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STRATIGRAPHY AND URANIUM POTENTIAL OF THE BURRO CANYON FORMATION IN THE SOUTHERN CHAMA BASIN, NEW MEXICO

by

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INTRODUCTION

The Chama basin is both a structural and a topographic basin situated in the center of Rio Arriba County, New Mexico. Highway 84 runs north-south through the Chama basin and divides it into almost equal portions. The southern part of the basin is one of the few areas in New Mexico outside of the Grants Mineral Belt in which potentially economic uranium mineralization has been discovered in recent years. The objective of this article is to attempt evaluation of the uranium potential of this area. In order to do so it will be necessary to discuss the stratigraphic relations of the principal uranium-bearing unit, which is a whitish, massive-appearing, conglomeratic sandstone lying between the Upper Cretaceous Dakota Formation and the Late Jurassic Morrison Formation. Its relationship to the productive members of the Morrison in the Grants Mineral Belt is important in economically evaluating the exploration potential of this area.

Portions of this paper, in particular the isopachous map, could not have been included without the consent and helpful cooperation of the following companies: Atlantic Richfield Company, Bokum Resources Corporation, Continental Oil Company, Earth Resources Company, Kerr-McGee Corporation, and United Nuclear Corporation. These companies, however, are in no way responsible for the interpretations or conclusions that are presented.

STRATIGRAPHY

The geology of the Chama basin is fairly well known, mostly through publications of the New Mexico State Bureau of Mines and Mineral Resources, and from a number of University of New Mexico Master's theses. In reviewing the earlier work one finds that the prospective unit has been placed in the Morrison Formation by some workers (Lookingbill, 1953; and Sears, 1953), and in the Dakota Formation by others (Smith, and others, 1961: McPeek, 1965; Muehlberger, 1967; Bingler, 1968; and Doney, 1968). The stratigraphic position of this unit is important not only for establishing the boundary between the Jurassic and Cretaceous Systems, which is rather academic, but also for economic reasons. With the discovery of uranium, the tendency has been to correlate this unit with the "Jackpile Sandstone" of the Laguna area. The "Jackpile Sandstone" is the host for two of the largest sandstone uranium deposits known. The correlation with the "Jackpile Sandstone" has been on the basis of stratigraphic position and similar lithologic character. Ordinarily these criteria would be unassailable; however, the major regional unconformity at the base of the Dakota Formation must be taken into consideration. Over most of the state this unconformity is angular with strata beneath it dipping at a very low angle to the north and northeast. As pointed out by Silver (1948), and Craig and others (1955), the Dakota Formation overlies progressively younger formations from south to north across the state.

Rocks of Lower Cretaceous age have been identified below the Dakota in southeast Utah, southwestern Colorado, the extreme northeastern corner of Arizona, and in northwestern and northeastern New Mexico (Craig and others, 1955). In north-central New Mexico, rocks of Lower Cretaceous age have not been distinguished, but should be present as indicated in Figure 1. Silver (1951) reported:

> "Rocks of early Cretaceous age have been tentatively identified by Reeside (1944) only in the northern part of the (San Juan) Basin near the town of Dolores in Montezuma county, Colorado, where they have a thickness of approximately 100 feet. They consist of white, medium to fine grained sandstones and green and gray shales. Similar rocks of like thickness appear to be locally present in northern New Mexico, 150 miles to the east at the head of Arroyo Canjilon in

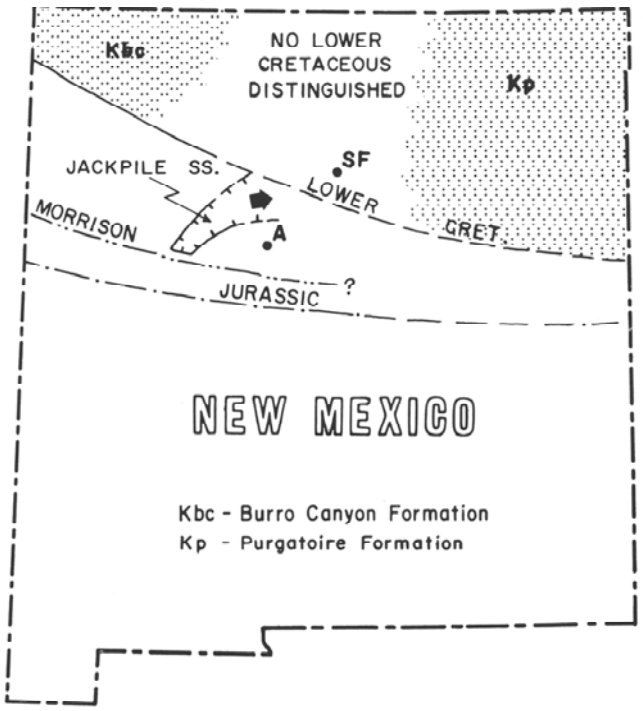

Figure 1. Sub-Dakota paleogeologic map showing truncated edges of the Lower Cretaceous, Morrison Formation, and Jurassic System in northern New Mexico. The stipled pattern indicates the extent of Lower Cretaceous units which are recognized in New Mexico.

> T25N, R4E. Subsurface information from the few wells presently drilled to that horizon indicates that these rocks are generally present in the subsurface through the north half of the basin."

All subsequent workers in the Chama basin have acknowledged the probability of Lower Cretaceous Burro Canyon in the Chama basin, but have arbitrarily included these rocks in either the Dakota or Morrison Formations. The one exception is Swift (1956) who believed that this persistent and easily recognized unit in the Chama basin was at least partly equivalent to the Burro Canyon, and he proposed the name Deadman's Peak Formation. Contrary to Swift, McPeek (1965) affirmed that the Burro Canyon is present in the Chama basin, but he places it in the Dakota Formation on the basis that it is not a mappable unit. According to McPeek (1965), E. H. East of Union Oil Company of California has traced the Burro Canyon by a series of measured sections, from southwestern Colorado to North El Vado Dome in the middle of the Chama basin. McPeek also presents two stratigraphic cross-sections which tie the Burro Canyon of the San Juan Basin to his measured section south of El Vado Reservoir. There appears to be sufficient evidence, therefore, to correlate this unit with the Burro Canyon Formation of southwest Colorado. While acknowledging that a new formation name may be appropriate for this unit in the Chama basin as proposed by Swift (1956), it will be referred to as the Burro Canyon Formation in this paper. Emphasis will be on the relationship of this unit to the Jackpile Sandstone.

Burro Canyon Formation

The name Burro Canyon was proposed by Stokes and Phoenix (1948) for a relatively thin sequence of rocks lying between the Morrison Formation and the Dakota Formation. The type locality is in Burro Canyon (Sec. 29, T44N, R18W) in San Miguel County, Colorado. They described the formation as consisting of alternating conglomerate, sandstone, shale, limestone, and chert ranging from 150 to 260 feet in thickness. The sandstones and conglomerates are gray, yellow, and brown, and the shales are faintly varicolored, mainly purple and green. The lower contact was placed at the base of the lowest, resistant, light-colored, conglomeratic sandstone above the varicolored Brushy Basin Shale Member of the Morrison Formation. The upper boundary was picked at the top of the highest varicolored beds so as to exclude any carbonaceous shales or sandstones in which plant fragments are abundant. This contact has no topographic expression but was found to be remarkably persistent and usable over a wide area. Fossil collections from this formation in Utah and Colorado, consisting of conifers, ferns, cycads, charophytes, dinosaur bones, pelecypods, gastropods, ostracods, and fish scales have dated the Burro Canyon in Colorado as Lower Cretaceous (Stokes, 1952).

Lithology

The Burro Canyon in the southern Chama basin is very similar to that of the type locality. It consists of white, light-yellow to buff, massive, conglomeratic sandstones with thin discontinuous lenses of pale green and pink mudstones. The sandstones range from fine to very coarse-grained, are poorly sorted, and consist mostly of quartz with abundant interstitial kaolinite, especially near the top of the formation. The conglomerate is composed dominantly of white, sometimes pulverulent and vuggy chalcedony, varicolored quartzite and chert pebbles. The pebbles range from 'A inch to 1 inch in diameter, and are well rounded when whole, but are commonly broken. Lookingbill (1953) describes the conglomerate as having a "popcorn" appearance which results from the great number of white, tripolitized chert pebbles. This white altered conglomerate is one of the most distinctive lithologic features of this formation in north-central New Mexico. The mudstone lenses in the Burro Canyon are similar to the mudstones of the underlying Brushy Basin Member of the Morrison Formation; however, the green and pink colors appear to be more "washed out," or of a pastel shade in the Burro Canyon.

The Burro Canyon Formation forms massive, vertical cliffs below the more resistant Dakota Sandstone. It is universally trough cross-bedded, and commonly displays intraformational scoured contacts with associated clay galls. The sedimentary structures, along with occasional silicified logs, indicate that the unit was deposited by streams flowing in a generally northeast direction.

Contacts

Although the Burro Canyon is widely exposed around the southern periphery of the Chama basin, the base of the formation is seldom well exposed due to talus which accumulates at the bottom of the steep cliffs. The Burro Canyon overlies the massive, green to varicolored mudstones of the Brushy Basin Member of the Morrison Formation. Elsewhere in the northern San Juan Basin, the contact has been described as conformable and gradational (Craig and others, 1961). It is possible that along the southern margins of the Burro Canyon in New Mexico, the basal contact may be a minor disconformity. The subsurface information available for this study was inadequate to determine the character of this contact, but it appears to be fairly sharp.

The Burro Canyon is overlain unconformably by the Dakota Formation and the contact is usually one of sandstone upon sandstone. On the outcrop the white, kaolinitic upper Burro Canyon is fairly easy to distinguish from the overlying more limonitic and highly carbonaceous Dakota sandstone. It is more difficult to pick this contact precisely in drill cuttings. Carbonaceous samples can usually be considered Dakota, whereas the occurrence of green or pink mudstone is diagnostic of the Burro Canyon. The conglomerate does not always show up in cuttings, because the altered chert pebbles are soft and are usually pulverized by the drill bit. It is not uncommon for as much as 80% of the pebbles to be tripolitized. The lower 40 to 50 feet of Dakota sandstone is fluvial and sometimes conglomeratic, especially at the base, so the occurrence of pebbles is not too diagnostic. The lower Dakota sandstone is overlain by a black carbonaceous shale, and the base of this shale shows up as a distinct "kick" on the gamma ray log. This shale, which is the upper part of the Oak Canyon Member of Landis and others (1973), is present throughout the area and can serve as a useful marker 40 to 50 feet above the unconformity.

Figure 2 is an isopachous map of the Burro Canyon in the southern Chama basin. This map shows the gross variations in thickness of the Burro Canyon, which can be as much as a 100 feet in less than half a mile. The range in thickness is from about 80 feet to over 200 feet. The map shows a distinct north to northeasterly trend of the thick "channels" in the Burro Canyon. This trend is confirmed by cross-bedding measure-

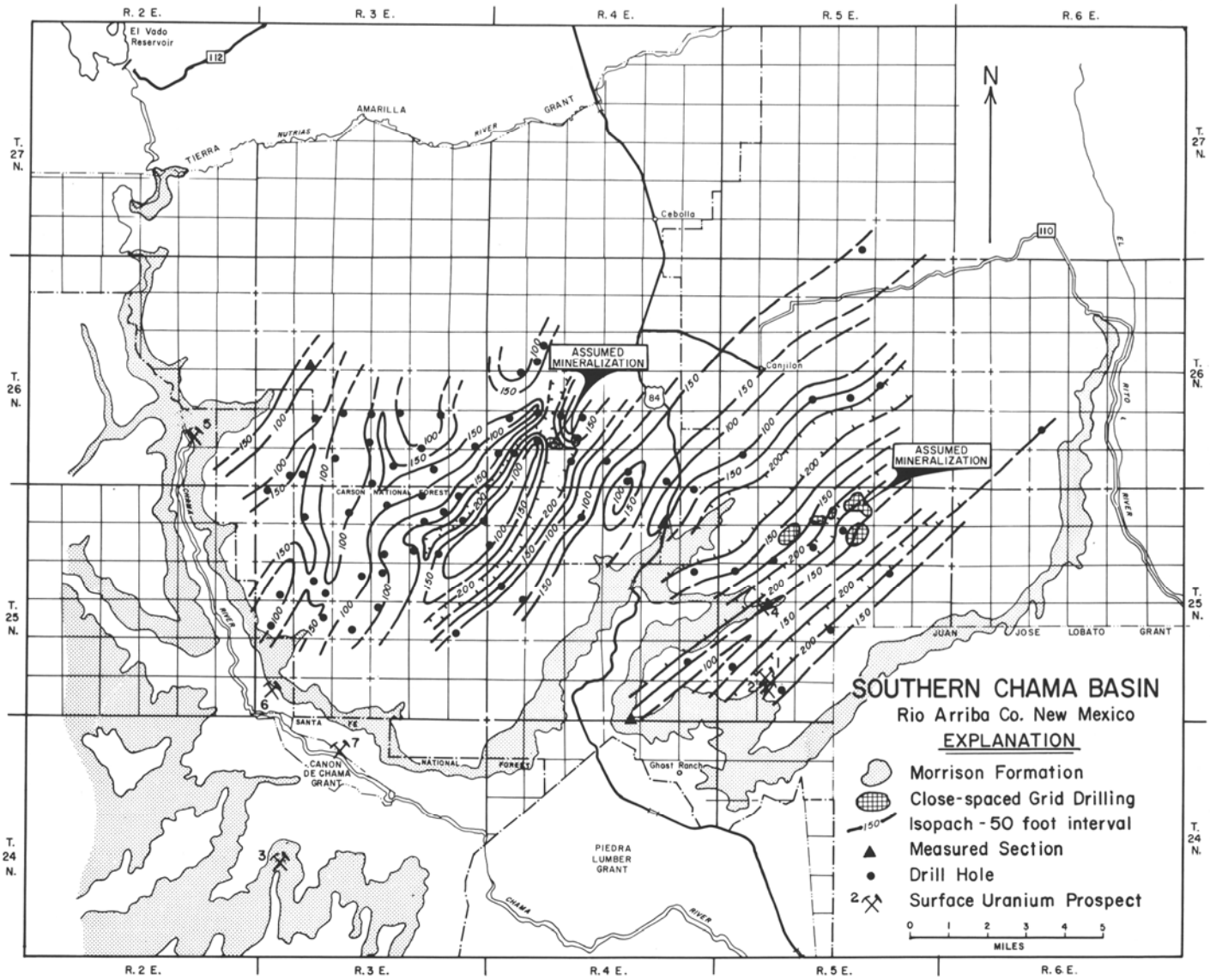

Figure 2. An isopachous map of the Burro Canyon Formation in the southern Chama basin. The map also shows the known surface and subsurface occurrences of uranium in the area.

ments on the outcrop. The source of this coarse, fluvial sandstone was from the southwest.

Depositional History

The Burro Canyon is lithologically similar to the Morrison Formation, and indeed, may represent a continuation of Morrison deposition into Lower Cretaceous time. In order to investigate the relationship between these two formations, a regional stratigraphic cross-section was constructed from measured sections available in the literature. Figure 3 shows the location of the line of section along the east margin of the San Juan Basin. The cross-section was constructed using the base of the Todilto Limestone as a datum. The assumption is that the Todilto Limestone is as close to being a horizontal time plane as is available in the Jurassic section. This stratigraphic section, which is number 1 in Figure 4, indicates that the Burro Canyon is stratigraphically higher than the "Jackpile Sandstone." The "Jackpile" trends more easterly, as shown in Figure 1, and goes out of the line of section to the north. The thin erosional south edge of the Burro Canyon may lie, in places, directly upon the "Jackpile Sandstone" between sections 8 and 9, but in other places it appears to be separated by about 25 to 30 feet of green mudstones. This relationship is exposed along the hogback in the northeast corner of the Ojo Del Espiritu Santo Grant in Township 18 North, Range 1 West, between towns of Cuba and San Ysidro.

The real confusion arises when the cross-section is hung using the base of the Dakota Formation as a datum. The lower cross-section (No. 2) in Figure 4 illustrates the conflicting model obtained when the datum is the unconformity. Structural movements that probably began during Westwater Canyon deposition continued, and were enhanced, prior to Dakota deposition. The result is an apparently continuous sandstone unit under the Dakota Formation from Laguna to the Chama basin. The strongest argument against correlating the Jackpile with the Burro Canyon Formation of the Chama basin is that the "Jackpile Sandstone" is not conglomeratic (Schlee and Moench, 1961; and Nash, 1967). However, the Burro Canyon,

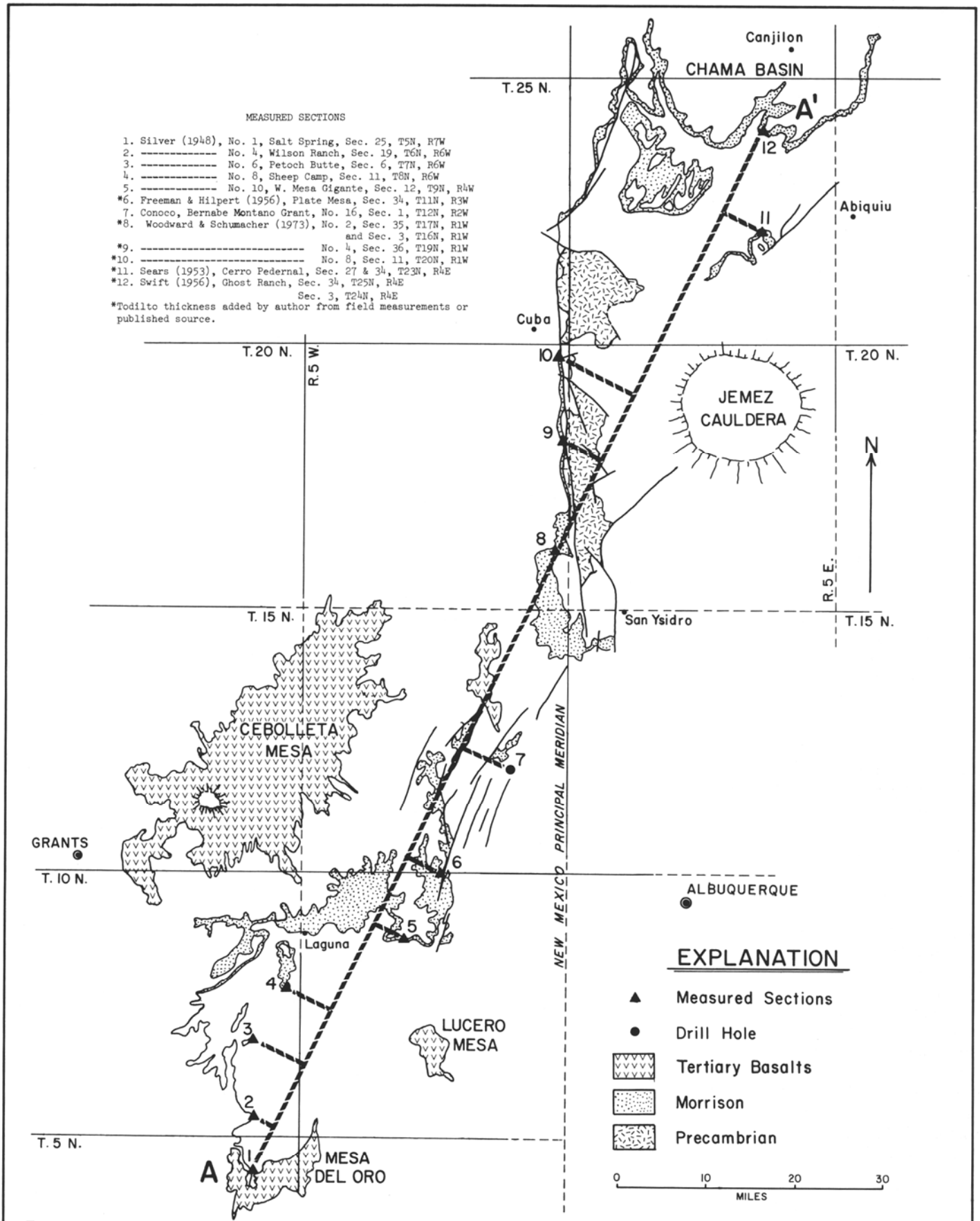

Figure 3. Index map of part of northwestern New Mexico showing the locality numbers of measured sections which have been projected into the line of section A-A'. The geology is adapted from the state geologic map (Dane and Bachman, 1965).

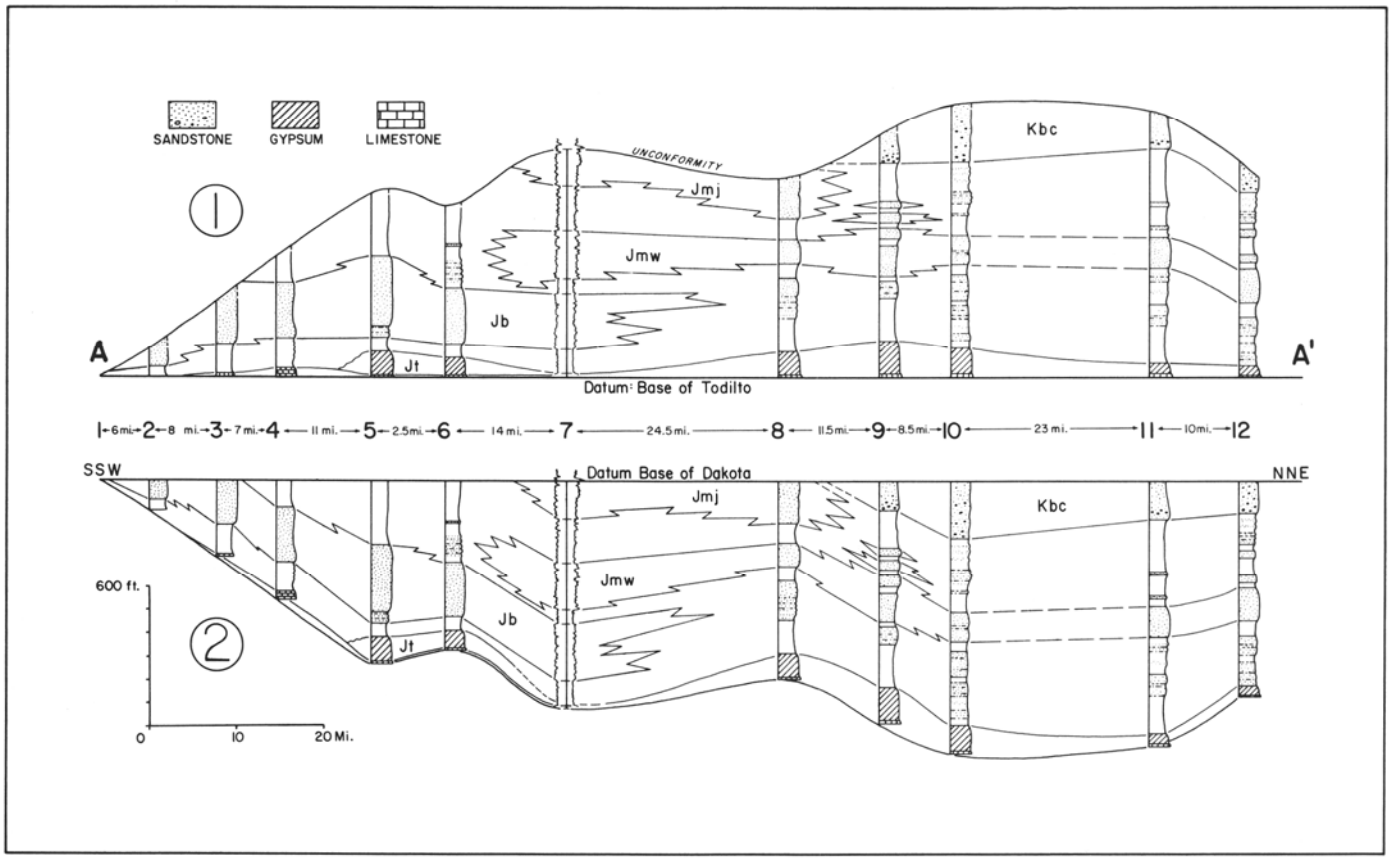

Figure 4. Graphic sections of the Morrison and related formations along the east margin of the San Juan basin. The line of section is shown in Figure 3. Both sections are A-A', but section number 1 is hung on the base of the Todilto Limestone for stratigraphic correlations, and section number 2 is hung on the base of the Dakota Formation in order to illustrate pre-Dakota structure. The stratigraphic letter symbols are: Burro Canyon Formation (Kbc); "Jackpile Sandstone" (informal mem.) (Jm); Westwater Canyon Member of the Morrison Formation (Jmw); Bluff Sandstone (Jb); and Todilto Limestone (Jt).

which is farther from the "Jackpile" source area, is characterized by conglomerate. Except for the conglomerate, the two units are similar lithologically. The probable explanation is that the Burro Canyon Formation is, in fact, reworked Morrison Formation. Continued uplift and tilting of the Mogollon Slope (Kelley, 1955) after deposition of the "Jackpile" resulted in the erosion and removal of the coarse, proximal portion of the "Jackpile" fluvial channel system. This coarse "J ackpile"-derived sediment was carried farther down slope and deposited in the subsiding Chama basin. The faded mudstones in the Burro Canyon are reworked Brushy Basin, and the tripolitized chert pebbles are evidence that the sediment experienced an additional cycle of erosion and transportation. A tremendous amount of coarse, conglomeratic sandstones and green mudstones in the Morrison Formation were stripped from the lower Mogollon Slope in northern Arizona and west-central New Mexico. The Lower Cretaceous units from southeastern Utah to northeastern New Mexico are most probably composed of reworked Jurassic units along with a contribution from some of the older strata.

URANIUM

Uranium mineralization was discovered on the outcrop in a number of places in the southern Chama basin during the late 1950's. The following tabulation lists these occurrences according to the formation and section in which they occur.

No.	*Formation*	*Location*
1.	Dakota	S/2, Sec. 29, T25N, R5E
2.	Dakota	N/2, Sec. 32, T25 N, R5E
3.	Burro Canyon	SE/4, Sec. 19, T24N, R3E
4.	Burro Canyon (?)	NW/4, Sec. 20, T25N, R5E
5.	Morrison (2 pits)	SW/4, Sec. 26, T26N, R2E
6.	Todilto	N/2, Sec. 31, T25N, R3E
7.	Chinle	SW/4, Sec. 4, T24N, R3E

The locations of these surface prospects are shown on Figure 2. The uranium mineralization at location 1 is associated with macerated plant material in very thin to laminated, rippled, fluvial to marginal marine sandstones near the base of the Dakota. Location 2 appears to be the same mineralized horizon in a slump block across the Arroyo del Yeso Canyon. All the drilling to date in the Chama basin has penetrated the Dakota Formation, but no significant mineralization has been discovered in this unit. The two widely spaced anomalies at locations 3 and 4 are associated with limonitic staining in the Burro Canyon Formation. This formation has become the most prospective horizon in the basin. There are two prospect pits at location 5 near the base of the Morrison Formation and the mineralization appears to be associated with fossil bone and petrified wood near the outcrop. An attempt at mining

was unsuccessful due to the rarity of bone and logs. Drilling depths in excess of 1000 feet combined with poor lithologic character have discouraged any extensive Morrison exploration in the basin in light of what has been found to date. Some mineralized Todilto float ranging up to 3.0% U_3O_8 has been reported at location 6 (Hilpert, 1969), yet Todilto mineralization is unusually rare in this area when one considers how well exposed it is. Thin, spotty anomalies were found associated with plant debris in part of the Salitral Shale Tongue, and in the top of the Agua Zarca Sandstone Member of the Chinle Formation at location 7 (Hilpert, 1969).

No significant production is recorded from any of these uranium prospects. Additional information concerning these occurrences can be found elsewhere in this volume or in Hilpert (1969). The significant points about the occurrences is their wide stratigraphic distribution and the fact that they attracted attention to the Chama basin during the renewed uranium activities in the late 1960's.

The present cycle of uranium exploration in the southern Chama basin began in 1968. Prior to this time, a few scattered holes had been drilled in the basin by uranium exploration companies, mostly for stratigraphic information. Rumor that United Nuclear had encountered mineralization southeast of Canjilon early in 1969 added momentum to a large scale land play that was already in progress. Much of the southern part of the basin is in the Carson National Forest, and this acreage was claimed in large blocks. By the end of 1969, over 700 exploration holes had been drilled, and to date, the figure is probably approaching 2,000, although activity has dropped considerably. Most of these holes bottomed in the top of the Morrison Formation, and their average drill depth is about 500 feet. As a result of this flurry of activity, significant mineralization as indicated by close-spaced drilling, was discovered in the Burro Canyon in two separate areas. These patches of grid drilling, some of which has been as close as 25 feet, are shown in Figure 2.

The mineralization encountered in sections 28 and 29, T26N, R4E is mostly in the lower Burro Canyon and is reportedly low grade. The Burro Canyon is reduced and apparently lies at, or below, the water table. The mineralization in the Burro Canyon Formation southeast of Canjilon in sections 3, 4, 8, and 10, T25N, R5E, is divided between two companies. Drilling has been with air in this area, so the host rock is well above the water table. The mineralization appears to be in pods strung out to the south and southwest. Cuttings indicate that the southwest string of mineralization is at an oxidation-reduction interface 300 to 400 feet deep. This probably represents a uraniferous roll-front that was moving down dip to the northwest in the lower half of the formation. A thin mudstone in the middle of the Burro Canyon divides the unit into about equal halves. Mineralization in sections 3 and 10 is in the upper half of the Burro Canyon, at a depth of 200 to 300 feet, and appears to have been a roll-front moving to the east or northeast. The ore pods in the upper Burro Canyon are close to a large fault and are badly oxidized. Although the pods are relatively small, thicknesses of up to 50 feet of ore grade material have been encountered. Apparently these discoveries are uneconomic to mine at the present time. Perhaps *in-situ* leaching may be used to recover some of this uranium.

In summary, one may speculate that the mineralization is related to redox interfaces that migrated down dip from the outcrop. Tongues of oxidation may have extended farther down dip along the thick "channel" trends. The source of the uranium in the roll-front deposits may have been derived from weak solutions originating in the Mogollon Highland far to the south, or from disseminated uranium within the Burro Canyon which came from reworked Morrison deposits. Another possibility is that the uranium was leached from late Tertiary volcanics that once blanketed the southern Chama basin. This idea would help explain the wide stratigraphic distribution of minor, almost surficial, uranium mineralization around the basin. This type of mineralization is known to exist on La Ventana Mesa south of Cuba, where a coal bed near the top of the mesa apparently collected uranium leached from the Bandelier Tuff that once covered the mesa (Cannon and Starrett, 1956). This situation is not at all uncommon and may be a plausible explanation in this instance.

CONCLUSIONS

The prospective unit in the Chama basin appears to correlate with the Lower Cretaceous Burro Canyon Formation of the northern San Juan Basin, rather than with the "Jackpile Sandstone" to the south. Large uranium deposits are usually limited to definite stratigraphic units, which suggests that the uranium, whatever its source, was available only during certain brief periods of geologic time. During "Jackpile" deposition it is obvious that a rich source of uranium was available, which contributed to the development of large ore bodies. During Burro Canyon deposition a plentiful source of uranium may or may not have been available, therefore the exploration risks are greater. It appears highly unlikely that large, tabular, "Jackpile"-type ore bodies will be discovered in the Chama basin. There is a good possibility that additional deposits will be discovered, but these new discoveries will probably be similar to those already found and will undoubtedly be deeper. Any additional reserves, however, may contribute to the development of a mining situation in the Chama basin, especially in view of the favorable economic forecasts for uranium.

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