grams might give somewhat different results. There may be other operative causes than those just mentioned, but these are apparently sufficient to explain why a divergence between the two lines (possibly a greater divergence than that found) might be expected.

A deduction, that evidently might be drawn from the general parallelism of these lines, is that the factor of the rainfall, approximately shown in fig. 8, is of great, possibly dominating climatic importance. It is true that such deduction might prove to be erroneous and the parallelism be a mere accidental coincidence. This is a question, which can only be solved by further observation, and, pending such crucial test, the force of the obvious suggestion remains. Another obvious inference, deducible from the general parallelism of these lines, is that the fluctuations of the level of the lake, in the past, indicate similar fluctuations in this function of the precipitation. It ought from this consideration to be inferred that among the operative forces, if periodic, there are some of very long period, apparently longer than half a century, which have considerable effect.

That the fluctuations in the level of Great Salt Lake would, to some extent, affect the condition of the surrounding country might, for *a priori* reasons, be expected. The fall of the lake would lower the drainage level, and thus reduce the height of the underground water and the saline contents of the soil. The fact seems to be that since the country was settled in 1847 the character of the vegetation in the lands west of Salt Lake City has changed, the grasses being replaced by greasewood and other salt resisting plants. Doubtless, the present condition of these lands is unnatural and much affected by the acts of man. Overpasturing, canal seepage, and excessive irrigation, have all contributed their part toward producing the present condition. This, however, does not touch the fact that when the valley was settled the waters of the lake were low, that they rose steadily for more than a quarter of a century, and have since been receding. The total rise and fall being about thirteen feet or more. Nor does it affect the facts that these lands were less saline, when the country was settled, that their salinity as indicated by the vegetation increased before there was any irrigation, and that of late years their character has much improved. These salient facts are entirely independent of the acts of man. It is unfortunate that slow natural changes, like those under consideration, are difficult tc appreciate. After a series of years the observer may indeed notice an apparent change, but in the absence of full notes of prior observations recourse must necessarily be had to more or less uncertain recollections, perchance tinctured by preconceived opinions; so that the conclusions must always be unsatisfactory. That these changes might all be explained by the rise and fall of the lake is obvious, but it must be remembered that the lands referred to are not those immediately adjacent to it, but were at least four or five miles distant from its shores when it was highest, and that their surface was, at that time, several feet above the lake.

When it is said that the level of the underground water would be raised by a rise in the waters of Great Salt Lake and lowered by their fall only one factor of the change which takes place has been considered. If the level of the lake remained the same those natural forces which produce the fluctuation in its level would change the gradient of the underground water, for this gradient depends upon an equilibrium of supply and discharge, as controlled by frictional resistances, and any increase in the supply or discharge changes the gradient. The movement of water in soils is not a simple, but a dual phenomenon. If the soil is not surcharged with water, the movement results from the capillary forces explained by Mr. Briggs in his paper on the Movement and Retention of Water in Soils, published in the Year Book of the Department of Agriculture for 1898; but when, on the other hand, the soil is surcharged with water under pressure, its movements are controlled largely, if not wholly, by frictional resistances. These frictional resistances are functions of the pressure or head, which vary with the pressure, and the movements of the water are asymptotic in character. To illustrate their character, assume a water-tight vessel to be divided into two parts by a porous partition resembling a thin sheet of sand or clay, and that one of the parts is filled with water, which percolates through the partition into the other; then since the flow of water depends upon the head and decreases as the head diminishes, vanishing only when the head becomes zero, it follows that if no other force were operative it would take an infinite period before the water on both sides of the partition stood at the same level. Practically if the partition were very thin, a sensible agreement of level might result in a comparatively short space of time; but as from the increased frictional resistance the flow decreases very rapidly as the thickness of the partition increases, it requires very long periods of time with a thick partition to reduce the gradient of the flow to even sensible horizontality. For this reason the underground waters usually have high gradients.

In wet seasons the quantity of underground water to be discharged will be increased and in dry diminished, and the gradient flatten or steepen; but since from the slowness of the discharge it cannot be assumed that all the increase of the underground water in any one year, even when the level of the outlet remains constant, is discharged during that year, it is probable that a succession of wet or dry years causes the level of the underground waters, even when the point of discharge remains the same, to fluctuate as does the level of Great Salt Lake.

When the soil is not surcharged with water under pressure and the movement of the soil water depends upon capillary forces, the same results would apparently follow, for these are relatively weak forces.

Assuming that at a certain depth below the surface the moisture in the soil remains constant, while above it the soil is wet by precipitation and dried by evaporation; then there is apparently no reason why the level of normal soil moisture should remain constant. If wet years were succeeded by wet years, this level should rise, and if dry years followed dry years it should fall, just as the level of Great Salt Lake does, these oscillations of level being largely influenced by the accumulated deviation from the mean precipitation.

If the level of this normal soil moisture has, as it might well have, some influence on vegetation, then it is apparent that it becomes a climatic feature of some importance.

These *a priori* conclusions can of course merely establish probabilities, which may or may not be verified by observation and experiment, and they are only valuable as indicating along what lines observation and experiment might be made, in the hope of obtaining important results. Obviously, if it be conceded that the fluctuations of the level of Great Salt Lake are typical of climatic conditions which may prevail everywhere to a greater or less extent, the first step toward the study of these conditions would be the tabulation of the departures of the total precipitations from the mean or normal precipitation.

FOG STUDIES ON MOUNT TAMALPAIS: NUMBER 5—WRECK OF THE PACIFIC MAIL STEAMSHIP RIO DE JANEIRO.[1]

By ALEXANDER G. MCADIE Forecast Official.

On the morning of Friday, February 22, 1901, the Pacific

[1] The publication of No. 4 is delayed by nonarrival of half-tone plates. It may be expected in the March REVIEW.—ED.

Mail steamship *Rio de Janeiro* ran upon the Fort Point Reef during the fog. Within fifteen or twenty minutes from the time of striking the vessel sank, and of the 210 persons on board, 130 were lost. Another statement, purporting to be official, makes the total number aboard 207 and the lost 127.

The following facts are obtained chiefly from the statements of Pilot F. W. Jordan; the ship's master, Capt. William Ward, went down with the vessel. The pilot boarded the *Rio de Janeiro* in the vicinity of the 9-fathom buoy, near the bar buoy, and anchored in 13 fathoms at a little before six o'clock Thursday night, February 21. The weather being foggy, the ship remained at anchor till about 4 a. m., one hundred and twentieth meridian time, when the fog lifted and the Cliff House light could be seen, but not the Point Bonita light. Preparations were in progress to steam into the harbor, when a dense fog came out from the Golden Gate, obscuring everything. There is some difference of testimony as to whether the captain or the pilot gave the orders to proceed in the fog, but the vessel was started on a northeast course with Lime Point straight ahead, steering by the whistle. The pilot expected to get an echo of the ship's whistle from Point Diablo, but heard none. The course was changed north-northeast with the intention of running close to Lime Point. The vessel was not moving at full speed and was subject to a strong cross current, which, apparently acting at right angles to the length of the vessel, carried the ship to the south, far out of the proper course. The first officer was standing on the starboard side listening for the Fort Point bell. No soundings, however, were taken. The vessel struck a short distance to the southwest of the Fort Point light. At the moment of striking the pilot saw the white flash at Fort Point and heard the Fort Point bell.

The pilot had had eleven years' experience in the harbor and was considered one of the most capable pilots in San Francisco. He had never previously met with an accident. There appears to be no doubt of the existence of the strong cross current, inasmuch as other vessels entering the harbor about the same time on the same morning came near going on the rocks. The Pacific Mail Steamship Company has a rule that vessels must not enter or leave a harbor when fog prevails. On the morning in question the fog lifted for a few moments and then settled down again; but by 9 a. m., local time, the fog had dissipated. The rest of the day was clear and balmy and the water as smooth as a mill pond.

The vessel struck about 5:30 a. m., with the pilot and captain on the bridge, the first officer on the starboard side of the bridge listening for the bell, and the second officer at the telegraph. When the vessel struck the captain blew the danger whistle, a long blast. Ordinary fog blasts (long enough to count six or seven) had been blown previously.

The details of the accident, particularly with reference to the whistles, the course steered, and the motion of the current are given, because from such evidence as can be obtained at this writing, it appears that even after the vessel struck the sound of the whistle was not heard plainly at Fort Point not more than half a mile distant, where a lookout of the life-saving station was on duty, and where a life-saving crew could have hurried to the rescue and probably reached the ship within five minutes, without doubt saving many of those whose lives were lost. There was also a sentry walking post within a short distance of the lookout. It is stated that some soldiers heard voices and also a whistle, but the evidence is very conflicting and it seems improbable that if the long danger blast was clearly heard it should pass without notice and subsequent action.

The Weather Bureau records show that about the time of the accident a mongrel tule fog prevailed over the Bay of San Francisco. At Mount Tamalpais the weather was clear with a wind of 13 miles per hour from the northwest. At San Francisco dense fog prevailed with little if any wind. The wind vane at the Mills Building indicated a southwest wind blowing about one mile per hour. From 1 a. m. till 6 a. m. but 9 miles of wind were recorded.

When all is said and done, it appears that the fog was the prime factor in causing the loss of the vessel. Owing to the aberration of the sound waves in the fog, the pilot was unable to hear the fog signals from either Point Bonita or Lime Point to the north, or the tolling of the bell at Fort Point to the east and north. It has not, however, been shown that the bell was certainly ringing. The Lime Point whistle has great penetrative power. The fog bell at Fort Point is 40 feet above the water and should be heard for at least a mile. It is supposed to be struck every ten seconds. It is a strange fact that in a paper upon the Fogs and Fogs Signals of the Pacific Coast, by Ferdinand Lee Clark, published in 1888, there should occur this statement concerning the fog bell at Fort Point—

> In point of fact it is said to be hardly ever heard except when too late to be of use. * * * If mariners depended upon its sound to tell them how near they were to the point they would generally have no time after hearing it to clear the danger.

The loss of the *Rio de Janeiro* proves that the bell at Fort Point in its present position is sometimes of little value.

The temperature at the time of the accident was 50° F. at sea level, and 52° at a height of 2,500 feet. The thickness of the fog probably did not exceed a few hundred feet; and as indicated above it was a land fog rather than a sea fog.

As a general thing the reflected sounds from Point Bonita and Lime Point are heard better on the south side of the channel. On the accompanying rough sketch of the channel the lines of natural reflection are drawn and also the zones of inaudibility.

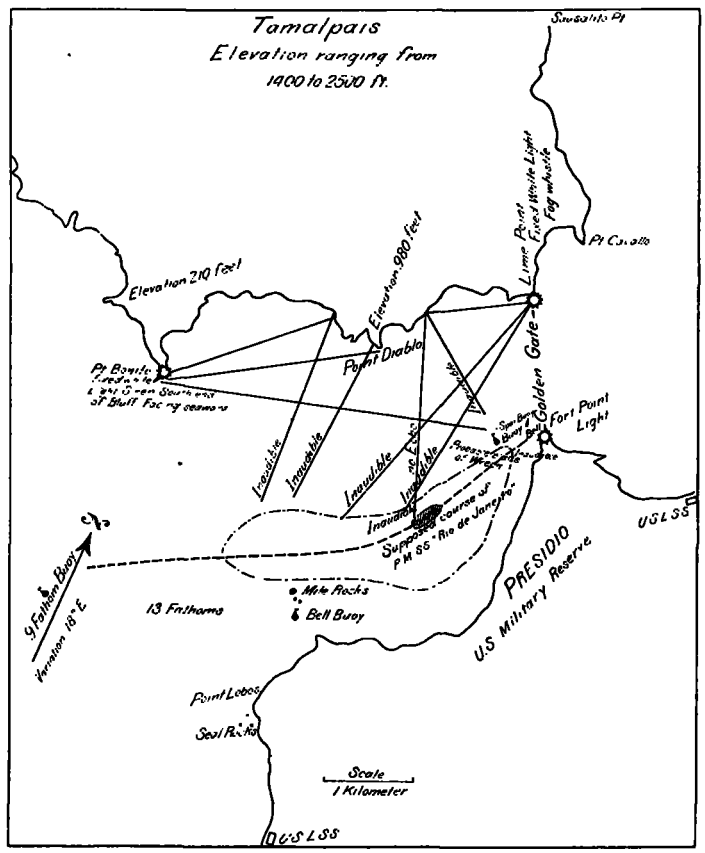

FIG. 9.—Probable conditions at time of wreck, February 22, 1901.

It is not difficult to account for the failure of the echo of the ship's whistle from some portion of the northern shore, as the distance of the vessel from Point Diablo was too great.

The sound waves from the fog whistle at Lime Point, however, should have been heard, and as the moderate southwest wind would tend to cause a deflection of the sound wave upward, it is possible that while the sound was inaudible on the deck of the vessel, it might have been heard by a lookout at the masthead.

The catastrophe furnishes a remarkable illustration of the utter helplessness of a vessel in fog despite lights and fog whistles. It would seem that under such conditions nothing short of some method of fog dissipation will suffice.

It has occurred to the writer, although the suggestion may prove of no value in practice, that if a strong sound had been made under water by some automatic contrivance at either Lime Point or Point Diablo, and the *Rio de Janeiro* been provided with some suitable device rendering audible the sound wave through the water, the strong cross current would have facilitated the passage of the sound, and a zone of audibility would have been established in the water while in the atmosphere above the fog signals would have been inaudible.

The accompanying photographs, Plate I, are submitted to show that to a certain degree the captain and the pilot were justified in assuming that they might soon run into areas free from fog. As a matter of fact on the day in question the fog soon disappeared and a delay of perhaps two hours would have prevented the accident. It should not be forgotten, however, that the captain was unwilling to enter the harbor during the fog Thursday night, and that the vessel remained at anchor for a period of nearly twelve hours, and was thereby exposed in a large degree to the danger of collision.

LAKE LADOGA FROM A THERMIC POINT OF VIEW.

By JULES DE SCHOKALSKY, St. Petersburg, Russia. Translated from Comptes Rendus, Paris, June, 1900.

Lake Ladoga occupies the first place among the bodies of fresh water in Europe; its surface is thirty-one times larger than that of Lake Leman; its length is 202 kilometers and its width attains 75 kilometers. Its cartography and hydrography have been studied by a scientific expedition which worked, with interruptions, from 1858 to 1873, under the direction of the Hydrographic Service of the Imperial Russian Navy. The expedition having more especially a hydrographic aim had not time for the study of the chemical composition of the waters of the lake nor for the thermic study of its deep strata layers. The Imperial Russian Geographical Society, at my suggestion, decided to begin these studies and, thanks to the Hydrographic Service and the Ministry of Roads and Communications, who respectively gave the instruments and the use of a small steamer, without which it would have been impossible to carry on the work, I was enabled to make two trips on the lake, both at nearly the same season of the year, during the first half of July, 1897 and 1899.

The temperatures at great depths were measured with the thermometers of Negretti and Zambra, verified as to zero point.

The relief of the bottom of the lake is such that the depth increases regularly from south to north, the greatest depths being found in the northwest portion (120 fathoms = 219 meters). Upon the chart there are two sets of broken lines, one solid, the other in dashes, which show the courses that I sailed. The stations at which the thermometric soundings were made are marked by roman numerals; in 1897 14 were made; 1899, 20; a total of 34, some of which coincide with each other, as will be seen by the chart accompanying this summary.

In 1897 the principal fact that I established was the following: At all of the stations I found that the thermal stratification was *direct*. The temperature of the surface waters and those of the lower strata, at identically the same depths were different at the south and at the north ends of the lake. At the south end in July the water at the surface was relatively warm, 13.1° C. and 11.3° C., but in proportion as we approached the north the temperature became lower; in the middle of the lake it was 10.7° C. and in the deepest part 6.8° C. At the south, the abyssal strata, in shallow water had quite a high temperature, at 10 meters, 11° C.; at the north, at the IXth station, at 45 fathoms (82 meters), I found a temperature of 4° C., and at the VIIIth station, from 50 fathoms (91 meters) to 120 fathoms (219 meters), or the bottom, the temperature remained nearly constant, 3.9° C.

One might be tempted to think that these temperatures for the surface waters and for the deep strata observed in the month of July, 1897, were already quite low for a season so near to the month of August, in which they reach their maximum for the whole year. But in 1899 I found them still lower, particularly at the northern part of the lake which is the deepest; the two stations marked on the chart show this clearly.[1]

But what was especially interesting was the fact that the thermic stratification in July, 1899, at all the deep stations in the north of the lake was distinctly *reversed*, whereas one might have expected that in Ladoga, which according to the classification of Prof. F. A. Forel, belongs to the type of temperate lakes, the inverse stratification would have come to an end at the beginning of summer.

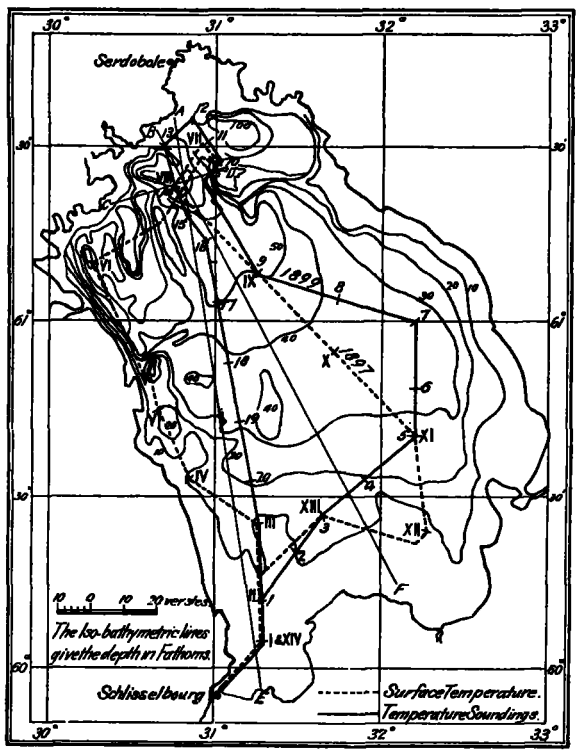

FIG. 10.—Soundings and courses on Lake Ladoga.

The divergences in the results of the two years were caused by the differences in the temperature of the air in the neighboring countries during the springs of 1897 and 1899. If we observe the temperatures of the months of April, May, and June of these two years, and if we compare them with the normals, which are given in the new Atlas Climatologique de Russie, published by the Central Physical Observatory, we shall find that the temperature of the air during these three months at seven stations distributed around the lake, was much higher than the normal in 1897 and lower in 1899. According to the Bulletin Mensuel Météorologique all the northwest portion of Russia enjoyed temperatures much

[1] The scale of the published chart is too small to show all these stations.—ED.

FIG. 1.—Fog studies at Mount Tamalpais. Fog drifting from sea inland.

FIG. 2.—Fog studies at Mount Tamalpais. Fog stratum: clear above and cloudy below. Will dissipate in about three hours. Fog stratum as shown here is about 20 miles square. The elevation of the under surface is 1,000 feet; the thickness of the stratum is between 400 and 800 feet.

Plate II.

Fog Studies. Helmholtzian Fog Billow. View from U. S. Weather Bureau Observatory, Mount Tamalpais, Cal.