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AMBROSIA LAKE--NEW MEXICO'S NEWEST URANIUM BONANZA

A PANEL DISCUSSION BY J. W. GABELMAN, R. G. YOUNG AND G. K. EALY
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HISTORIC BACKGROUND AND GEOLOGIC SETTING

by
John W. Gabelman

Uranium was first discovered on Haystack Butte near Grants, New Mexico, in the spring of 1950. Early development demonstrated that uranium occurred as uraninite intergrown with fluorite as replacements of Todilto limestone. In 1951, uranium ore was found in sandstone lenses at the bottom of the Brushy Basin mudstone member of the Morrison formation. In sandstone, uranium occurs as coffinite intergrown with asphaltite.

Within a short time prospecting was extended completely along the Jurassic outcrop escarpment from Grants to Gallup. Prospecting methods used included airborne scintillometer survey, rim walking and stripping, and shallow wagon drilling directly behind the outcrop. Drilling depths seldom exceeded 200 feet.

The Grants district is on the northeast flank of the Zuni uplift on the southern side of the San Juan Basin in northwestern New Mexico. The two flanks of the Zuni uplift trend northwest and converge to a sharp nose near Gallup. The southeast end of the uplift is blunt and trends north-northeast to north-south. The Grants district is at the junction of two homoclines representing the northeast flank and the southeast end of the uplift. The homoclines are expressed physiographically by large cuestas with escarpments which face the uplift. The northeastern flank which has produced the most uranium is called the Thoreau homocline and is characterized physiographically by two cuestas with a broad intervening valley developed on Cretaceous Mancos shale. The southwest cuesta is capped by the Dakota sandstone and Jurassic sediments outcrop on its escarpment. Principal uranium production is from the Todilto and Morrison formations on this escarpment. The northeast cuesta is capped by the Hosta sandstone of the upper Mesaverde group; and upper Mancos and lower Mesaverde rocks crop out in the escarpment. Ambrosia Lake is in the Mancos Valley between the cuestas. Most recent exploration has been concentrated on the Dakota dip slope behind the Jurassic cuesta and in the Mancos shale valley.

On the Jurassic escarpment all the ore discoveries were between Grants and the Bluewater fault near Thoreau. However, as exploration progressed it became apparent that not this entire interval was favorable. Deposits are confined to blocks of mineralized ground spaced along the outcrop with barren areas intervening. It was noticed that the block spacing coincided with marked advances and recessions of the escarpment itself. The advances and recessions may possibly have resulted from a series of broad, shallow cross folds plunging 3 to 5 degrees down the gentle northeast flank of the Zuni Mountains. Also spaced along the flank of the uplift are zones of faults generally parallel to the postulated cross folds and perpendicular to the rim. Uranium deposits seemed to be clustered in northeast trending synclines that contain or are related to fault zones. Anticlines with or without fault zones and synclines without fault zones were barren. Further, each block is enclosed by an alteration zone in which normal rock colors are bleached to gray or white. These zones also appeared to extend northeast. Detailed study and mining disclosed that within synclines limestone ore is confined to the crests of east-west or north-south anticlines resulting in linear ore bodies of great length. However, ore bodies in the sandstone are confined to the lowest portions of channel-like lenses which generally trend east-west. The sandstone ores seem to be as low as they could get under sedimentary control and the limestone ores seem to be as high as they could get under structural control. Thus, though evidence indicated some structural control over ore emplacement, this control was not accepted as a prospecting tool because of the vague nature of synclinal control of ore areas and a conlficting evidence of control over ore bodies. Early suggestions that the Jackpile mine in the Morrison formation on the Laguna Reservation occurred in the crest of shallow anticlines were not well received because the presence of such shallow folds could not be demonstrated without accurate surveys. The blocks of mineralized ground are from east to west, the Grants Mesa area, the Gay Eagle area, the Poison Canyon area, the Haystack Butte area, and the Bluewater fault area. Deposits were known only near the escarpment but the controlling structures and deposit cluster trends indicated the blocks extend northeastward perpendicular to the strike of outcrop.

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Although until 1955 exploration and development were confined to the escarpment areas, it was obvious that exploration would move northeastward down the dip of the favorable sediments along the northeast trends of the mineralized blocks. Several proposed drilling projects were not undertaken because of uneconomic depths.

Thus, it was not surprising that the first significant downdip discovery was made within the northeastward trending Haystack Butte block at Ambrosia Lake. However, the synclinal structure present at the southwest end of the block does not persist into the northeast end. The type of structural control changes and uranium deposits at Ambrosia Lake tend to occur in anticlines rather than synclines. The size of the anticlines is comparable to the size of the synclines near Haystack Butte. In contrast to the drilling depths under 300 feet on the Jurassic escarpment discoveries are currently being made in the Ambrosia Lake area at depths approaching 1000 feet. Such depths do not seem to discourage continued exploration.

Downdip mineralization was suspected late in 1954 by Mr. Lewis Lothman of the Mid-Continent Exploration Company, who in search of potential ground available on reasonable terms tested the cuttings from Dysart No. 1 well drilled on the Ambrosia Lake dome in 1925. This dome was of interest because the Morrison formation was more shallow here than at any other locality northeast of the Dakota dip slope. The section containing the oil well was leased from Mrs. Dysart after discovery that the cuttings were radioactive and a drill hole was started north of the old well. Of interest to geophysicists, in the spring of 1955 Mr. Lothman hired Mr. Robert A. Stothard to survey Section 11 with an ionization chamber. Mr. Stothard was a self-styled doodlebugger who had constructed an ionization chamber which he claimed could detect radon which seeped to the surface through small cracks from depths of up to 500 feet. Thus mineralization could be detected up to 500 feet in depth. Radon gas normally will not rise unless under pressure and its short half life would cause its destruction before it could rise far. For this reason neither Mr. Stothard's theory nor his equipment were well accepted by the uranium industry. At Ambrosia Lake Mr. Stothard outlined an L-shaped mineral deposit. In addition to approving the hole Mr. Lothman was already drilling, he located two additional holes at the extremities of the body 1000 and 1500 feet respectively from the first hole. The original hole was mineralized and the two holes recommended by Mr. Stothard were ore holes, the ore being over 300 feet in depth. To check Stohard's statement that barren ground lay outside the "L", Mr. Lothman drilled two holes outside the area and both were barren.

The initial discovery was made in April 1955. Shortly thereafter Mr. Lothman secured financing from Dunn Brothers, a pipline company of Irving, Texas, and he proceeded to drill the south half of Section 11, with two rigs drilling on 100 foot centers. Of the first 50 holes, 48 were ore holes containing from one to many feet of ore.

From the initial drilling it appeared that the ore occurred just off the crest of the Ambrosia Lake dome at the south end of the Ambrosia Lake anticline. If this occurrence proved correct, Ambrosia Lake would be one of the few areas on the Colorado Plateau where uranium so obviously occurred under anticlinal control. This control would be one of the most critical prospecting tools yet developed in uranium exploration. In order to determine the validity of this structural control and to develop the exploration tool, soon after the Mid-Continent discovery the Atomic Energy Commission began preparation of a structural contour map on top of the Dakota sandstone, the most reliable structure indicator.

By June of 1955 almost the entire dip slope of the Dakota sandstone behind the Jurassic escarpment from Prewitt to San Mateo had been leased. Land ownership in the Ambrosia Lake area was complex and the resulting disposition of mineral right control appeared as a giant checkerboard with individual sections being divided among more than 30 organizations. Alternate sections were railroad land. Other sections are either private ranch lands or Indian allotment land. Many ranchers control only the surface rights which left some sections open for claim location. With the complex ownership picture and the large size and widespread distribution of mineralized areas, the individual companies were hampered in their efforts to value their one or more isolated sections without any knowledge of general geologic conditions for the area. Thus in addition to the testing of geologic criteria, the AEC was in a position to make a substantial contribution to the uranium industry by compiling subsurface stratigraphic and structural data critical in exploration. An agreement was reached with the majority of the companies engaged in exploration whereby stratigraphic and structural information compiled by the Commission would be made available to the entire group.

The Commission's specific aims in this program were to compile ore reserve data, to prepare a surface geologic map, a subsurface structural contour map on top of the Dakota sandstone, and as many subsurface stratigraphic sections as needed to allow correlation between drill holes.

Land surveys in the area were old and inaccurate and correct base maps and subdivision control were needed on which to record structural information as well as to determine ownership. Conflicts arising from the inaccurate location of sections corners were common. One transit crew was employed in bringing triangulation control from the Haystack Butte area and in locating section corners. Low level photographs were flown by the Atomic Energy Commission on which geologic data were recorded. In addition several plane table crews were engaged in preparing aerial geologic maps of selected areas. Data from photographs and plane table sheets were compiled on a master map in the field office by photogrammetric methods which allowed the removal of photographic distortion. A planimetric land subdivision and surface geologic map resulted. Stratigraphic sections were measured with a plane table.

For the compilation of subsurface and ore reserve data, transit and plane table crews determined the location and elevation of drill hole collars. Core holes were rare; however, two Commission gamma ray logging units logged rotary drill holes as soon as possible after completion. Both assay and lithologic data were interpreted from logs and posted on the subsurface geologic and ore reserve maps. It was found possible to determine and correlate lithologic units of the Morrison formation from the gamma ray logs. Although radon gas contamination was a problem early in the logging program, interpretation of uranium mineralization from the logs has proved fairly reliable.

The preparation of the structure contour map was not simple. In areas where drill hole information was not available, depth to the Dakota sandstone had to be calculated from measured stratigraphic sections and from structural attitudes. At the surface lithofacies variations in the complex lithologic intertonguing Mancos and Mesaverde sediments had to be interpreted and accurately predicted behind outcrops to provide any accuracy for the structure contour map. For this phase of the investigation the Commission was fortunate in having available Mr. Robert G. Young, an authority on Mesaverde stratigraphy. Mr. Young will describe the stratigraphy of the region and the details of map preparation.

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STRATIGRAPHY AND STRUCTURE

by

Robert G. Young

The Introduction

Discovery of uranium ore at Ambrosia Lake in April 1955, and ensuing intensive exploration in the area served to accentuate the need for a usable geologic map of the region. The only available map covering this area was that of C.B. Hunt published in 1936 with a scale of one inch to the mile.

Accordingly the AEC decided to map in detail Township 14 North, Range 10 West and those portions of the surrounding townships included in the Ambrosia Lake area. The result of this mapping was the completion of a surface geologic map accompanied by a structure contour map on top of the Dakota formation and by a map showing color changes in the Westwater Canyon sandstone, all on a scale of 3.3 inches to the mile. A preliminary edition of the structure map is scheduled to be released soon. Final editions of all maps are now being drafted and should be available in the near future.

General Stratigraphy

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

JURASSIC

Morrison Formation: The three members of the Morrison formation present are, in ascending order, the Recapture Shale, Westwater Canyon sandstone and Brushy Basin shale. These members crop out on the slopes below the Dakota scarp which marks the southern edge of the Ambrosia Lake area.

1. Recapture shale: The Recapture is typically a series of intercalated beds of red to white claystone, siltstone, and weakly cemented argillaceous sandstone. Locally this unit consists almost entirely of massive sandstone but the greater clay content and red-brown color serve to distinguish it from the Westwater sandstone. The Recapture is believed to intertongue with the underlying Bluff sandstone but this is not evident in this area. However, it does exhibit some intertonguing with the overlying Westwater. Since most drill holes in the Ambrosia Lake are bottomed in the Recapture, its entire thickness is seldom penetrated. It is believed to average about 150 feet.

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2. Westwater Canyon sandstone: The Westwater is a massive, medium - to coarse-grained, friable, arkosic sandstone which contains conglomeratic lenses and minor beds of dark reddish-brown siltstone, and green claystone. The usual color of the Westwater is a yellowish orange but in large areas it has been bleached to gray. Bleached Westwater appears yellow on the outcrop because of oxidation of pyrite. As a result of interfingering with the underlying Recapture and overlying Brush Basin members, the thickness of the Westwater varies from 110 to 250 feet. Its usual thickness is 170-180 feet. Channel type cross-bedding characterizes the entire unit.

In the southeast portion of the area ore is mined from a massive sandstone in the Brush Basin member about 10-15' above the Westwater. This sandstone, known as the Poison Canyon sandstone, is identical in composition with the Westwater with which it merges to the west. This tongue of the Westwater disappears into Brushy Basin shales a half mile east of the Poison Canyon mine. On the Ambrosia Lake dome the Westwater is 110 to 250 feet thick which may reflect an earlier structure.

3. Brush Basin Member: The Brushy Basin consists largely of green and gray claystone and a few thin lenticular sandstones which are lithologically similar to the Westwater. It has a thickness of about 100 feet throughout the area. Pre-Dakota erosion is evidenced by the slightly undulating contact between the Dakota and Brushy Basin, but very little erosion seems to have occurred.

UPPER CRETACEOUS

Dakota Formation: This hogback-forming unit, which has an average thickness of 75 feet in the Ambrosia area, consists of two distinct parts. The lower 20-30 feet consist of gray to black, silty carbonaceous shales and a few thin intercalated sandstones. The upper part is a massive, buff, medium-to fine-grained, quartzose sandstone which consists of one to three ledge-forming beds. In most places the sandstone exhibits upper and lower fore-shore cross-laminae, but in a few localities eolian bedding can be observed. The slightly disconformable upper surface of the Dakota is readily recognized in drilling. In spite of the disconformity this surface serves as an excellent horizon for correlation.

Mancos Shale: Disconformably overlying the Dakota is a unit consisting largely of gray marine shale averaging about 910 feet thick. This is the main body of the Mancos but other tongues, which inter-finger with the Mesaverde, appear higher in the section.

This massive shale contains near the base three thin, fairly persistent sandstone beds (Tres Hermanos). These beds, which form minor scarps within the broad strike valley developed on the Mancos, are probably not exact equivalents of the three sandstones described as "Tres Hermanos" by Hunt near Seboyeta, 30 miles to the east. The second "Tres Hermanos" sandstone is characterized by a fossiliferous concretionary zone near the base in which abundant Exogyra columbella and unidentified gastropods are present. The Gryphaea Newberryi zone occurs 30-40 feet above the third "Tres Hermanos" sandstone. Near the top of the Mancos is another thin sandstone referred to by the USGS as the fourth Mancos sandstone. The upper limit of the Mancos is placed in the gradational base of the Gallup member of the Mesaverde at the point where sandstone becomes dominant over shale.

Mesaverde formation: The Mesaverde in this area 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. In the Ambrosia Lake area several tongues of Mancos shale are included in the beds here described as Mesaverde. The mesaverde, treated here as a formation rather than as a group, is divided into five members which are in ascending order: Gallup sandstone, Dilco coal member with the "Stray" sandstone at the top, Dalton sandstone separated from the Dilco by the Mullato tongue of the Mancos, Gibson coal-bearing member, and Hosta sandstone. Only the lower two members are here described.

The Gallup consists of two sandstone tongues separated by a tongue of Mancos 90 feet thick. The lower or first Gallup is a regressive, fine-grained, silty sandstone with a sharply defined top and gradational base. In most places, a dark brown iron stone concretionary bed one to two feet thick is present at the top. Though the total thickness varies from 3-15 feet, the outcrop is recognizable throughout most of the area and thus is a key horizon. The upper or second Gallup is lithologically similar to the lower but reaches 100 feet in thickness in the eastern portion of the area. It is a readily recognizable unit as a result of its cliff-forming habit but, unlike the first Gallup, it climbs rapidly in the section toward the northeast, at the expense of the overlying Dilco.

Overlying the Gallup is the Dilco member, a series of coal-bearing shales and sandstones with an average thickness of about 200 feet. The thickness decreases rapidly to the east as the result of replacement by offshore bar sandstones of the

second Gallup and as the result of normal thinning. In the western portion of the area a massive sandstone 40-80 feet thick forms the upper part of this unit. This sandstone, the "Stray" sandstone of Hunt, contains cobbles of quartzite, sandstone, and limestone up to 10 inches in diameter as well as numerous sharks' teeth, bone fragments, and shells of Ostrea sp. It is not present in the eastern portion of the area.

Map Making

The first task to be undertaken was the construction of an areal geologic map. This was accomplished by the use of aerial photos in the field for tracing and plotting outcrops. This information was then transferred to a suitable base by a photogrammetrist in the field office as described by Mr. Gabelman.

Next a structure contour map was constructed on the top of the Dakota. This horizon was selected because of its proximity to the Westwater sandstone, its ease of recognition, the absence of any major unconformity in the overlying Cretaceous rocks, and the extensive areas of Dakota outcrop. After choosing the Dakota as datum, dips and strikes were obtained on all outcrops which would aid in establishing structural control throughout the area. Elevations were obtained on outcrops of beds whose positions in the stratigraphic section were known. (Such units as the first and second Gallup sandstone, fourth Mancos sandstone and "Tres Hermanos" sandstones). Since the stratigraphic intervals between these units and the top of the Dakota had been previously determined from numerous measured sections and drill hole information, Dakota elevations were obtained by subtracting these intervals from the surface elevations. Wherever possible these outcrop elevations were supplemented by drill hole data obtained from examinations of cuttings and logs. In those areas in which there was no drill data, and no "key" horizons were present, dips and strikes were taken on other outcrops and projected to the Dakota. Most of the companies operating in this area willingly contributed their drill hole data which was of untold value in constructing the maps.

The color change map was constructed on information obtained from examination of cuttings and outcrops plus data contributed by the companies.

STRUCTURE

With completion of the mapping, the detailed structural picture came more clearly into focus. The dominant structural feature is the northeast homoclinal dip off the northeast flank of the Zuni uplift (the Thoreau homocline). Five fairly well-defined anticlinal folds were mapped. For the sake of discussion these will be referred to as the Prewitt, Silver Spur, South Ambrosia, Poison Canyon, and Gay Eagle anticlines.

Domal features are present on two of these folds but that on the Gay Eagle fold is very small with a closure of only about 50 feet. This closure has probably resulted from the faulting of the nose of the Gay Eagle fold. The Ambrosia Lake dome at the south end of the South Ambrosia anticline is a much more pronounced feature with an indicated closure of over 500 feet on the Top of the Dakota. It lies near the south end of the fold where the north-south trending fold axis makes an abrupt turn to the southeast to parallel the Zuni uplift. Thinning of Jurassic sediments over the dome seems to indicate that a small structure with an axis parallel to the Zuni uplift probably existed here in late Jurassic time. It probably also aided in localizing the compressional forces which later determined the location of the South Ambrosia anticline.

Faulting, which is almost entirely restricted to anticlinal crests, seems to have resulted primarily from tension following the folding. Most are nearly-vertical, normal faults which in many cases show very little movement. A striking feature of most of these faults is the down warping of sediments on both sides of the fault as though the fractures had separated sufficiently to allow the strata to slump or fold into them. In many cases faults can be traced for short distances through the Mancos shale by the presence of large tilted blocks of Gallup sandstone which apparently slumped into the open fissures. The double down warping could conceivably be the result of two periods of compression of different intensity with reversal of relative movement along the fault planes. However, this fails to explain the large erratic blocks of sandstone in the fault zones.

Three prominent directions of faulting can be discerned--N.10-30°E., N. 50-70° E, and N. 10-20° W. The first two directions are those of the major fracture sets.

Both anticlinal and fault traps as well as stratigraphic traps are present. The most obvious trap is the Ambrosia dome around which most of the ore deposits are clustered. However, several deposits seem to have no control. The traps in these cases may be formed by small faults which have not been recognized as yet or may be sedimentary in nature. Studies in the Poison Canyon and Mesa Top mines indicate the ore solutions may have been localized in lenses of coarser sandstone.

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Regional tilting to the northeast must have occurred simultaneous with or immediately following folding. It is possible that flushing, following the tilting, removed most of the oil from the Ambrosia dome leaving an asphaltic residue. The oil must have been flushed or was in the process of being flushed at the time of introduction of the ore solutions to allow them to enter the trap. The following sequence of major events is postulated for this area:

1. Early Zuni uplift and incipient Ambrosia dome (late Jurassic?).
2. Migration of oil into dome.
3. Folding, tilting and some faulting (late Cretaceous, early Tertiary?).
4. Flushing of oil and introduction of ore solutions (Early Tertiary?).
5. Tension faulting (Tertiary).

Several lines of evidence seem to date the major period of faulting as post ore. Several ore bodies are crossed and apparently offset by faults. Secondary uranium ores are rare but have been reported in a few drill holes very near faults. A large ghost ore body has been outlined near a large fault indicating that solutions moving outward from this fault have removed the uranium.

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MINERAL DEPOSITS IN THE AMBROSIA LAKE AREA, McKINLEY COUNTY, NEW MEXICO

by

Gene K. Ealy

DISCUSSION

The original discovery in Sec. 11, T. 14 N., R. 10 W., became the general focus of interest of Sabre Uranium Company, which controlled a number of surrounding sections. Sabre began drilling close to the discovery and exploration proceeded southward directly away from the discovery. After having drilled several discouraging holes they finally completed a hole in which the Westwater was bleached, just as in Section 11. The third hole drilled, after encountering this bleached zone, found good ore. When it became apparent that Section 11 was not the only locus for mineralization in the area, tens of companies became interested; some acquired land and began drilling.

From the time of the original discovery, drilling has progressed more or less blindly. The great degree of success in finding ore with the meager exploration criteria is evidence of the abundance of ore. Formerly the procedure consisted of acquiring land in the general vicinity of known ore, moving a drill rig in, and starting to drill on an arbitrarily chosen geometric grid. Mr. Lothman, the original discoverer, chose a grid with holes on 100 foot centers. Others have used 250, 500, or 1,000 foot centers. When encouraging results appeared the interval between holes was reduced and, in most cases, a strike was made.

Atomic Energy Commission gamma ray logging units probed many of the holes in the Ambrosia Lake area and gave copies of the logs to the operators. It was soon discovered that the ore was out of equilibrium. In many cases the indicated radiometric equivalent assay was twice as much as the chemical assay. By coring between holes that had been logged by AEC gamma ray units, then logging these core holes with the gamma ray units, and having the core assayed, curves were made correlating gamma ray logs with chemical assay. These curves did not vary widely from one deposit to the next. By correlating gamma logs with assayed core the number of core holes necessary to make ore estimates was greatly reduced. In order to calculate ore reserves by this method, it must be assumed that the ore is continuous from one hole to the next; and, from the high percentage of ore holes compared to total holes drilled, it is reasonable to assume that the ore is continuous.

Some confusion in the logging operation was introduced when it was observed, in the Mid-Continent deposit, that background count was often from 100 to 1,000 counts per second more when the probe came out of the hole than when it entered the hole. This resulted from radon gas accumulation in the hole. The daughter products of radon are solids. The half lives of the daughter products of radon through radium C, which is the source of practically all measured gamma radiation, are less than 30 minutes. These daughter products contaminated the metal of the probe and resisted every effort to remove them. It was decided that for practical purposes the excess background count due to probe contamination could be subtracted from the total count in an ore horizon and thus achieve an estimate of the percent U_3O_8.

From the original discovery in Sec. 11, of T. 14 N., R. 10 W., discoveries were made throughout that township and into T. 14 N., R. 9 W. to the east. Significant deposits to date have been found in Sections 10, 11, 12, 13, 15, 22, 23, 24, 25 and 26 in T. 14 N., R. 10 W. Uranium also occurs in Sections 9, 14, 21, 33, and 35 of the same township. Deposits have been found in Sections 18 and 32, T. 14 N., R. 9 W., but to date drilling has not been sufficient to show the extent of uranium occurrence in that township nor even in T. 14 N., R. 10 W.

X-ray analyses made by the U.S.G.S. indicate that the uranium mineral in the Ambrosia Lake area is coffinite associated with asphaltite. The Westwater Canyon member of the Morrison formation is the host rock. It is poorly-sorted, ranging from a pebble conglomerate to a medium-to coarse-grained sandstone. 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. Shape ranges from angular to rounded. The coarsest host rocks contain the highest percentage uranium although small lenses of fine-grained material within a coarse-grained rock may be richer than the coarse surroundings.

Some of the ore-bearing rocks have calcite as the principal cement. Others have no calcite whatsoever, the asphaltic material being the principal cement. Pyrite occurs as an accessory in both types. The age relationship between the calcite and the asphaltic material is vague, but there is some indication that the calcite is the later mineral.

The uraniferous asphaltic material embays and replaces detrital grains, especially feldspar. The replacement of detrital grains and the entry of the asphaltite into minute cracks in the host rock indicate derivation from petroliferous material rather than from a woody material.

In places in the ore zone calcite is so highly concentrated that numerous grains have optical continuity and give the appearance of one large cleavage face, six inches to a square foot in area. Outside the ore zone calcite appears only as a minor cement which would suggest that the uraniferous solutions also brought in these larger concentrations of calcite.

Over a large portion of the areal extent of the Westwater, hematite cementing material causes the sandstone to be reddish in color. Uranium in the Ambrosia Lake area occurs in bleached zones of the Westwater. Of the hundreds of holes logged in the area, only one possibly mineralized hole has been reported in the unbleached or red sandstone. In the bleached zone the Westwater is generally gray and weathers yellow on an exposed face. The Westwater is not always grey throughout a hole intersecting ore, however, for in at least one large ore body, the upper portion of the sandstone is red and the lower zone grey. At this particular locality the red is separated from the grey by a mudstone layer. In another case the Westwater is red except at the base, where it is grey.

A brief discussion concerning the cause of these color changes may suggest a clue as to the origin of the uranium. As mentioned before, the Westwater is usually red which is believed to be due to hematite. Locally, solutions carried the hematite away. Later, or possibly contemporaneous with this solution activity, pyrite was introduced with uranium. Pyrite is commonly associated with ore in the area. On an exposed surface, such as a cliff face, the pyrite has been oxidized to form limonite responsible for the yellowish color to the Westwater on such exposed surfaces. Since ore is found only in the grey, bleached zones and these grey zones are underlain by other red sandstones, it is indicated that uranium has been brought in by laterally migrating solutions. And, since the ore bodies in the greater Grants area are all in close proximity to the major faults, is it not reasonble to assume either that laterally migrating uraniferous solutions were guided to the more open blocks of ground by these faults, or that the faults themselves were the vertical access channels?

There is no specific stratigraphic horizon in the Westwater that is everywhere mineralized. Ore occurs anywhere from the Westwater-Brushy Basin contact to the Westwater-Recapture Creek contact. The Brushy Basin has commonly been mineralized where it contains sandstone lenses. There is at least one report of uraniferous sandstone facies of the Recapture Creek near the Westwater contact.

The mineralized zones in the Ambrosia Lake area range in thickness from less than a foot to over 100 feet. One hole contained three ore zones of 30, 15, and 7 feet respectively, in a mineralized interval over one hundred feet thick. This entire thickness averaged over 0.15 percent U_3O_8 radiometrically. This relationship of several ore zones stacked one over the other holds true in many of the ore deposits.

As Mr. Young pointed out in his paper there are numerous structural traps in the Ambrosia Lake area. Hydrocarbons are in these traps. The Ambrosia Lake dome may or may not have contained enough petroliferous material to be termed an oil pool. In either case there is petroliferous material there today; and, in every case where there is ore, it is associated with this petroliferous material. Contrarily, there are numerous bleached areas in the Westwater that are not on structure, hence do not contain petroliferous material; these areas are barren. This suggests that the uraniferous solutions passed through a relatively large area but that uranium occurs only where a precipitating agent, i.e. hydrocarbon, is present.

(over)

Therefore, although it cannot be said that structure controls the ore, structure does control the hydrocarbons that may determine the location of an ore body. If channels containing woody carbonaceous material were present instead of structure, sedimentary control might be the case.

Although evidence is insufficient to state this absolutely, the trend of the ore bodies in the Ambrosia Lake area seems to follow the structure contours. A preponderance of uranium discovered to date occurs where the top of the Dakota ranges between 6,600 and 7,100 feet elevations. However, significant deposits are known as low as 6,200 and as high as 7,400 feet elevations on the Dakota structure map.

The Westwater ranges in thickness from 110 feet to 250 feet or more. Ore has been discovered throughout this thickness range. Work has begun on an isopach map but has not advanced to the point where conclusions can be drawn. However, preliminary examinations of drill hole data indicate that the ore is not restricted to channels or thickened lenses.

In conclusion I would like to emphasize three points. First, in the greater Grants district uranium occurs in the more severely faulted zones. The Ambrosia Lake area lies within one of these zones. Secondly, in the Ambrosia Lake area ore deposits occur in bleached zones of the Westwater. Thirdly, ore deposits are located in structural traps containing hydrocarbons. If in reconnaissance work a locale is found where evidence suggests these three criteria apply, chances of locating a uranium deposit are increased many--fold.

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