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URANIUM OCCURRENCES IN THE AMBROSIA LAKE AREA, McKINLEY COUNTY, NEW MEXICO

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URANIUM OCCURRENCES IN THE AMBROSIA LAKE AREA, MCKINLEY COUNTY, NEW MEXICO

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MCKINLEY COUNTY, NEW MEXICO

INTRODUCTION

The Ambrosia Lake area includes all of T. 14 N., R. 10 W., and portions of adjacent townships in McKinley County, approximately 20 miles north of Grants, New Mexico (fig. 1). Uranium was discovered in April, 1955, and extensive exploration drilling followed. The area is rimmed on the north by high cliffs of the Mesaverde formation; and drilling was largely confined to the broad strike valley developed on Mancos shale and the dip slope of the underlying Dakota formation. This valley is bounded on the south by the Dakota escarpment, and the underlying Morrison and Bluff formations crop out in the steep south face of that escarpment. Surface elevations range from about 6,750 feet to 7,650 feet.

The uranium deposit first discovered was apparently related to geologic structure, and in August, 1955, the Atomic Energy Commission began preparation of structural and surface geologic maps in order to test the hypothesis of structural control. Aerial photographs were used as the base for surface geologic mapping. The structure contour map is based on drill hole data and elevation control on key horizons by alidade and altimeter. Private companies contributed much drill hole data and other information, including surface maps. Gamma-ray logging of hundreds of drill holes, by the Atomic Energy Commission, was useful in correlating formations and developing structural and ore reserve information.

The climate is semiarid with an average rainfall of about 14 inches. Most of this precipitation is in the form of snow, but heavy rains occur during the late summer months. This moisture is insufficient to hamper exploration and mining activities to any great extent. Pinon and juniper trees clothe sandstone dip slopes although the shale valleys support only a sparse growth of sagebrush, greasewood, and grass. In no place is vegetation sufficiently dense to obscure outcrops completely. Access roads are numerous but poor.

REGIONAL GEOLOGY

The Ambrosia Lake area is on the northeast flank of the Zuni uplift where the strata dip gently into the San Juan Basin. Rocks exposed on this

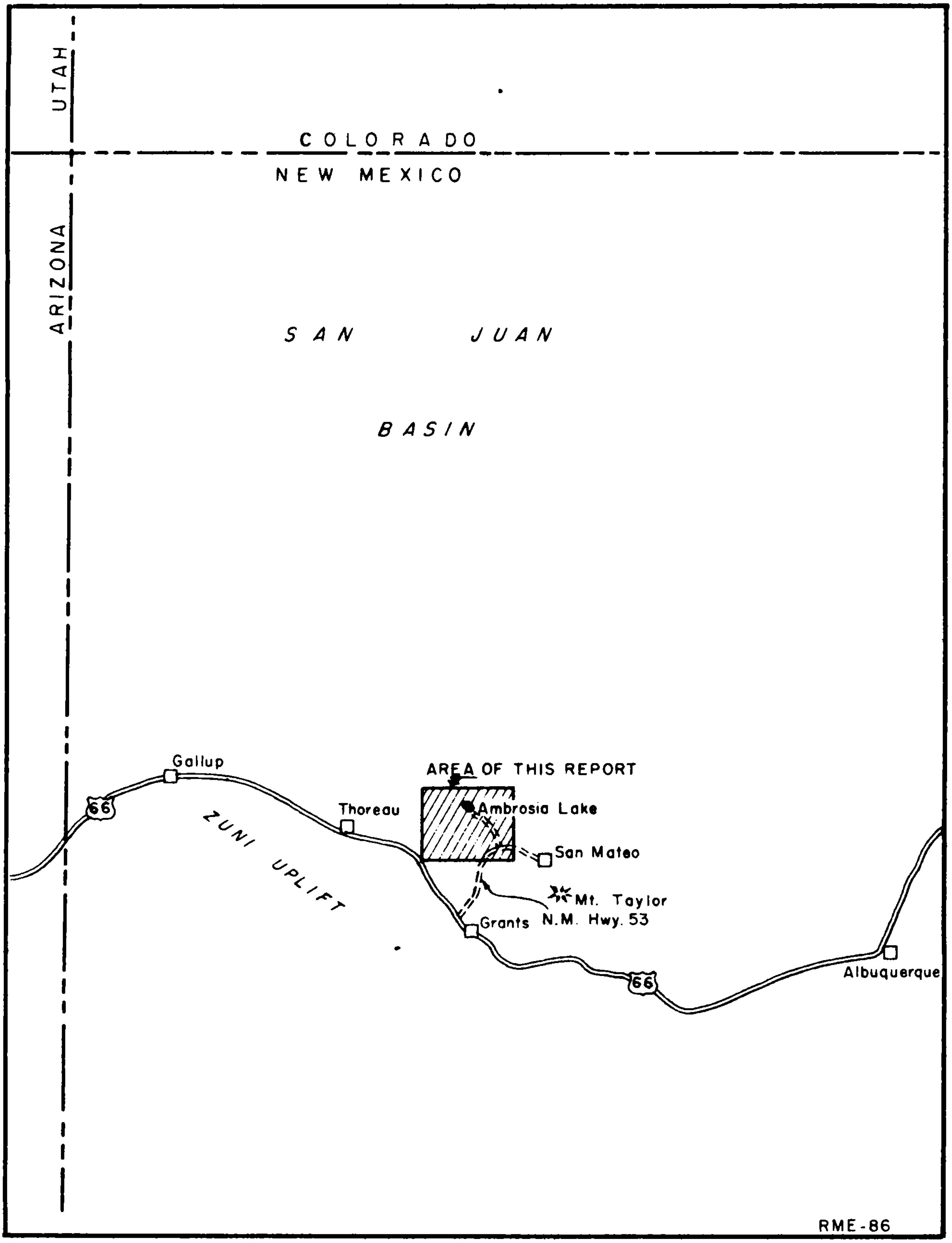

Figure 1. Index map of Ambrosia Lake area, McKinley County, New Mexico

flank of the uplift range in age from the Precambrian igneous core to Quaternary lava flows and alluvium. Sedimentary rocks range from Permian to Upper Cretaceous in age.

The regional dip of the strata is three to five degrees northeast. Superimposed on this regional dip is a series of broad northeast plunging cross-folds, the crests of which are broken by numerous high angle normal faults.

Stratigraphy

Strata exposed in the Ambrosia Lake area range in age from the Upper Triassic Chinle formation to the Upper Cretaceous Mesaverde formation. Since the major uranium deposits occur in the Westwater Canyon member of the Upper Jurassic Morrison formation, only the Morrison and overlying Cretaceous rocks which crop out in the Ambrosia Lake area will be treated here.

Morrison Formation

The three members of the Morrison formation are, in ascending order, the Recapture shale, Westwater Canyon sandstone, and Brushy Basin shale. These members crop out on the slopes below the Dakota escarpment which marks the southern boundary of the area.

1. The Recapture shale is typically a series of intercalated beds of red to white sandy claystone, siltstone, and weakly cemented argillaceous sandstone. Its contact with the underlying Bluff sandstone is usually conformable, with grain size and type of cross-bedding being the distinguishing features. It grades into and interfingers with the overlying Westwater Canyon sandstone. Locally, as at Haystack Butte, the Recapture may consist almost entirely of massive sandstone, but in such places its greater clay content and red brown color serve to distinguish it from the Westwater Canyon. Most drill holes do not penetrate the entire Recapture, but its thickness at the outcrop averages one hundred and fifty feet.

2. The Westwater Canyon sandstone is a massive, medium- to coarse-grained, friable, arkosic sandstone characterized by scour-and-fill type cross-bedding. It contains lenses of conglomeratic sandstone and minor amounts of dark reddish-brown siltstone and green claystone. The usual color of the sandstone is yellowish-orange but in large areas it has been bleached to gray, probably as a result of the passage of uraniferous solutions. At the outcrop the bleached sandstone appears yellow because of oxidation of included iron sulphides. Most cementing materials are clay and hematite, but in some areas calcite or asphalt serve as cement. As a result of interfingering with the underlying Recapture and overlying Brushy Basin members, as well as normal

thickening and thinning, the Westwater varies in thickness from 110 to more than 250 feet.

At the Poison Canyon and Mesa Top mines, in the southeast part of the area, uranium ore is mined from a sandstone fifty feet thick in the Brushy Basin. This sandstone, known as the Poison Canyon tongue of the Westwater, is separated from the remainder of the Westwater by about ten to fifteen feet of gray to green claystone. It is identical in composition with the main body of the Westwater with which it merges to the west. It disappears in Brushy Basin shales about one-half mile east of the Poison Canyon mine.

3. The Brushy Basin shale consists largely of weak gray to green, slightly bentonitic claystone, and a few lenticular sandstones lithologically similar to the Westwater. It has a fairly uniform thickness of about 100 feet. Pre-Dakota erosion, as evidenced by the slightly undulating upper surface, appears to have been negligible.

Dakota Formation

Overlying the Brushy Basin is the Dakota formation of Upper Cretaceous age. This hogback-forming unit is usually called the Dakota sandstone but in the Ambrosia Lake area it consists of two lithologically distinct parts and is here called a formation. The lower twenty to thirty feet are gray to black, silty, carbonaceous shales with a few thin intercalated medium- to fine-grained sandstones. The upper part is a massive, buff, medium- to fine-grained quartzose sandstone consisting of one to three ledge-forming beds, with a total thickness of about 50 feet. In most places the sandstone exhibits both upper and lower foreshore cross-laminae but in a few localities eolian bedding can be observed. The upper surface of the sandstone is slightly undulating, probably as a result of scouring during the marine transgression preceding deposition of the overlying Mancos.

Mancos Shale

Resting on the Dakota is a unit consisting largely of gray marine shale averaging 910 feet thick. This is the main body of the Mancos shale, but other tongues of Mancos, which interfinger with the Mesaverde formation, appear higher in the section. This massive shale contains, near the base, three thin fairly persistent sandstone beds known as the "Tres Hermanos." These beds, which form minor escarpments along the south flank of the broad strike valley developed on the Mancos, serve as excellent horizons for correlation. The second of the "Tres Hermanos" is characterized by a fossiliferous concretionary bed near the base in which abundant Exogyra columbella and numerous unidentified gastropods are present. The Gryphaea Newberryi zone occurs thirty to forty feet above the third or upper "Tres Hermanos" sandstone. A fourth thin lenticular sandstone near the top of the Mancos, referred to as the fourth Mancos sandstone, probably is a sandstone tongue of the Mesaverde. The upper contact of the Mancos is placed at the gradational base of the Gallup member of the Mesaverde, where sandstone becomes dominant over shale.

Mesaverde Formation

The Mesaverde formation consists of about 1600 feet of interbedded sandstone and shale with minor amounts of coal. This predominantly non-marine unit intertongues in a northeast direction with the marine Mancos shale, and several tongues of Mancos are included in the section here described as Mesaverde. The Mesaverde is here treated as a formation in accordance with local usage, although future work may justify classifying it as a group. It is divided into five members which are, in ascending order, Gallup sandstone, Dilco coal member, Dalton sandstone, lower Gibson coal member, and Hosta sandstone. Only the lower two members are described here.

1. The Gallup sandstone member consists of two regressive littoral marine sandstone tongues separated by a tongue of Mancos shale 90 feet thick. The lower or first Gallup is a fine-grained, silty, buff to gray sandstone with a sharply defined top and gradational base. In most places a dark brown concretionary iron stone bed 1 to 3 feet thick is present at the top. Though its thickness varies from only 3 to 15 feet, the outcrop is recognizable throughout the area. The upper or second Gallup is a cliff-forming sandstone lithologically similar to the lower, but varies in thickness from 60 feet in the western part to over 100 feet in the eastern part of the area. This increase in thickness is the result of the appearance of several bar sandstones as the member is traced eastward through the Ambrosia Lake area. Thus the upper Gallup rises rapidly in the section at the expense of the overlying Dilco member.

2. Overlying the Gallup is the Dilco coal member, a lagoonal deposit consisting of carbonaceous shales and sandstones with an average thickness of about 200 feet. The thickness decreases rapidly to the east as a result of a replacement by offshore bars of the Gallup, and normal thinning. In the western portion a massive sandstone with a maximum thickness of 80 feet forms the upper part of the member. This sandstone, the "stray" sandstone of Sears, Hunt, and Hendricks (1941) contains cobbles of quartzite, sandstone, and limestone up to ten inches in diameter as well

as numerous shark teeth, bone fragments, and Ostrea sp. The "stray" thins rapidly eastward and is absent in the eastern part of the area.

Alluvium

A large portion of the Mancos shale valley is covered with Quaternary alluvium varying from a few inches to thirty feet or more in thickness. At the present time deep gullies are eating headward into this fill.

Structure

The dominant structural feature is the northeastward homoclinal dip off the northeast flank of the Zuni uplift (Thoreau homocline). The northeastward dip is the product of at least three periods of tilting, as evidenced by disconformities at the base and top of the Dakota formation, and at the base of the Tertiary Mesa Chivato lava flow in the Mount Taylor region just east of the Ambrosia Lake area. Five fairly well-defined northeast plunging anticlinal folds are also present. For the sake of reference these are here named, from west to east, the Prewitt, Silver Spur, South Ambrosia, Poison Canyon, and Gay Eagle anticlines.

Domal features are present on two of these anticlines. That on the Gay Eagle fold is small with a closure of about 50 feet and is apparently a faulted nose. The Ambrosia Lake dome, on the south end of the South Ambrosia anticline, is considerably larger with an indicated closure of more than 500 feet on top of the Dakota. That the Ambrosia Lake dome is an old structure is suggested by thinning of Jurassic sediments over the crest. The Westwater Canyon sandstone varies in thickness from 110 to a possible 250 feet over the crest. The greatest thinning occurs on the south flank of the present structure indicating the original crest was south of the present one. Some thinning also occurs in the Brushy Basin shale and some possible thinning has been noted in the Dakota, but thinning of the latter units may be the result of attenuation or differential compaction. This old structure probably aided in localizing the effects of late Cretaceous compressional forces which formed the South Ambrosia anticline and the other northeast plunging anticlines. It is also probable that the axis of this old structure was parallel to that of the Zuni uplift, thus accounting for the abrupt bending of the South Ambrosia anticlinal axis over the dome.

Faulting, which is almost entirely restricted to anticlinal crests, appears to have resulted primarily from tension following relaxation of compressional forces after folding, although a few faults were probably active during the folding. Most are high-angle normal faults showing very little movement. Faults are particularly pronounced in the competent beds of the Mesaverde and the Dakota formations, but most die out rapidly where traced into the Mancos shale. A striking feature of many of these faults is the downwarping of sediments toward the fault on both sides of the fault plane, as though the fractures had opened sufficiently to allow the strata to subside or fold into them. In several places, near the Mesaverde cliffs, faults with only a few feet of throw can be traced for short distances across Mancos outcrops by the presence of large tilted blocks of the upper Gallup sandstone which apparently subsided into the open fissures. Three prominent directions of faulting can be discerned--N. 10° to 30° E., N. 50° to 70° E., and N. 10° to 20° W. The first two directions are also those of the major joint sets.

The interpretation of structural history is intimately associated with the accumulation of asphaltic material and uranium mineralization. It is believed that oil began to accumulate in the Ambrosia Lake dome sometime during the late Jurassic. That a gas cap existed on this pool is suggested by a lack of asphaltic residue on the crest of the old dome. The oil must have been at least partially flushed from the dome before the ore solutions could enter. This flushing, resulting from up-dip erosional exposure of the sandstone, must have occurred after the late Cretaceous or early Tertiary compressional folding which was undoubtedly accompanied by tilting down to the northeast. Uranium mineralization is associated with asphaltic material which is believed to have been derived from the oil formerly present.

The following sequence of significant structural events is postulated:

1. Early rise of the Zuni uplift and growth of incipient Ambrosia Lake dome during deposition of Westwater and Brushy Basin in late Jurassic time.

2. Migration of oil into dome, starting in late Jurassic time and possibly continuing into late Cretaceous time.

3. Tilting down to the northeast and slight erosion, possibly beginning in latest Jurassic time, and preceding Dakota deposition.

4. Tilting down to the north and slight erosion of the Dakota, early in late Cretaceous time.

5. Compressional folding, further tilting down to the northeast, and some faulting, accompanied by flushing of oil and entry of ore solutions, in late Cretaceous to early Tertiary time.

6. Tension faulting in the late Tertiary.

MINERAL DEPOSITS

The only commercial mineral deposits in the Ambrosia Lake area are those containing uranium. Uranium was discovered early in the spring of 1955 by examination of cuttings from an old oil well in sec. 14, T. 14 N., R. 10 W., which proved to be radioactive. Subsequent drilling near the old well disclosed a large body of uranium ore. After the original discovery, drilling proved ore throughout many adjoining sections and to the east in T. 14 N., R. 9 W.

Although other mines in the general area are located in the Dakota and Brushy Basin, all of the major uranium deposits in the immediate vicinity of Ambrosia Lake occur in the Westwater Canyon member of the Morrison formation. The deposits occur throughout the entire vertical range of the Westwater and in many cases occur at several horizons, one over the other in a vertical sequence. Ore bodies in general are quite large.

Mineralogy (Laverty, 1956)

All of the ore consists of uranium-bearing asphaltic material which cements the Westwater Canyon sandstone. Analyses made by the U. S. Geological Survey indicate that the uranium mineral is coffinite associated with asphaltite. Coffinite, $U(SiO_4)(OH)$, is a black uranium mineral almost impossible to identify megascopically. Its presence as the ore mineral at Ambrosia Lake was detected only by X-ray analyses. Since the ores at Ambrosia Lake are very similar to those of the Poison Canyon and Mesa Top mines to the south, which contain uraninite, it is expected that uraninite also occurs with coffinite here, although to date no positive identification of uraninite has been made. Tyuyamunite occurs in at least one ore body located in very close proximity to a fault.

The host rock is poorly sorted, ranging in grain size from a pebble conglomerate to a medium- to coarse-grained sandstone. Particle shape ranges from angular to rounded. It is cemented dominantly with clay but calcite is a minor cementing material. In addition to the quartz grains there are a few percent each of feldspar, jasper, mudstone, chalcedony, quartzite, and granite. The uraniferous asphaltic material appears to embay and replace detrital grains, especially feldspar. The entry of the asphaltite into minute cracks in the host rock indicates fluid movement, and probable derivation from petroliferous material rather than from woody material. The coarsest host rocks contain the highest percentage of uranium, although small lenses of fine-grained material within a coarse-grained rock may be richer than the coarse surroundings.

Ore Bodies

Accessory hematite in the cementing material causes the Westwater Canyon sandstone to be reddish in color throughout a large portion of its areal extent. Uranium in the Ambrosia Lake area occurs in bleached zones, however, where the Westwater Canyon is generally gray but weathers yellow on an exposed face. The sandstone is not always gray throughout a drill hole intersecting ore, however, in at least one large ore body the upper portion of the sandstone is red and the lower part gray. At this particular locality the red is separated from the gray by a mudstone layer. In another case the Westwater is red except at the base, where it is gray.

No specific stratigraphic horizon in the Westwater Canyon sandstone is everywhere mineralized. Ore may occur at any horizon. Commonly the Brushy Basin has also been mineralized where it contains sandstone lenses, and there is at least one report of a uraniferous sandstone facies of the Recapture near the Westwater contact.

Mineralized zones in the Ambrosia Lake area range in thickness from less than a foot to over 100 feet. One hole encountered three ore zones of 30, 15, and 7 feet, respectively, in a mineralized interval over one hundred feet thick which averaged over 0.15 percent U_3O_8 radiometrically. Similar occurrences of several ore zones stacked one over the other are present in many of the ore deposits.

The Westwater Canyon ranges in thickness from 110 feet to 250 feet or more, but ore occurrences are apparently unrelated to the thickness. Preliminary examinations of drill-hole data indicate that the ore is not restricted to channels or thickened lenses.

The trend of the ore bodies in the Ambrosia Lake area follows the structure contours. A preponderance of uranium discovered to date occurs where the top of the Dakota lies between 6600- and 7100-foot elevations. Significant deposits are known, however, where the top of the Dakota is as low as 6200 and as high as 7400 feet.

ORIGIN OF ORE

There are numerous structural traps in the Ambrosia Lake area. Hydrocarbons occur in these traps. The Ambrosia Lake dome may or may not at any time have contained enough petroliferous material to be termed an oil pool, but petroliferous material is present today; and, in every case where ore is known, it is associated with petroliferous material. Contrarily, there are numerous bleached areas in the Westwater that are not on structure, do not contain petroliferous material, and are barren of ore. This suggests that uraniferous solutions passed through a relatively large area but that uranium occurs only where a precipitating agent, i.e., hydrocarbon, was present. Although structure does not directly control the ore, structure did control the hydrocarbons that have determined the location of an ore body. If channels containing woody carbonaceous material were present, instead of structurally controlled hydrocarbons, the ore distribution might be controlled by such sedimentary features.

As mentioned before, the usual red color of the Westwater Canyon is believed to be due to hematite. Locally, solutions apparently removed the hematite and produced gray bleached zones. Later, or possibly contemporaneously with this solution activity, iron sulphide was introduced with uranium. Iron sulphide is commonly associated with ore in the area. On an exposed surface, such as a cliff face, the iron sulphide has been oxidized to form limonite responsible for the yellowish color of the Westwater on such exposures of the bleached zones. Introduction of uranium by laterally migrating solutions is indicated because ore is found only in gray bleached zones which are commonly underlain by red sandstones. It is assumed that either laterally migrating uraniferous solutions were guided to the more open blocks of ground by faults, or that the faults themselves were the vertical access channels, for the ore bodies in the general area are all in close proximity to major faults. It is considered that post-faulting oxidation is responsible for the occurrence of secondary uranium mineralization, i.e., tyuyamunite, which was noted near a fault in at least one ore body.

MINES

Although many drilling projects have discovered large ore bodies, the only mine in the Westwater Canyon to date is the Stella Dysart No. 1. This mine is located on the site of the original discovery in the area. The shaft has cut two ore horizons and underground inspection reveals the hydrocarbon control of the ore. Drilling, before the shaft was sunk, disclosed three ore horizons which in places were overlapping. The horizons are sufficiently continuous over large areas to warrant sinking the shaft for any one of the three horizons. The ore is coffinite associated with asphaltic material.

Five other mines have long been active in the area encompassed by the accompanying map. They are the Silver Spur mine in sec. 31, T. 14 N., R. 10 W., where carnotite and tyuyamunite occur in the Dakota formation; the Mesa Top, Poison Canyon, and Beacon Hill mines in sections 19 and 20, T. 13 N., R. 9 W., where both channels and structure control the ore; and the Blue Peak mine, section 24, T. 13 N., R. 10 W. All these mines are located in the Poison Canyon sandstone and both secondary replacement of woody carbonaceous material and primary coffinite-uraninite associated with asphaltic material are present. Ore controls in the Poison Canyon sandstone mines have been discussed in a separate paper (Konigsmark, 1956).

SUGGESTIONS FOR EXPLORATION

All known uranium deposits in the Ambrosia Lake area occur in bleached zones of the Westwater Canyon, and in the vicinity of major faults. Ore controls may be structural, sedimentary, or a combination of both, in the zones of faulting. All known deposits occur in structures suitable for the trapping of hydrocarbons. The majority of the bleached zones trend northeast. Projecting these bleached zones behind the rim, structural mapping to ascertain hydrocarbon traps, and ascertaining where the Morrison formation is at economical drilling depth, can greatly reduce exploratory drilling costs and increase manyfold the chances of locating uranium.

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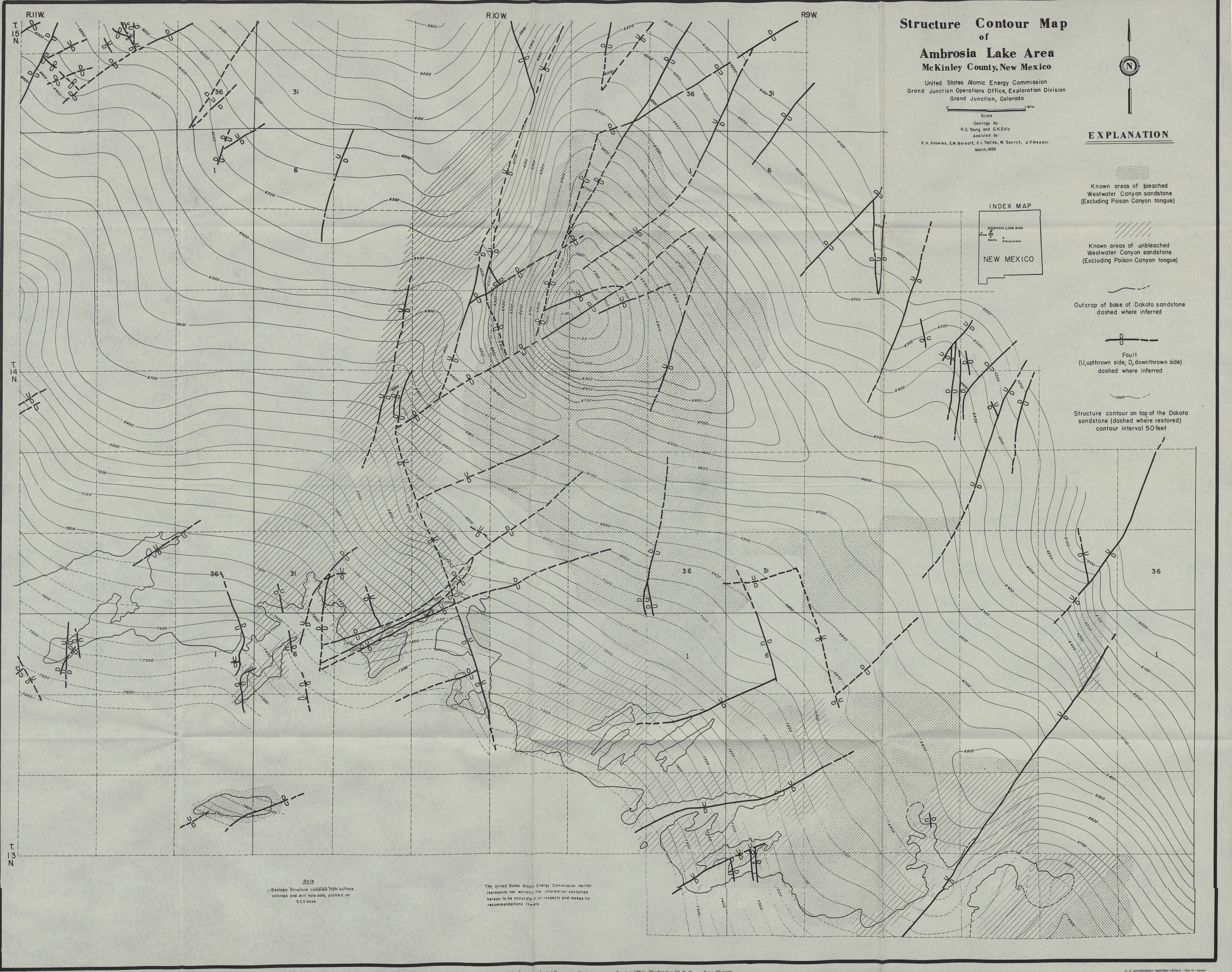

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