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GENERAL GEOLOGY OF URANIUM-VANADIUM DEPOSITS OF SALT WASH SANDSTONES, LA SAL AREA, SAN JUAN COUNTY UTAH

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INTRODUCTION

Important uranium-vanadium deposits occur in the uppermost sandstone "rim" of the fluvial Salt Wash member of the Jurassic Morrison Formation in the La Sal area, approximately 50 km south of Moab, Utah. The deposits are concentrated in an east-west trending belt approximately 19 km in length. The mineralized trend is virtually continuous from the community of La Sal Junction, Utah, on the west to the Utah-Colorado state line on the east. Utah Highway 46 parallels the mineralized trend and provides easy access to either the Union Carbide uranium mill at Uravan, Colorado, 100 km to the east or to Atlas Minerals uranium mill at Moab, Utah, 50 km to the north (fig. 1). Uranium deposits are located in the southernmost sections of T.28S., R.24 and 25E. and the northernmost sections of T.29S., R.24 and 25E.

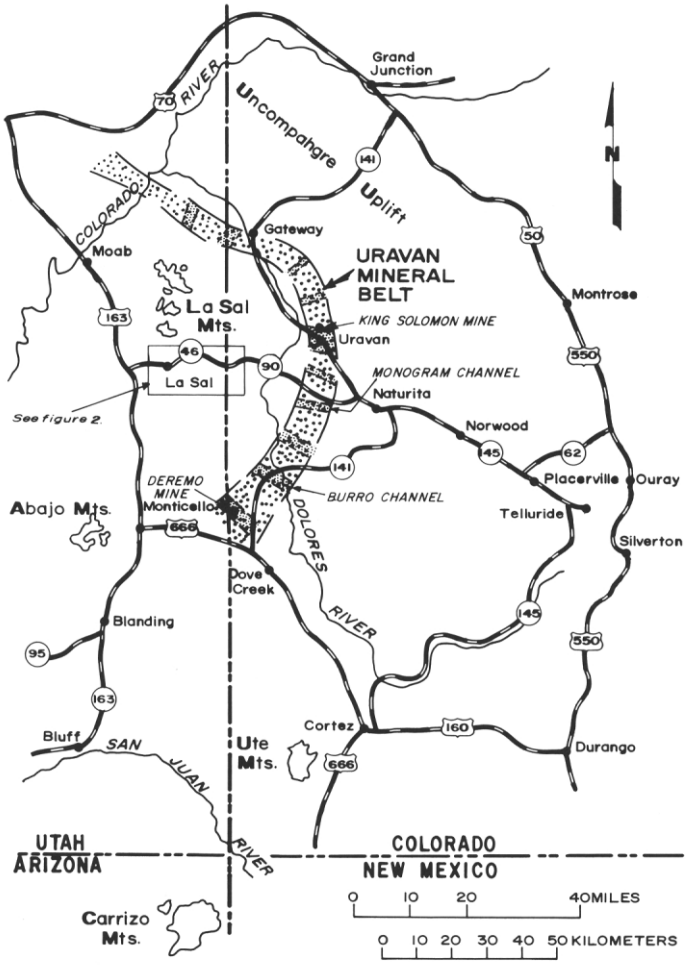

Figure 1. Index map of the Uravan Mineral Belt (modified from Chenoweth, 1978).

Mining and exploration activity have progressed both eastward and westward in recent years, from an early start in the La Sal Creek area on the east, and the La Sal Junction-Rattlesnake area on the west. The majority of the existing reserves lie in the central La Sal area between the Pine Ridge collapse and the old Continental Materials Corporation Rattlesnake Pit. Production grades for La Sal and La Sal Creek ores are somewhat higher in vanadium and uranium than production grades from other localities (Table 1). The La Sal-La Sal Creek district is the largest Salt Wash production area outside the main Uravan mineral belt with future forecasts calling for substantially more production. Union Carbide Corporation and Atlas Minerals control the overwhelming land position, and both have operating mines in the area: Beaver Shaft, Mike, Snowball, Heckla, La Sal; and Pandora, respectively.

GEOLOGY

The La Sal area lies within the Paradox Basin of southwest Colorado and southeast Utah. Four major structural features resulting from salt tectonics and Tertiary intrusive activity dominate: La Sal Mountains, Lisbon Valley anticline, Pine Ridge anticline, and Coyote Wash syncline (fig. 2).

The La Sal Mountains, a laccolithic intrusive of predominately diorite porphyry with lesser amounts of monzonite and syenite porphyries, are considered to be late Cretaceous to early Miocene in age (Carter and Gualtieri, 1965). Teritary gravel derived from the

Table 1. Uranium ore production from the Salt Wash Member for the principal ore districts, based on U.S. Department of Energy records (modified from Thamm and others, 1981).

DISTRICT	Tons of Ore	Pounds U_3O_8	% U_3O_8	% V_2O_5
Uravan Mineral Belt	13,987,000	68,590,000	0.25	1.29
La Sal–La Sal Creek District	989,000	6,426,000	0.32	1.46
Lukachukai–Carrizo District	846,000	4,009,000	0.24	1.15
Green River District	670,000	2,632,000	0.20	0.19
Other Districts	1,153,000	4,254,000	0.18	1.21
TOTAL	17,645,000	85,911,000		
AVERAGE (weighted)			0.24	1.25

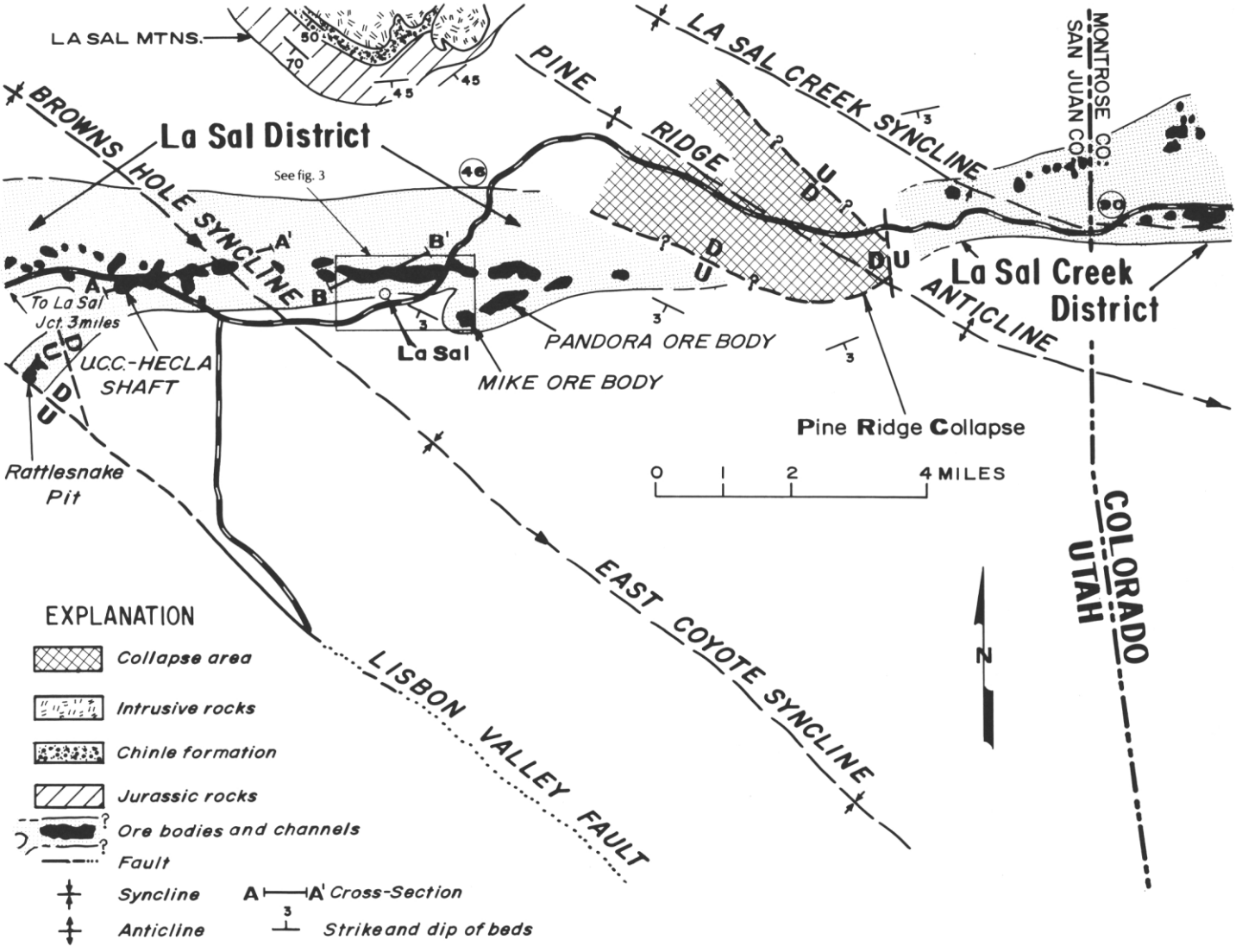

Figure 2. Map showing Salt Wash channels and mineralization of La Sal area; cross-section index.

La Sal Mountains covers a portion of the La Sal area with thicknesses up to 61 m.

The Lisbon Valley anticline, south of the La Sal area, is an elongated, breached salt anticline associated with the production of oil, gas, copper, and Triassic uranium ores. Lisbon Valley appears to have been a slightly salient feature during the time of lower Salt Wash deposition based upon interpretation of Salt Wash stratigraphic sections. Holes drilled by Union Carbide through the complete Salt Wash section on the western end of the major mineralized trend yield stratigraphic sections lacking lower Salt Wash sandstone development. In contrast, holes drilled by Union Carbide on the eastern end intersected a normal Salt Wash sequence. These data would seem to indicate that the Lisbon Valley anticline was slightly salient during lower Salt Wash deposition.

The Pine Ridge anticline in the eastern La Sal area is a large collapse feature with a vertical displacement of some 90 m (Carter and Gualtieri, 1965). The collapse separates an older and well-explored La Sal Creek mineral belt from the larger, more recently discovered deposits lying to the west (fig. 2). Exploration test holes drilled by Union Carbide in the collapse area intersected mineralized Salt Wash sandstones, although core recovery was hampered by highly fractured ground, and stratigraphic relationships of the mineralized sandstones are difficult to ascertain. More importantly, the information dates the collapse as post deposition and mineralization of the Salt Wash.

The Coyote Wash syncline trends northwesterly between the La Sal Mountains and the Lisbon Valley anticline. The La Sal mineral trend crosses the Coyote Wash syncline with the major portion of the trend lying on the north flank of the syncline where dips are approximately four degrees to the southwest. Test holes drilled across the syncline intersected a normal Salt Wash section which implies development of the synclinal flexure after deposition of the Salt Wash.

Salt Wash deposits of the La Sal area and La Sal Creek mineral belt are physically separated and lie west of the larger arcuate belt of collective mineralized Salt Wash channels that Fischer and Hilpert (1952) named the Uravan mineral belt (fig. 1). The La Sal and La Sal Creek deposits occupy a unique position in relation to the other mineral deposits in that they are located in a relatively straight channel west of and perpendicular to the main arcuate Uravan belt. The separate and centralized position of the La Sal Channel resembles the central hub of a wheel with the other mineral belt Salt Wash deposits representing the rims and spokes. Deposits from both mineralized belts are similar in ore habit, ore-

body configuration and sedimentological association, and are obviously part of the same overall depositional and genetic province.

LA SAL CHANNEL

The main La Sal mineralized trend was a late discovery. Carter and Gualtieri (1965) stated: The La Sal Creek mineral belt is a favorable zone 305 to 915 m in width and 8.0 km long, with the western extremity of this belt not clearly defined (p. 40). Exploration of the area between the La Sal Creek mineral belt on the east and the Rattlesnake Pit on the west may discover that mineralized ground is continuous between them (p. 73). The discovery of the Pandora orebody in eastern La Sal in the late 1960s and early 1970s marked the beginning of the definition of the extension and continuation of the mineralized belt.

The La Sal channel appears to afford an opportunity to understand the depositional and mineralizing systems of the Salt Wash by virtue of its uninterrupted linear and lateral extent. In a few cases, mineralization and channel sands are continuous for several kilometers (i.e., Burro, Monogram, Deremo channels), but none of these trends approach the 19.0 km length of the La Sal trend. The study of the relationships of mineralized channels and deposits within the Uravan mineral belt is complicated by the highly dissected topography of the belt.

The magnitude of the La Sal channel was unknown due to limited surface exposure. Channel sandstones in the La Sal townsite area exceed 37 m in thickness and have lateral continuity for over 1.6 km in width. In contrast, sandstones exposed on the eastern and western extremities of the trend are of a multiple, thin nature and average 12-15 m in thickness. The coalescing of channels on the western end and the bifurcation of the main channel on the eastern end illustrates the overall depositional regime common to channels of the Salt Wash, but does not explain the single channel deposition seen at La Sal townsite. The thick accumulation of sandstones along portions of the main trend and at the townsite can be interpreted as representing the coalescing and superimposition of two channels and not necessarily the deposition of a single channel. A thorough geologic reconstruction which would reveal the relative merit of either interpretation is tenuous. Immediately west of La Sal Junction, widespread erosion has stripped away the Salt Wash from all of the Canyonlands country. The next exposures are found on the east side of the Henry Mountains approximately 112 km to the west.

The La Sal channel shares many characteristics with other Salt Wash channels, although several characteristics are apparently more distinctive or are merely better developed and more observable in the La Sal channel: 1) coarser-grain size; 2) relatively straight configuration; and 3) unusual thickness. The main La Sal channel is designated as that channel system east of the Rattlesnake Pit and west of the Pine Ridge collapse. Salt Wash sandstones from Egnar Plains to Polar Mesa are typically characterized by fine to medium grain size, whereas La Sal sandstones are medium to coarse. Grain-size characteristics vary little from mineralized to unmineralized sandstones, or between red and gray-channel sandstones, which implies that grain size had little effect on the diagenetic preparation of the host rocks.

The La Sal channel is a large, gray, diagentically reduced sandstone channel which displays small variations in color, grain size, carbonaceous debris, internal sedimentary structures, or other visually measurable parameters. Mudstones underlying the channel are a favorable greenish-gray color and reflect diagenetic alteration of red mudstones commonly found away from favorable channels.

The main La Sal channel appears to be unusually straight, void of numerous bends and meanders characteristic of braided and meandering fluvial channel sandstones. The apparent channel straightness may be a reflection of the ore body alignment and the undissected nature of the terrain at La Sal.

The La Sal channel can be interpreted to represent the junction of two channels: 1) one trending northeasterly which comprises the mineralized area surrounding the Rattlesnake Pit, and 2) the weakly mineralized channel system trending due east from La Sal Junction. The junction of the two channels results in the thick channel system referred to as the main La Sal channel. One conclusion that could be drawn is that the La Sal channel is a major trunk or distributary stream; therefore it is closer to the sediment source than other channel sandstones and feeds the majority of the channels which comprise the remainder of the Uravan mineral belt. Young's (1978) conclusion after studying the Salt Wash was that three distributary channels are found west of the Uravan mineral belt: Yellow Circle, La Sal, and Coyote Wash. Neither the Yellow Circle nor the Coyote Wash distributaries are found to be of the same magnitude as the La Sal channel and, therefore, the dominant role of the La Sal channel suggests that it is the principal distributary.

ORE DEPOSITS

Exploration of the channel proved somewhat frustrating due to the widespread favorable nature of the sandstones. Numerous holes were drilled exploring the central and northern portions of the channel with success being limited to several small isolated clusters of ore-grade intersections. Significant mineralization is concentrated on the southern downdip channel margin where the gray channel sandstones begin to interfinger with red and pink sandstones and red overbank mudstones. Significant mineralization appears proximal to red bordering sediments as described in recent published work on the Salt Wash (Thamm and others, 1981). Figure 2 illustrates the preferential characteristic of the orebodies and also demonstrates their pronounced linearity.

Salt Wash deposits resemble other epigenetic tabular sandstone uranium deposits found in the United States in that they are found entirely within reduced gray sandstones, and are not associated with tongues of oxidized sandstone as are roll-front type deposits. They are intimately associated with carbonaceous debris and are overlain by tuffaceous sediments. There appears to be no problem of remobilization of ore due to disequilibrium primarily because of the abundance of vanadium in the ores.

The La Sal uranium-vanadium deposits have a consistent black primary mineral suite comprised of uraninite, coffinite, montroseite, and vanadium aluminosilicates. The ore impregnates the matrix of the sandstone and replaces some detrital quartz and feldspar grains, and is homogeneously distributed, except for heterogeneities within the sandstone. Ores found in the central channel region are all primary ores, whereas oxidized ores are common to several mines in the La Sal Creek mineral belt. Primary mineral suites are modified by progressive secondary oxidation above the water table to form an oxidized mineral assemblage dominated by corvusite, carnotite and tyuyamunite (Weeks and others, 1959).

Shape of Deposits

Salt Wash deposits are normally elongated parallel to sedimentary trends and are roughly elliptical in plan view. Mineralization is typically tabular and concordant to bedding, although the ore can abruptly cross bedding to form "rolls" (Fischer, 1942).

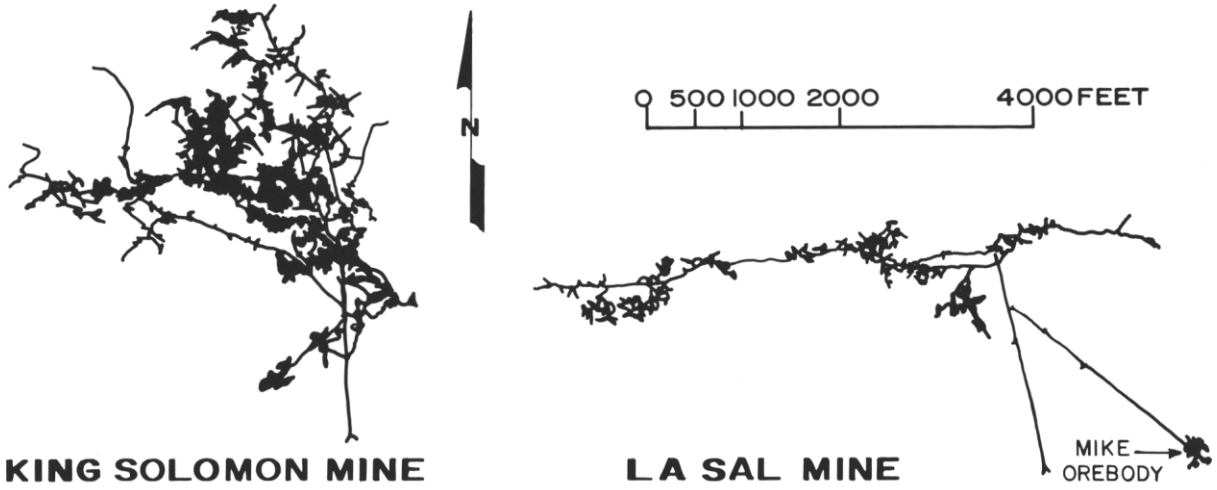

Figure 3. Plan view maps of the King Solomon and La Sal Mines illustrating the pronounced linearity of the La Sal deposits.

Deposits found in the main La Sal channel tend to be similar although perhaps more strongly elongated than typical Salt Wash deposits found in other areas. The La Sal Mine (fig. 3) is much narrower and more noticeably elongated parallel to the channel direction than comparably large deposits such as the Deremo and King Solomon mines. The King Solomon Mine (fig. 3) is more amoeboid in plan view even though the ore is not continuous. Additional mining experience of La Sal deposits will perhaps alter this observation, although it seems compatible with the overall strong linearity of the deposits.

Mined areas of the La Sal Mine reveal certain unusual aspects of the ore when viewed in cross-section. As seen at the La Sal Mine, multiple vertical ore horizons are not a common characteristic of Salt Wash deposits, since the deposits tend to be strongly tabular with ore concentrated in tabular bodies in the lower one-third of the sandstone. The La Sal Mine has ore in tabular bodies which is distributed in multiple horizons through the sand (figs. 4 and 5) with barren sandstone occurring between horizons.

Cross sections drawn through most Salt Wash deposits reveal the strong concordant and tabular control of most mineralization.

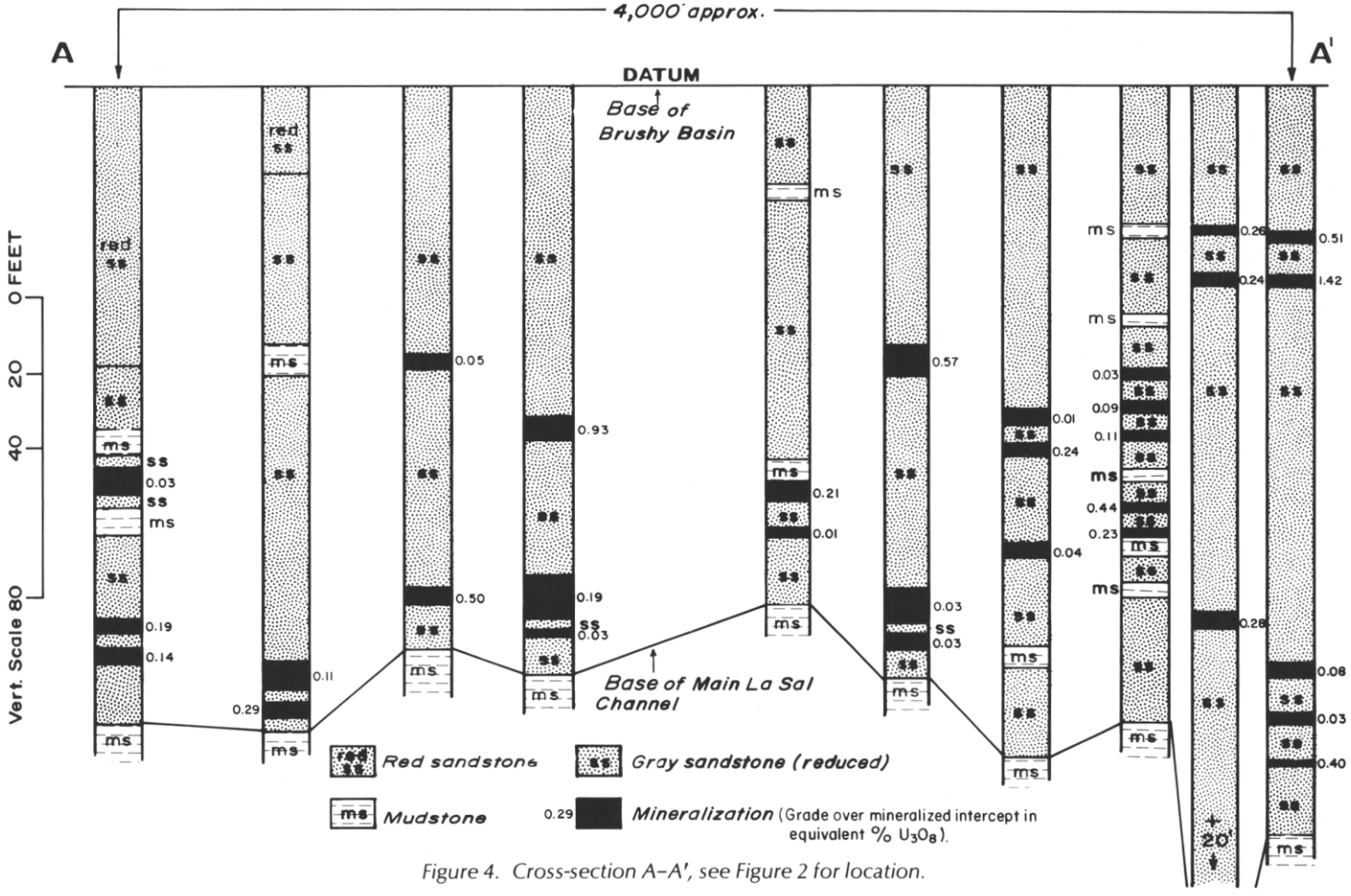

Figure 4. Cross-section A–A', see Figure 2 for location.

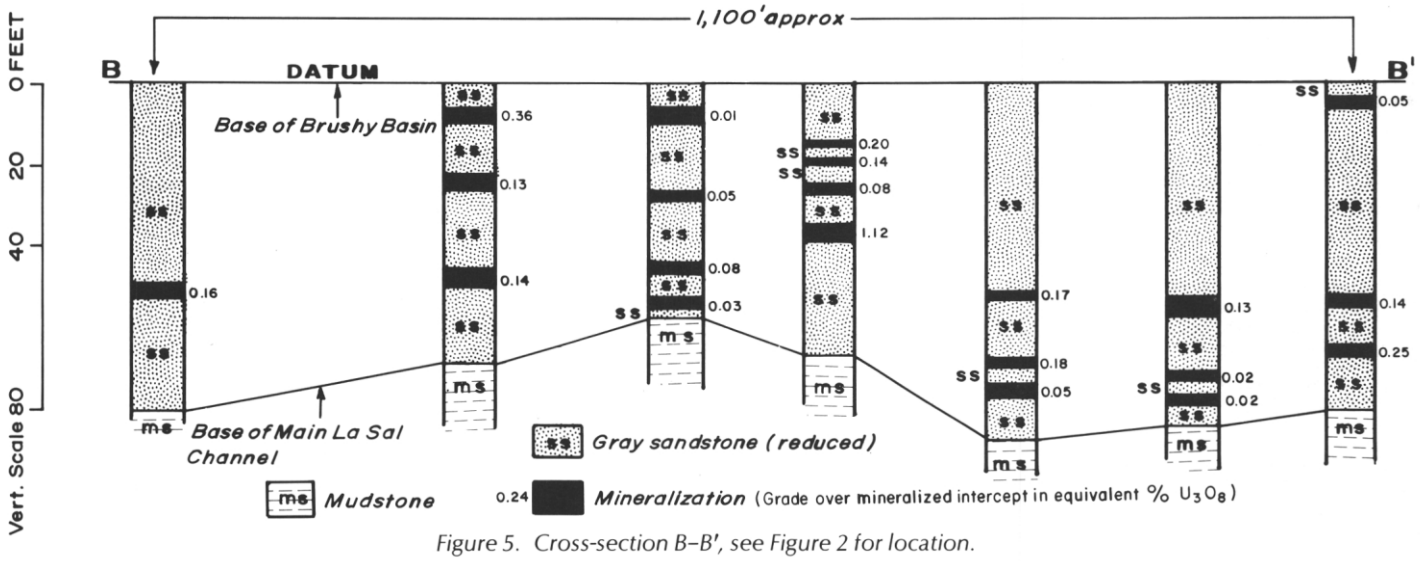

Figure 5. Cross-section B–B', see Figure 2 for location.

"Rolls" are certainly common to tabular orebodies, but the central La Sal ores appear to be atypical in that they are comprised of a high percentage of "roll ore." Shawe (1956, 1959) correlates the occurrence of "roll ore" with numerous well-defined mudstone layers interbedded with thin sandstone layers near the base of thick sandstone channels. While this observation is verifiable in many deposits, the La Sal channel appears in many areas as a thick homogeneous sandstone void of well-defined mudstone layers, but hosting a strong development of "roll ore." The coarser grain size and relative homogeneity of the sandstone may also play a role in determining the development of "roll ore" in addition to the well-defined mudstone layers.

Deposits found in the La Sal Creek mineral belt are more representative of the typical Uravan mineral belt deposit in that they are described as having an average ore thickness of 1 meter and are tabular, but are modified by "rolls." Like the majority of the deposits, they are intimately associated with carbonaceous trash and with depressions and scour surfaces within and along the margin of the channels. In general, the ore deposits are measured in tens of thousands of tons (Carter and Gualtieri, 1965).

One major meander has been interpreted to exist and is believed to host the Mike and Pandora orebodies (fig. 2). The Mike orebody lies to the southwest and is an extension of the much larger Pandora orebody. The Mike orebody is bounded on three sides by reddish-brown barren sandstones which quickly grade into red floodplain mudstones. Closure on three sides gives the Mike orebody a half circle appearance in plan view which probably mimics the curvature of the stream meander. Identification of this meander is due to the fact that it is mineralized and extensively drilled. There is a high probability that other meanders exist and they should be entertained as exploration targets.

CONCLUSIONS

The La Sal mineralized trend must certainly be considered as part of the same depositional and mineralizing systems that are responsible for the uranium-vanadium deposits of the Uravan mineral belt. Certain aspects of the deposits and of the host sandstones are unusual but not of sufficient magnitude to require alternative explanations.

Exploration potential of the La Sal area should be considered excellent. Targets include meander bends, possible bifurcating channels, and the north side of the channel. Additional large channels could be present to the south unless the Lisbon Valley Salt anticline deflected the deposition of channel sandstones away from the area.

Major production of ore from Salt Wash sandstones will gradually move westward with La Sal and Shootaring Canyon being dominant areas. La Sal will play an important role in the uranium future of the Canyonlands country.

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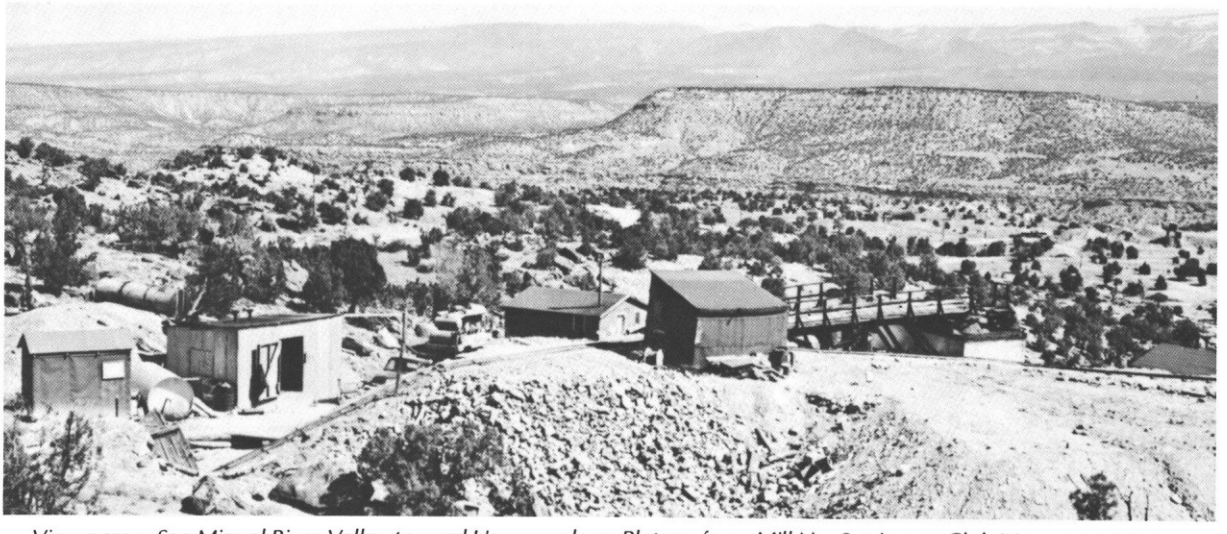
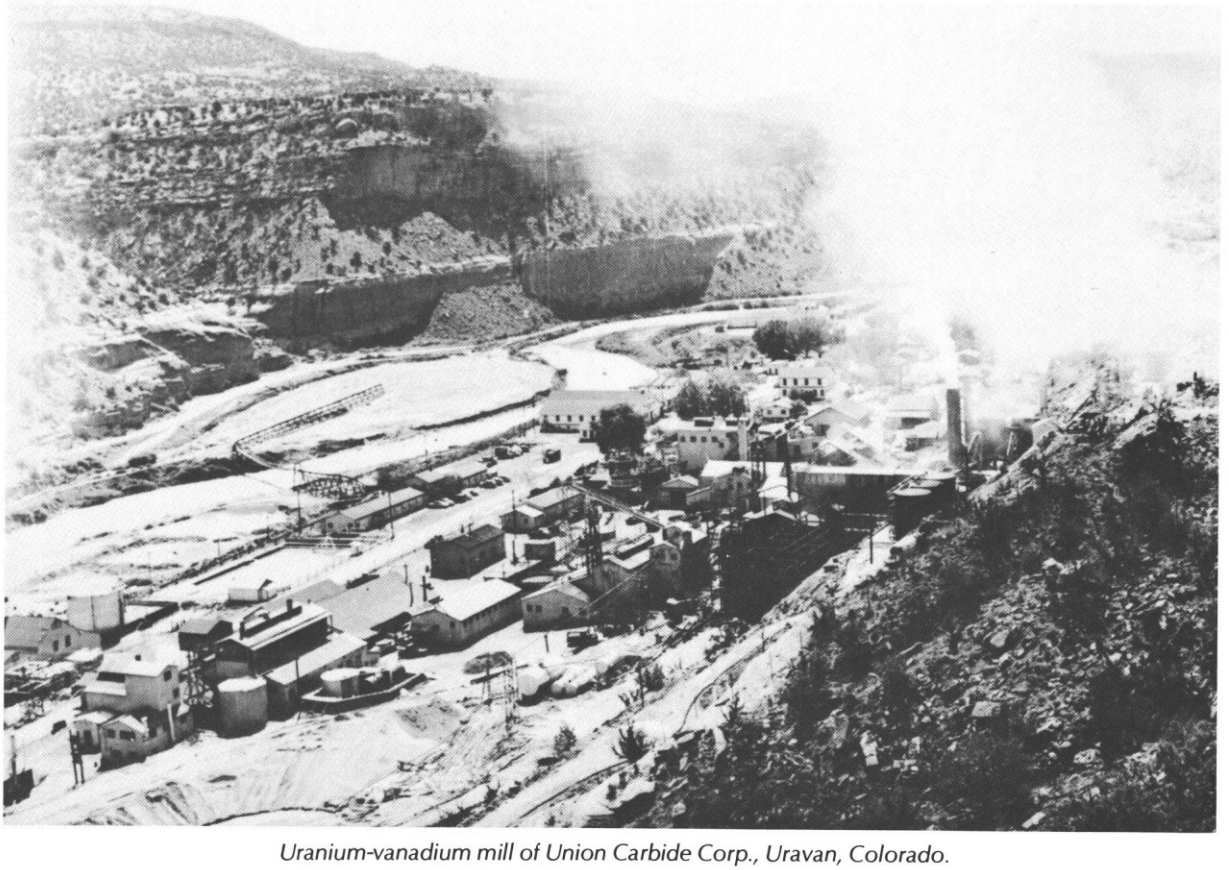


View across San Miguel River Valley toward Uncompahgre Plateau from Mill No. 2 mine on Club Mesa, near Uravan.



Uranium-vanadium mill of Union Carbide Corp., Uravan, Colorado.