HISTORY OF THE SALTON SEA

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INTRODUCTION

The Salton Sea of southeastern California occupies a basin or sink whose southern boundary is the delta of the Colorado River. The crest of the delta, which is 15 to 20 miles south of the California-Mexico border, separates the desert basin from the head of the Gulf of California. The normal flow of the Colorado is into the head of the Gulf, which lies about 50 miles south of the crest of the delta. However, since the lowest point on the delta crest is only 35 feet above present mean sea level, and since the Salton Sink (also called the Cahuilla Basin) is well below mean sea level (the lowest point is —273.5 feet), the flow of the Colorado may be either northward into the Salton Sink or southward into the Gulf of California.

The Sea is a large body of shallow water surrounded by desert. There is sparse vegetation along the shores except where cattail sedges, tamarisk, and bamboo are present in freshwater drainages. Along the rest of the shore the vegetation is typical of an "alkaline flat," where various species of salt-bushes are dominant. Among the perennials submerged by rising water are cottonwood and mesquite.

The beaches bordering the Sea are sandy in certain areas, but most of the shore is silt or mud with a mixture of snail and barnacle shells. The bottom has an organic mat above the sand or silt, the mat consisting of settled plankton organisms and, near shore, blue-green algae. There are a few areas of rocks at the south shore where volcanic buttes form islands in the Sea.

EXPLORATIONS

Historical knowledge of the region dates from Spanish explorations, beginning in 1539 and ending in 1776, which were reviewed by Sykes (1914 and 1937) and LaRue (1916). In 1826, a British naval officer, Lt. R. W. H. Hardy, reached the mouth of the Colorado. He reported on the great range of tides there, and prepared a map of the estuary (see Sykes, 1937). American explorations of the delta region began with a journey of a trapper, James O. Pattie, down the Colorado to tidewater in 1827 (Pattie, 1833). In 1848, a military reconnaissance, led by Lt. W. H. Emory, crossed the Salton Sink en route from Ft. Leavenworth, Missouri to San Diego, California (Emory, 1848). In 1849 and 1850, emigrants were following Emory's trail to California, crossing the Colorado River at Yuma.

Trouble with Indians led to establishment of a military post at Yuma with Major S. P. Heintzelman in command. In October 1850, Heintzelman and John L. LeConte journeyed to the delta to verify reports of volcanic activity. LeConte (1855) reported discovering mud volcanoes near what came to be called Volcano Lake, a transient sheet of water at the foot of Cerro Prieto on the west side of the delta crest. In the winter of 1850-51, Heintzelman led a supply party down the Colorado

River from Yuma to meet Lt. G. H. Derby of the U. S. Topographical Engineers who came up the river from its mouth. Derby had been assigned the task of mapping the main channel of the river in the hope that supplies might be brought to the military post by water. The channel was navigable, and the chart of Derby (1852) proved useful to the river-boat men who, from the early 1850's to the late 1870's, supplied the military garrison, the ferrymen, and the emigrants at Yuma. The arrival of the railroad at Yuma in 1877 ended the river traffic.

THE DRAINAGE OF THE COLORADO RIVER THROUGH THE DELTA

The key to understanding the formation of the present Salton Sea is the delta of the Colorado, which in its own way is as impressive as the Grand Canyon from which its sediments originated. The delta has been described by Sykes (1926 and 1937) as a "T" with arms extending 200 miles from north (Salton Sea) to south (Pt. San Felipe), and with a stem 70 miles long extending from Pilot Knob, eight miles west of Yuma, to Cerro Prieto, an outlier of the Cocopah Mountains in Baja California (Figure 1). Dowd (1952), in refuting rumors of seepage to the Salton Sea from the Gulf, likened the delta to a dam 300 feet high, 140 miles thick at the base, and 8 to 10 miles wide at the top.

The channel of the Colorado may wander through the many miles of relatively flat delta which has a fall of less than two feet per mile. During the last half of the ninteenth century, the river meandered down the east side of the delta into the Gulf, maintaining a navigable channel, but occasionally flowing into the Salton Sink. According to Sykes (1937), water from the Colorado entered the Sink five times during the middle of the last century: 1840 (probably when the New River was formed), 1842, 1852 (forming a sea discovered by Blake in 1853), 1859, and 1867. In June 1891, a flow of water formed a lake of some 100,000 acres. Investigating this flow into the Salton Sink, Sykes found the mouth of the Alamo River (not known until then) and made his way to the Sea via Beltran's Slough, thus showing the connection to the Colorado River for the first time. Another expedition seeking the source of the 1891 flooding was reported by Cecil-Stephens (1891). The water of the 1891 flooding evaporated, leaving a salt marsh, centered west of the railroad station at Salton, and a salt deposit which was mined by the New Liverpool Salt Company. A boring made by the salt company in 1892 showed a seven-inch crust of sodium and magnesium chlorides above a 22-foot stratum of black ooze (Blake, 1914). The presence of this ooze may have started the rumor of a continuous stratum to the Gulf through which water could enter the Salton Sea.

GEOLOGY OF THE SALTON SINK AND RECORDS OF LAKE CAHUILLA

The first geological survey of the Salton Sink was made in 1853 by a party led by Lt. R. S. Williamson, exploring for railroad routes south of the Sierra Nevada. W. P. Blake, the geologist of the party, reported discovering San Gorgonio Pass (which became the route of the Southern Pacific Railroad) and was the first to recognize that the Salton Sink was below sea level (Blake, 1858). Blake revisited the region after the

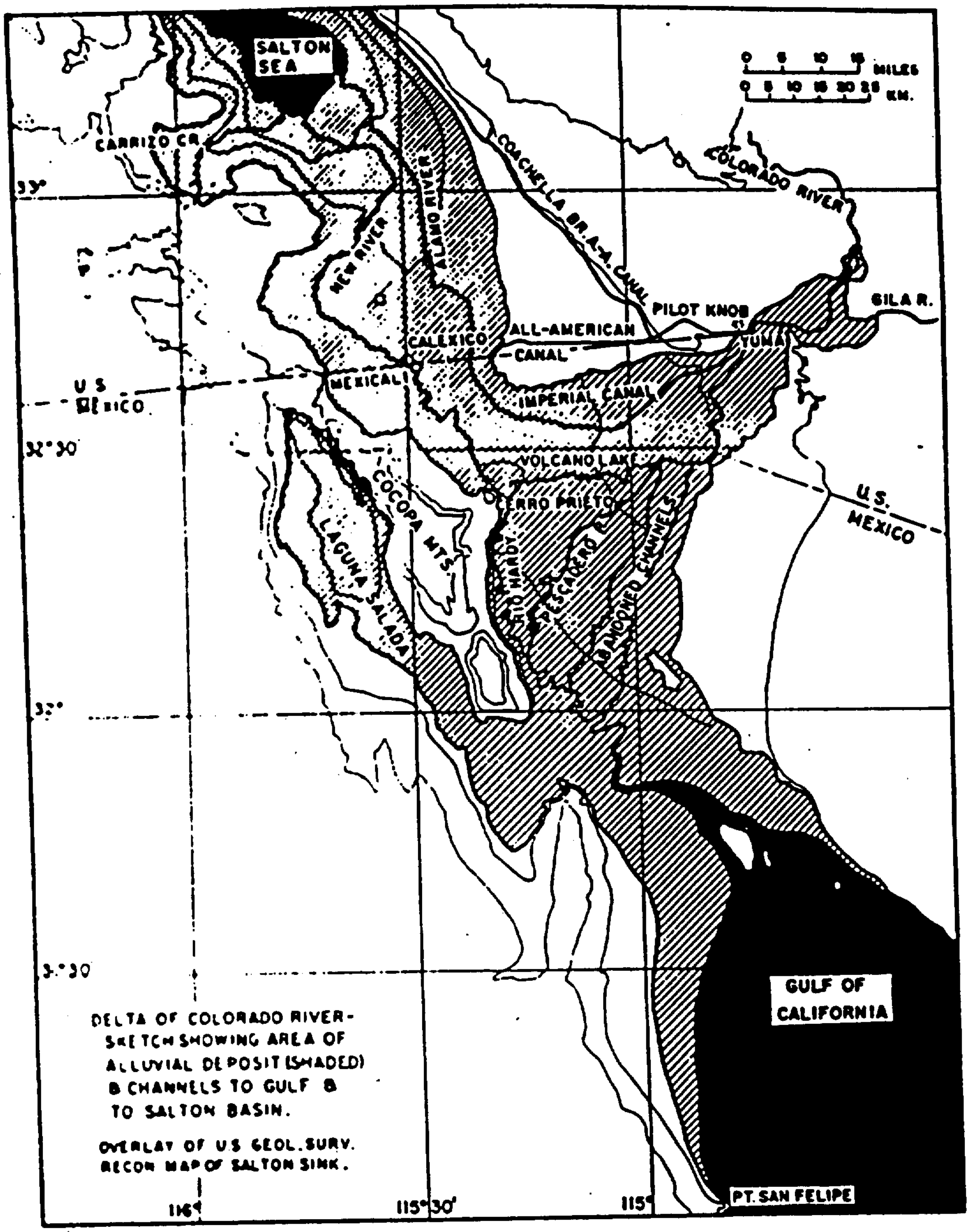

FIGURE 1. Delta of the Colorado River. Based on U. S. Geol. Surv. Map of Salton Sink, 1908.

present body of water was formed in 1907, and agreed that the name "Salton Sea" was appropriate (Blake, 1907). He suggested that it was the residual of a more extensive ancient lake which he called Lake Cahuilla, just as the Great Salt Lake is the residual of Lake Bonneville. Blake (1914) interpreted what he named the Cahuilla Basin (after the local Indian tribe) as a cut-off arm of the ocean; that is, he suggested it had been a continuation of the Gulf of California prior to the formation of the delta of the Colorado River. Sykes (1914) agreed with Blake that the approximately 2,200 square miles of the Cahuilla Basin represented the former upper extremity of the Gulf of California. According to this view, the ocean extension had been present during the middle Tertiary and was cut off by continental elevation and delta formation during a "pluvial" period of the Pleistocene. There followed a period during which the lake (Lake Cahuilla) received water from the Colorado and drained into the Gulf. The former lake, 100 miles long and 35 miles wide, left a conspicuous beachline 22 to 58 feet above present mean sea level according to U. S. Geological Survey Reconnaissance Map of the Salton Sink, California, 1908, reprinted in 1947. However, according to a recent survey by George Stanley (personal communication from Carl L. Hubbs) the beachline is fairly constant at about 45 feet above current mean sea level.

Free (1914) presented a different interpretation of the formation of the Salton Sink. To Free, it represented a trough between mountain ranges of Mesozoic (Jurassic?) origin with Tertiary foothills above a playa with a small salt body, similar to that described by Emory in 1848: a salt lake about three-fourths of a mile long, one-half mile wide, and about one-foot deep. Paralleling the axis of the trough, a line of mud volcanoes extended from Volcano Lake (described by LeConte) to the southern shore of the present Sea. The ancient shoreline and the series of strands visible below it were, according to Free, evidence of a lake that had disappeared by gradual evaporation—"little by little" according to Indian legends. Free discussed two possibilities: first the interpretation of Blake, and others, that the Cahuilla Basin was the cut-off former head of the Gulf of California; and second, his own suggestion that Lake Cahuilla was of fresh water, and that it, and the mud hills of the region, were of continental origin. The trough may have been above sea level until after formation of the delta and may thus never have been occupied by the ocean. The marine Miocene fossils found by Blake in the Carrizo area (the southwestern part of the Sink) were interpreted by Free to be remnants of a period prior to the Pleistocene when the trough was formed. Later it was pointed out by Brown (1923), that during the Miocene the land was 1,000 feet lower than at present: the marine fossils of the Carrizo are now 1,000 feet above sea level. According to Free's interpretation, delta formation by the Colorado kept pace with a gradual depression of the Sink relative to sea level.

In support of Free's theory, the freshwater nature of Lake Cahuilla is evidenced by shells of small snails (*Hydrobia protea* Frauenfeld and *Physa-humerosa* Gould) which were discussed by Stearns (1902) with the comment, "there is probably no area of equal extent on the face of the earth with such an immense number of shells of the genera above named." Further evidence of a lengthy freshwater period is the deposit of calcium carbonate (travertine or calcareous tufa) which is 30 inches thick on Travertine Rock, then near the shore of Lake Cahuilla but now an outcropping a mile west of the present shoreline of the Salton Sea. Jones (1914) pointed out that such deposits were left by all Quarternary lakes of the Great Basin.

Other interpretations of the Cahuilla Basin and of the freshwater lake that left the ancient shoreline are those of Brown (1922 and 1923), Kniffen (1932), Buwalda and Stanton (1939), Cockerell (1946), and Hubbs and Miller (1948). Both Brown and Kniffen considered the Salton Sink to be a dropped fault-block or graben, and discussed the San Andreas, Indio, and San Jacinto faults in reference to the Sink. The San Jacinto fault, which runs through the Sink, through Mexicali and on into the Gulf, is a "line of structural weakness" (Sykes, 1937) along which volcanic activity has created cones which now form buttes or, occasionally, islands at the southern shore of the present Salton Sea. Volcanic activity is currently limited to the mud volcanoes and hot springs which extend from the southern part of the Sea southward through the delta.

In the most recent account of the geologic history of the Salton Sink, Hubbs and Miller (1947) concluded that the main stage of Lake Cahuilla (which they call Lake LeConte, after the naturalist reporting the region in the 1850's) occurred in the Pleistocene, and that it lasted for centuries. Indian artifacts and legends provide evidence for another, more recent, high stage. Hubbs and Miller cited estimates, made by Mendenhall (1909) and by Rogers (1939), that a lake filling the basin to the ancient beachline existed between 1,000 and perhaps as recently as 300 years ago. Between the time of the main stage (Pleistocene) and the recent high stage, Hubbs and Miller postulated an inflow of water from the Gulf, and reported having found marine molluscs left by it. They postulated that at the end of the Pleistocene the ocean may have been 30 feet higher than at present, as evidenced by the alluvial apron that skirts the mountains at the head of the Gulf. The apron is apparent at the foot of the Cocopah Mountains and continues around another basin, called the Pattie or Macuata Basin, in which at times there is a lake, Laguna Salada, comparable to the Salton Sea. As the ocean level fell, it left the 30-foot apron, which Kniffen (1932) interpreted as a continuation of the Lake Cahuilla shoreline. However, the truncated margins of the apron were regarded by Hubbs and Miller as evidence of erosion by a recent higher-than-present level of water in the Gulf during a time when a 30-foot tide might have topped the crest of the delta at Volcano Lake. This, they pointed out, could have created the trough which later provided drainage for the Colorado River either south via the Rio Hardy to the Gulf, or north via the New River into the Salton Sea. A 30-foot tide would not be unusual because from seven feet at the ocean end of the Gulf, the tidal range increases to 20 feet at Pt. San Felipe, and to over 30 at the mouth of the Colorado River (Kniffen, 1932; Lawson, 1950). The "bore" produced by the incoming tide is pictured by Sykes (1937).

In any event, if a recent saltwater inflow did occur it must have been of short duration, admitting only a minor quantity of ocean water because, as pointed out by Ross (1914) and by Buwalda and Stanton (1939), analyses of the water in Salton Sea showed the salts were in the proportions expected from evaporation of Colorado River water, rather than of the ocean.

PAST AND PROBABLE FUTURE STAGES OF THE SEA

Blake's report in 1857 that the Salton Sink was below sea level led to several non-consummated plans, prior to 1900, to bring water from the Colorado River to the southern end of the Sink (the Imperial Valley) in order to reclaim the land for agricultural use. It was not until 1901 that water was first brought into the region via the Alamo channel. According to Sykes (1937), the 150,000 acres under cultivation by 1904 were being served by 600 miles of canals from a head near Yuma. In the winter of 1904-05, a flood of the Colorado and the Gila River, which enters the Colorado near Yuma, cut through the headworks and enlarged the irrigation channel. A summer flood in 1905 poured into the Salton Sink through this channel. An expedition from the New York Botanical Garden, led by D. T. MacDougal, was collecting on the delta and witnessed the 1905 flooding. Several members of this expedition, under the sponsorship of the Carnegie Institution of Washington, reported on various aspects of the newly-formed Sea in a combined publication edited by MacDougal (1914). Among the collaborators was Sykes (1914), who in a later paper (Sykes, 1937) reported that in 1906 he had observed the Sea rising at the rate of four inches per day with a rapid advance of the water across the nearly level floor of the basin. In May 1906, the surface elevation was —240 feet, and the Sea was 50 feet deep. The break in the irrigation headworks was repaired in February 1907, and the flow of the Colorado was redirected into the Gulf. The Sea formed by the two-year inflow was described by Blake (1914) as having "a length of 45 miles, a maximum breadth of 17 miles, and a total area of 410 square miles with a maximum depth of 83 feet." The maximum surface elevation (—195 feet) was reached in 1907.

Since 1907, water entering the Salton Sea has been controlled by irrigation practice. For many years after the maximum surface elevation was reached, little water entered the Sea and the level fell due to evaporation. Studies have shown the annual evaporation is about six feet (Young and Blaney, 1947; Blaney, 1954). Records of the U. S. Department of the Interior, Geological Survey, show that the surface elevation fell from —195 feet in 1907 to —250 feet in 1925. During the first quarter of the 20th century, there was difficulty maintaining the flow of the Colorado southward, and various levees were built in efforts to keep it moving into the Gulf. Sykes (1937) discussed the changes in the drainage of the Colorado River through the delta. The 1905-1907 breakthrough into the Salton Sink resulted in a westerly shift of the main channel, making the channel on the eastern side of the delta non-navigable after 1909, and sending the main flow down the Rio Hardy.

From 1925 to 1935, the level of the Sea fluctuated between —250 and —243 feet. There had been a desire to stabilize the level since 1907, and the 1927 Holbrook report predicted stabilization at between —223 and —226 feet. In 1928, lands lying below —220 feet were withdrawn from public entry.

After completion of Hoover Dam in the late 1930's, extra water was available, so additional land was put under irrigation and more water was "wasted" into the Sea, which acts as a sump for irrigation drainage. The Alamo channel was replaced by the All-American Canal, and the Coachella Branch of this canal brought Colorado River water into the Coachella Valley, which is the northern part of the Salton Sink. The additional water entering the Sea raised the level to —240 feet in 1948 and to —234.5 feet in 1956. The rise in surface elevation subsequent to World War II revived interest in probable future stages and possible stabilization. Estimates of the future stages of surface elevation were made by Bradshaw, Donnan and Blaney (1951) level at which inflow and evaporation of water would be equal). In a more recent prediction, Blaney (1954) estimated that the level would stabilize at —220 feet sometime between 1970 and 1985. However, the rise of the Sea, which was most rapid in 1950-1951, has slowed since then. Irrigation district engineers now believe, on the basis of known rates of water inflow and evaporation, that it may be possible to stabilize the Salton Sea at about the current surface elevation of —235 feet.