THE LOCALIZATION OF SODIUM SULFATE DEPOSITS IN NORTHEASTERN MONTANA AND NORTHWESTERN NORTH DAKOTA

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ABSTRACT. The sodium sulfate deposits of northeastern Montana and northwestern North Dakota are confined to depressions within the glacial drift. The alignment of the deposits, many of which are linear, suggests some form of glacial control. It is believed that the localization of these deposits is related to buried channels that have been formed marginal to the ice.

Two types of channels are recognized. One type was formed during the withdrawal of the last ice. It is filled with sand and gravel and, as far as known, contains no exploitable sodium sulfate deposits. The other type of channel was formed during a temporary stillstand of the ice and was later buried beneath till of a renewed advance. In places, the till was thick enough to fill completely the former channels. Elsewhere, the till merely surfaced the channels. These elongate, till-surfaced swales, which contain channel sediments, trend irregularly across the area, and contain commercial deposits of sodium sulfate in depressions within them. The alignment of the deposits results from their position within the till-surfaced channels.

It is thought that the buried channel sediments contain the sulfate-rich waters under artesian head, and that these waters locally escape upwards into the depressions of the till-surfaced swales where evaporation causes concentration.

INTRODUCTION

DURING the summers of 1946 to 1948 the U. S. Geological Survey mapped a large area including parts of Sheridan and Roosevelt Counties in northeastern Montana and parts of Divide and Williams Counties in northwestern North Dakota. This work was part of the Geological Survey investigations in the Missouri River Basin.

In the course of the work I became interested in the numerous sodium sulfate (Glauber's salt) deposits in the eastern half of the area (plate 1). Many of these deposits are so aligned as to suggest more than mere coincidence in their location. The field work indicated an intimate relationship between the locations of the saline deposits and the glacial history. This paper presents an hypothesis to explain the location and pattern shown by many of these deposits.

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667
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REDROCK STRATIGRAPHY AND STRUCTURE

The Fort Union formation of Paleocene age underlies the surficial deposits. In general, the Fort Union strata consist of silt, clay, shale, sandstone, and some lenticular lignite beds. Laterally, the strata change facies rapidly and marker horizons are practically nonexistent.

This area is along the northwest margin of the structural Williston Basin, and the regional dip is southeastward at about 20 feet to the mile. Little evidence is available to suggest local deformation. Townsend (1950, p. 1552), however, has reported some local deformation of the Fort Union formation in an area northeast of this locality.

SURFICIAL DEPOSITS

The area is mantled by thick and extensive deposits of glacial debris. As yet, it is not known how many times continental glaciers advanced across the area; field evidence in adjacent areas (Howard, 1950) suggests at least three, and possibly four separate advances. The age of these advances is uncertain, although the last three are probably Wisconsin.

The topography has been modified by glacial erosion of the high places and deposition in the low places. The area is a broad, till-covered upland, traversed by wide outwash-filled valleys.

The till is a compact clayey mass, light buff on outcrop. It ranges in thickness from a thin film to much more than 100 feet, and is completely unsorted. Rock debris from the Canadian Shield, ranging in size from fine sand to boulders as much as 10 feet in diameter, is embedded in the till and mantles its
surface. Included with the debris, however, are large amounts of brown, well-rounded pebbles of quartz, quartzite, and chert, characteristic of the Flaxville Plain (Collier and Thom, 1918, p. 179).

Similar debris, although better sorted and completely unconsolidated, floors many of the outwash channels. Pebbles of limestone, granite, gneiss, and schist predominate.

Till and bedrock alternate irregularly along valley walls suggesting that, in places, the present valleys lie astride the sinuous courses of former channels now filled with till.

**MODE OF OCCURRENCE OF SODIUM SULFATE DEPOSITS**

The geological setting of the sodium sulfate deposits in eastern Montana and northwestern North Dakota is essentially the same as in Saskatchewan (Grossman, 1949, p. 8).

All the deposits, whether small or large, are in undrained depressions. Surface drainage is inward, although the numerous springs in and around the flanks of the deposits probably supply most of the lake water. Many of the springs feeding the saline sloughs are highly charged with sodium sulfate. Cole (1926, p. 76) passed a metal tube down the orifice of one of the Saskatchewan springs. The water that rose in the pipe was only slightly charged with sodium sulfate. This suggests that some of the springs may acquire their high sodium sulfate content as they pass upward through a buried sodium sulfate bed. Cole (1926, p. 83) reports a second type of spring that differs in having a much greater concentration of salines. These are called “true brine springs,” and their source waters apparently are highly charged with salines before reaching the buried sodium sulfate deposits.

The salines are concentrated chiefly by evaporation in these basins. When the rate of evaporation surpasses that of inflow, the lakes become saturated with sodium sulfate and crystals are deposited. A rise in temperature or addition of water will cause the crystals to redissolve. Hence, such precipitation may give rise to what is known as “the intermittent bed.” With long-continued uninterrupted precipitation a more massive deposit accumulates, not so susceptible to local variations in temperature or rainfall. Such a bed is called “the permanent bed.” A major deposit of sodium sulfate may have permanent beds as thick as 70 feet (Lavine and Feinstein, undated, p. 5).
The origin of the sodium and sulfate components is unknown. They may be derived from the underlying Fort Union formation, from the till, or from both.

ALIGNMENTS OF SALINE DEPOSITS

The deposits within the United States align with those in Saskatchewan in a northwestward-trending zone, about 30 miles wide, more or less parallel to the so-called Altamont moraine. Whether this till-covered prominence influences the saline deposits in any way is not known.

Individual deposits are of various shapes. In Canada, many of them are elongate and sinuous (fig. 1). Within the United States
States, however, only a few show such elongation. Numerous deposits are within broad valleys that can be traced for many miles. Lake of the Rivers and Willowbunch Lake in Saskatchewan are in such a broad valley (fig. 1). Both are saline (Cole 1926, map). The valley including these lakes can be traced southeastward to include Big Muddy Lake and the Coteau Lakes. Cole (1926, p. 122) states that the Coteau Lakes (i.e., Sybouts Lakes) are saline.

Similar sinuous patterns of deposits within valleys can be found in Montana and North Dakota. Here, however, they are not as clearly delineated as in Saskatchewan.

Hypotheses for Localization of Sodium Sulfate Deposits

This alignment of the saline deposits has been noted by both American and Canadian geologists. Alpha (undated, p. 7) has suggested that the northeastward alignment and localization of the deposits in this area (fig. 2) is along the preglacial courses of the Missouri and Yellowstone Rivers. In late Tertiary or early Pleistocene time these two streams may have flowed northeastward to Hudson's Bay (Alden, 1932, p. 58). Although this might explain the northeastward alignment of several American deposits, it cannot explain the Canadian deposits which lie far beyond the lateral limits of the Missouri River drainage.

Canadian authorities (Anonymous, 1947, p. 57) suggest that the alignment of the Saskatchewan deposits is along valleys cut during the withdrawal of the last ice, but later becoming stagnant reservoirs into which runoff waters charged with salines emptied. Concentration and deposition of the salts resulted from evaporation.

Although the saline deposits are associated with glacial channels, as suggested, I do not believe the Montana and North Dakota deposits are associated with the recessional-type channel described.

Tomkins (1948, p. 72) suggests that these deposits form where aquifers closely approach the surface and that the waters containing the salts accumulate in undrained basins, usually in sandy or gravelly areas. Cole (1926, pp. 121, 122), referring to the Coteau Lakes (fig. 1), indicates that the confining walls are of till. In eastern Montana and western North Dakota till not only walls the basins, but also underlies them.
A recessional channel would be floored with sand and gravel. Dagmar Channel (fig. 2) within this area is such an example, and contains no saline deposits. Actually, fresh-water lakes are present in such channels.

HYPOTHESIS OF PRESENT PAPER

Two types of channels are present in this area. One is floored with sand and gravel, and represents cutting during the withdrawal of the last ice. The surface of this type channel is till-free (fig. 3, stage C). The other type may have been formed at any time preceding or during the last advance of the ice, and was buried by that advance. It is till-surfaced. The till-surfaced swale in the south half of T. 34 N., R. 58 E. (fig. 2) is an example of this type of channel.

These buried channels in many places form discontinuous
Plate 1. Typical sodium sulfate slough in northeastern Montana. White encrustation along the rim of the lake is part of the intermittent bed. Center of slough is occupied by saline-rich brine.
shallow, sinuous swales in the till-covered landscape. Apparently in some places the till forms a mere veneer, whereas in others it is thick enough to obliterate the former valleys completely. Undrained depressions are commonly within the floor of the swale.

Stage A.—A marginal channel is cut by outwash waters during a stillstand in the advance of a continental ice sheet.

Stage B.—A renewed advance of the ice buries the first marginal channel, and a subsequent stillstand results in a second marginal channel being formed beyond the first.

Stage C.—With subsequent melting of the ice, till-covered surface is exposed. The first marginal channel, which was over-ridden by the ice, now has its former course reflected by elongate undrained depressions whose bottoms are often occupied by shallow saline lakes. The second marginal channel, which was not buried by the ice, is till-free, and shows as a broad sand and gravel tract occupied by a small intermittent stream.

FIGURE 3—THREE STAGES IN THE DEVELOPMENT OF TILL-SURFACED VALLEYS
Locally, a further complexity has masked the geological setting. During the withdrawal of the last ice, streams flowing southwestward away from the ice mantled many of the existing glacial features with sand and gravel. Thus, some of the till-surfaced channels were themselves thinly layered with sand and gravel, so that in places the till-free and till-surfaced channels superficially resemble one another. Stady and Grenora Channels (fig. 2) were formed by such distributary streams. Dagmar Channel was not. The sand and gravel veneer comprising the Stady and Grenora Channels mask a till-surfaced channel that is probably outlined by the string of sloughs consisting of Brush Lake Saline Slough, Horseshoe Lake, Twin Lakes, Stink Lake, and Grenora Lakes Nos. 1 and 2 (fig. 2).

It is suggested that the sodium sulfate deposits are here localized along the till-surfaced channels which were formed marginal to an ice front and later buried by a renewed ice advance (fig. 3).

The sodium sulfate lakes probably formed in undrained depressions within these till-surfaced channels. Their alignment, thus, is a reflection of the buried valleys. The ground water within these buried sand-and-gravel courses was under hydrostatic pressure. Wherever the till thinned, a spring probably reached the surface. Once the artesian waters broke through to the surface they were prevented from leaking out by the impervious till of the basin floor and sides. The waters that collected in these undrained basins were probably only slightly saline at first. With continued evaporation the salines were concentrated until saturation was reached, and an intermittent bed of crystals was deposited from the brine. Continued formation of these intermittent beds gave rise finally to the more massive permanent bed. Those springs within the center of the deposit were able to keep their passages free, as the permanent bed increased in thickness.

In a few places fresh-water lakes are close to saline sloughs. Examples are fresh-water Brush Lake and the saline slough due south of it known as the Brush Lake Saline Slough (T. 33 N., R. 58 E.) (fig. 2). I believe that these two different types of lakes result from the juxtaposition of a till-surfaced channel and a till-free channel. Within the till-free channel subsurface drainage permits flushing out of the salines, whereas in the till-surfaced channel the impermeable till prevents this. Grossman
(1949, p. 60), however, explains this phenomenon by a process of "basin integration." He notes that the saline sloughs, in several localities, are topographically lower than the adjacent fresh-water lakes. Thus, during periods of excessive rainfall the water rises in both lakes until the higher lake decants its salines into the lower. Hence, one lake will be fresh and the other saline. Insufficient data are available to test this hypothesis. It does not, however, affect the major premise presented in this paper.

CONCLUSION

Two types of glacial outwash channels are present in this part of the northern Great Plains. One type was formed during the withdrawal of the last ice and is filled with sand and gravel. Sodium sulfate deposits are not believed to form within this type of channel. The other type of channel has been buried by ice advances and now appears as a till-surfaced sinuous swale of relatively short length. Local depressions are within these swales. In certain of these depressions, the till was thin enough to permit the subsurface water flowing within the buried sand-and-gravel courses to break through to the surface. The weakly charged saline solutions, unable to escape through the impermeable till, were concentrated by evaporation until sodium sulfate crystals were deposited. In time, thick deposits accumulated. Hence, the major deposits of sodium sulfate are within depressions in the floor of this type of channel. The location and alignment of these deposits is controlled by the former course of the buried channel.

REFERENCES


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