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GEOLOGY OF THE LISBON VALLEY URANIUM DISTRICT, SOUTHEASTERN UTAH

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INTRODUCTION

The Lisbon Valley uranium district, or the Big Indian uranium district, is located in the east-central part of the Colorado Plateau (fig. 1). The district is approximately 50 km southeast of Moab, Utah. The majority of the uranium deposits occur in the Moss Back Member of the Chinle Formation (Triassic); however, minor amounts of ore have been produced from sandstones of the Cutler Formation (Permian).

Uranium was first discovered in the area in 1913 at the southern end of the district in Chinle sandstones (Wood, 1968). By 1948, a low-grade deposit had been developed in upper Cutler sandstones. In July of 1952, Charles A. Steen intersected 4 m of high-grade uranium in the lower sandstones of the Chinle Formation. The first ore produced from this discovery was on December 4, 1952 (Stocking, 1975), and in the following years the largest uranium district in southeast Utah was delineated.

GEOLOGIC SETTING

The oldest rocks which outcrop in the Lisbon Valley area are the Pennsylvanian-age Hermosa Group (fig. 2). The limestones and sandstones of the Hermosa are overlain by the Cutler Formation of Permian age. At this location, the Cutler is composed of red sandstones, siltstones, and minor limestones which were apparently deposited in environments which alternated between westward-flowing streams and eastward marine transgressions. The sedimentology of this formation is being reconstructed by Campbell (1978, personal communication) in an effort to relate the depositional environments to the occurrence of uranium in the Cutler Formation.

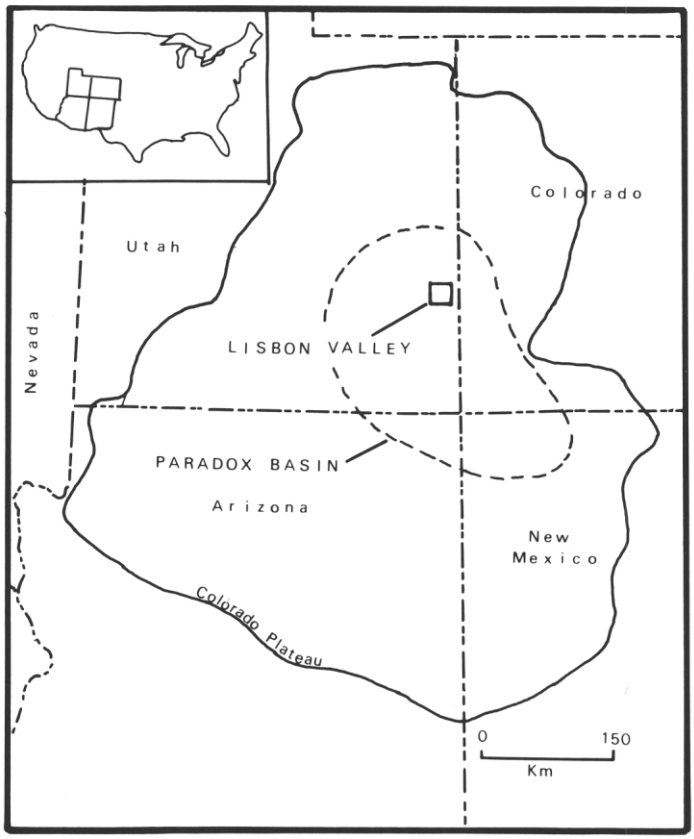

Figure 1. Index map of Lisbon Valley uranium district.

The upper contact of the Cutler Formation is an unconformity. The entire Moenkopi Formation is missing at Lisbon Valley due to erosion or nondeposition. Therefore, the Chinle Formation rests directly upon the Cutler Formation. The amount of angularity between the two formations varies but generally is under 5 degrees. The Chinle Formation originally covered the entire region. This formation of Late Triassic age has been informally subdivided into two parts: a lower bentonitic sequence and upper red-bed sequence (Stewart and others, 1972). The bentonitic sequence, predominantly gray in color, is composed of claystone, clayey sandstone, and widespread sandstone and conglomerate ledge formers. Montmorillonitic clay, which is thought to have been derived from volcanic ash, comprises the claystones of this sequence. The continental deposits of the bentonitic sequence formed in rivers, flood plains, and associated lakes.

The red-bed sequence is composed of reddish-brown or reddish-orange siltstones with sparse sandstones and limestones (Stewart, 1969). The rocks which comprise this sequence are thought to have formed mainly in a large, shallow lake. However, part of this sequence in east-central Utah may have formed in a somewhat different environment as indicated by the larger percentage of sandstone in the section.

Regionally, the Chinle Formation is composed of seven formal members and several informal members which are generally equivalent to the named members. The seven units in ascending order are: Temple Mountain, Shinarump, Monitor Butte, Moss Back, Petrified Forest, Owl Rock, and Church Rock.

Several opinions exist as to what members of the Chinle Formation actually are present in the Lisbon Valley area. The Shinarump Member and the Monitor Butte Member are generally believed to be absent at the Lisbon Valley section (Stewart, 1969). The basal sandstone interval which rests unconformably on the Cutler Formation is generally called the Moss Back Member and the remaining part of the Chinle is called Churck Rock Member. Stewart and others (1972) suggested that the lower sandstones of the Chinle in this area may not, in fact, be the Moss Back Member but rather a younger sandstone. However, Young (1978, personal communication) suggested the lowermost sandstones of the area may be in fact the Shinarump Member. O'Sullivan and MacLachlan (1975) preferred not to use the traditional member names for the upper Chinle; instead, they adopted an informal lithologic breakdown of the claystone member, limy member, and siltstone member.

The Lisbon Valley uranium district is located on the southwestern flank of a faulted anticline. This structure, the Lisbön Valley anticline, is one of the main salt anticlines of the Paradox basin. However, the anticline is different from the majority of the others as the Pennsylvanian salts did not penetrate to the surface.

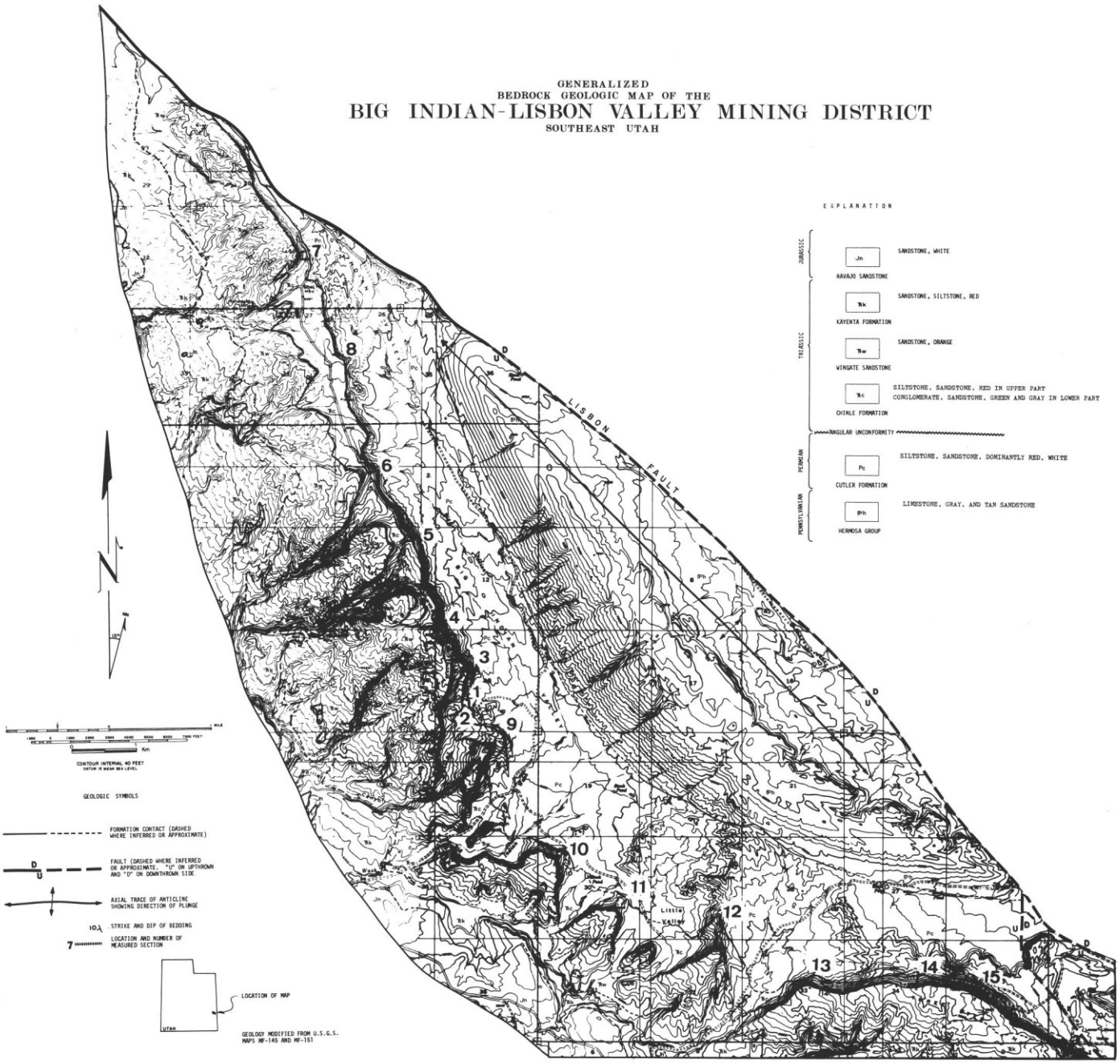

Figure 2. Geologic map of the Big Indian–Lisbon Valley district.

The northeastern side of the anticline has been faulted down along the Lisbon fault approximately 1,200 m along the crest and shows a displacement of about 606 m near the North Alice and Rio Algom (Lisbon) mines (Wood, 1968). Coyote Wash syncline is about 6.5 km northeast of Lisbon Valley and the Hatch Rock syncline is about 13 km west of the district.

It appears that the anticline was positive and an active feature at the beginning of the Triassic Period. This is indicated by the absence of the Moenkopi Formation in the Lisbon Valley area and its presence between the Chinle and Cutler strata in adjacent synclinal areas (Wood, 1968, and Budd, 1960). Butler and Fisher (1978) suggest that small variations of Chinle thickness along the outcrop of the southwestern flank of the Lisbon Valley anticline indicate that minor uplift of parts of the anticline may have occurred during Chinle sedimentation. Tectonic activity during Laramide time or later faulted the anticline along the axis and displaced the northeast block downwards along the Lisbon fault.

CHINLE FORMATION

Stratigraphic information, obtained from 15 measured sections in the Lisbon Valley area (numbered in fig. 2) and 22 drill holes west of the district, is shown on Figures 3 and 4. The Chinle Formation is composed of an upper siltstone and sandstone unit and a lower sandstone unit called the Moss Back Member.

The general vertical sequence of the upper unit in the northern part of Lisbon Valley consists of a lower greenish-gray siltstone, a middle reddish-brown to pale red sandstone, and an upper reddish-brown siltstone. Both siltstone intervals commonly are par-

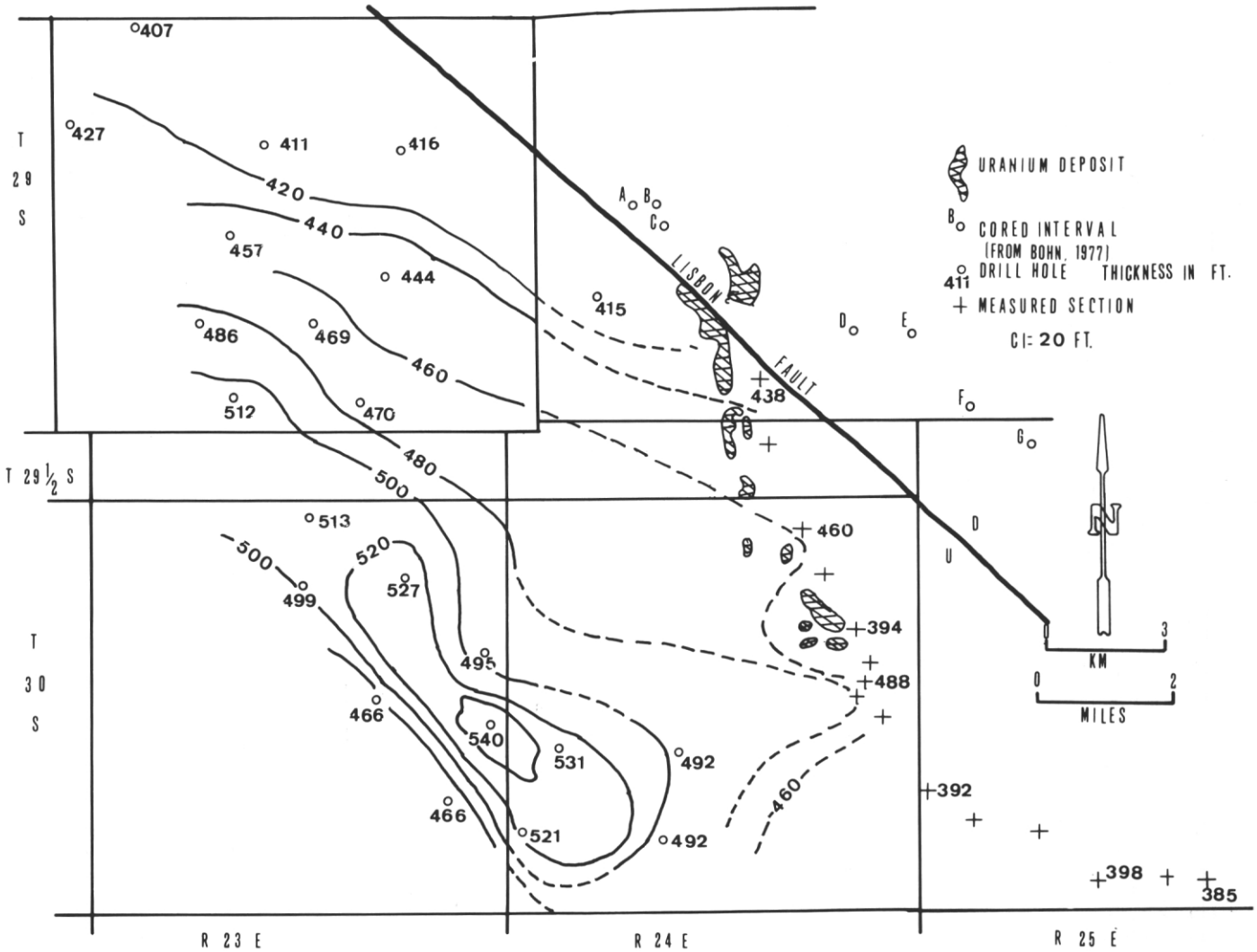

Figure 3. Isopach map of Chinle Formation in the Big Indian–Lisbon Valley district.

tially covered; however, small lenticular sandstones are believed to be present in the siltstones beneath the covered slopes. The middle sandstone interval generally is very fine- to fine-grained, well to moderately sorted, with subrounded grains. Locally, the basal part of the sandstones contain conglomerates composed of quartz pebbles. Stratification types include plane bedding, large-scale trough cross-bedding, some tabular cross-bedding, and ripple-marked zones. The upper sediments of the Chinle Formation along the south part of the district are also principally siltstones. However, the middle sandstones appear to be more discontinuous than those to the north.

In Lisbon Valley the Moss Back Member is composed of a lower sandstone unit and an upper sandstone unit. The main facies of the lower unit as calculated from the measured sections include: 15 percent parallel-bedded conglomerate, 15 percent trough cross-bedded sandstone, 66 percent interbedded siltstone and sandstone, and 4 percent other facies. The generalized depositional model for the lower unit starts with a scour surface upon which channel lag conglomerates were deposited. This facies is overlain by trough cross-bedded sandstone indicating overbank deposition. The large amount of fine-grained sediments (siltstones), the depth of scouring, abundant mudstone clasts in the conglomerate, and a poorly defined fining-upward sequence suggests deposition by a meandering stream. However, the lack of the upper point bar facies of parallel lamination and ripple-marked sandstones presents a problem. It is possible that the reason for this apparent absence of upper point bar sediments is that the river which deposited these sediments belonged to the coarse-grained, point bar, meander-belt model. In this type of river, the sediments of the upper point bar are removed by chute erosion. Conglomerate lenses overlain by trough cross-bedded sandstones locally were observed between the measured sections in the upper part of the unit and may represent chute fill. This model is not wholely satisfactory because large foreset bedding, characteristic of chute bars, was not observed at the outcrop. The Donjek-type braided river model (Miall, 1977) commonly contains point bar deposits similar to those described. However, the large amount of fine-grained overbank material associated with the lower unit is not common to the braided river model.

The main facies observed in sandstone of the upper unit as calculated from the measured sections include: 22 percent parallel-bedded and trough cross-bedded conglomerate, 32 percent trough cross-bedded sandstone, 32 percent parallel-bedded sandstone, 10 percent ripple-marked sandstone, and 4 percent other facies. These percentages do not include the siltstones which occur at the top of the sequence. The reason that the overlying silt-

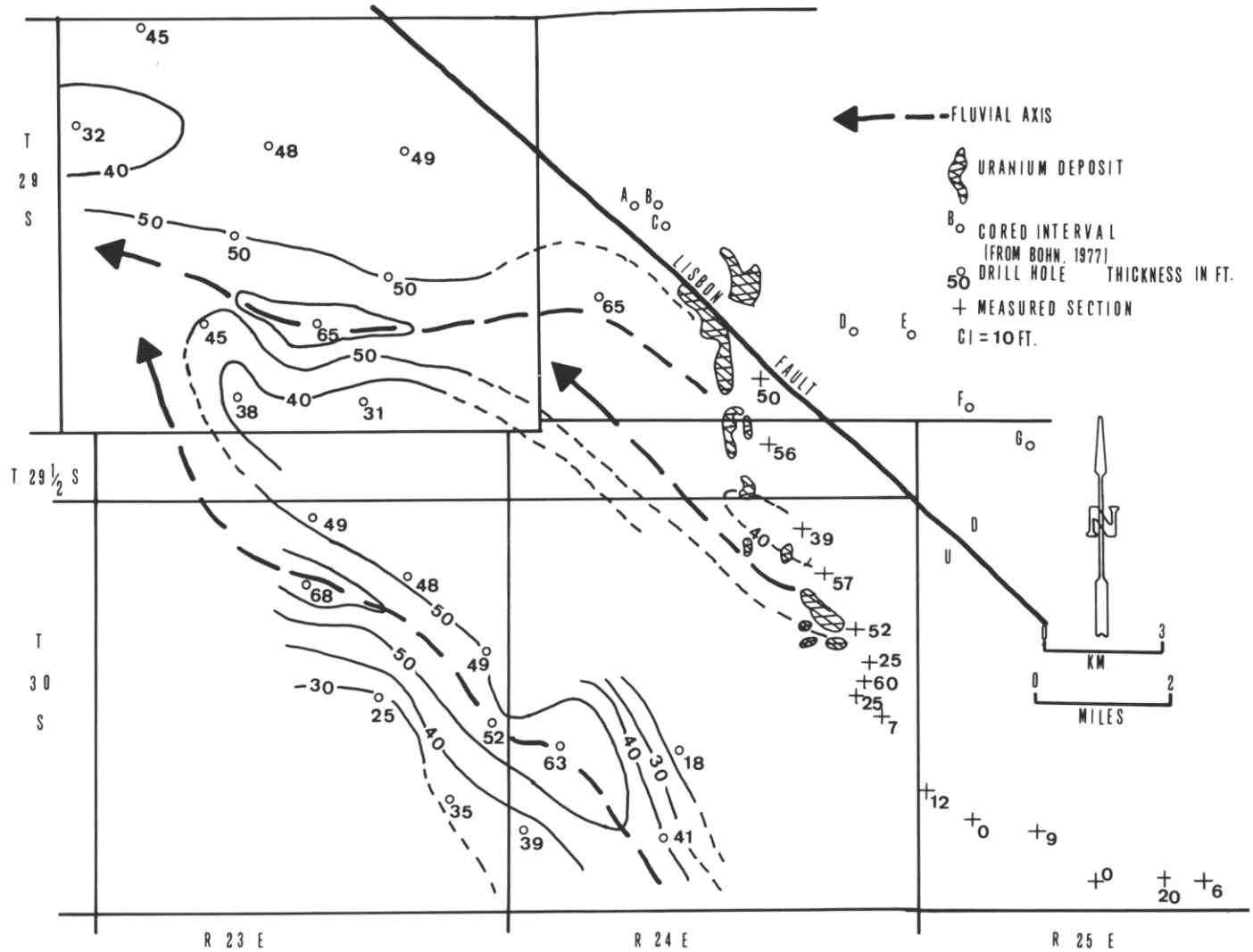

Figure 4. Isopach map of lower Chinle sandstones in the Big Indian–Lisbon Valley district.

stones were not incorporated into the breakdown of the facies is that it was not possible to ascertain what thickness of siltstones were deposited by the channels of the upper unit. The generalized depositional model of this unit starts with a channel lag conglomerate followed by channel-fill facies of trough cross-bedded and parallel-bedded sandstones. The upper part of the sequence contains ripple-marked sandstones capped by siltstones. This model is suggestive of point bar deposits. The abundance of siltstone at the top of the sandstone interval and vertical sequence of sedimentary structures suggests a fine-grained, point bar, meander-belt model. However, the occurrence of trough cross-bedding in the upper part of the interval and poorly defined upward fining of grain size suggests a coarse-grained, point bar, meander-belt model.

The geology of the mineralized area north of the Lisbon Fault (Lisbon mine) and along the southern part of the outcrop in T.30S., R.25E. (fig. 4) is different from the rest of the district. The dominant lithologies within these areas are siltstones, fine-grained sandstones, and mudstone-pebble conglomerates. These mudstone-pebble conglomerates are contained in a sandstone matrix which is fine- to medium-grained. The large amount of siltstone, flat-pebble conglomerate and thin sandstone beds suggests sedimentation in an environment different from the rest of the district. The depositional environment is interpreted as marginal to the main channel system, where the dominant sedimentation was in an overbank environment of crevasse-splay deposits into a flood basin. This is supported by the abundance of mudstone clasts and generally finer-grained sediments contained in the two areas. The mudstone clasts are composed of both reddish-brown and greenish-gray colored fragments. The reddish-brown clasts may have been derived from the higher, oxidized part of the natural levee and the greenish-gray clasts may have come from the lower and more reduced part of the levee.

Figure 3 is an isopach map of the Chinle Formation. The increase in total thickness in the region of the Hatch Rock syncline (southwestern part of the map) suggests that this structure may have been active during Chinle deposition and influenced sedimentation. In general, the formation appears to be thinning in a north and northeastern direction. It is possible that this reduction in total thickness could have been influenced by the Lisbon Valley anticline if it were a positive feature during Chinle time. Figure 4 is an isopach map of the lower Chinle sandstones in the area. Two main stream systems are indicated on this map. The northern one apparently swings to the north immediately west of Lisbon Valley and then turns to the west. The second stream system apparently flowed northwest along the Hatch Rock syncline where it joined the northern system and flowed westward. Based on the isopach

map of the total lower Chinle sandstones, it appears that the small anticline may have influenced sedimentation, as indicated by the thinness of lower sandstones found in the northwest corner of T.28S., R.23E. A gravity low which may indicate the presence of a minor salt cell underlying this anticline has been reported by Byerly and Joesting (1959). If this area were slightly positive, then it may have acted as an intra-stream divide and most of the sediments at that locality would be the finer-grained overbank deposits.

The trend of the thickest part of the lower Chinle sandstones along Hatch Rock syncline also indicates the possibility of tectonic influence on sedimentation. In this area, the elongate nature of the sandstone isopach follows the synclinal axis.

The results of the outcrop study and the drilling program suggest that the Lisbon Valley area was the site of two main belts of fluvial sedimentation in the Moss Back Member. These northwesterly trending belts averaged about 6.5 km in width except in the area of T.29S., R.23E., where the width may be from 10 to 16 km. The nature of the vertical sequences of the sedimentary structures, and the various facies of fine-grained sediments and massive conglomerates, suggest the lower Chinle sandstones at Lisbon Valley were deposited by a river belonging to a coarse-grained, point bar, meander-belt model or a Donjek-type braided river model. It is interesting to note that the main Lisbon Valley uranium deposits appear to be located perpendicular to a fluvial belt that has been interpreted as characteristic of a coarse-grained, point bar, meander-belt model. This is in agreement with the observation of Rackley (1976) that most of the uranium deposits of the western United States occur in sediments deposited by coarse-grained, point bar, meander-belt rivers.

URANIUM OCCURRENCES

The Lisbon Valley district, also known as the Big Indian Valley district, can be subdivided into two areas of mineralization (fig. 5). The southern area, which is the smaller of the two, includes the Service Berry, Divide, and Continental mines. Atlas Minerals Corporation has recently announced the discovery of a new high-grade uranium deposit in this part of the district. The northern area contains the majority of the reserves in a narrow belt which is about 1 km wide and about 10 km long. The mines in this area include: Louise, Mi Vida, Ike-Nixon, La Sal, Cord, Radon, Far West, North Alice, and Rio Algom (Lisbon mine). Wood (1968) describes the ore bodies as irregular, amoeba-shaped masses that are concordant to bedding. The average thickness is about 2 m but ranges from a few centimeters up to over 13 m in thickness with an average grade of 0.39 percent U308. The total production for the district is over 68 million pounds of uranium oxide (Chenoweth, 1981, personal communication). .

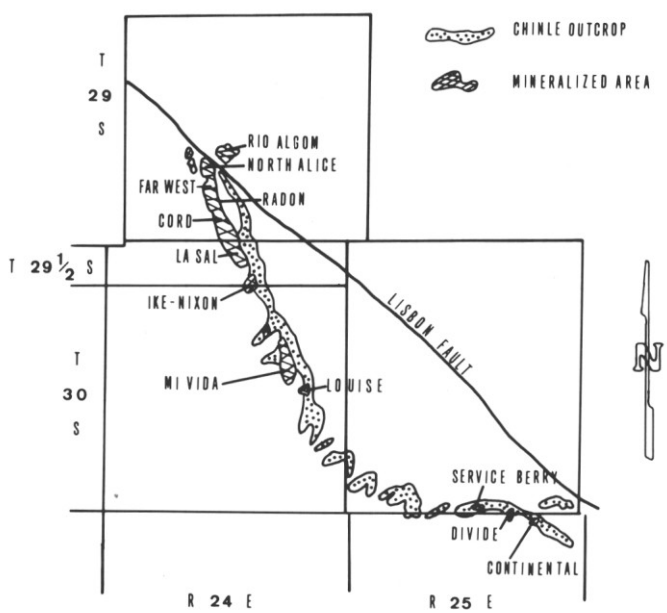

Figure 5. Uranium mineralized areas and mines in the Lisbon Valley district.

The uranium deposits of Lisbon Valley occur in the lowest sandstone or conglomerate of the Moss Back Member. Sedimentological controls of the uranium mineralization were not recognized in the Moss Back Member in Lisbon Valley. However, the isopach map of the lower Chinle sandstones (fig. 4) shows a spatial relationship between sandstone thickness and uranium mineralization. The mineralized areas seem to occur where the thickness of lower sandstones exceed 12 m. The thinness of the sandstones in the middle of the belt suggests that an intra-stream divide may have existed during Moss Back deposition.

Based on the stratigraphic interpretation of the lower Chinle sediments, the uranium deposits in the northern part of the district, from the Mi Vida mine to the Rio Algom mine (fig. 5), are restricted to the lower unit of the Moss Back Member. Here, the main uranium deposits are spread out from the southern edge of the sandstone belt all the way across the channel deposits to the northern edge, and in the case of the Rio Algom mine, the mineralization spreads past the banks into the crevasse-splay deposits.

If the interpretation of the Rio Algom mine area is correct, then the northern extent of mineralization would be limited by the pinchout of the crevasse-splay sandstones into the flood basin deposits. The uranium deposits in the southern part of the district also are believed to be hosted in crevasse-splay deposits.

Geochemical zoning of several elements has been found to occur over the deposits. Kennedy (1961) found that a molybdenum halo extended up to about 3 m above the uranium mineralization in the northern part of the district. Calcium was also found to be concentrated above the ore for about 0.6 m. Recent work by Brooks (1978, personal communication) provides a detailed look at the mineral zoning. Sampling on approximately 15-cm spacing revealed the ore body at the Far West incline to have an upper molybdenum maximum value underlain by the uranium zone which in turn was underlain by a vanadium zone followed by a copper zone. This sequence of zoning is characteristic of the upper limb, or more generally the outer side of a geochemical cell (i.e. roll-type deposit), as described by Rackley (1976) and Harshman (1974).

SUMMARY

The sandstones of the lower part of the Chinle Formation at Lisbon Valley were deposited in a fluvial environment. Facies analysis of these sandstones suggests that this fluvial environment was of the coarse-grained, point bar, meander-belt type or possibly the Donjek-type braided stream of Miall (1977). Sedimentation during Moss Back time, as well as for the rest of the Chinle Formation, appears to have been influenced by tectonic activity. This is shown by the sub-surface geometry of the sandstones of the Moss Back Member as well as the thinning of the total Chinle Formation to the north towards the Lisbon Valley salt anticline.

Uranium mineralization in the Lisbon Valley district occurs in the basal sandstones and conglomerates of the Moss Back Member.

The long axes of the ore bodies are approximately perpendicular to the northwest-trending channel system as mapped in the subsurface. The uranium mineralization is not solely hosted by channel sandstones. In the Rio Algom mine (Lisbon mine), the host rock for the mineralization is believed to be of crevasse-splay origin. The geochemistry of the uranium deposits reveals similarities to the oxidation-reduction geochemical cell uranium deposits of the Wyoming basins. The distribution of elements in a vertical sequence from the top downward has been reported to be molybdenum, calcium, uranium, vanadium, and copper.

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