THE FORMATION AND GEOLOGY OF THE SALT DEPOSITS.

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When this planet emerged from its long aqueous night, and the new-born internal forces began the work of creating the continents, the conditions essential to the formation of saline deposits prevailed. Salt was the predominating mineral held in solution by the water, and may even have been an element of the primary rocks. During the mighty uplifts, numerous depressions filled with salty water were, naturally, elevated above the ocean level. Some of the lakes thus formed had the magnitude of seas. The most of them probably had no inlet or outlet. Others may have had both for a considerable portion of their existence, but a gradual diminution of the water supply would finally force the lake below the level of the outlet. Evaporation then produced a gradually strengthening brine, which eventually became so heavy that the salt crystals began settling to the bottom of the lake.*

All deposits formed in this manner are necessarily of great antiquity. Another class of deposits, comparatively recent, was formed from what were originally fresh-water lakes, and many of these lakes probably occupied valleys once dry. In such cases, the salt came from tributary streams, whose washings for hundreds of thousands of years, coupled with evaporation, finally produced conditions identical with those which obtained in the more ancient lakes.

There is yet a third and smaller class of deposits which have no particular age classification. Occasionally a land-locked bay was detached from the ocean by the formation of a sandbar across its mouth. It then became a great natural evaporating pan. The supply of salt water was derived from the influx of the tide over or through the sandbar. Since only water sufficient to replace that lost by evaporation could enter, the precipitation continued without interruption until some disturbance of nature either submerged the bay or elevated it above the ocean level.

Very little saline precipitation results from a body of water until it has become greatly reduced in size. If the water were originally of the same strength as that of the Atlantic Ocean, only approximately one-seventh of the first bulk would remain, provided there were no tributaries. To better illustrate this statement, suppose a lake 1000 feet deep, with perpendicular sides and a level bottom. Not until evaporation had reduced the depth to about 143 feet would the real work of making a deposit begin. Of this remaining 143 feet, 35 feet would be solid matter, chiefly salt. Since the ancient lakes were probably on the same lines as those of the present day, they must originally have covered from two to six times the area of their salt beds, the deposit representing only the deepest portion.

If we allow that, as a rule, these lakes covered three times the area of their deposits and that their average depth was one-third of their greatest depth, we have the equivalent of the preceding paragraph. Based on this proposition, a deposit 50 feet thick would presuppose a lake having a maximum depth of 1430 feet, by using the Atlantic's percentage of solid matter (0.035), although the ancient oceans were undoubtedly less saline. The greater part of the thicker deposits was probably contributed by streams (which were comparatively fresh) or by tides, as some of them would have required a depth of water much greater than now exists in the open ocean.

There is nothing improbable, consequently, in the supposition that some deposits 200 feet thick or more came from lakes which never had a depth exceeding 2000 feet. In such a case, the original contents of the lake would account for 70 feet of the deposit, leaving 130 feet to be derived from other and generally less prolific sources. Tributary streams are a factor wanting in the case of land-locked bays, while a deposit of any given thickness which came from a lake originally fresh would require a much greater volume of water. These figures are, of course, conjectured, but they indicate the proportion the salt deposits must bear to the bodies of water from which they were derived.

Any estimate of the length of time consumed by nature in making a deposit would be pretty much at random. The size of the lake basin, the seasons, and the number and size of streams are important factors of which we have no knowledge. From the number of alternating strata of shale and salt found in some deposits, however, we know that there were numerous seasons of excessive rains, when the streams furnished sufficient water to raise the lake level many feet—perhaps to the overflow point. At such times the water became fresher and saline precipitation was indefinitely suspended. These seasons were not such in the modern meaning of the word, for they probably comprised scores or even thousands of years. The layers of mud, which later became hardened into shale, were thickest and most numerous near the mouths of the streams, but they occasionally covered the entire bed of the lake. Judge of the volume of water discharged and the amount of sediment it must have carried in order to cover areas of more than a thousand square miles with a layer nowhere less than several feet thick!

Although the chief substance found in ocean water is chloride of sodium, it contains very small amounts of other minerals. Its average density is about 1.025.

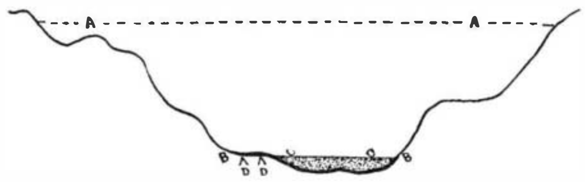

Fig. 1.—Contour of a supposed lake showing the proportion of salt which would come from its original contents. *A*, *A*, original level of the lake; *B*, *B*, thin layer of gypsum; *C*, *C*, deposit of salt; *D*, *D*, point from which the water receded after the gypsum was deposited but before the saline precipitation occurred.

Of the 0.035 per cent of solid matter in the Atlantic ocean, less than 0.030 per cent is salt. The various minerals and their percentages of the total matter are as follows: Chloride of sodium, 77.07; chloride of potassium, 3.84; chloride of magnesium, 7.86; sodium and magnesium bromide, 1.30; calcium sulphate (sulphate of lime or gypsum), 4.64; magnesium sulphate, 5.29. While this list fairly represents the ingredients of the ancient lakes, the percentages have very little bearing, owing to local causes. Particularly noteworthy is the greater proportion of gypsum in some of the deposits.

Fig. 2.—Present size of Great Salt Lake and two of its prehistoric stages.

These minerals do not all separate from water at the same stage of evaporation or density. Distilled water at the temperature of 60 deg. Fahr. is the unit of comparison. The first mineral to separate is the calcium sulphate, when a density of about 1.13 has been reached—equivalent to 17 per cent of solid matter. If it is deposited under a pressure of ten atmospheres (about 146 pounds to the square inch), or at

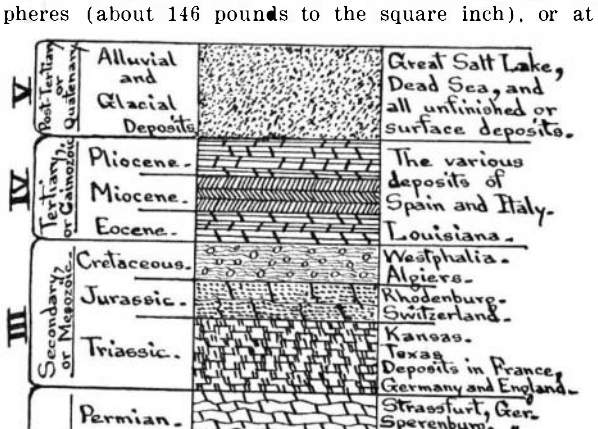

Fig. 3.—Geological location of the principal salt deposits. Geological time to produce periods II, III, IV, and V is estimated at from 10,000,000 to 60,000,000 years.

the bottom of a lake 335 feet deep, it will contain no water of crystallization and is called anhydrite. Usually, however, it includes a considerable percentage of water, and then it is more properly known as gypsum. Following the gypsum comes the chloride of sodium, the precipitation taking place in a density ranging from about 1.20 to 1.30. This includes the sodium bromide. The last to precipitate are the magnesium and the potassium. If the process were interrupted by an unusual inflow of fresh water, the order of precipitation would be repeated from the beginning. Judging from the number of strata of the different minerals found in some deposits, this was the rule rather than the exception.

For much of our knowledge regarding the formation of salt deposits, we have only to study the modern examples in various stages of completion. The Dead Sea, 40 miles long, 9 miles wide and 1,286 feet below the level of the Mediterranean, is a noted example. Its greatest depth is 1,100 feet, but all of the southern end below the peninsula of Lisan, or about one-fourth of its area, is very shallow, nowhere exceeding 13 feet. The principal contributing stream is the river Jordan, which is said to carry 52 parts chloride of sodium and 30 parts chloride of magnesium to every 100,000 parts of water. The water of the sea itself long ago reached the point of saturation and now contains 24 per cent of solids. A little over one-third is chloride of sodium, the greater proportion being made up of chloride of magnesium and calcium chloride. This is excellent proof that the brine is very old, most of the salt already having been precipitated.

The Dead Sea is probably the remnant of a larger one, formed by the uplift which drained a large portion of Western Asia, joined that continent to Africa and nearly imprisoned the Red Sea. Ancient beach lines, from the level of the Mediterranean down, indicate the successive changes through which it has passed. It once had an outlet southward into the Gulf of Akabah by way of the narrow valley of Akabah. A saline plain which extends many miles to the south shows that precipitation occurred long before it became contracted to its present area. The shallow southern end may once have been dry land (as the Bible seems to indicate), the resubmersion taking place during the eruption which destroyed Sodom and Gomorrah. This, however, would affect the level of the sea only a few feet, and proves that in 3,800 years there has been surprisingly little change.

The finest example of natural salt making, however, is to be found in our own country. Great Salt Lake is the largest body of brine in the world. It has a singularly great elevation of 4,200 feet, considering the fact that salt lakes are usually near or below the ocean level. The area which it covers greatly varies from the wet to the dry seasons (winter and summer), but upon the average it is about 70 miles long and 30 miles wide. Four rivers flow into it—the Jordan from the south, the Bear from the north and the Ogden and the Weber from the east, besides many minor streams. Despite this great influx of fresh water, the lake contains 23 per cent of solid matter, nearly all of which is chloride of sodium. It is extremely shallow, the greatest depth being only about 35 feet, while the average is little more than one-third of that.

The basin which Great Salt Lake originally occupied is of very irregular shape. The surface of the lake was then about 1,000 feet higher than it now is. Its extreme length was 346 miles and extreme width 145 miles, the total area being 19,750 square miles, or more than nine times its present size. At that level it remained thousands of years, making a well-defined shore line on the surrounding mountains. To this stage of its history geologists have given the name of Lake Bonneville. A second great and even more prolonged stage occurred when the lake had fallen to the 625-foot level, and this is known as the Provo shore line. During both stages it had an outlet northward by way of the Snake and the Columbia rivers. Besides the season changes, the level of the present lake fluctuates through periods of considerable length not yet clearly determined. In 1847, it covered an area of 1,700 square miles, but in 1869 the area had increased to 2,360 square miles, its extreme dimensions being: Length, 83 miles; width, 51 miles; depth, 49 feet. A decrease then began.

Salt deposits are common to nearly every formation of the earth's crust and constitute a sort of geological step-ladder which the average layman can understand. The point-blank assertion that millions of years were required to lay down the deposited portion of the earth is apt to stagger him. A stratum of rock hundreds of feet thick conveys no meaning to him because he knows nothing of the process by which it was formed. Judging from the slowness with which the modern deposits are being laid down, however, he can get an idea of the almost illimitable time that some of the ancient and larger deposits must have required. Many of them were completed long before either the continents or oceans were inhabited. Neither animal nor vegetable life could have survived the oft-repeated and awful convulsions of nature which emphasized their history. Placed in comparison, Niagara and the great chain of inland seas are as infants of to-day. Even the great glacier which preceded them and is supposed to have lasted about 30,000 years, belongs to the post-tertiary or present period of the world's existence. Back of this are three great periods comprising a dozen different formations!

* Under ordinary conditions, water can hold in solution about 25 per cent of salt. In salt making, this is known as the point of "saturation."