Uranium minerlaization near Cameron, Arizona

Bollin, E. M. Kerr, Paul F.

1958, pp. 164-168. https://doi.org/10.56577/FFC-9.164

in:

Black Mesa Basin (Northeastern Arizona), Anderson, R. Y.; Harshbarger, J. W.; [eds.], New Mexico Geological Society 9th Annual Fall Field Conference Guidebook, 205 p. https://doi.org/10.56577/FFC-9

This page is intentionally left blank to maintain order of facing pages.

URANIUM MINERALIZATION NEAR CAMERON, ARIZONA

by E. M. BOLLIN and PAUL F. KERR
Columbia University

INTRODUCTION

The Cameron uranium mining district lies along the southwestern boundary of the Navajo Indian Reservation within the valley of the Little Colorado River. The town of Cameron is at the intersection of U. S. Highway 89 and the Little Colorado River 52 miles north of Flagstaff, Arizona (Fig. 1). Mining activity is restricted to a curved belt approximately two miles wide extending six miles north of Cameron along U. S. Highway 89 and 18 miles southeast along the Little Colorado River. The area encompasses portions of townships 27 to 29N., Ranges 9-10 E. (Gila and Salt River meridians). Ore is beneficiated at Tuba City, Arizona, 28 miles north and east of Cameron.

Structure and erosion have combined to expose a wide belt of nearly flat-lying Chinle sediments near the base of the formation south and west of the Black Mesa basin. The rock is a fluvatile, medium to coarse grained, poorly sorted, arkosic sandstone deposited in a series of channel scours or depressions in bentonitic claystones and mudstones. Loci of ore deposition occur in abrupt depressions along the channel or at changes in direction. Higher grade ore generally occurs on the steepest bank of the channel reflecting the method of entrapment of carbonaceous material within the lens.

A complex mineral suite with soluble uranium constituents and heavy metal sulphides suggests that the ore-bearing solutions did not move far along channels from points of introduction. The absence of altered channel sand away fom the depression indicates that the channels were not completely saturated.

Primary ore bodies are closely associated with organic detritus and mineralization consists of uraninite with minor amounts of coffinite. Alteration accompanying primary mineralization has been slight and consists of the redistribution or removal of hematite.

Oxidized ore bodies are influenced by the permeability of the host rock which regulated migration from the unoxidized centers. Clay pellets have served to some extent as loci for replacement. Alteration has produced profound effects on the color, cementation, permeability, and composition of the host rock.

The discovery of uranium in the Cameron district was made early in 1952 by Charlie Huskon, an Indian prospector. The Arrowhead Uranium Company was named lessee and developed the major portion of the exposed ore bodies. Development ore was shipped to the Blue Water mill in New Mexico. Activity in the area was accelerated by the purchase of the Arrowhead Uranium holdings and the construction of a mill at Tuba City, Arizona, by the Rare Metals Corporation of America. Milling facilities were in operation by June of 1956, but production was limited by mill capacity. Subsequent enlargement of the mill has permitted development of the Cameron properties at the discretion of the individual mine operators.

Nearly all commercial ore bodies in the Cameron district lie just within the southwest corner of the Navajo Indian Reservation (Fig. 2). Exploration, mining activity, and land status are governed by the Tribal Council at Window Rock, Arizona.

STRATIGRAPHY

Permian to late Tertiary formations are exposed in the Cameron district. The Permian Kaibab formation is composed of light yellowish arenaceous dolomite overlain by the Triassic Moenkopi formation of red sandstones, shales, silts, mudstones, and limestones. A marked depositional break occurs at the base of the conglomeratic Shinarump member of the Chinle formation. Upwards through the Chinle the greatest percentage of the sequence is composed of bentonitic muds and clays of the variegated "Painted Desert." Intercalated with this volcanic debris is a normal detrital component gradational from the bottom of the Shinarump as a conglomerate; the grain size decreases upward and culminates in limestone at the top of the formation (Wilson, 1955). Sedimentation trends from the Permian to the close of the Triassic were dominantly north-northeast. The massive sandstones and shales of the Jurassic Glen Canyon Group overlie the Chinle and have a dominantly southwesterly trend (Harshbarger and others, 1955). Cretaceous to early Tertiary rocks are absent. Late Tertiary rocks are composed of basaltic lavas and cinder cones (Colton, 1937). Numerous deposits of well rounded gravels from resistant portions of older formations cap remnants of pediments (Childs, 1948).

STRUCTURE

The dominant regional structure near Cameron is the East Kaibab monocline (Babenroth and Strahler, 1945). South of the Grand Canyon the structure curves to the east beyond the Coconino salient. The eastern continuation of

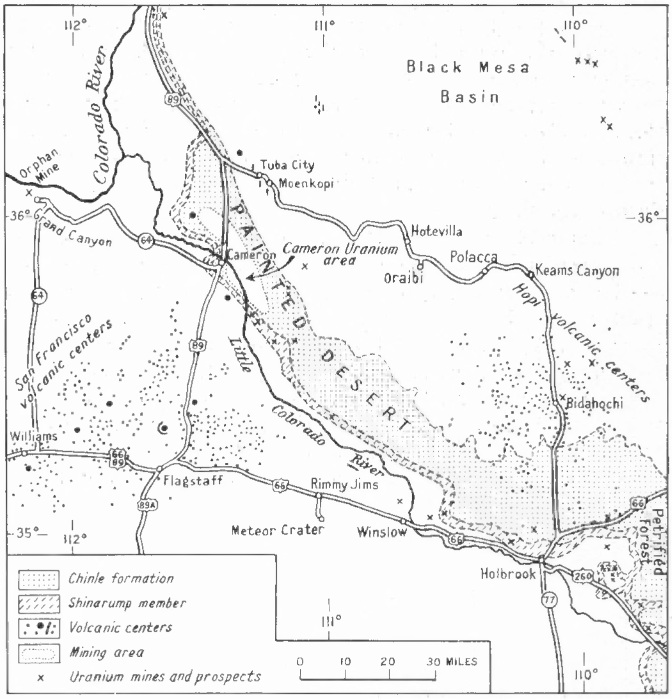

FIGURE 1. Index and location map of the Cameron uranium area.

the structure, the Black Point monocline, forms the southern limit of the district.

The western boundary of the district is formed by marginal arching and erosion peripheral to the Coconino salient and the gradual rise of the Marble platform. The northern and eastern boundary is formed by upper Chinle and Jurassic rocks which overlie the productive portion of the Chinle in a series of cliffs which border the Black Mesa basin. The cliffs are known as Wards Terrace, Wingate Cliffs, and Navajo Cliffs.

Structurally the district constitutes the southwest corner of the Black Mesa basin with a dip of 1-1½ to 3 degrees to the northeast. Superimposed on this regional dip are two sets of small undulations oriented north-northeast and west-northwest. These gradually disappear to the east from a maximum development near the western border of the district in the vicinity of Shadow Mountain. The largest undulations are shown on the structural diagram (Fig. 2) to the southeast of Shadow Mountain. The general eastward extension across the district is established by drill data. The local structures postdate Pleistocene gravels (Reiche, 1937).

URANIUM DEPOSITS

Stratigraphically, uranium ore is found from the Moenkopi formation to the Kayenta formation with the major portion of commercial ore in the lower part of the Petrified Forest member of the Chinle formation. Primary mineralization throughout the sequence consists of uraninite with copper the dominant accessory in the Moenkopi and upper Chinle, cobalt-manganese in the Petrified Forest member proper, and manganese in the Kayenta formation. Lateral distribution shows no distinct variation aside from a minor appearance of phosphate at the eastern end of the district.

Nearly all deposits are highly oxidized with small remnants of high grade primary uraninite. Drilling and mining of one ore body shows that the ore remains in an unoxidized condition under sufficient cover; the grade becomes higher, but the size becomes correspondingly smaller. The total amount of uranium remains relatively the same, indicating that secondary enrichment has not occurred and movement during oxidation has yielded some lateral expansion.

Distribution of oxidized ore within an individual lens is controlled by the method of introduction, the range in permeability, and to a great extent, the distribution of carbonaceous material. The latter two variables have been greatly influenced by the configuration of the channel scour and the velocity of transport as filling occurred. The asymmetry of the channel scour and the corresponding distibution of uranium concentration is shown in Figure 3.

Distribution of primary minerals within the ore lenses is controlled by a combination of fracturing and faulting providing access of solutions to the lens where sufficient carbonaceous material was present to accelerate precipitation. A two-fold orientation of a major part of the ore bodies is observed with lineation at large angles to the sedimentary trends (Fig. 4). This suggests a linear introduction mechanism. Faulting with mineralization halos, and faulting with an established connection with the underlying Shinarump artesian springs points to localization of primary introduction.

A large amount of pyrite and marcasite was formed with the uraninite. During oxidation sulphuric acid reacted with carbonate to produce gypsum and limonitic alteration halos. The carbonate content of the oxidized ores is low — generally in the range of 0.01-0.4 percent. Appreciable carbonate is found only in small veinlets cutting the unoxidized uraninite logs and in one or two relatively unoxidized ore bodies. Here the carbonate content may run as high as 65 percent.

The primary mineralization is found associated with organic detritus. Unoxidized logs may contain as much as 35 percent uranium and 50 percent pyrite or marcasite. Small amounts of copper, cobalt, manganese, and molybdenum mineralization are noticeable in many of the mines.

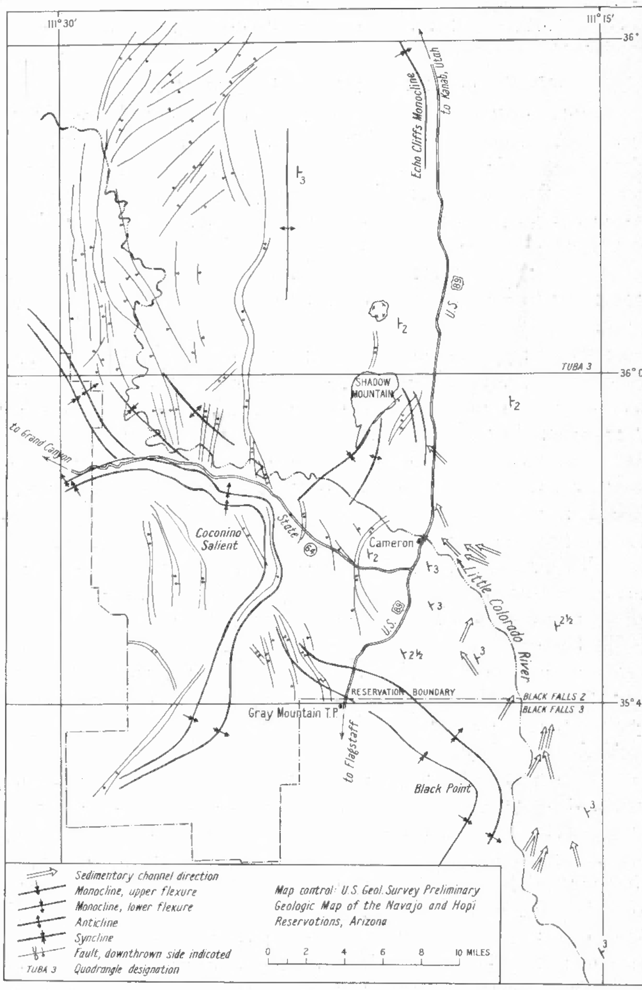

FIGURE 2. Structural diagram showing sedimentary directions of the Petrifed Forest member of the Chinle formation.

The absence of vanadium has been reflected in a complex suite of highly soluable oxides and sulphates of uranium. The uranium minerals tend to be the same color as the abundant limonite and jarosite and the bright colors of the vanadian ores are not observed.

A rather comprehensive description of the mineralogy was prepared by Austin in 1958 and is as yet unpublished. Notes on mineralogy have been furnished by Hinckley (1955 and 1957); Williams and Barret, (1953); Gruner and others (1954); and Austin (1957). The following list is a summary of the above sources coupled with field identification:

Uranian	Non-uranian
Primary Minerals	
Uraninite, Coffinite	Barite, Bornite, Calcite, Chalcopyrite, Covellite, Dolomite, Galena, Greenockite, Hematite, Marcasite, Pyrite, and Smaltite
Secondary Minerals	
Andersonite, Autunite, Beta-uranophane, Beta-zippeite, Boltwoodite, Carnotite, Gummite, Meta-autunite, Meta-torbernite, Metauranocircite, Phosphuranylite, Sabugalite, Schroeckingerite, Schoepite, Torbernite, Tyuyamunite, Uranophane, and Zeunerite	Alunite, Atacamite, Azurite, Barite Bieberite, Chalcedony, Copiapite, Covellite, Ferrimolybdite, Gypsum, Halotrichite, Hematite, Ilsemannite, Jarosite, Jordisite, Limonite, Malachite, Metasideronatrite, Opal, Pyrolusite, and Sphaero-cobaltite

ROLE OF SOLUTIONS IN EMPLACEMENT

Syngenetic origin and leaching of volcanic ash have been mentioned as possible souces of uranium (Hinckley, 1957; and Wilson,1956). However, the known associations in the Cameron district only serve to confirm the numerous objections summarized by McKelvey, Everhart, and Garrels (1955, p. 498-50). These objections are valid for the Cameron district and have become so well recognized that their restatement here would be superfluous.

A channel network provides the most likely conduits for ore solutions to reach permeable host sandstone lenses which form the loci of mineralization. Deposition of uranium in the scour depressions only, makes it unlikely that the porous sands were entirely saturated with ore-bearing solutions. Only a small portion of the pemeable host lithology is altered even by secondary bleaching which diminishes rapidly away from the ore bodies.

Sandstone lenses with channel scour bottoms are seldom continuous for more than a mile. Barren lenses with suitable lithology and carbonaceous material are found between ore-bearing lenses even in an intermediate position in a cluster of ore bodies. Such distribution precludes extensive mass migration laterally through the paleo-hydrological network.

Tectonic Influence

Strata surrounding the host lithology are largely impermeable and the channel sands are disconnected (Fig. 5). Access of solutions has been restricted to a minor portion of the host lithology. The permeability range of the host rock and the distribution of the carbonaceous material are directly controlled by the sedimentary conditions during deposition. The distribution of oxidized ore depends largely on the distribution of cabonaceous material. Thus uranium concentrations should tend to parallel sedimentary directions (Fig. 3).

The orientation diagram (Fig. 4) of the ore bodies of the district indicates a dominant orientation nearly normal to the sedimentary trends. Such a configuration is inconsistent with a distribution of mineralization by sedimentary features. Comparison of the structural diagram of the district (Fig. 2) with these orientations shows that one dominant structural trend to the northeast nearly parallels certain ore body orientations. The existence of an orientation at variance with the factors of the sedimentary environment is a major feature. A trend which overcomes the combined effects of pemeability orientation and carbonaceous distribution is strong. The parallelism of this orientation with one of the major fault directions of the district constitutes further evidence for assuming fault or fracture control of solutions as a major factor in the Cameron district.

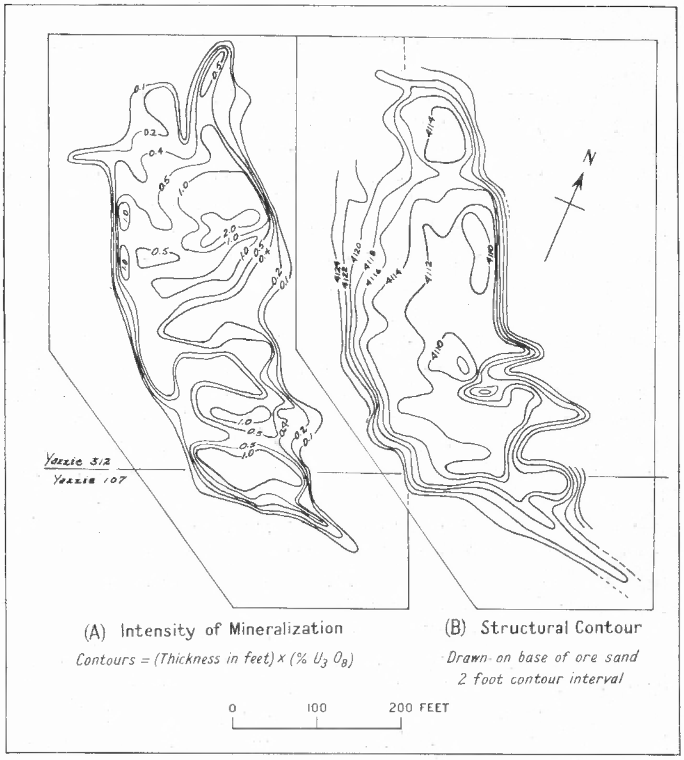

FIGURE 3. A comparison of the intensity of mineralization (A) with channel configuration (B).

Access of Shinarump Solutions to Chinle Host Rock

The possibility should be considered that the Shinarump member provided major access for the ore-bearing solutions to the sandstones in the Petrified Forest member. The Shinarump is an excellent aquifier in the Cameron area and is only slightly silicified. Mineralization or highly radioactive aeas occur in nearly every outcrop and are more abundant than mineralized areas in the Petrified Forest member. Because of a large amount of leaching and unfavorable equilibrium ratios ore bodies are few and only scattered production has resulted. Uranium has been preserved only in areas where silicification has restricted ground-water leaching. The Shinarump is highly altered where no ore or mineralization is now noticeable. Evidence suggests that the Shinarump member at one time contained considerably larger amounts of uranium than the Petrified Forest member .

The hydrostatic head in the Shinarump would provide adequate pressure for positive flow of solutions from the Shinarump to the Chinle ore sands dependent upon the presence or absence of a passageway between the Shinarump and the ore sands. The almost universal shattering of the mudstones surrounding the host lithology would provide such a passageway. Faulting is also believed to provide a passageway in some mines (Huskon 1 and 5; and RAMCO 20-22-Ryan-2). Also, some of the channels of the Petrified Forest member are in direct contact since they are scoured downward into the Shinarump (Huskon 3,4, and 10). The presence of a passageway is well shown in the Alyce Tolino No. 1 mine. When the mine was opened it was found that a series of flowing springs issued from the bottom of the mine along a fault line which traversed the pit (Fig. 6). The highest uranium content is along the fault and presumably represents introduction along the fault. However, as the sedimentary channel is parallel to the fault the channel could be a major controlling factor.

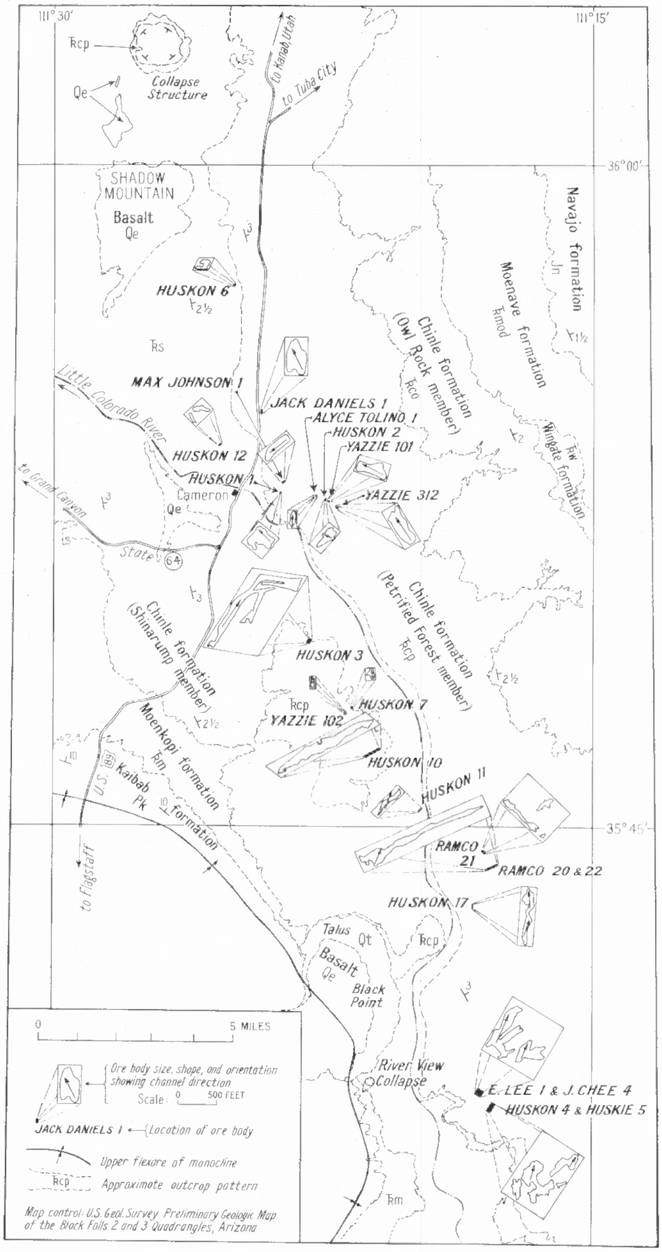

FIGURE 4. A diagram showing the size, shape, and orientation of the Cameron ore bodies.

Source of Solutions

A source of uranium-bearing solutions discharging into the Shinarump artesian system is readily available in the Cameron district. Igneous extrusives are pesent at both ends of the district with closely associated uranium-bearing collapse structures. The igneous sources are apparently post-ore; however, they indicate that weakness in the crust existed at the point of rupture and may represent rejuvenation of previous weaknesses present during the ore episode.

Detailed work on the purity and sedimentary structure of the bentonite in the Chinle by Wilson (1955) suggests a local source of volcanism in the vicinity of Shadow Mountain for at least a part of the Chinle ash. This would

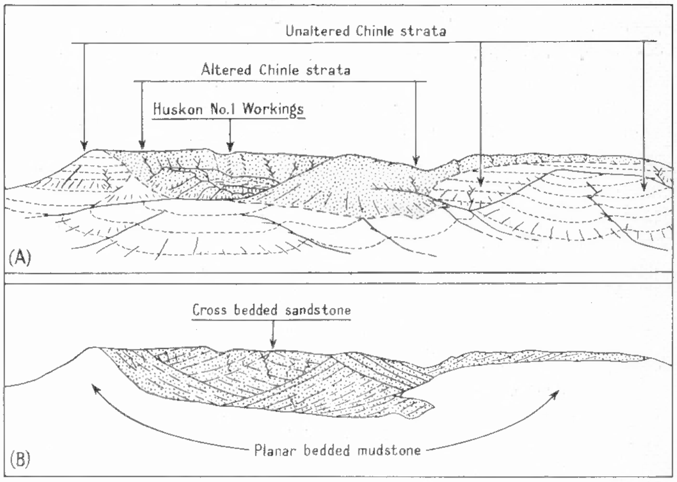

FIGURE 5. Channel development in bentonitic mudstones at the Huskon No. 1 mine.

imply that a structural weakness sufficient to allow volcanism existed in the Cameron area as early as the Triassic.

Both of the known mineralized collapse structures within the district contain ore grade material and the River View collapse, located at the point where the axis of the Black Point monocline is sharply deflected to the southwest (Fig. 4), has produced commercial ore. The collapse at the north end of the district is located at the northern end of a series of cinder cones and flows known as Shadow Mountain (Fig. 4). The collapse is approximately two miles in diameter and contains Chinle sediments in its center. Extensive exploration drilling indicates, however, that mineralization is too deep to be profitably exploited.

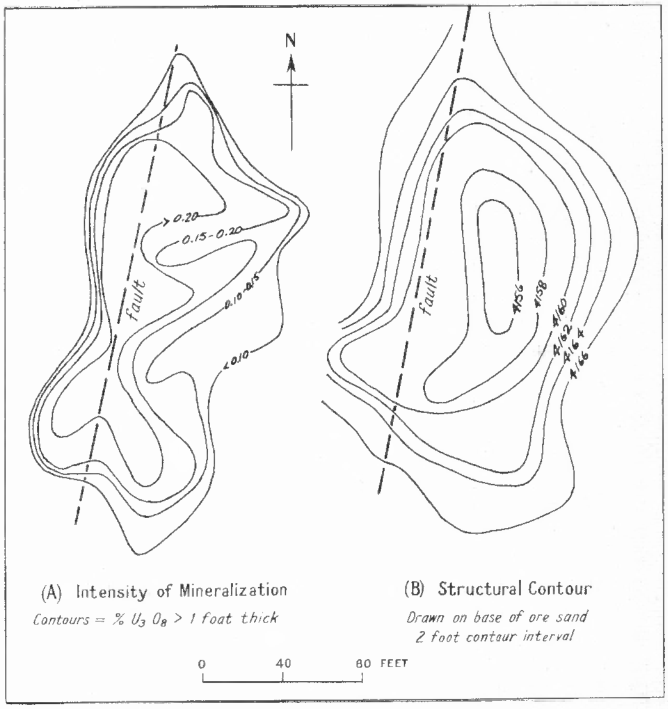

FIGURE 6. Comparison of uranium distribution (A) along faulting and channel scour (B).

A third collapse, the Orphan Lode mine (Fig. 1), is located 42 miles from the center of the district in the Grand Canyon National Park. This collapse is located at the base of the Permian Coconino formation and extends downward for an unknown distance containing high grade uranium ore. Mineralogy in the upper portions of the mine is genetically compatible with the mineralogy of the Cameron area in most of its accessory elements and assumes a characteristic hydrothermal character at depth.

The collapse structures in the Cameron district have not been opened to sufficient depth to confirm or deny a definite hydrothermal source, but the possibility of such a source exists. The significance of these collapse structures has only recently been realized, and active exploration is in its initial stages. A cursory reconnaissance has revealed that additional collapse structures occur in the district, and mineralization and bleaching or alteration of considerable extent is associated with them.

ACKNOWLEDGMENTS

This paper has been made possible through the cooperation of the U. S. Atomic Energy Commission. Both the Division of Research and the Division of Raw Materials have assisted this work in many ways.

REFERENCES

Austin, S. Ralph, 1957, Recent uranium redistribution in the Cameron, Arizona deposits: ASME 2nd Nuclear Eng. and Science Conference, paper No. 43, 8 p.

....................., 1958, Mineralogy of the Cameron area, Arizona: U. S. Atomic Energy Comm., Raw Materials Exploration report (in press).

Babenroth, Donald L. and Strahler, Arthur N., 1945, Geomorphology and structure of the East Kaibab monocline, Arizona and Utah: Bull. Geol. Soc. Amer., v. 56, No. 2, p. 107-150.

Childs, Orlo E., 1948, Geomorphology of the valley of the Little Colorado River, Arizona: Geol. Soc. America Bull., v. 59, p. 353-388.

Colton, Harold S., 1937, The basaltic cinder cones and lava flows of the San Francisco Mountain volcanic field, Arizona: Museum of Northern Arizona, Bull. 10, p. 1-15.

Gruner, J. W., Gardner, L., and Smith, D. K., 1954, Minerals associated in uranium deposits, Colorado Plateau: U. S. Atomic Energy Comm., RME-3092.

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, 79 p.

Hinckley, David N., 1955, Reconnaissance in the Cameron area, Coconino County, Arizona: U. S. Atomic Energy Comm., Raw Materials Exploration report (unpublished).

....................., 1957, An investigation of the occurrence of uranium at Cameron, Arizona: M. S. Thesis, University of Utah, 67 p.

McKelvey, V. E., Everhart, D. L., and Garrels, R. M., 1955, Origin of uranium deposits: Econ. Geol. 50th Anniversary Volume, Pt. 1, p. 464-533.

Reiche, Parry, 1937, Quaternary deformation in the Cameron district of the Plateau province: Am. Jour. Sci., 5th Ser., v. 34, No. 200, p. 128-138.

Williams, Floyd J., and Barrett, Donald C., 1953, Preliminary report of reconnaissance in the Cameron area, Arizona: U. S. Atomic Energy Comm., RME-4002.

Wilson, Robert, 1956, Stratigraphy and economic geology of the Chinle formation, northeastern Arizona: Ph.D. Thesis, University of Arizona.