INTRODUCTORY ACCOUNT OF THE INLE LAKE.

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(With Map.)

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GEOGRAPHY OF THE LAKE.

Situation of the Lake.

The Inlé Lake[1] lies in the State of Yawnghwe on the Shan Plateau at a height of 3,000 feet above sea-level, in Lat. 20° 35′ N., Long. 96° 57′E. It is thus well within the Tropics but at an altitude that mitigates the violence of a tropical climate. The lake occupies the central part of a trough between two ranges of hills, which, like all the ranges of that part of Burma, run almost due north and south. At its two ends, and to a lesser extent on the western side, alluvial plains have been formed, and are gradually extending outwards into the water. Several streams run through the northern plain and combine in the swampy ground between land and water. None of these streams are of any great size. They come from the north and from the west ; one of the most important of them flows from a dried lake-basin situated only a few miles to the north-west of the Inlé Lake but 800 feet higher. This stream makes its way with a very sudden drop through a narrow gorge in the hills. The dried lake-basin, to which I shall have to refer frequently, is the He-Ho plain. On the western

[1] *Inlé* means the " Lake (*in*) of the Four " (*lé*). The name is said to be derived from a league of four villages which at some troublous period of history made themselves independent of the local Shan chief.

side a rather larger stream enters the lake by several mouths, coming also from the north-west, and rising in the high ground that separates the watershed of the Irrawaddy from that of the Salween. Before reaching the lake, and on the other side of a range of hills, it disappears, running for some miles at a great distance beneath the surface. This is a habit of rivers on the Shan Plateau, a habit that may have had considerable influence in the distribution of the fauna. On the eastern side a few hill-streamlets enter the lake ; many of them dry up in winter, and all are very short. From the south end of the lake a larger river makes its way southwards ; like the stream on the western side it disappears into the ground, but at some considerable distance south of the lake. Its subterranean wanderings are unknown, but there can be little doubt that much, if not all, of its water finally reaches a tributary of the Salween.

The lake is thus, in a sense, the centre of a closed system, without direct communication with any of the important river-systems of Burma, but, in a wider sense, it may be considered to belong to the system of the Salween.

Dimensions of the Lake.

For reasons that will be made clear shortly, it is impossible to state the dimensions of the Inlé Lake precisely. It is about 14 miles long, and about 4 miles broad. The depth varies with the seasons. In March it is nowhere greater than 12 feet, and the average depth is not more than 7 feet ; but at the end of the rainy season the greatest depth must be at least 20 feet.

Water.

The water is remarkable for its extreme clearness. It is thus possible, when there is no breeze, to watch the animals at the bottom almost as if they were in an aquarium. All the silt brought down by the streams is deposited before it reaches the middle of the lake. The clearness of the water is probably correlated with its chemical composition. Mr. R. V. Briggs has analysed a sample which came from the surface in the middle of the lake, with the following results :—

	Per litre.
Total Solids	0·1710
Organic matter	0·0160
Calcium	0·0222
Magnesium	0·0279
Chlorine	0·0017
Sulphate (SO_4)	0·0017
Silica	0·0010
Carbonic Acid (CO_3)	0·1030
Iron	Less than 1 part in 5 million.

No precise details are available as to the temperature of the water. We found it remarkably constant at the beginning of March, not varying more than 2 degrees Fahrenheit. The average surface temperature was about 71°F. (21·7° C.) at that season, and the average bottom temperature one degree Fahrenheit lower ; the average air temperature being about 73°F. (22·8° C.).

Nature of the shore.

I have already alluded to the impossibility of stating the exact dimensions of the lake. This is because of two facts, firstly because its size increases greatly in the wet season, secondly because it has not at any time of the year what may be called a solid margin, for it is completely surrounded by floating islands formed by the growth and decay of vegetation. These islands, which are massed together round the edge of the lake, are one of its most characteristic features. Many different kinds of plants take part in their formation, but those of primary importance are certain large grasses and sedges that send out long floating runners from which new upright stems arise. Floating plants such as duckweed become entangled amongst these runners, and at the same time submerged weeds, especially a species of *Ceratophyllum*, grow up to the surface, where their upper parts are killed by the heat of the sun or the growth of algae. The mass of vegetation thus entangled is further agglutinated by the luxuriant growth of an alga belonging to the family Rivulariaceae which forms large brownish masses. These elements of the island in the making both decay and grow. Their decay forms a kind of fen-peat, which is prevented from sinking by their floating and growing parts.

Floating Islands.

A floating island covered with rich soil is thus formed, and plants[1] of a great variety of species grow up upon it, forming dense entangled masses. Even conspicuously flowering orchids and small shrubs flourish in a little time. These islands not only afford shelter and food for a large part of the fauna, but are of great importance in practical agriculture. When a cultivator wishes to grow tomatoes, cucumbers, or indeed any kind of vegetable, he cuts off a piece of a floating island sufficiently large to form his field, and then ties a rope to it and tows it to a suitable situation. The next operation is to turn the island upside down, which is easily achieved as its equilibrium is by no means stable, to anchor it with a bamboo pole thrust through it into the bottom of the lake and then to pile up more peat from the bottom upon the exposed surface until it becomes solid enough for him to walk upon, and even to build a house or erect a pig-sty. The gardens thus formed are extremely fertile.

The presence of the floating islands, cultivated or in their natural state, causes a very distinct differentiation of the lake into two regions, an open central region and a swampy marginal zone. As we shall see, the fauna of these two regions is very distinct. I have also been able to recognize an intermediate zone, where the two regions meet.

At the ends of the lake, and especially at the southern end (to which floating matter is carried by a quite perceptible current), a considerable area is covered with floating islands, merging gradually into swampy land.

Nature of the bottom.

The bottom of the marginal zone, beneath the islands, is composed very largely of a black peaty substance somewhat inimical to animal life. That of the central region is of a very peculiar nature. Strictly speaking, indeed, the lake has not a solid bottom at all. Beneath the water there is a layer of semi-liquid consistency composed of extremely

[1] Large botanical collections were made and have been deposited in the herbarium of the Botanical Survey of India.

small particles of a greenish grey colour suspended at a constant level, but never in their natural position becoming consolidated even into real mud. These particles are largely of a calcareous nature, as is shown by the following analysis of a dried specimen from the bottom of the northern part of the central region. This analysis also was made by Mr. R. V Briggs :—

	Per cent.
Insoluble siliceous matter	0·98
Alumina	1·30
Oxide of Iron	2·25
Lime	45·31
Magnesia	1·25
Potash	0·12
Soda	0·46
Moisture	3·10
Carbonic acid .	33·15
Phosphoric acid	0·17
Sulphuric acid	0·41
*Organic matter and combined water by difference	11·50
	100·00
*Containing Nitrogen 0·619	

On being dried the pea-soup-like mass forms a grey, very friable clay in which fragments of vegetable matter are abundantly present.

At some places the bottom is almost bare, the only growth upon it being a scanty one of such plants as *Potamogeton crispus*, *P. pectinatus*, *Hydrilla verticillata* and a species of Characeae, but over the greater part of this region dense masses of *Ceratophyllum* flourish, binding the bottom together with their roots to some extent, but not sufficiently to make it solid. The submerged thickets thus formed rise up to a height of at least 7 or 8 feet, and sometimes almost reach the surface. In some places they are in a flourishing condition even when their growing parts are almost in contact with the surface film, but at others they exhibit towards their upper extremities all the symptoms of ill-health, probably because of the growth of algae of various kinds among them.

Structure of the Surrounding Country.

In order to understand the history and origin of the lake, and therefore of its fauna, it is necessary to consider the structure of the surrounding country. The lake lies in the great Limestone Zone of the Shan Plateau thus described by Middlemiss[1] :—

" In its essentials, and not considering the younger minor zones that are inlaid with it, it is a rugged, rocky country. The dark grey limestone frequently weathers almost black into sharp-edged honey-combed masses, into pinnacled crags and weather-beaten towers and walls : into deep basins and swallow-holes (often as regular and circular in outline as a gigantic amphitheatre, but sometimes funnel-shaped) : into strange valley systems without connection one with the other, and that often end mysteriously either as underground passages down which streams precipitate themselves and become lost, or as marshes and lakes where evaporation helped out no doubt by subterranean percolation causes a disappearance of the waters : into innumerable caves and passages beneath the ground, some now high and dry from the waters that caused them and which are locally mined for the nitrates that have accumulated upon the floors from the decomposition of cave animal deposits, others used as show places and temples ; others again unknown to fame and rich in their virgin beauty of stalactitic growths."

[1] *General Report of the Geological Survey of India for 1899-1900* : " Report on a Geological Reconnaissance in parts of the Southern States and Karenni," p. 130.

The age of the rocks is uncertain, but it is sufficient for our purpose to know that they are of marine origin, and very ancient, and that their formation must have long preceded the hollowing out of the Inlé basin.

Superficial deposits.

The superficial deposits of the district have great interest in relation to the living fauna in that they prove the former existence of lacustrine molluscs at places now devoid of water, particularly in the He-Ho plain and in smaller valleys among the hills of Yawnghwe. The shells from the deposits will be discussed later in a paper dealing primarily with the living forms.

The deposits are of four kinds :—(*i*) Red Soil, (*ii*) Peaty Deposits, (*iii*) Grey Clay and (*iv*) Recent Tufa.

Red Soil.

La Touche [1] has shown that the red soil which covers a great part of the Shan Plateau is the insoluble debris of limestone rocks dissolved by water. Soil of this kind covers most of the He-Ho plain and also of the flat ground at the head of the Inlé Lake. In a small valley, that of the Hsin-Dawng stream, about three miles east of the town of Yawnghwe and at several hundred feet above the level of the plain, there are two small limestone caves, the floor of which is formed of red soil and contains fossil shells and mammalian remains. The shells are closely related to but distinctly different from those both of the He-Ho and the Inlé basins.

Peaty Deposits.

An enormous amount of peaty matter is always being formed round the Inlé Lake and in other damp situations on the Shan Plateau. Together with the silt brought down by the streams that flow into the lake, it must in the end fill up the basin completely. On the He-Ho plain, especially round the margin of the old lake, there are considerable deposits of this origin. They contain numerous shells in a fossil or subfossil condition. These shells belong to the same genera and in many cases to the same species as those now living in the Inlé Lake.

Grey Clay.

At the western end of the He-Ho plain, between two small limestone spurs, a short distance above the point at which the He-Ho stream begins to descend through its gorge into the Yawnghwe valley, there is a deposit of grey clay exactly similar to that which is formed when the semi-liquid substance from the bottom of the existing lake is dried. The stream has cut through this deposit to a depth of at least 20 feet. It is full of shells differing in some cases from those found in the peaty deposits of the same neighbourhood but closely allied to them.

Recent Tufa.

One of the most extraordinary phenomena to be observed in the Shan States is the formation of calcareous tufa owing to the deposition of lime from solution in water. This phenomenon is thus described by La Touche [2] :

Calcareous Dams.

"The enormous extent to which the limestone of the plateau is being removed in solution by percolating waters has already been alluded to, and it is not surprising to find that, when the water comes again to the surface in springs and rivers, and is either evaporated or loses the carbonic acid which keeps the carbonate of lime in solution, the deposits thrown down should reach correspondingly huge dimensions. Indeed I doubt whether any other limestone tract

[1] *Mem. Geol. Survey Ind.*, Vol. XXXIX, p. 322.
[2] *Mem. Geol. Survey Ind.* Vol. XXXIX, p. 325.

can show deposits of this kind of such magnitude, at least in the open air. In the ordinary "Karst" region the evaporation usually takes place as the water trickles into the caverns and hollows worn out of the rock, with the formation of stalactites and stalagmite; but in the Shan States there are no open caverns in the great bulk of the limestone, owing to its universally shattered condition, which causes the mass to settle down as underground solution proceeds; though in the superjacent, more compact, Permo-Carboniferous limestones caverns are common enough. Thus the carbonate of lime which would ordinarily be deposited on the walls of the caverns and fissures is in this region brought to the surface and thrown down in the open. The brecciated structure of the rock also allows water to percolate freely through the mass in all directions, and this no doubt adds to the rapidity with which it is dissolved."

One can watch the formation of rocks where the lime-laden water is trickling over masses of leaves and roots. At the head of the He-Ho pass what appears at first sight to be a fossil coral-reef is actually in process of formation owing to water dripping upon the roots exposed when a bank of earth is washed away by heavy rain. The lime is deposited in concentric layers round each root, the organic matter of which gradually decays and disappears, leaving a hollow tube. On the He-Ho plain Dr. Gravely found curious ridges of tufa running for considerable distances some feet above the surface of the soil and clearly representing the beds of now perished streams. They were full of shells of the same species as those found in the peaty deposits.

Even from this brief description, which should be read in connection with the papers by La Touche and Middlemiss already cited, it will be clear that the surface of the Shan Plateau has been, and still is, subject to great changes with which the waxing and the waning of the Inlé Lake are intimately connected.

ORIGIN AND HISTORY OF THE LAKE.

The lake belongs to the type known as solution lakes—lakes with their basins hollowed out of limestone by the dissolving action of water. A common feature of such lakes is the presence somewhere in their bottom of a "sink" or deep pit down which the whole or a part of the water is liable to disappear. No "sink" exists in the Inlé Lake at present, but the point at which the river that flows out of it disappears underground may very possibly have, at one period, been beneath its waters. I have not seen this place and can, therefore, only point out again that a very large tract of country to the south of the lake must at one time have been covered by its waters, and have been gradually filled in by the two processes referred to above, *i.e.*, by the deposition of silt and the formation of peat, especially by the latter agency.

The lake must thus at one time have covered a much greater area than it does at present, and it must have been much deeper, though we have no evidence as to the height to which its waters reached. It may have been over a hundred miles long and several hundred feet deep. Moreover it is by no means the only lake that once existed in the neighbourhood. Indeed, superficial deposits in the emptied basins scattered amongst the hills of the Shan Plateau make it evident that the country was once a regular lake country. Some of the lakes must have disappeared at a remote period, but others have dried up recently, perhaps even in historical times. There are traditions which seem to point to this having occurred at He-Ho. The deposition of silt and the form-

ation of peat have not been the only factors that have led to the disappearance of water from the basins. Another cause has been the eating through of limestone rocks by water rendered acid by the decay of vegetation. The He-Ho stream makes its way down into the lower plain through an ancient limestone ridge, and it is not improbable that the water may have been finally drained from the upper plain by its cutting through this ridge in a comparatively short time under exceptionally favourable conditions.

It is not surprising, therefore, to find that the fauna of the Inlé Lake is a very highly specialised one, differing from any other aquatic fauna yet discovered. The lake is merely the last, shrunken relic of a once extensive system, the connections of which may have been greatly different at different periods in its history. It has, however, been isolated for a considerable time, and evolution has taken place rapidly and widely. To illustrate these facts the different groups of animals must be considered separately, and then the whole summarized. To do this is the object of the present volume.