Virgin Valley Salt Deposits, Clark County, Nevada

by

L. E. Mannion
Stauffer Chemical Co.

ABSTRACT

The Virgin Valley salt is one of a number of salt occurrences lying within the Virgin-Detrital Valley trough in southeastern Nevada and northern Arizona. Locally the salt makes up more than 1600 feet of the lower Muddy Creek formation of Pliocene (?) age. The Muddy Creek was laid down under lake, playa, and border zone conditions in a number of basins.

Tectonic activity, particularly faulting, accounted for the troughs in which salt was deposited. Faulting and folding has also deformed the Muddy Creek beds in various degrees. Salt has been exposed in local dome-like bulges on the crest of anticlines.

In the vicinity of the salt, the Muddy Creek formation consists predominantly of clays and siltstones. These grade into anhydrite and glauberite beds which cap and underlie the salt. Anhydrite layers and coarse glauberite crystals occur sporadically through the deposits. No beds of calcium or magnesium carbonate were found.

It appears likely the evaporite constituents were derived from marine salt deposits in southern Utah and northern Arizona. Basins closer to the source probably collected the bulk of the detrital and carbonate material and acted as decantation basins for the Virgin-Detrital Valley evaporite accumulations.

INTRODUCTION

The Virgin Valley salt deposit is one of several in southern Nevada and adjacent Arizona (Figure 1). Salt has been drilled also in Detrital and in Red Lake Valleys, Arizona. Although the known occurrences are of similar age, they probably do not represent a continuous deposit but formed in local deeps in separate basins.

GENERAL GEOLOGIC SETTING

Salt occurs in the lower part of the Muddy Creek formation of Pliocene (?) age. (Longwell, 1936, p. 1419, and personnel communication.) The Muddy Creek consists of thick, non-marine, basin filling which underlies thousands of square miles of valley and mesa area in Nevada, Utah, and Arizona (Figure 2). It originated largely as lake, playa, and fluviatile material but includes volcanic rock and landslide debris. During early Muddy Creek time great thicknesses of salt and much sodium and calcium sulfate were deposited in saline lakes. Later periods were characterized by playa environments in which fine to medium grained clastic material was dominant.

The ancient Muddy Creek basins corresponded to a considerable extent to present valleys except that for a long time the intervening highlands were lower and some of the basins more extensive than now. These highlands are composed of a variety of sedimentary, metamorphic, and igneous rocks varying in age from Precambrian to Recent. In many places uplift and wedging of

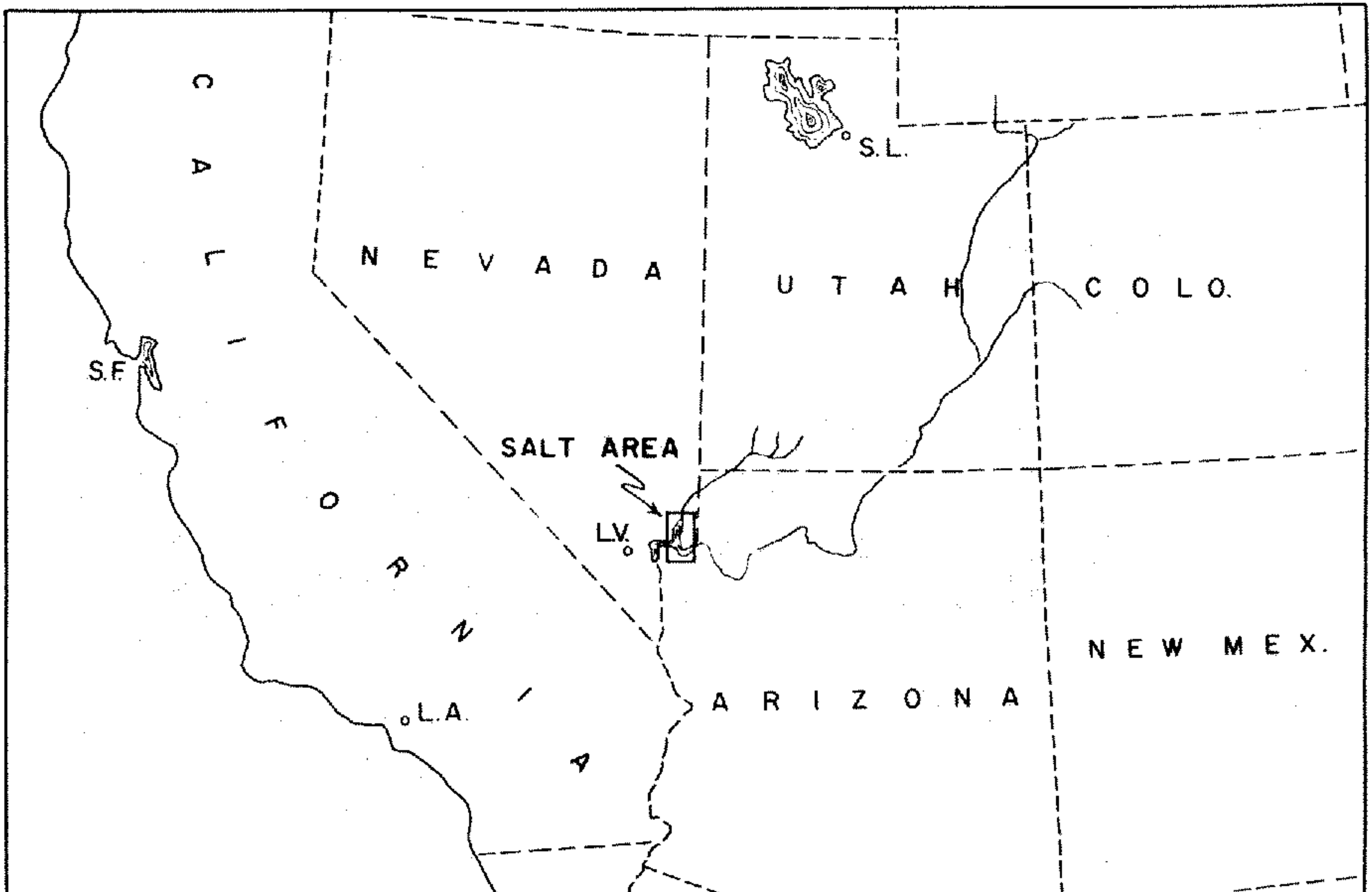

FIGURE I. INDEX MAP FOR VIRGIN VALLEY SALT AREA
CLARK COUNTY, NEVADA

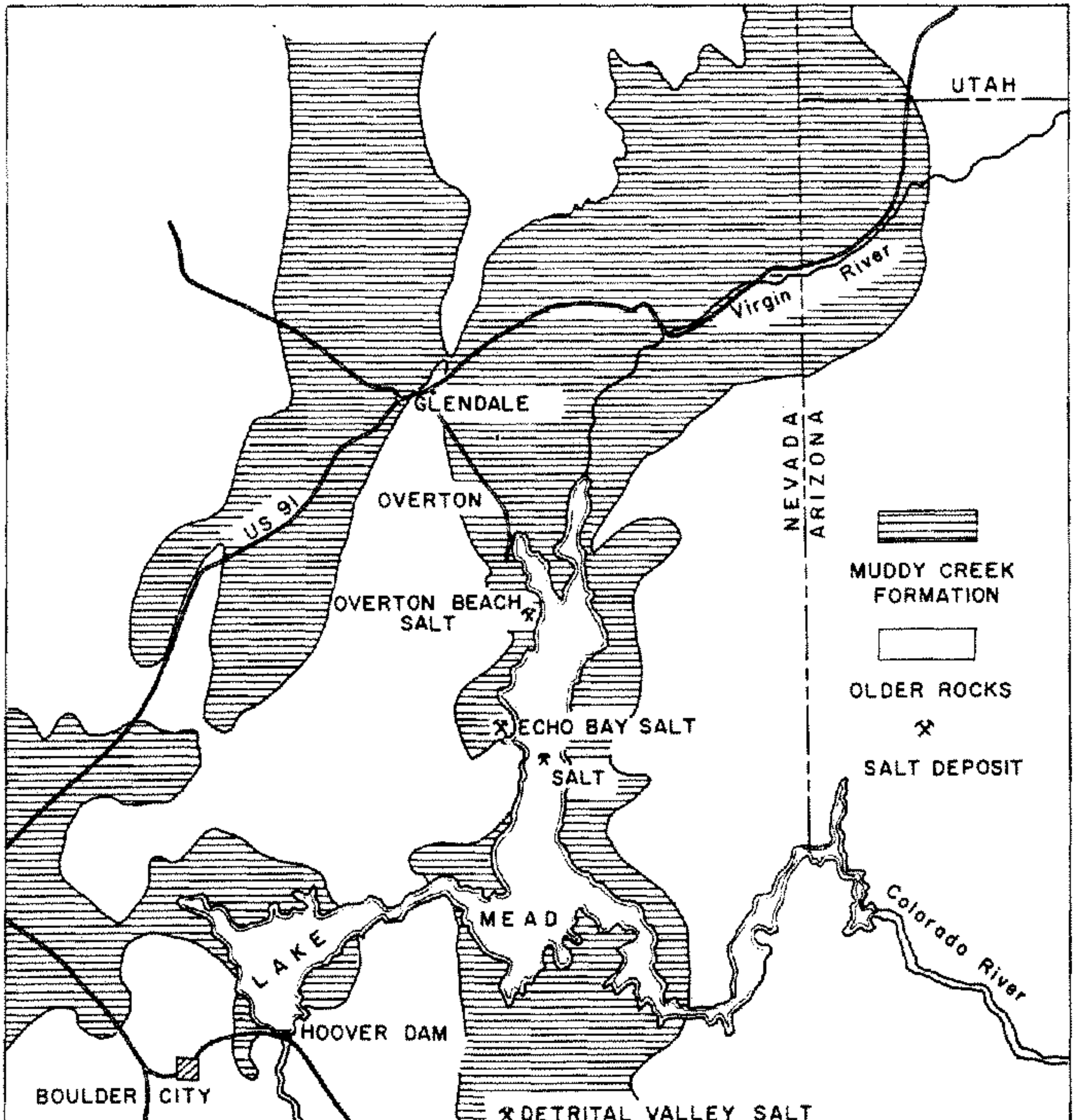

FIGURE 2. PARTIAL DISTRIBUTION OF MUDDY CREEK FORMATION SHOWING SALT OCCURRENCES IN SOUTHEASTERN NEVADA AND ARIZONA

0 6 12 18 24 30

SCALE IN MILES

the marginal rock mass against the basins deformed the Muddy Creek formation both during and after its deposition.

A notable feature of the Muddy Creek formation is the prevalence of fine grained material within a few hundred feet of the contact with older rocks. Coarse detritus, even near the basin edges, appears confined to local areas. In some places the marginward material is obviously of local derivation; in many others it is not. There is also a considerable uniformity in the fine grained material over large areas. These factors and the presence of thick evaporite deposits suggest that much of the basin filling was brought from afar by major streams.

In Virgin Valley the exposed Muddy Creek formation consists predominantly of siltstone, claystone, and sandstone beds, all commonly gypsiferous. Longwell, (1936, p. 1420) has described the stratigraphy before much of the valley was covered by Lake Mead. The strata are for the most part weakly consolidated and nearly horizontal. Badland topography is characteristic of many exposures. Bedding is usually thin, consisting mostly of alternations of silt, sand, and clay in layers 1 to 4 inches thick. Superficially the layering appears uniform but, although some layers can be traced for hundreds of feet in outcrop, most are less extensive and form distinct thin lenses. Locally in the coarser material scour and fill structures and cross bedding are present. In the Virgin Valley a conspicuous basalt layer or group of layers up to 100 feet thick makes a useful marker in the upper part of the formation. Elsewhere, the section of basalt flows reaches almost 500 feet in thickness. Sparse rhyolitic tuffs up to three feet thick are scattered through the section.

The maximum thickness of the Muddy Creek formation in Virgin Valley probably exceeds 5,200 feet. In many places the subsurface slope of the basin sides doubtless resembles that of the present mountain fronts and the increase in depth of fill toward the valleys is rapid. Locally, flat lying Muddy Creek beds rest with depositional contact on older rocks; elsewhere the beds are in fault contact and are tilted more or less steeply.

VIRGIN VALLEY SALT DEPOSITS

The Virgin Valley salt deposits lie 10 to 25 miles south of Overton, Nevada, and are partly overlain by the Overton arm of Lake Mead. Their existence was formerly indicated by natural exposures of rock salt and saliferous soil along the course of the Virgin River. Major groups of outcrop occurred in the Overton Beach and Echo Bay areas. These were described by Longwell (1928, p. 93) prior to Lake Mead filling. Some of these were mined by Indians and early settlers. All but the two outcrops located south of Overton Beach are now covered by Lake Mead. The size and extent of the salt bodies have only recently begun to be realized. Within the trough of the Virgin and Detrital Valleys the distance between the northernmost and southermost known salt is 40 miles, and thicknesses of many hundreds of feet have been drilled. It is not at all certain, however, that these represent a continuous deposit of salt; rather there are probably several bodies which were deposited separately in lakes which were only intermittently connected.

Salt exposures along the former Virgin River were and are associated with severe structural deformation in the Muddy Creek formation (Figure 3). In the Echo Bay area before flooding by Lake Mead there were, within the complex core of an anticline, a number of salt outcrops. Over a considerable area near Echo Bay the remaining unsubmerged rocks are steeply tilted and faulted beds of varied lithology which present a complex picture. On the other hand, the strata in Overton Beach area are rather broadly folded although, in the immediate vicinity of old salt outcrops, the structure is highly disturbed. The salt outcrops south of Overton Beach have been exposed in sharp bulges on top of an anticline. Some of the structures in the vicinity of the salt outcrop resulted from regional tectonic forces, some from flowage and intrusive movement of salt, and most recently, others were caused by solution collapse along the lake margin.

OVERTON BEACH AREA

The Overton Beach area contains the thickest section of salt yet found in the region. The geologic structure is dominated by a rather broad syncline flanked by more abrupt anticlines

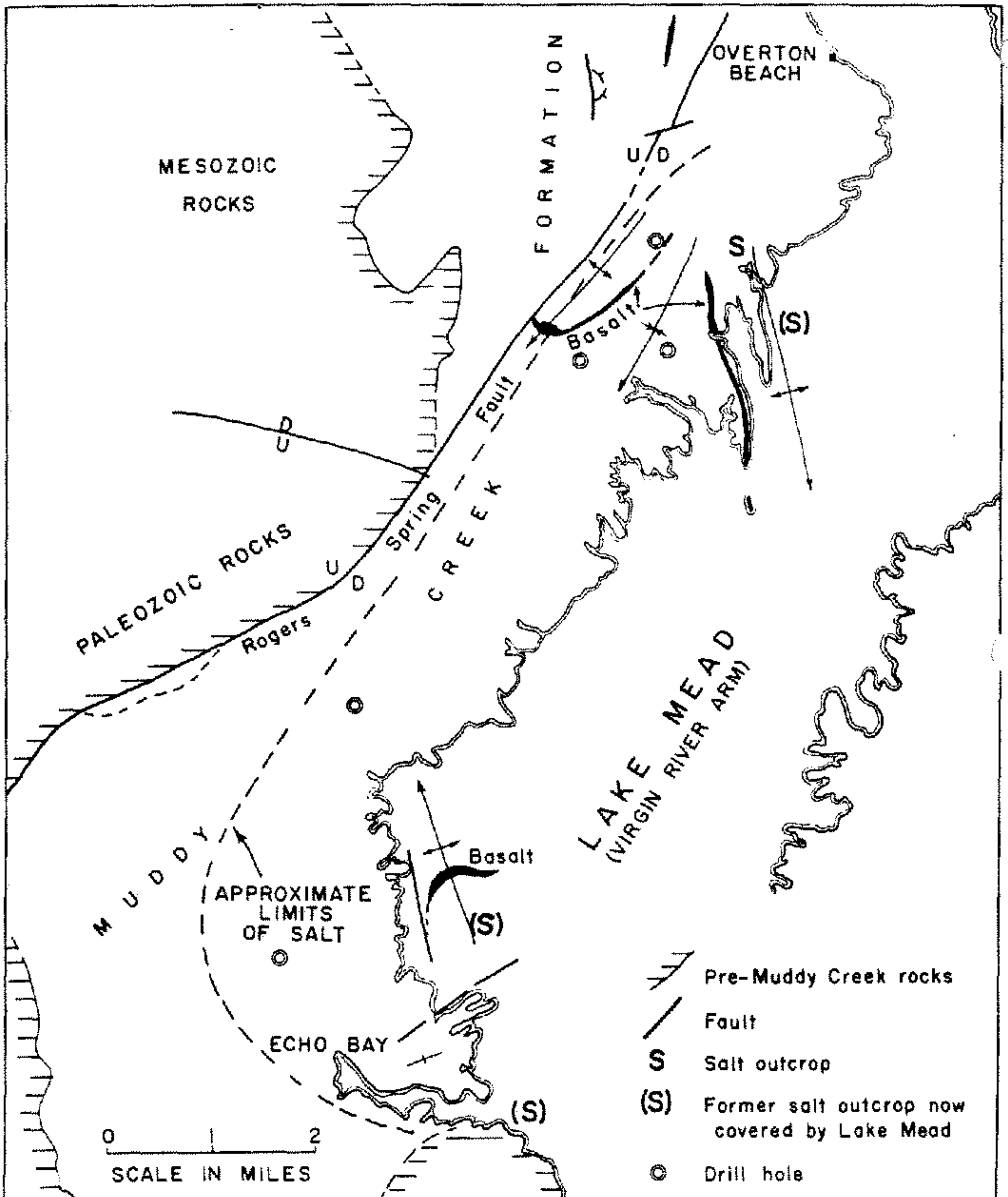

FIGURE 3. MAP OF THE VIRGIN VALLEY SALT AREA CLARK COUNTY, NEVADA

(Figure 4). The syncline opens and plunges gently southward. Outcrops of a basalt flow tend to make an inverted "V" pattern outlining the structure. Only one of three drill holes penetrated entirely through the salt section and then found almost 1200 feet of salt bearing beds. The other two penetrated 1000 and 1700 feet of salt and bottomed in halite.

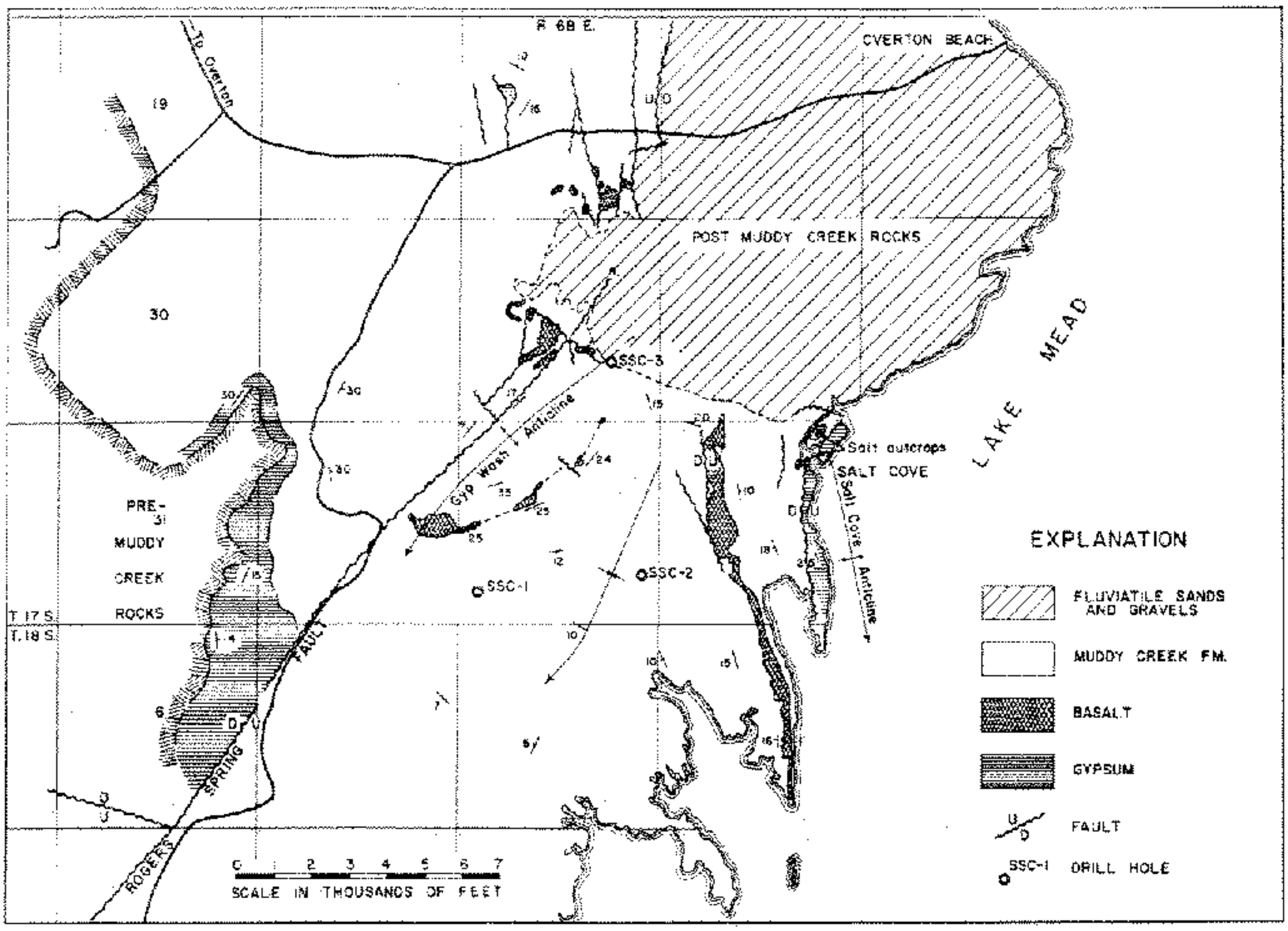

FIGURE 4 SIMPLIFIED GEOLOGIC MAP OF THE OVERTON BEACH AREA
CLARK COUNTY, NEVADA

The seemingly simple anticlines are complicated by faults. The west or Gyp Wash anticline is cut off on the northwest by an extension of a major feature, the Rogers Spring fault (Longwell, 1928, p. 112), and is also affected by other breaks. Most of the east or Salt Cove anticline is concealed by Lake Mead but its west limb is cut by several strike faults. Almost all show as downthrown the side away from the axis of the fold. These are high angle, normal faults which are probably related to upward movement of salt within the anticline.

Upward salt movement in the Salt Cove anticline is also indicated by the domal bulges in which salt was or is exposed. A salt outcrop in the core of one dome is an apparently structureless mass of salt 200 feet across and 50 feet high. The top of the salt is draped or capped with gypsum whose bedding parallels the contact and steepens to 60 to 70 degrees on the flanks. A fault with a stratigraphic displacement of about 1100 feet bounds the dome on the west. The nearly vertical flanks of other bulges in the area are also in part faulted. The faults, the external and internal form of the domes, and the sharp contrast of the silt and clay lithology of the surrounding terrain with the salt and gypsum in the domes indicate semi-intrusive relationships of salt with overlying Muddy Creek strata. Figure 5 is a west to east section through the Overton Beach salt deposit showing the overall structure.

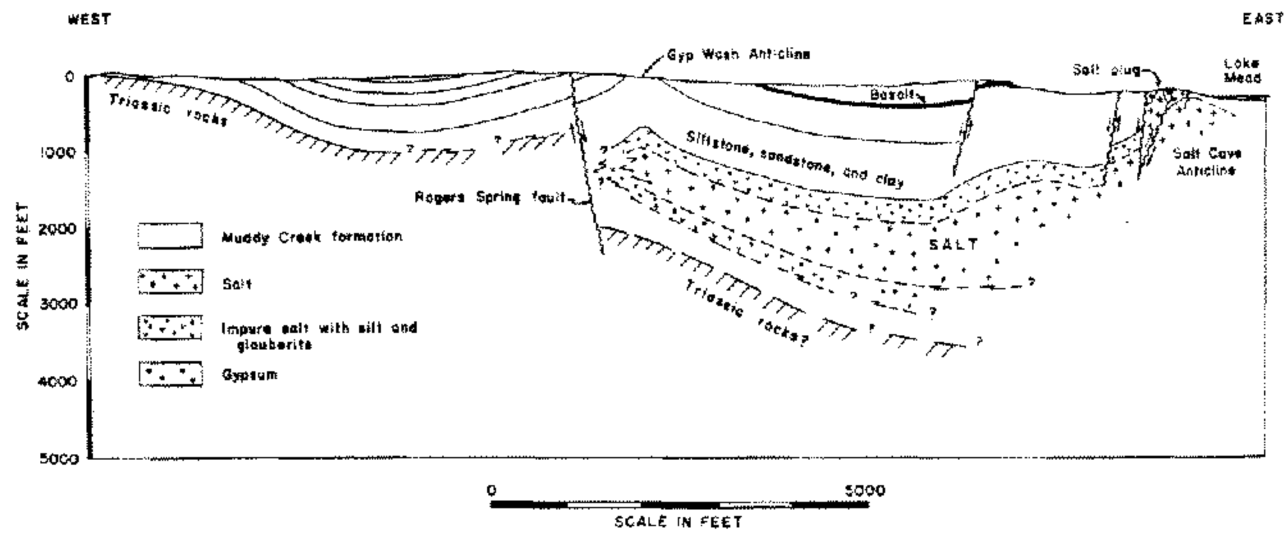

FIGURE 5. SLIGHTLY DIAGRAMMATIC GEOLOGIC SECTION THROUGH THE OVERTON BEACH SALT DEPOSIT SOUTHEASTERN CLARK COUNTY, NEVADA

The subsurface synclinal structure within the upper part of the salt deposit appears from drill cores to be essentially conformable to the surface attitudes. No severe contortions were evident. However, in one drill hole at depths below about 2900 feet, the salt was found to be strained, shattered, and crushed. Some salt shows faults, slickensides, and sheared textures. Curved fibrous masses of deformed salt are not uncommon as well as salt cut by myriad nearly horizontal shear surfaces. Evidently movement has taken place in the deeper masses of salt, but core recovery was too poor to permit even an estimate of the pervasiveness of the disturbance. The presence of unhealed fractures suggest that stresses have acted too rapidly and too recently for the salt to recrystallize in the dry conditions prevailing within the salt body.

Despite the evidence of structural disturbance both on the surface and at depth, the more than 1700 feet found in SSC-2 hole is probably not an excessive real measure of salt thickness. Support for this includes: (1) dips of 10 to 20 degrees or so measured in cores of both salt and shale are not out of keeping with surface attitudes, (2) at least the upper part of the salt body appears concordant structurally with a lava flow some 1300 feet above, and (3) the hole was drilled near the middle of a broad, regular syncline in which thinning rather than thickening might be expected.

Stratigraphy

The Overton Beach evaporite body is overlain by rather typical Muddy Creek materials. From the surface downward, the Muddy Creek section in the area consists first of more than 2000 feet of rather monotonous, greenish brown to brown, or tan, clay and silt beds with lesser sandstone and local gypsum. A sheet of basalt is intercalated in these strata about 1200-1300 feet above the top of the evaporite section. The onset of evaporites is gradual. Above the topmost halite there are perhaps 100 to 200 feet of silty beds containing much glauberite ($Na_2SO_4 \cdot CaSO_5$) which increases in quantity downward, and a few anhydrite beds. For several hundred feet below the uppermost halite the salt is highly impure containing abundant fine sand, silt, clay, and glauberite. In an irregular fashion it becomes increasingly pure with greater depth. Anhydrite is essentially absent within the salt body itself. A few beds up to 10 feet thick occur above and below the salt sections.

In the Overton Beach area a drill hole that penetrated entirely through the salt found a lower impure section, about 400 feet thick, which resembles that found in the upper 100 to 200 feet of the evaporite mass. Near Echo Bay, on the other hand, a rather impure, thin salt section rests directly on anhydrite, sandstone, and volcanic rocks which may not belong to the Muddy Creek formation. The red bed-limestone-salt association so characteristic of marine evaporites is absent from the Muddy Creek. Even anhydrite comprises but a very minor portion of the total sequence.

The shape and extent of the Overton Beach salt mass is not known. Drill holes seem to suggest a thick lens thickening eastward. But of the three put down in the Overton Beach area only one, SSC-3, penetrated entirely through the salt. SSC-1 found halite from 2070 to 3058, and SSC-2 halite from 1880 to 3634 feet. Both holes bottomed in salt. SSC-3 drilled halite beds from 863 to 2030 feet, but much of this is very impure. Doubtless the salt wedges out to the northwest against the Rogers Spring fault. It may thicken to the east and southeast. Although the impure section in SSC-3 suggests that the salt thins to the northeast, this is not certain because the drill hole is rather close to the Rogers Spring fault. Movement on this fault probably started before or during early Muddy Creek time and has persisted almost to the present. If the fault is projected northeast across Lake Mead, it appears to coincide with the southeast flank of a long finger or Precambrian rock projecting from the Virgin Mountains southwestward toward Overton Beach. Uplift along the north side of the fault may have resulted in a ridge across the ancient Muddy Creek basin and formed a northern boundary to salt deposition.

Composition

Within the salt body the halite is coarsely crystalline, generally brownish or gray, and contains only sparse indications of bedding. Salt crystals mostly range from one quarter to one half inch in diameter. Layers of glauberite, clay, and tuff are the principal evidence of stratification. Some layers show distortion and a few are completely disrupted, evidently through recrystallization of the salt. The overall quality below the upper 400 feet of salt is about 93 percent sodium chloride. Impurities consist mostly of grains, blebs, and interstitial masses of light brown, fine sand, silt, and glauberite between and within salt crystals. Locally, masses of exceptionally pure, recrystallized salt occur in which cleavage surfaces more than three inches across have been seen. The shape and orientation of these recrystallized masses are not known but they can hardly be bedded.

Glauberite is an abundant and ubiquitous constituent of the evaporite body probably averaging more than three percent of the total deposit. It occurs as saccharoidal to coarsely crystalline beds, and as euhedral crystals of plowshare habit up to two inches long dispersed or interlocked in salt and siltstone. The euhedral crystals are randomly oriented although near vertical attitudes are perhaps most common. Fine intermixtures of silt and glauberite present a speckled brown and white appearance. The mineral exhibits some interesting physical and optical characteristics including the property of dissolving incongruently leaving a calcium sulfate residue which recrystallizes in the laboratory to the fibrous variety of gypsum. This gives rise to the possibility that some of the gypsum found in the Muddy Creek formation was derived from weathering and solution of glauberite beds. Near the salt outcrops selenitic gypsum, apparently pseudomorphous after glauberite, is abundant both as beds and dispersed crystals in shale. A large outcrop of glauberite was reported by Longwell (1928, p. 94) prior to the filling of Lake Mead. Glauberite has a markedly lower solubility in fully saturated sodium chloride brine than in that which is only a few percent below saturation. It seems likely, therefore, that glauberite would tend to crystallize along with halite which, indeed, is the association in the deposit.

The presence of considerable sodium sulfate in the parent brine doubtless accounted for the almost complete absence of anhydrite or gypsum in the salt deposit.

The magnesium, potassium, and sulfide contents of the Overton Beach salt are very low.

ORIGIN OF THE SALT

Muddy Creek salt probably underlies hundreds of square miles with thicknesses of many hundreds of feet. Such enormous quantities of salt are unlikely to be derived from the erosion of nonsaline terrain. The rocks lying to the south, west and north of Virgin Valley are predominantly types which carry little chloride, that is, crystalline and volcanic rocks, limestone and dolomite, with but relatively minor amounts of sandstone and shale. However, to the east, especially in the Colorado plateau region of southern Utah and northern Arizona, evaporite bearing sedimentary rocks and sodium chloride deposits are known. The Permian and Triassic rocks of the Colorado plateau are reported to contain disseminated sodium chloride (Krumbein, 1951, p. 70). The Jurassic Arapien shale in Sevier Valley, Utah, contains large salt deposits (Hardy, 1952). It is conceivable that, from as far east as the Paradox basin, waters leaching anticlines containing Pennsylvanian salt may have contributed to Muddy Creek evaporite deposition.

Uplift of the Colorado plateau region and westward drainage probably began in Miocene time (Hunt, 1956, p. 77) and at the same time block faulting in the Basin and Range province provided imponded basins for the accumulation of the derived sediment. Uplift of the plateau would have been accompanied by rapid initial leaching of the chloride followed by greater and greater proportions of calcium sulfate with the later stages essentially free of sodium chloride. This would be reflected in the presence of gypsum and lack of halite in the upper Muddy Creek formation. The desert environment of the Basin and Range region during late Miocene-Pliocene time would have provided conditions for concentration and precipitation of salts.

Possibly applicable here is the concept of separation of clastic materials from soluble constituents by deposition in distinct yet connected decantation basins. Gravity measurements by the U.S. Geological Survey (Kane, M.F. and Carlson, J.E., 1951) indicate the presence of deep basins in the area of Mesquite, Nevada, and southwestward along the approximate course of the lower Virgin River. An ancestral Virgin River may well have deposited its detrital load carried down from the Colorado plateau in the first of the deeps around Mesquite while the soluble content was carried into the basins beyond. The absence of limestone in the lower Virgin Valley may reflect the low concentration of calcium carbonate in drainage waters or removal by precipitation in the Mesquite area. The considerable amount of sodium sulfate contained in the glauberite was probably more a contribution of local desert drainage than of the salt-bearing Colorado plateau rocks.

Assuming decantation basins to catch most of the clastic material coming from afar, the dominance of silt and fine sand rather than clay in the insoluble portion of the Virgin Valley salt deposits suggests either strong periodic flooding or local sources for much of the insoluble impurity. Since the saline lake was probably quite shallow, either or both of these sources are equally possible.

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