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1967, pp. 78-85. https://doi.org/10.56577/FFC-18.78

in:

Defiance, Zuni, Mt. Taylor Region (Arizona and New Mexico), Trauger, F. D.; [ed.], New Mexico Geological Society 18th Annual Fall Field Conference Guidebook, 228 p. https://doi.org/10.56577/FFC-18

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THE URANIUM DEPOSITS OF THE LUKACHUKAI MOUNTAINS, ARIZONA

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INTRODUCTION

Location And Accessibility

The Lukachukai Mountains are located on the Navajo Indian Reservation in northeastern Apache County, Arizona. The Navajo community of Cove, Arizona, including a day school and trading post, is located at the northeastern foot of the mountains. Companies mining in the area maintain field camps at Cove.

Cove is reached by traveling south from Shiprock, New Mexico, seven miles on U. S. Highway 666 to a graveled crossroad, then west 33 miles. Unimproved dirt roads lead from Cove to the mines and drilling areas in the Lukachukai Mountains. Haulage distances from the mines to Cove range from four to thirteen miles. An airstrip suitable for light planes is located 2½ airline miles northeast of Cove.

Geography

The Lukachukai Mountains are the northwestern spur of the Chuska Montains and Lukachukai Pass separates them from the main mountain mass. "Lukachukai" is a Navajo word meaning "patches of white reeds" and no doubt refers to the many lakes occurring on the main flat-topped ridge of the mountains. The elevation of this ridge is about 8,800 feet above sea level but isloated ridges rise as much as 100 feet higher. The Lukachukais trend northwestward and, except where the join the Chuskas, terminate as precipitous cliffs. Elevation at the mines ranges from 7,200 to 7,700 feet. Finger-like mesas and deep, steep-walled canyons combine to form very rugged topography. Except for the higher mountain slopes above the heads of the canyons, rock exposures are excellent and fairly continuous, though in many places inaccessible. The rugged topography makes roadbuilding difficult and hazardous.

The finger-like mesas are not true mesas but were named and numbered as such by personnel of the U.S. Atomic Energy Commission (AEC) in late 1950. The prominent mesas on the north side of the mountains are numbered I through VII toward the northwest terminus at Mexican Cry Mesa. The southside mesas bear such descriptive names at Two Prong, Camp, Cisco, Three Point, Knife Edge, Bare Rock, Flag, Step, Fall Down, and Thirsty. In general, the mines are named for the mesas on which they occur and hence such minor divisions as Mesas I½, I¾, II½ and IV½ do occur on the north side.

* Publication authorized by the Atomic Energy Commission.

Aerial view of the northwest end of the Lukachukai Mountains looking northeast into Red Rock Valley. The finger-like mesas in the foreground are part of the Lukachukai mineralized district where uranium deposits are being developed and mined, primarily from the Salt Wash Member of the Morrison Formation. The sheer cliffs below the steep slopes are developed in the Summerville and overlying Bluff Sandstone.

Photograph by W. L. Chenoweth

Previous Work

Soon after the discovery of uranium in the Lukachukai Mountains, the AEC began geologic studies in the area, and a few brief reports were published. These included Mesa V (King, 1951), Mesa VI (Ellsworth and Hatfield, 1951) Mesa VII (King and Ellsworth, 1951), and the southwest rim (Masters, 1951). Masters (1953) summarized the geologic work throughout the entire area. At the same time, Lowell (1953) demonstrated the application of cross-stratification studies to uranium exploration. Stokes' (1954) studies of the relation of sedimentary trends and structure to uranium deposits included the Lukachukai Mountains. Laverty and Gross (1956) described some of the Lukachukai ores in their paragenetic studies of the Colorado Plateau uranium deposits. Dodd (1956) included a description of the 4B mine on Mesa IV½ in his examples of uranium deposits in the Morrison Formation. Dare (1961) reported on Kerr-McGee's mining operations and gives an excellent review of the prob-

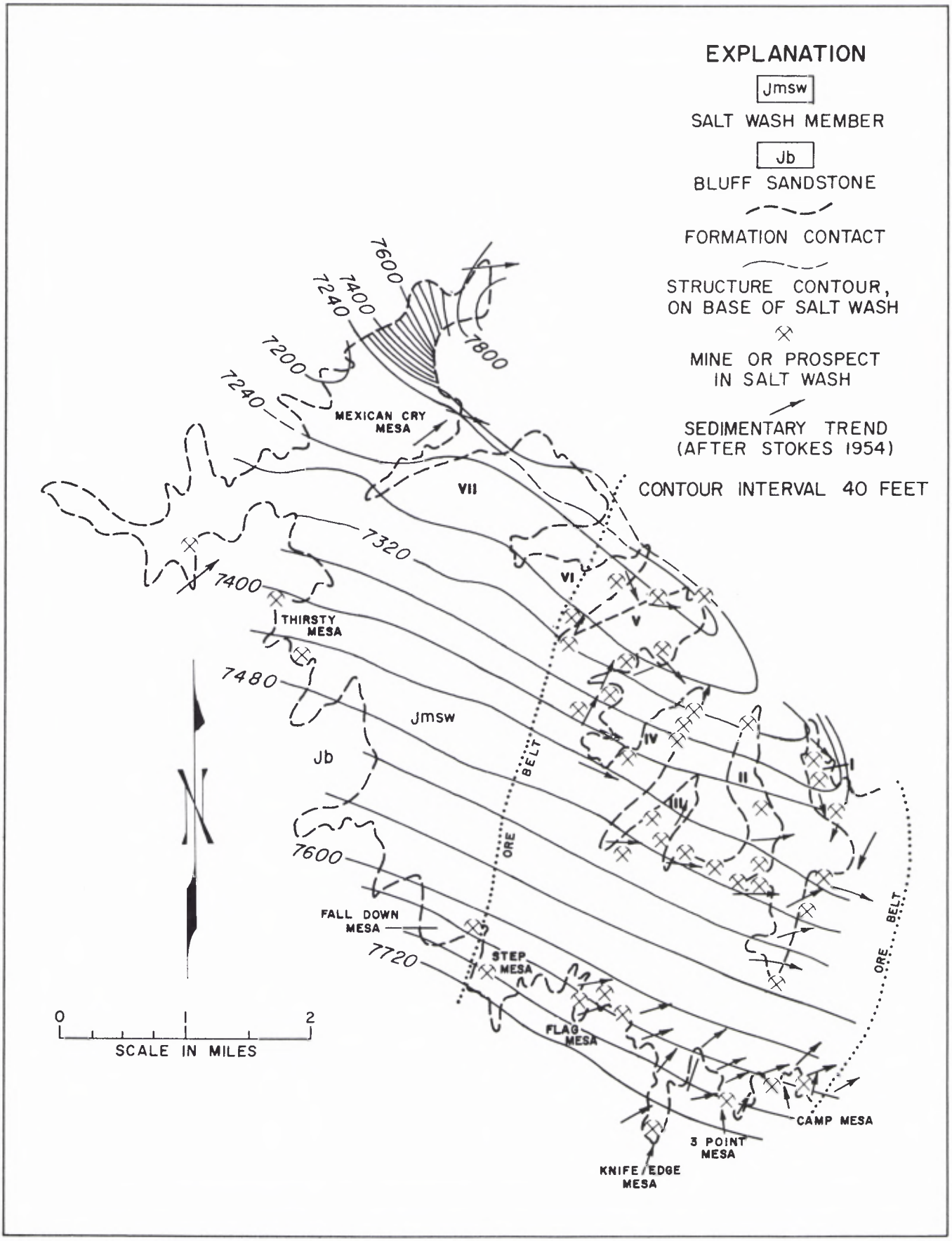

FIGURE 1.
Sedimentary trends, Structure, and Mines in the Lukuchukai Mountains, Arizona.

lems and costs. The relative sizes of the uranium deposits are plotted on the map of the Shiprock quadrangle by O'Sullivan and Beikman (1963).

This paper is largely the result of geologic studies by the author and the late R. K. Nestler during the late 1950's when 10 mines were mapped in detail to determine and evaluate the comparative importance of sedimentary and tectonic ore controls. Thanks are due R. A. Laverty for critically reviewing the paper.

HISTORY OF EXPLORATION AND MINING

Uranium ore was first discovered in the Lukachukai Mountains by Navajo Indians. F. A. Sitton, Dove Creek, Colorado, leased and operated the first property on Mesa I, and in early 1950 he shipped the first ore. By late 1951, two companies were producing ore from five mines. In September, 1950, the Atomic Energy Commission began the first drilling project which was followed by five others that continued intermittently to August, 1955. During this time, mine operators expanded exploration and development activities, and production increased steadily.

Kerr-McGee Oil Industries, Inc., acquired properties in the Lukachukai Mountains in May, 1952 and negotiated a contract with the AEC for the construction of a mill at Shiprock, New Mexico, in August 1953. This 400-ton per day capacity mill went on stream in November, 1954. Meanwhile (in March, 1964) Vanadium Corporation of America acquired Kerr-McGee's mill and mines, which they continue to operate today.

As of January 1, 1967, 4,049,700 pounds of U_3O_8 have been produced from the Morrison Formation in Apache County, Arizona, and in San Juan County, New Mexico; 3,390,000 pounds or 84% of the total has been produced from the Lukachukai Mountains.

Although some shallow or exposed ore bodies in the district have been successfully mined by stripping and open pit methods, most ore bodies are mined underground by the room and pillar method, or modifications of it. Major operators mine the year round on a two or three shift basis. As of January 1, 1967 there were about 50 mines in the Lukachukais.

The area is part of the Navajo Indian Reservation and is under the jurisdiction of the Bureau of Indian Affairs, U. S. Department of the Interior. Leases and mining permits are obtained from the Navajo Tribal Council at Window Rock, Arizona.

GENERAL GEOLOGY

The Lukachukai Mountains lie on the northeast flank of the Defiance Uplift which separates the San Juan Basin, on the east, from the Black Mesa Basin on the west. The mountains are an erosional remnant of sedimentary rocks which range in age from Triassic to Tertiary. About 3,500 feet of continental and marginal marine sediments are exposed. All Cretaceous rocks and any pre-Chuska Tertiary rocks have been removed and an angular unconformity separates Jurassic rocks from the Chuska Sandstone of Tertiary age. Rocks older than the Chinle Formation of Upper Triassic age are not exposed in the area, but a hole drilled on Beclabito dome, about 21 miles northeast of Cove School, penetrated 3,515 feet of Paleozoic rocks and was completed in sediments of Devonian (?) age.

North of the Lukachukais are the Carrizo Mountains. The Carrizos are composed of sills, laccoliths and dikes of diorite porphyry which intrude rocks as young as Upper Cretaceous.

STRATIGRAPHY AND SEDIMENTARY ROCKS

The stratigraphy of the Lukachukai Mountains has been described by Strobell (1956) and the reader is referred to him for a more complete description of the exposed formations. Only the Morrison will be described in any detail.

TRIASSIC STRATA

Chinle Formation

The fluvial and lacustrine Chinle Formation is exposed in broad valleys around the mountains. Uranium minerals have been found in bleached parts of the lower Chinle sandstones where carbon trash is present. The Shinarump Member, although not exposed in the Lukachukai Mountains area, is silicified in exposures on the south flank of the Carrizo Mountains, and is regarded as unfavorable for desposition of uranium. The Chinle thickens eastward.

Wingate Sandstone

Eolian sandstones and siltstones of the Wingate Sandstone are exposed around the foot of the mountains in steep ledgy slopes and picturesque vertical cliffs. The greatest thickness of Wingate in the Colorado Plateau is found in the vicinity of Red Rock Valley from where the formation thins rapidly eastward and more slowly to the north and west.

JURASSIC (?) STRATA

Kayenta Formation

The fluvial Kayenta is exposed as a wedge edge on the northeast side of Mexican Cry Mesa. It pinches out as a result of non-deposition in the area and thickens to the north and west.

JURASSIC STRATA

Navajo Sandstone

The eolian Navajo Sandstone, which is nearly coextensive with the Kayenta Formation, is exposed as a wedge edge on a bench northwest of Mexica Cry Mesa. The sandstone thickens to the northwest.

Carmel Formation

The Carmel Formation consists of marginal marine siltstone and mudstones which thin southeastward and pinch out in the Lukachukai Mountains area. It overlaps

the Kayenta and Navajo feather edges and rests conformably on the Wingate Sandstone. Thinning may be due to pre-Entrada erosion or by lateral gradation into the silty facies of the Entrada Sandstone, or both.

Entrada Sandstone

The marginal marine sandstones and siltstones of the Entrada are partly sub-aerial and partly sub-aqueous. The formation is exposed around the perimeter of the mountains and rests conformably on the Carmel where present; where the Carmel is absent, the Entrada rests unconformably on the Wingate Sandstone.

Todilto Limestone

The Todilto Limestone is absent; its nearest exposure is on the east flank of the Carrizo Mountains.

Summerville Formation

The marginal marine interbedded sandstones and siltstones of the Summerville Formation overlie the Entrada Sandstone and are exposed around the perimeter of the mountains. The typical red and white banding described in other localities is usually absent in the Lukachukai Mountains. The Summerville grades into and intertongues with the overlying Bluff Sandstone.

Bluff Sandstone

The Bluff Sandstone is of eolian origin and is exposed around the perimeter of the mountains. It locally grades into or intertongues with the overlying Salt Wash Member of the Morrison Formation, but the contact usually is easy to distinguish.

Morrison Formation

Salt Wash Member

The Salt Wash Member of the Morrison Formation is the only commercial ore bearing unit in the Lukachukai district. It crops-out continuously around the perimeter of the mountains. Festoon cross-stratification, current lineation, rib-and-furrow, and ripple marks are common sedimentary structures in the sandstone units. Their azimuths provide data on paleostream direction. Sand-filled mud cracks and preconsolidation slump structures also are common.

Cross-stratified sandstones are interbedded with siltstone and claystone. The sandstone commonly contains mud-galls and claystone splits; mudstone pebble conglomerate or edgewise conglomerate lenses or splits often separate individual sandstone lenses within a sandstone unit. Carbonized material, ranging in size from small flecks to logs, is widely distributed and locally abundant.

The base of the Salt Wash is marked by the lowest cut-and-fill type bedding, and over most of the area by six inches to two feet of white calcareous sandstone which is the uppermost part of the Bluff Sandstone (Master, 1953). Sandstones of the Bluff are medium grained, well rounded and frosted; basal Salt Wash sandstones are fine or very fine grained, usually subangular, and are not frosted. The contact generally is easy to distinguish, but on the west side of Mesa II the contact is gradational through a vertical zone of five feet in which Bluff- and Salt Wash-type lithologies are present.

The upper part of the Salt Wash intertongues with the overlying Recapture Member, and the lithologies are so similar as to make distinction between the two members nearly impossible without microscopic examination. On gamma-logs, a characteristic two-pointed deflection marks a gray lacustrine mudstone bed near the contact with the Recapture Member, and this bed is arbitrarily picked as the top of the Salt Wash.

The Salt Wash crops out continuously around the mountains as far southeast as Mesa I and Two Prong Mesa, but beyond this it has been removed by pre-Chuska erosion. In all, only 12.5 square miles of the mountains are underlain by this member of the Morrison.

The Salt Wash (Craig, et al, 1955) was deposited by an aggrading, braided stream system on an alluvial fan, the apex of which is near where the Colorado River enters Arizona. The major source of the sediments probably was west-central Arizona and southeast California. The sediments were derived mainly from older sedimentary formations, and only minor contributions came from igneous and metamorphic rocks. Fresh angular feldspar and quartz grains in outcrops of the Four Corners region suggests that some material was brought by north-flowing streams from the same source area as the overlying Recapture (see below). In the Lukachukai Mountains sediments deposited by northeast-flowing streams cut into and through sediments deposited by east or southeast-flowing streams. The thickness of the Salt Wash ranges from about 100 feet on Mesa I to 180 feet on Thirsty Mesa. The Recapture Member is thinnest in areas where the overlying Salt Wash Member is thickest.

Regionally, the Salt Wash of northeastern Arizona and northwestern New Mexico represents a separate lobe of the main Salt Wash fan in Utah and Colorado. The Lukachukai Mountains are near the thickest part of this lobe which pinches out by non-deposition to the southeast near Toadlena, New Mexico and to the north in the Aneth, Utah area.

Masters (1953) postulates that three facies of the Salt Wash, representing different depositional environments, are present across the Lukachukai Mountains. He states that a thick continuous sandstone facies grades southeastward into a lenticular sandstone and mudstone facies, which in turn grades southeastward into a mudstone and stray sandstone facies. He states also that the lenticular sandstone and mudstone facies exactly coincides with the ore trend or belt.

Sedimentary trends do not substantiate this pattern, which would normally be the result of deposition by predominantly east to southeast-flowing streams over the whole area. Moreover, new data show that thick, continuous sandstones comprising up to 90 percent of the Salt Wash are present in the lenticular standstone and mudstone facies near the change to mudstone and stray sandstone. This new evidence suggests that the boundaries of facies changes, as outlined by Masters, are oversimplified

and that they do not exert the control over configuration of the ore belt as originally believed.

Recapture Member

The fluvial interbedded sandstones and mudstones of the Recapture Member crop out on the higher parts of the mesas, but are usually rather poorly exposed. The major source of Recapture sediments (Craig, et al., 1955) was probably in west-central New Mexico in an area of pre-existing igneous, metamorphic, and sedimentary rocks. The member was deposited by streams in an alluvial fan environment similar to that of the Salt Wash.

The Salt Wash and Recapture fans coalesced in a wide belt near the Four Corners region. Probably the anomalous north and northeast trending stream patterns in the Salt Wash sandstones and the similar lithology of Recapture and Salt Wash sandstones of the Lukachukai Mountains are a result of the influence of Recapture streams and clastics on Salt Wash deposition.

Sub-ore-grade uranium deposits are found in the Recapture on Mesa I, Flag, Step, and Three Point Mesas. Ore-grade uranium deposits occur in the upper Recapture near Sanostee, New Mexico, about 22 miles southeast of Cove.

Westwater Canyon Member

The Westwater Canyon Member consists of fluvial sandstone and minor amounts of mudstone. Locally pre-Chuska erosion has removed the member from the southern part of the area. Facies distribution of the member (Craig, et al., 1955) indicates a major source in west-central New Mexico in an area of igneous, metamorphic, and sedimentary rocks. The member was formed as a broad, fan-shaped alluvial plain similar to that of the Recapture.

The Westwater Canyon Member in the Grants Mineral Belt is generally similar to that in the Lukachukai Mountains except that in the Grants area there appears to be more oganic matter and feldspar.

Brushy Basin Member

The Brushy Basin Member has been locally removed from the Lukachukai Mountains area by pre-Chuska erosion, but it is exposed east of the area around the flanks of Beautiful Mountain, to the south.

CRETACEOUS STRATA

Pre-Chuska erosion has removed all Cretaceous rocks which may have been deposited in the Lukachukai Mountains area. Dakota Sandstone, Mancos Shale, and Gallup Sandstone are exposed just east of the area around the flanks of Beautiful Mountain.

Tertiary Strata

Chuska Sandstone

The eolian Chuska Sandstone is exposed on the upper slopes of the mountains. A resistant silicified unit of the Chuska caps the main mountain ridge. The Chuska unconformably overlies the folded and truncated Triassic and Jurassic rocks so that, from northwest to southeast, it rests on successively older beds.

IGNEOUS ROCKS

A small dike which intrudes the Salt Wash on Mesa I is the only exposed igneous rock in the uranium area of the Lukachukai Mountains. The rock is a member of the minette-vogesite group (S. R. Austin, written communication 1957). The dike contains numerous xenoliths, one of which was identified as quartzite, formed by contact metamorphism of argillaceous sandstone. Sills, dikes, plugs, volcanic flows, and a laccolith are present in the surrounding area.

There is no evidence to suggest a direct time or space relationship between the igneous rocks and the formation of ore bodies, either in the Lukachukai Mountains or in surrounding areas. However, at the Zona No. 1 mine in the Carrizo Mountains post-ore silicification and metamorphism suggest that the uranium mineralization occurred before the intrusion of the Carrizo laccolith. Similar age relations in the Carrizos were described by Corey at the Nelson Point Mine (written communication, 1958).

STRUCTURE

REGIONAL

The Lukachukai Mountains are a north-bending structure 110 miles long and 50 miles wide. To the west the rocks dip gently toward Black Mesa basin which is separated from the Defiance uplift by the Sheep Creek, Chinle, and Rock Mesa monoclines. To the east, strata dip steeply along the Defiance monocline into the San Juan Basin. The northeast limit of the Defiance uplift is marked by the Toadlena anticline, which, in conjunction with the Chuska syncline, on its southwest flank, trends northwest for nearly 45 miles oblique to the long axis of the Defiance uplift. The Lukachukai Mountains lie in the northwestern part of the Chuska syncline.

A smaller structure, known as the Red Rock monocline, turns away from the northeast flank of the Toadlena anticline near Red Rock Trading Post and trends north for about 12 miles. The monocline dips to the east about five degrees or less. Few faults are present in the area surrounding the Lukachukai Mountains.

LOCAL

The Chuska syncline and Toadlena anticline are the dominant structural features of the Lukachukai Mountains area. From Mesa I, the axis of the Chuska syncline strikes about N. 45 W. for 4½ miles to the north side of Mesa VII, turns to N. 65 W. and continues for 3½ miles to the west edge of Mexican Cry Mesa. Beyond Mexican Cry, the axial line swings westward, then northward for several miles before the fold dies out. The axis plunges to the northwest but not at a constant rate. From Mesa I to the southeast side of Mesa VI, the plunge is about one-half degree; from Mesa VI to the east side of Mexican Cry Mesa the plunge is only one-tenth degree; across Mexican Cry Mesa the plunge is again about one-half degree.

The Chuska syncline is sharply asymmetric. The steeply dipping limb of the syncline faces southwest opposing the

regional dip off the Defiance uplift. The axis of the Toadlena anticline nearly parallels that of the syncline and plunges northwest at a variable rate. Although the Toadlena anticline may be the surface expression of a deep-seated fault, no faults as such are known in the area.

Although the joints which were measured do not form a well-defined pattern, they may be divided into three major sets and one minor east-west set. Of the major sets, one is nearly parallel to the axis of the syncline, another is nearly perpendicular to the axis. These two sets may be classed as a tension system of longitudinal and cross joints, possibly related in origin to the plunging syncline, and are distributed widely over the entire area. The strike of the longitudinal and cross joints changes across the mesas so that they are always nearly parallel and nearly perpendicular to the curving axis of the syncline until, on Mexican Cry Mesa, the longitudinal and cross joints are nearly north-south and east-west.

The other major set of joints strike N 5 E to N 25 E and form a 45 to 60 degree angle with the axis of the syncline. These obliquely striking joints were found only in the area corresponding to the ore belt. Similar joints were found in the northwestern tip of Mexican Cry Mesa but these strike N 50-60 E.

The east-west striking joint set appears to be a minor set, but it also was found in the area of the ore belt. Since the only area of any extent which contains the N 5 E to N 25 E joint set is the ore belt, the inference may be drawn that the location of the ore belt is genetically related to the joints. Furthermore, in the vicinity of ore deposits north of the Lukachukais, on East and West Mesas, on Cove Mesa, and in other ore-bearing areas around the Carrizo Mountains, joints striking N to N 25 E—such as those present in the ore belt of the Lukachukai Mountains—are a prominent set. Similar sets were not found at any of the barren localities around the Carrizo Mountains where joints were measured, (R. E. Hershey, personal communication).

DESCRIPTIONS OF DEPOSITS

Host Rocks

Ore bodies in the Lukachukai Mountains are in the Salt Wash Member of the Morrison Formation, but sub-ore grade deposits have been found in the overlying Recapture Member, and in the Chinle Formation. The stratigraphic position of host units within the Salt Wash ranges from 30 to 80 feet above the Salt Wash-Bluff contact, roughly in the two middle quarters of the Salt Wash. Neither ore nor protore is known in the lower 20 feet of the Salt Wash, but protore may occur at any other stratigraphic position within the member.

Lithology

The host sandstone units, ranging from 10 to 40 feet in thickness, are white, gray, limonitic brown, or red, and contain mud galls, claystone splits, and mudstone pebble conglomerate lenses. The host sandstone changes from its normal color of pink or reddish-brown to gray or tan in the vicinity of ore bodies, which usually contain red, brown, and black stains. The sandstones are fine-grained, lenticular, and cross-stratified; carbon is locally abundant, particularly in sandstones deposited by east-and southeast-flowing streams. Claystone and/or siltstone units, which are laterally continuous across one or two mesas, nearly always underlie and frequently overlie the host units. The vertical interval of the host unit through which ore is distributed seldom extends through the total thickness of the host unit; instead, barren rock nearly always separates the ore from the bottom and frequently from the top of the host unit.

The most common occurrences of uraniferous material are: 1) in cross-stratified sandstone containing red, brown, and black stains and cements which give the ore a characteristic mottled or banded appearance, 2) in limonite-stained, cross-stratified sandstone associated with halos and bands of limonite, 3) in and around carbonaceous plant material, 4) in mudstone pebble conglomerates or associated with claystone splits and partings, and 5) as joint fillings. Sandstones containing some interstitial clay, or having irregular bedding seem to be preferred loci for the deposition of ore. Calcium carbonate concretions and bands, most of which are stained dark gray or reddish-black, are commonly associated with ore, but similar bands and concretions, though most are unstained, are common in barren rock.

Mineralogy

In any of the above partly or completely oxidized occurrences, tyuyamunite, the uranium vanadate, is by far the most common ore mineral. It may be irregularly disseminated, concentrated in lenses, or distributed in bands. It may fill the sand interstices, or only coat sand grains, or it may replace calcite and carbon. Other vanadium minerals which have been identified include corvusite, pascoite, hewettite, metarossite, vanadium clays, and possibly montroseite (S. R. Austin, personal communication). In general, the vanadium to uranium ratio of the ores shipped from the Lukachukai Mountains has averaged 4:1. Uraninite has been identified as a replacement in carbonized wood and as a cement in some ore bodies that are not completely oxidized (Laverty and Gross, 1956).

Ore Geometry

The uranium deposits consist of one or more individual masses of ore surrounded or separated by protore. The term ore body, as here applied, refers to the composite extent of both ore and the surrounding protore. The individual masses of ore are here called ore shoots, and such shoots may range up to 350 feet in length. In exceptionally large and rich deposits, the aggregate length of the ore shoots may exceed 1,000 feet.

Nearly all ore bodies are elongate at least three times the width, and most of the ore shoots within the ore bodies are elongate at least twice the width. The overall elongation of every ore body is parallel to paleostream depositional trends measured in and near the ore bodies. More specifically, although the ore body may extend across sev-

eral separate sand lenses presumed to be deposits in paleostream channels most of the ore shoots lie within and are elongate parallel to sand lenses. All of the ore bodies are lenticular in cross section. Thickness of the ore bodies ranges from one foot to 22 feet.

ORE DISTRIBUTION

All the larger ore bodies and nearly all of the smaller ones are in a belt which trends slightly east of north, oblique to the axis of the Chuska syncline. Within this belt, ore bodies are found in clusters, and the larger clusters are located either in reentrants at the heads of canyons or near the back end of the mesas. This distribution is probably the result of several factors. Deposits on the narrow, finger-like mesas are most subject to oxidation and probably have been leached.

Drilling depths to the host unit are much greater toward the core of the mountains, and much of this area has been inadequately tested. Perhaps the apparent clustering of ore bodies near the rims is merely a result of greater drilling in these areas where drilling depths are shallow.

All ore bodies are on the southwest limb of the Chuska syncline with the exception of several large deposits on Mesa I and a small deposit on the northern tip of Mesa V which are located on the northeastern limb of the syncline. Within the ore belt only a very small amount of Salt Wash is preserved on the northeastern limb of the syncline. Thus the two occurrences strongly suggest that ore bodies at one time were present on the northeast limb but have since been removed by erosion. No direct relation is apparent between the fold and the location of ore bodies, ore clusters, or the ore belt.

As previously noted, all ore bodies are elongate parallel to paleostream depositional trends, but this is not true of all ore shoots. In many times, projections of ore which deviate from the paleostream depositional trend are elongate parallel to prominent joint sets in the mines. Similarly, ore grade and thickness contours, the overall pattern of which closely follow sedimentary trends, show lobes and projections which parallel the prominent joint set. The largest ore shoot in the Hall Mine on Thirsty Mesa is roughly L-shaped, one branch being parallel to the sedimentary trend, the other parallel to the dominant joints. Thus, joint patterns bear a close relationship to the distribution of ore shoots within an ore body, but whether this relationship is a primary feature or is the result of secondary redistribution is unknown. No faults are present in the vicinity of the mines which were mapped.

ORE GUIDES

In all of the mines mapped, the host unit in the vicinity of the ore bodies is predominantly gray, white, or limonitic-brown. At or near the edges of the ore bodies, these colors either abruptly abut or grade into the red color of the surrounding country rock. Data concerning whether the color change is a result of the passage of ore solutions is contradictory; however, because of the gray color in down dip oil tests in the San Juan Basin the author believes that at least some, if not most, of the red coloration is a result of oxidation of originally gray sandstone, and that not all favorably colored areas resulted from the passage of ore solutions which altered originally red rocks to gray.

The ore bodies in all of the mines mapped are elongate parallel to paleostream depositional trends, and although the ore body may extend over several small channels, most of the ore shoots are elongate parallel to and lie within sand-filled channels on the order of 25 to 150 feet wide. The lateral extent of most ore shoots is controlled by the extent of the small channel in which the ore shoots lie, but some ore shoots and extensions are controlled by joints.

The upper limits of ore shoots and ore bodies is often controlled by an overlying claystone, but control of the lower limits is not. Paleostream sedimentary channels, festoons, lineation, and rib-and-furrow trends measured in the mines did not always agree with channel trends outlined on mudstone:sandstone ratio maps of the same area. Over a limited area of one or two mesas, ore is confined to one or possibly two mappable, lenticular units which thicken and thin perceptibly. The ore bodies occur in units showing most rapid variation in thickness. Ore often occurs in muddy sandstones in preference to cleaner sandstones above or below.

Carbon is widely distributed and locally abundant. Some ore is closely associated with carbon trash and logs, but as is common in oxidized deposits, the biggest part of the ore is not closely associated with carbon. In the Lukachukai Mountains carbon in the form of logs and branches is most abundant in sandstones deposited by east and southeast-flowing streams.

SUMMARY

All of the known large uranium deposits and most of the smaller deposits in the Lukachukai district are located within a rather well-defined belt which trends nearly north-south across the southeastern end of the Lukachukai Mountains. The ore bodies are elongate and horizontally lenticular in shape and consist of one or more ore shoots surrounded or separated by protore. The composite length of ore bodies consisting of two or more ore shoots separated by protore ranges up to 1,100 feet; individual ore shoots range up to 350 feet in length. The length is usually at least three times the width and is parallel to paleostream depositional trends measured in and near the ore bodies. Claystone and/or siltstone units nearly always underlie and frequently overlie the host sandstone units.

Ore occurs most frequently in trough-type, cross stratified sandstone which fills scours and channels in the underlying claystone units. Lithofacies maps and mine mapping show that ore bodies are restricted to areas of rapid lateral color change which in general are also areas of rapid change in the ratio of mudstone to sandstone. Location of the ore belt apparently is controlled by the intersection of a set of N. 5 E. to N. 25 E. striking joints and particularly favorable facies of the Salt Wash sandstone.

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