

ART. II.—*Lake Parinacochas and the Composition of its Water*; by GEORGE S. JAMIESON and HIRAM BINGHAM.

A SAMPLE of water from Lake Parinacochas was collected by one of us (H. B.) of the Yale Peruvian Expedition of 1911. The analysis of this sample is discussed in the present paper.

Lake Parinacochas is situated in Peru, between 15° and 16° S. latitude and 73° and 74° longitude, west of Greenwich. In other words, it is about 150 miles N.W. of Arequipa, and about 170 miles S.W. of Cuzco. Its elevation is about 11,500 feet above sea level. It is fed by half a dozen small streams or large brooks, and at present has no visible outlet. In past geological history it was much larger, and had an outlet which is still visible. In a river valley not many miles from the lake, and at a lower elevation, there are a considerable number of large springs which may possibly be fed by the lake. On the borders of the lake are also numerous small springs, which generally occur in swampy hillocks, three or four feet higher than the surrounding plain. The natives told us that in the wet season the lake was higher than in the dry season. The truth of this is evident from the marks of the salt left by evaporation of the lake as it shrinks during the dry season. In general the surrounding region is at present semi-arid, and is inhabited by a pastoral population. Thousands of sheep and some hundreds of cattle feed in the pastures which were formerly the bed of the lake. There are ruins of villages and agricultural terraces, indicating that at a previous period there was a much larger population here and that agriculture was more common than at present.

We spent eight days (Nov. 5-12, 1911) in three different camps on the shores of the lake and navigated it in a folding boat, the first boat or canoe that had been seen on the lake, according to the natives. We found that the lake was at present about 18 miles in length, and 7 miles in width, with a nearly uniform depth at the time of our visit, November, 1911, of $4\frac{1}{2}$ feet. Several hundred soundings failed to show more than 5 feet anywhere. Judging by the salt marks on the shore, the lake is probably about a foot deeper in the rainy season. The natives told us that in the dry season the lake sometimes was very much lower than we saw it. The water has had a reputation of being brackish for nearly a century,—ever since any one took the trouble to say anything about it in print. The first and only reference to the character of the water that I have been able to find is in the *Memoirs of General William Miller* (London, 1828), where on a rough sketch-map he notes that the water of Lake Parinacochas is brackish.

FIG. 1.

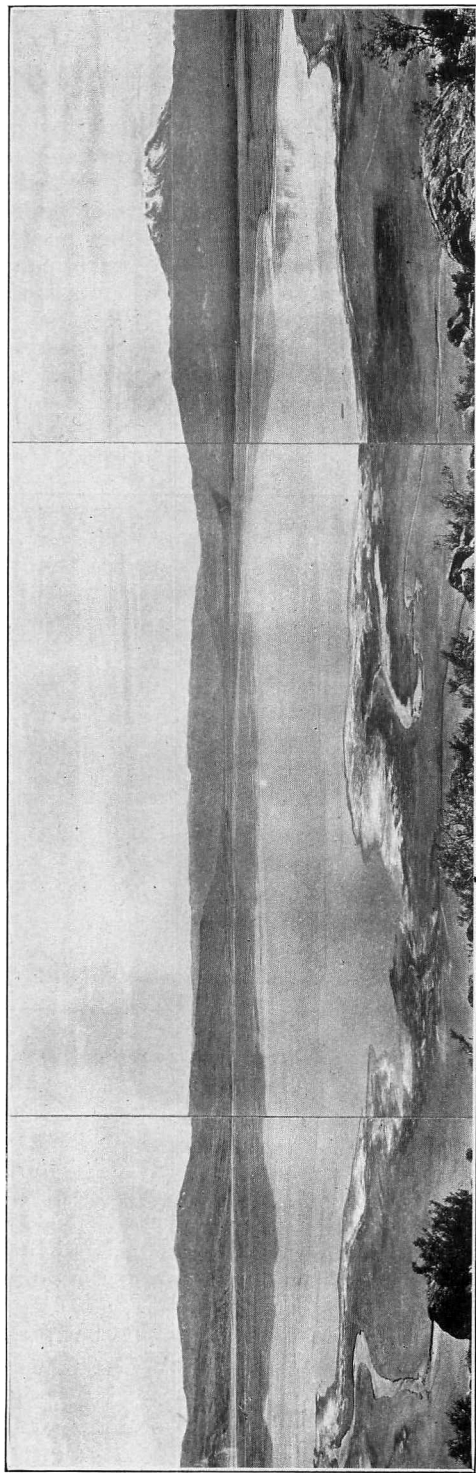


FIG. 1. Lake Parinacochas, looking northeast. The extinct volcano Sarasara shows on the right, the former outlet of the lake in the center, salt-covered shores in the foreground. The specimen of water whose analysis is published herewith was secured at the right-hand extremity of the lake. The panorama was taken by Mr. H. L. Tucker, archeological engineer of the expedition, from a hill partially covered with the ruins of a very ancient village.

Parinacochas is a contraction from the Quichua word "Parihuanakocha," which means *the lake of flamingoes*. The Quichua or Inca word for flamingoes is "Parihuana"; "Kocha" means lake. There are thousands of pink flamingoes, but we could find no evidence that they nested here. We found the lake to be the home of a great many birds, which, in the order of the frequency with which we saw them, are as follows: flamingoes, gulls, small divers, large black ducks, sandpipers, black ibis, large teal ducks, large geese, ground owls, and woodpeckers. Owing to the shallowness of the lake and the fact that a sweet marsh grass is abundant in

FIG. 2.

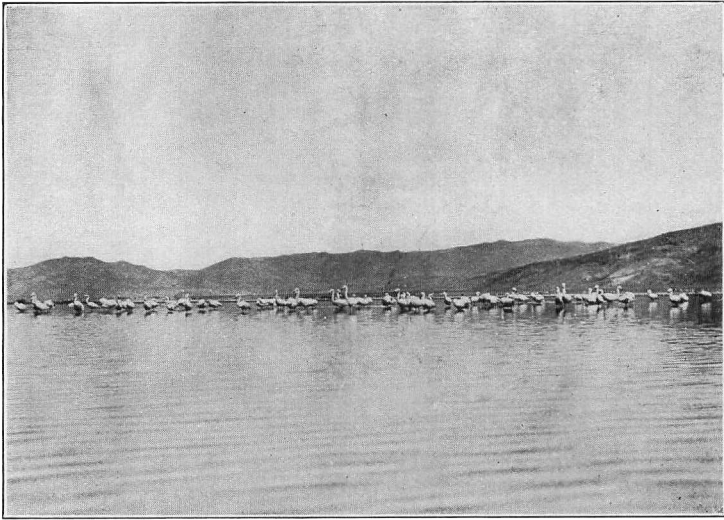


FIG. 2. Lake Parinacochas. Flamingoes wading in the lake.

it, the cattle are accustomed to wade sometimes as much as three quarters of a mile from shore, in order to get the particularly succulent grasses and water weeds. We saw no fish, and were told by the natives that there were no fishes in the water, but there was a great deal of small animal life. Large parts of the lake are covered with algæ, making it very difficult to row. In camps, near the banks of the lake, at night the temperature went as low as 22° F.

It will be seen at a glance, from the table, that the temperature of the water of the lake varies from 61° to 67·5°, depend-

ing chiefly on the time of day. In the mornings there is no wind, and the water near the surface is warmed by the sun. Shortly after noon a strong wind arises and stirs up the water and cools it near the surface, causing a slight fall in its temperature. The specimen of water was taken near the shore, in a location much frequented by birds and cattle.

Temperature of Water 10 in. below surface.

Water, near shore, 10:00 A. M., 61° F.	
“ 2½ ft. deep, ¼ mile from shore, 10:30 A. M., 63·5° F.	
“ 3½ ft. “ ¾ miles “ “ 11:00 A. M., 64° F.	
“ 16 in. “ 150 yds. “ “ noon, 65·5° F.	
“ 3½ ft. “ ½ mile “ “ 12:30, 67·5° F.	
“ 4½ ft. “ 1¼ miles “ “ 1:00, 65° F.	
“ 4½ ft. “ 1½ “ “ “ 1:30, 63° F.	
“ 4½ ft. “ 1 mile “ “ 2:00, 63·5° F.	
“ 4 ft. “ ½ “ “ “ 2:30, 65° F.	

The sample of water, which measured about 300°, had a brackish taste and a slight brown color. The following results were obtained by analysis:

	Milligrams per liter.	Percentage com- position of the inorganic constituents.
Chlorine (Cl).....	5650·0	46·87%
Sulphate (SO ₄).....	1276·0	10·59
Carbonate (CO ₂).....	264·0	2·16
Borate (B ₂ O ₃).....	164·0	1·36
Nitrate (NO ₃).....	47·7	0·40
Phosphate (PO ₄).....	5·9	0·05
Silica (SiO ₂).....	8·0	0·07
Sodium (Na).....	3935·0	32·64
Potassium (K).....	464·0	3·83
Calcium (Ca).....	142·0	1·18
Magnesium (Mg).....	99·0	0·82
Iron (Fe).....	3·4	0·03
Salinity.....	12,059·0	100·00

The total residue obtained by evaporation at 100° C. was 12,548 milligrams per liter; the difference between the total residue and the salinity, amounting to 489·0 milligrams, represents in a measure the amount of organic matter held in solution. The following table gives the hypothetical combination of the acids and bases:

Sodium chloride.....	9324.0
Sodium sulphate.....	649.3
Sodium borate.....	212.4
Potassium sulphate.....	965.6
Potassium nitrate.....	78.0
Calcium sulphate.....	435.8
Calcium carbonate.....	33.8
Magnesium carbonate.....	342.8
Ferric phosphate.....	9.3
Silica.....	8.0

12,059.0

In order to compare the percentage composition of Lake Parinacochas with that of the Atlantic Ocean and several other typical saline waters, the following table is given. The analyses were taken from Bulletin No. 330 of the United States Geological Survey, entitled "The Data of Geochemistry," by F. W. Clarke, 1908 :

Water	Cl	SO ₄	CO ₃	PO ₄	B ₄ O ₇	Na	K	Ca	Mg	SiO ₂	NO ₃	Fe	Total Salinity
1. Lake Parinacochas	46.86	10.59	2.14	0.05	1.36	32.63	3.85	1.18	0.82	0.07	0.40	0.03	12,059
2. Soda Lake, Nevada	36.51	10.36	13.78	----	0.25	36.63	2.01	trace	0.22	0.64	----	----	113,700
3. Atlantic Ocean....	55.48	7.69	0.21	----	----	30.60	1.10	1.20	3.72	----	----	----	34,400*
4. Great Salt Lake....	55.69	6.52	trace	----	trace	32.92	1.70	1.05	2.10	----	----	----	230,355
5. Lagoon of Tamun- tica, Chile.....	50.44	9.17	----	----	----	35.35	2.29	0.01	0.60	----	2.14	----	285,500
6. Koko Nor, Tibet..	40.05	17.84	5.53	0.02	----	30.60	1.08	1.77	2.90	0.09	----	----	11,000*

Analysts: 1, G. S. Jamieson; 2, T. M. Chatard; 3, G. Dittmaes; 4, E. Waller; 5, F. San Román; 6, C. Schmidt.

* An approximation only. Not given in the Bulletin.

On comparing the percentage composition of the several waters given in the table above, it is seen that Lake Parinacochas occupies an intermediate position. Its salinity is about one-third that of the Atlantic Ocean, or about one-twentieth that of the Great Salt Lake. It is also noticeable that it contains much more carbonate and much less magnesium than either the Atlantic or the Great Salt Lake.

Yale University, New Haven, Conn.,
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