6H_2O$]. Significant uranium deposits occur in the Petrified Forest Member in the Cameron area, south of the Kaiparowits Plateau (Chenoweth and Malan, 1973) [Fig. 1].

TABLE 1. URANIUM OCCURRENCES IN THE KAIPAROWITS PLATEAU

Name	Location	Host rock (formation, member)	Uranium minerals	Reference*
1. Horse Creek	sec. 16, T. 34 S., R. 6 E.	Chinle, Shinarump	-	PRR (no file number)
2. Hatch	sec. 21(?), T. 34 S., R. 6 E.	Chinle, Shinarump	-	PRR (no file number)
3. Hot Shot	sec. 25, T. 35 S., R. 7 E.	Chinle, Shinarump	-	PRR (no file number)
4. Falling Star	sec. 35, T. 35 S., R. 7 E.	Chinle, Shinarump	-	PRR (no file number)
5. Farewell	sec. 2(?), T. 36 S., R. 7 E.	Chinle, Shinarump	Carnotite	PRR (no file number)
6. Honeybell	sec. 3(?), T. 36 S., R. 7 E.	Chinle, Petrified Forest(?)	-	PRR (no file number)
7. Last Chance	sec. 3(?), T. 39 S., R. 1 W.	Tropic(?)	-	PRR R.R.-207
8. Eastern Lady	sec. 3(?), T. 38 S., R. 2 W.	Henrieville Sandstone(?)	-	PRR R.R.-188
9. Shepard 1 & 2	sec. 3(?), T. 38 S., R. 2 W.	Henrieville Sandstone(?)	-	PRR R.R.-189
10. Sunset No. 1 & 2	sec. 3(?), T. 41 S., R. 1 W.	Dakota(?)	-	PRR R.R.-182
11. Barbara-Betty	sec. 15, T. 41 S., R. 2 W.	Chinle, Shinarump(?)	-	PRR R.R.-305
12. Blue Jack	sec. 15, T. 41 S., R. 4 W.	Chinle, Petrified Forest(?)	-	PRR R.R.-208
13. Radiant	sec. 25, T. 42 S., R. 2 E.	Chinle	-	PRR R.R.-144
14. Unnamed	sec. 2, T. 42 S., R. 3 W.	Chinle, Petrified Forest	Autunite(?) Torbernite(?)	PRR S.L.-219
15. Winona 1-6 Moqui 1-16	secs. 3, 4, 9, T. 42 S., R. 3 W.	Chinle, Petrified Forest	-	PRR R.R.-298
16. Paria Rd. 1-6	secs. 20, 29, T. 43 S., R. 4 W.	Chinle, Shinarump	-	PRR (no file number)

*PRR--Atomic Energy Commission Preliminary Reconnaissance Report, open-file.

The Morrison Formation was the target of intense exploration during the mid-1950s. Numerous mining claims are located throughout the project area, but no development work or radioactivity anomalies are associated with these claims. Peterson and Waldrop (1965) stated that the area was prospected by both airborne and carborne scintillometers, but no uranium discoveries were made. One area of anomalous radioactivity was reported on Cummings Mesa, south of the project area (Klosterman, 1954). A helicopter reconnaissance flown during this project failed to indicate any anomalies or development work. Deposits in the Salt Wash Member occur along the Waterpocket Fold and in the Henry Mountains just east of the project area. These deposits are small and high grade but are economic only where exposed at the surface or clustered closely together (Doelling, 1967).

Several Preliminary Reconnaissance Reports indicate prospecting activity in the Tropic Shale, Dakota Formation, and Henrieville Sandstone (Table 1). These small prospect pits are no longer visible, although the locations were slightly radioactive. Petrographic analyses indicated no uranium minerals.

FAVORABILITY CRITERIA

Chinle Formation

Characteristics of uranium deposits in the basal sandstones of the Chinle Formation in Garfield County are summarized by Doelling (1967): (1) uranium mineralization usually is associated with sandstone-filled channels cut into the Moenkopi Formation; (2) intermediate-size channels, from 1/2 to 1 mi in width, seem to be more favorable; and (3) uranium mineralization is associated with carbonaceous trash, clay galls, and slump debris along edges, banks, and bottoms of channels where permeable layers alternate with impermeable layers. The evaluation of the uranium favorability of the basal Chinle in the Kaiparowits Plateau project area is based on the above criteria, on consideration of a possible source of uranium, and on gamma-ray anomalies from test-hole logs.

The basal sandstone of the Chinle Formation contains uranium deposits in the areas adjacent to the Kaiparowits Plateau, such as Circle Cliffs and Lees Ferry. In these areas, mineralization occurs in channels at the base of the Shinarump and is associated with carbonaceous matter. In 32 of the 34 test-hole logs, the basal sandstone is present and is a relatively thick unit (Fig. 4). The sandstone appears to be a blanket deposit beneath the Kaiparowits Plateau.

Of the 34 test holes in the project area (Fig. 4), only three logs showed significant anomalies (more than 2X background). The anomalies are indicated on Figure 4.

The Chinle crops out in a narrow band in the western part of the project area (Fig. 2). Carbonaceous matter was lacking at all locations visited for this study. Logs in the basal sandstone near Paria were completely replaced by silica and possibly by calcite.

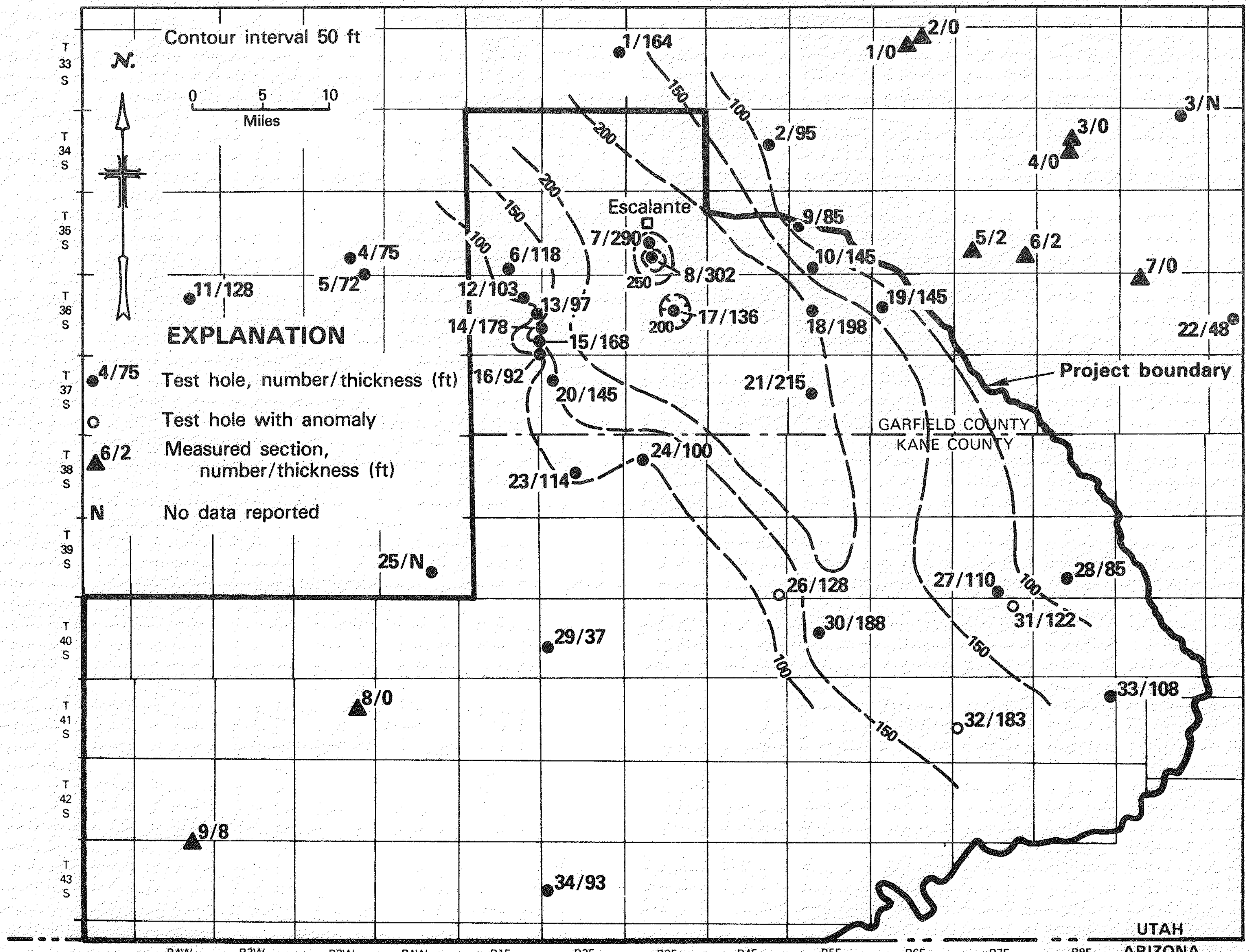

Figure 4. Map showing thickness of the Shinarump Member, location of test holes, and test holes with anomalies, Kaiparowits area.

According to Adler (1974), there are several current views as to the source of uranium: (1) weathering from tuffaceous rocks, (2) leaching of granitic rocks, (3) expelling of magmatic hydrothermal emanations, and (4) expelling of waters by compaction of shales or other sediments. The tuff-leach concept may be the most plausible (Adler, 1974). In the Kaiparowits region, the basal sandstone is overlain by the Petrified Forest Member. Much of the claystone in the Petrified Forest Member is believed to have been formed by alteration of volcanic debris (Stewart and others, 1972) and, therefore, may be a source of uranium.

Morrison Formation

Doelling (1975) described the characteristics of economic deposits in the Salt Wash Member in Garfield County: (1) the largest ore bodies have been found where the sandstone-mudstone ratios approach equality; (2) the largest ore bodies are in thick sandstone lenses; (3) ore bodies may occur at any stratigraphic level within the thick sandstone lenses, but most have been found at the base or edges of the lenses; (4) uranium is associated with carbonaceous material deposited along margins of former channels; and (5) in many places, halos of light-tan to brown limonite staining surround the deposits.

The sandstones of the Morrison Formation in the Kaiparowits region show few characteristics considered favorable for uranium mineralization. The thick, continuous, coarse-grained nature of the sandstones indicate high transmissivity, which would not impede the flow of mineralizing fluids (Mullens and Freeman, 1957). Sandstone lenses and channel edges that terminate in mudstones are seldom found because the Salt Wash is a massive unit. Overbank mudstones were not observed interfingering with the sandstones. Clay galls were not seen in outcrops, though distorted clay lenses were observed. Some clay beds are as much as 10 ft thick but most are thinner. Throughout most of the region, sandstone predominates over mudstone. The sandstone-to-mudstone ratio is greater than 5 to 1. Immediately below the thick sandstone beds, the mudstones are bleached as much as 6 in., and there is some limonite staining. None of the samples taken from this bleached zone showed enrichment in uranium or other trace elements. One sample taken from Collet Canyon (MAF 133, App. B) did show an arsenic anomaly. Although this may not be significant, arsenic enrichment in deposits in the Grants Mineral Belt has been noted, and some authors suggest that arsenic may be an important trace element in sandstone-type uranium deposits (Brookins, 1975). Although no anomalous uranium values occur near this locale, any further investigations in the Kaiparowits region should include the Collet Canyon anomaly. Sample locations are shown on Figure 5.

Carbonaceous debris was not observed in the outcrops although analysis of one sample indicated organic carbon content of almost 0.5 percent. According to Shawe (1976), any carbonaceous debris once present in the sandstone near the apex of the Salt Wash alluvial fan has been oxidized. Pyrite and limonite speckling is common. However, samples of iron-stained sandstones from the project area do not show enrichment in uranium or other trace elements commonly associated with uranium.

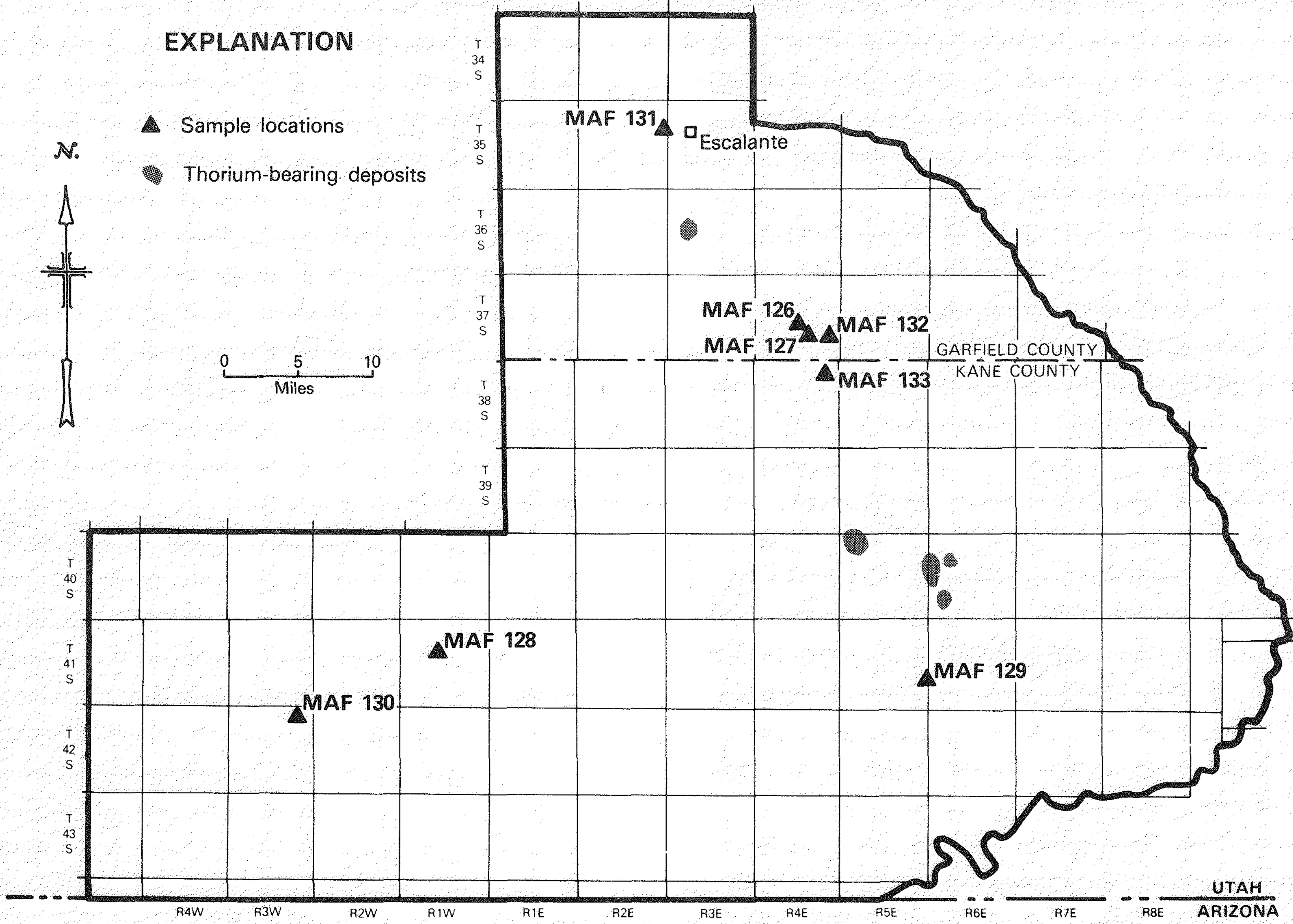

Figure 5. Sample locations and thorium-bearing deposits, Kaiparowits Plateau.

The tuffaceous strata of the Brushy Basin Member may have provided a source for uranium. Leaching of the tuffs and distribution of uranium by descending meteoric waters is a possible mechanism for the formation of uranium deposits (Adler, 1974).

Dakota Formation

Shale and lignite in the Dakota Formation are anomalously radioactive throughout the project area. These carbonaceous rocks were sampled in the early 1950s by Zeller (1955) to determine the uranium potential. Results of analyses performed for this project (App. B) are similar to those reported by Zeller. The widespread lignite and carbonaceous shale may be favorable for uranium deposits, but the low uranium values suggest that they would be very low grade. Sandstone-type uranium deposits in the Dakota Formation occur northwest of Kanab, Utah (Beroni and others, 1953), but are not known in the project area.

Straight Cliffs Formation

The only important concentrations of radioactive material in the Straight Cliffs Formation (Fig. 2) occur in titaniferous, thorium-bearing placer deposits in a massive white sandstone in the John Henry Member. These deposits represent beach-placer accumulations (Dow and Batty, 1961). Local enrichment of uranium occurs in some of the coals and carbonaceous rocks of this formation, but these are insignificant (Zeller, 1955).

The major thorium-bearing deposits in the Kaiparowits Plateau are shown on Figure 5. Thorium is present in monazite and zircon. The Kaiparowits deposits contain as much as 0.15 percent $eThO_2$ (Dow and Batty, 1961). Although these deposits may contain appreciable resources of thorium, the grade of these deposits and present demand for thorium make the deposits uneconomic at the present time.

CONCLUSIONS

Both the Chinle and Morrison Formations are relatively unfavorable in the Kaiparowits Plateau region. The basal Chinle sandstone and Salt Wash Member of the Morrison lack characteristics favorable for uranium mineralization.

Not only are the lithologic characteristics unfavorable, but much of the basal Chinle sandstone is deep. In the Kaiparowits area, these sandstones lie at depths greater than 3,000 ft. Thus, to be economic, the orebody would have to be large and high grade.

The sandstones of the Morrison Formation show few favorable characteristics. The high sandstone-to-mudstone ratio and the continuity of the sandstones suggest low favorability. Although the thickness and coarse-grained nature of the sandstones and the paucity of mudstone layers do not preclude the possibility of uranium mineralization, deposits found in similar environments, such as those in the Henry Mountains and the northwest Carrizo Mountains, tend to be small and highly localized (Chenoweth, 1955). Such deposits are economic only when exposed in outcrop or closely grouped. Lack of clay galls, lack of well-defined overbank deposits, and abundance of scour features within the coarse-grained sandstones reflect the high energy of the alluvial-plain system in the Kaiparowits region during deposition of the Salt Wash Member. Stream-channel directions in this environment would be highly variable; this would directly affect the development of lithologically hetrogeneous channel edges and retard the growth, burial, and preservation of organic matter. This may have resulted in the seeming paucity of carbon trash, although later oxidation of carbonaceous debris may have occurred.

BIBLIOGRAPHY

Adler, H. H., 1974, Concepts of uranium-ore formation in reducing environments in sandstones and other sediments, in Formation of uranium ore deposits: Athens, May 1974, Internat. Atomic Energy Comm. Proc., p. 141-168.

Beroni, E. P., McKeown, F. A., Stugard, F., Jr., and Gott, G. B., 1953, Uranium deposits of the Bulloch group claims, Kane County, Utah: U.S. Geol. Survey Circ. 239, 9 p.

Brookins, D. G., 1975, Uranium deposits of the Grants, New Mexico, Mineral Belt: U.S. Energy Research and Devel. Adm., GJBX-16(76), Open-File Rept., 153 p.

Chenoweth, W. L., 1955, The geology and uranium deposits of the northwest Carrizo area, Apache County, Arizona, in Four Corners Geol. Soc. Guidebook 1st Field Conf.: p. 177-185.

Chenoweth, W. L., and Malan, R. C., 1973, Uranium deposits of northeastern Arizona, in New Mexico Geol. Soc. Guidebook 24th Ann. Field Conf., Monument Valley and vicinity, Arizona and Utah: p. 139-149.

Craig, L. C., Holmes, C. N., Cadigan, R. A., Freeman, V. L., Mullens, T. E., and Weir, G. W., 1955, Stratigraphy of the Morrison and related formations, Colorado Plateau region - A preliminary report: U.S. Geol. Survey Bull. 1009-E, p. 125-168.

Davidson, E. S., 1967, Geology of the Circle Cliffs area, Garfield and Kane Counties, Utah: U.S. Geol. Survey Bull. 1229, 140 p.

Doelling, H. H., 1967, Uranium deposits of Garfield County, Utah: Utah Geol. and Mineralog. Survey Spec. Studies 22, 113 p.

______1975, Geology and mineral resources of Garfield County, Utah: Utah Geol. and Mineralog. Survey Bull. 107, 175 p.

Dow, V. T., and Batty, J. V., 1961, Reconnaissance of titaniferous sandstone deposits of Utah, Wyoming, New Mexico, and Colorado: U.S. Bur. Mines Rept. Inv. 5860, 52 p.

Gregory, H. E., and Moore, R. C., 1931, The Kaiparowits region, a geographic and geologic reconnaissance of parts of Utah and Arizona: U.S. Geol. Survey Prof. Paper 164, 161 p.

Hackman, R. J., and Wyant, D. G., comps., 1973, Geology, structure, and uranium deposits of the Escalante quadrangle, Utah and Arizona: U.S. Geol. Survey Map I-744, scale 1:250,000.

Harshbarger, J. W., Repenning, C. A., and Irwin, J. H., 1957, Stratigraphy of the uppermost Triassic and the Jurassic rocks of the Navajo Country: U.S. Geol. Survey Prof. Paper 291, 74 p.

Hintze, L. F., 1963, Geologic map of southwestern Utah: Utah Geol. and Mineralog. Survey, scale 1:250,000.

Hunt, C. B., 1956, Cenozoic geology of the Colorado Plateau: U.S. Geol. Survey Prof. Paper 279, 99 p.

Klosterman, G. E., 1954, Summary of airborne radiometric surveying in the Kaiparowits Plateau area, Kane County, Utah: U.S. Atomic Energy Comm. RME-73, Tech. Inf. Service, Oak Ridge, Tenn., 11 p.

Lessentine, R. H., 1965, Kaiparowits and Black Mesa basins: Am. Assoc. Petroleum Geologists Bull., v. 49, no. 11, p. 1997-2019.

Mullens, T. E., and Freeman, V. L., 1957, Lithofacies of the Salt Wash Member of the Morrison Formation, Colorado Plateau: Geol. Soc. America Bull., v. 68, no. 4, p. 505-526.

Peterson, Fred, 1969, Four new members of the upper Cretaceous Straight Cliffs Formation in the southeastern Kaiparowits region, Kane County, Utah: U.S. Geol. Survey Bull. 1274-J, 28 p.

Peterson, Fred, and Waldrop, H. A., 1965, Jurassic and Cretaceous stratigraphy of south-central Kaiparowits Plateau, Utah, in Goode, H. D., and Robison, R. A., eds., Guidebook to the geology of Utah, no. 19: Salt Lake City, Utah Geol. Soc. and Intermountain Assoc. Petroleum Geologists, p. 47-69.

Phoenix, D. A., 1963, Geology of the Lees Ferry area, Coconino County, Arizona: U.S. Geol. Survey Bull. 1137, 86 p.

Shawe, D. R., 1976, Geologic history of the Slickrock district and vicinity, San Miguel and Dolores Counties, Colorado: U.S. Geol. Survey Prof. Paper 576-E, 19 p.

Stewart, J. H., Poole, F. G., and Wilson, R. F., 1972, Stratigraphy and origin of the Chinle Formation and related upper Triassic strata in the Colorado Plateau region: U.S. Geol. Survey Prof. Paper 690, 336 p.

Stokes, W. L., and Heylmun, E. B., 1965, Tectonic history of south-central Utah, in Goode, H. D., and Robison, R. A., eds., Guidebook to the geology of Utah, no. 19: Salt Lake City, Utah Geol. Soc. and Intermountain Assoc. Petroleum Geologists, p. 3-11.

Thompson, A. E., and Stokes, W. L., 1970, Stratigraphy of the San Rafael Group, southwest and south central Utah: Utah Geol. and Mineralog. Survey Bull. 87, 50 p.

Young, R. G., 1964, Distribution of uranium deposits in the White Canyon - Monument Valley district, Utah-Arizona: Econ. Geology, v. 59, p. 850-873.

Zeller, J. D., 1955, Reconnaissance for uranium-bearing carbonaceous materials in southern Utah: U.S. Geol. Survey Circ. 349, 9 p.

APPENDIX A

TEST HOLES LOCATED IN THE KAIPAROWITS PLATEAU, GARFIELD AND KANE COUNTIES, UTAH

APPENDIX A. TEST HOLES LOCATED IN THE KAIPAROWITS PLATEAU, GARFIELD, AND KANE COUNTIES, UTAH (Fig. 4).

Well No.	Operator and well name	Location	Formations evaluated (this report)
1.	Skyline Oil - Skyline Federal #1	Sec. 12, T. 33 S., R. 2 E.	Chinle
2.	Mountain Fuel Supply - Collett #1	Sec. 14, T. 34 S., R. 4 E.	Morrison Chinle
3.	Superior Oil - #14-2 Swap Mesa Unit	Sec. 2, T. 34 S., R. 9 E.	Morrison Chinle
4.	Tidewater Oil - Johns Valley Unit #41-27	Sec. 27, T. 35 S., R. 2 W.	Morrison Chinle
5.	Tenneco Oil - John's Valley #1	Sec. 35, T. 35 S., R. 2 W.	Morrison Chinle
6.	Tenneco Oil - Upper Valley #37	Sec. 34, T. 35 S., R. 1 E.	Chinle
7.	Tenneco Oil - A.J. Button Oil Unit #1-A	Sec. 20, T. 35 S., R. 3 E.	Chinle
8.	Tenneco Oil - Button #2	Sec. 29, T. 35 S., R. 3 E.	Chinle
9.	Travis Oil - Federal - Travis #2	Sec. 18, T. 35 S., R. 5 E.	Chinle
10.	Champlin Petroleum - #3 Collett Unit 31-32 (35-5)	Sec. 32, T. 35 S., R. 5 E.	Chinle
11.	Lion Oil - #1 Bryce	Sec. 10, T. 36 S., R. 4 W.	Morrison Chinle
12.	Tenneco Oil - Upper Valley Unit #1	Sec. 11, T. 36 S., R. 1 E.	Morrison Chinle
13.	Tenneco Oil - Upper Valley Unit #3	Sec. 13, T. 36 S., R. 1 E.	Morrison Chinle
14.	Tenneco Oil - U.S.A. Upper Valley Unit #4	Sec. 24, T. 36 S., R. 1 E.	Morrison Chinle
15.	Tenneco Oil - Upper Valley Unit #20	Sec. 25, T. 36 S., R. 1 E.	Chinle
16.	Tenneco Oil - Upper Valley Unit #25	Sec. 36, T. 36 S., R. 1 E.	Chinle

APPENDIX A. (continued)

Well No.	Operator and well name	Location	Formations evaluated (this report)
17.	Oil Development Co. of Utah - W.R. Woolsey #1	Sec. 15, T. 36 S., R. 3 E.	Chinle
18.	Gulf Oil - Collett Unit Federal #1	Sec. 17, T. 36 S., R. 5 E.	Chinle
19.	Amoco Production - U.S.A. Amoco "H" #1	Sec. 18, T. 36 S., R. 6 E.	Chinle
20.	Tenneco Oil - Upper Valley #21	Sec. 7, T. 37 S., R. 2 E.	Chinle
21.	Webb Resources - #17-16 Federal	Sec. 17, T. 37 S., R. 5 E.	Chinle
22.	Romex Petroleum - Bull Frog #1	Sec. 21, T. 36 S., R. 10 E.	Chinle
23.	Tenneco Oil - Upper Valley South #1	Sec. 16, T. 38 S., R. 2 E.	Morrison Chinle
24.	Sun Oil - Lyons Federal #1	Sec. 8, T. 38 S., R. 3 E.	Chinle
25.	Marathon Oil - Butler Valley Gov't #1	Sec. 22, T. 39 S., R. 1 W.	Chinle
26.	Great Western Drilling - #2 Unit	Sec. 36, T. 39 S., R. 4 E.	Morrison Chinle
27.	D&B Oil - #1 Federal - Richter	Sec. 34, T. 39 S., R. 7 E.	Chinle
28.	Webb Resources - Federal #28-13	Sec. 28, T. 39 S., R. 8 E.	Chinle
29.	Tenneco Oil - Tibbitts Canyon #1	Sec. 19, T. 40 S., R. 2 E.	Morrison Chinle
30.	Cleary Petroleum - State #1-16	Sec. 16, T. 40 S., R. 5 E.	Chinle
31.	Shell Oil - #1 Unit	Sec. 2, T. 40 S., R. 7 E.	Chinle
32.	Romex - Rock Creek Federal #1	Sec. 19, T. 41 S., R. 7 E.	Chinle
33.	Sojourner Exploration - #1 Burger Federal (U-507)	Sec. 12, T. 41 S., R. 8 E.	Chinle
34.	Union Oil of California - Judd Hollow #1	Sec. 19, T. 43 S., R. 2 E.	Chinle

APPENDIX B

DESCRIPTION AND ANALYSES OF
SAMPLES, KAIPAROWITS PLATEAU

APPENDIX B. DESCRIPTION AND ANALYSES OF SAMPLES, KAIPAROWITS PLATEAU (Fig. 5).

Sample no.

MAF 126: uraniferous lignite in Dakota Sandstone, Collet Canyon - sec. 21, T. 37 S., R. 4 E.
U_3O_8: 70 ppm, Se: 9 ppm, Mo: 26 ppm, 500 cps*; no uranium minerals identified.

MAF 127: Brushy Basin Member(?) of the Morrison Formation, Collet Canyon - sec. 27, T. 37 S., R. 4 E.
U_3O_8: 2 ppm, Mo: 1 ppm, 180 cps*; clay analysis-equal amounts of illite, montmorillonite, and mixed-layer clays.

MAF 128: uraniferous lignite in Dakota Sandstone, Cockscomb area - sec. 16, T. 41 S., R. 1 W.
U_3O_8: 3 ppm, Se: 2 ppm, Mo: 5 ppm, 400 cps*; no uranium minerals identified.

MAF 129: underclay from Salt Wash Member of the Morrison Formation, Sit Down Bench area - sec. 24, T. 41 S., R. 5 E.
U_3O_8: 1 ppm, Mo: 2 ppm; clay analysis - 85% montmorillonite, 15% illite.

MAF 130: Petrified Forest Member of the Chinle Formation - sec. 2, T. 42 S., R. 3 W.
U_3O_8: 0.51%, V_2O_5: 0.04%, organic carbon: 0.13%; clay analysis - 85% montmorillonite, 5% illite, 5% kaolinite, 5% chlorite.

MAF 131: underclay from Salt Wash Member of the Morrison Formation, Wide Hollow - sec. 13, T. 35 S., R. 2 E.
U_3O_8: 4 ppm, V_2O_5: 208 ppm, Mo: 1 ppm, organic carbon: 0.44%; clay analysis - 50% montmorillonite, 25% kaolinite, 20% illite, 5% chlorite.

MAF 132: iron-stained sandstone, Salt Wash Member of the Morrison Formation, Collet Canyon - sec. 26, T. 37 S., R. 4 E.
U_3O_8: 2 ppm, V_2O_5: 85 ppm, Mo: 1 ppm, Fe: 0.64%, organic carbon: 0.14%, 50 cps*.

MAF 133: iron-stained underclay from Salt Wash Member of the Morrison Formation, Collet Canyon - sec. 11, T. 38 S., R. 4 E.
U_3O_8: 3 ppm, V_2O_5: 123 ppm, Mo: 2 ppm, As: 54 ppm, Fe: 1.82%, organic carbon: 0.02%; clay analysis - 50% illite, 40% montmorillonite, 10% chlorite.

*Counts per second - readings determined from Mt. Sopris portable scintillometer, model SC-132.

APPENDIX C

MEASURED SECTIONS IN THE KAIPAROWITS PLATEAU AND ADJACENT AREAS

APPENDIX C. MEASURED SECTIONS IN THE KAIPAROWITS PLATEAU AND ADJACENT AREAS (Fig. 4).

No.	Name	Location	Reference
1.	Horse Canyon (U-10)	sec. 9, T. 33 S., R. 6 E.	Stewart & others, 1972
2.	Lampstand Draw (Section 8)	sec. 3, T. 33 S., R. 6 E.	Davidson, 1967
3.	Muley Twist (U-11)	sec. 16, T. 34 S., R. 8 E.	Stewart and others, 1972
4.	Chinle (Section 10)	sec. 16, T. 34 S., R. 8 E.	Davidson, 1967
5.	Silver Falls Creek (U-14)	sec. 29, T. 35 S., R. 7 E.	Stewart & others, 1972
6.	Silver Falls (Sec. 9)	secs. 25 & 26, T. 35 S., R. 7 E.	Davidson, 1967
7.	Chinle (Section 11)	sec. 5, T. 36 S., R. 9 E.	Davidson, 1967
8.	Paria (U-24)	sec. 14, T. 41 S., R. 2 W.	Stewart & others, 1972
9.	Fossil Wood Wash (U-23)	secs. 34 & 35, T. 42 S., R. 4 W.	Stewart & others, 1972