ORDINARY MEETING.

JANUARY 6, 1882.

W. H. HUDLESTON, Esq., M.A., F.G.S., President in the Chair.

The list of donations to the library since the last meeting was read, and the thanks of the Association returned to the donors.

The following were elected members of the Association :—
Wm. Bushby, Esq.; Geo. Biddell, Esq.; W. M. Crossland, Esq., M.Inst.C.E.; Joseph Faulding, Esq.; G. J. Jones, Esq.; Wm. Smith, Esq.; Herbert Wailes, Esq.; Wm. White, Esq.

The following paper was then read :

ON LAKES AND THEIR ORIGIN.

By PROF. P. MARTIN DUNCAN, F.R.S., V.P. GEOL. SOC.

There is no subject connected with the present and past aspects of nature, which presents greater difficulties than that which relates to lakes. It is true that some kinds of these inland collections of water are very readily comprehended, so far as their causation is concerned, such, for instance, as the crater lakes of Germany, Italy, and Australia, or those bodies of water which are hemmed in by landslips or by ice, and the numerous large but shallow pieces of water in swampy districts, even if these rest upon a hard bottom.

But the larger lakes of the great continents, situated at very different altitudes, and some of them of profound depth, are excessively difficult to account for.

Imagination, however, has not been allowed to rust for want of scientific use, and many hypotheses, some ingenious and clever in the extreme, have enlivened and often materially influenced geological thought. For the lake is not a thing of to-day; it is the outcome of the past, a relic of former and different aspects of nature.

In explaining natural phenomena, the successful hypothesis, if it is to develop into a useful theory, must include the whole truth. And yet one fascinating hypothesis of the origin of lakes, omits the consideration of the origin and period of introduction of the animals of the lake, whilst another does not give any evidence that the physics of the deep sea have been comprehended by its author.

Thus the hypothesis of the glacial origin of lakes does not consider the biological question, and that which relegates the formation of large lakes to the former action of erosion on the sea floor, omits the fact that the sea does not erode at a depth of some scores of yards.

The relation of the natural history of the animals of lakes to their method of origin has been recognised as of importance by zoologists alone. The geologist, pure and simple, has hidden up the biological skeleton in his darkest closet.

Really one of the most interesting of the subjects connected with lakes is the study of the modifications which marine invertebrate forms undergo in their adaptation to a freshwater life; and another relates to this possible origin of many terrestrial species. I ventured to bring some of these facts and ideas before the Geological Society in one of my presidential addresses. In it the relationships of marine and fresh water animals were considered, and also the existence of marine forms and slightly modified marine forms in lakes remote from the sea. Moreover, the address stated, "It would be impossible for a fauna and a flora, like those of the great American, Scandinavian, and larger Swiss lakes, to have existed during the formation of a lake by glacial erosion. If the lakes had that origin, the fish, mollusca, and crustacea, must have been introduced subsequently. But, in many instances, there is no possibility of the migration of the Salmonoids to and from the lake, or of the crustacea into it. There has not been any since the country around received its relative level, and that was, in most instances, before the period of land glaciation." The Swiss lakes were in my thoughts, and the address proceeded: "There is no doubt that the lacustrine forms are not much influenced by cold. The depths of the Swiss lakes have a persistent temperature of from 40° to 60° F., yet the piscine forms are not surface ones only. The temperature of the ice-covered tarns of the extreme north of Europe is not sufficient to destroy the Charms." Finally, it was stated, "Deep lakes cannot have been formed by their running water alone, and certainly the study of their faunas carries back their date to a time when totally different physical and geographical conditions prevailed."

It would be simple waste of time, in addressing an assemblage of geologists, to venture to explain Ramsay's charming hypothesis of the erosion of lakes by glaciers. It is known to you all, and it

is also a fact that very distinguished geologists and physicists, who have paid great attention to the study of ice and glaciers, deny the possibility of lake erosion by stone carried in ice, or by the glacier stream.

Favre, Dana, Whitney, Bonney and Drew are amongst the disbelievers, and those amongst us, whose minds are sceptical, will do well to notice that the retreating glaciers of the Alps leave convex roundings on their floors, and not little concave hollows. A careful investigation of the work done by glaciers, on the grandest scale, leads to the belief that they have not originated their valleys, and that these grand features of the mountain are being slowly worn larger.

But admitting that fish and crustacea could not have originated or existed in lakes and hollows, whilst the presumed erosive process prevailed, it is perfectly evident that the lakes in certain latitudes and altitudes were in the midst of severe glaciation during the glacial period.

That deep valleys were filled with névé and glacier, there is no doubt, and it is equally certain that the lakes were frozen over during the winter to a great depth, and that the ice thawed, and moved, and floated stone in the hot summer.

Sir George Nares remarks that he encamped on a projecting spit of land, in May, 1876, not far from the winter quarters of the Arctic Expedition, and close to Dumbell Lakes. "Hill and plain were covered with snow. The ice in Dumbell Lake, which had not yet begun to thaw, was $91\frac{1}{2}$ inches thick, and the water from below, when reached, rose to within $8\frac{1}{2}$ inches of the surface of the ice. All the water in this lake had certainly not been frozen during the past winter, and afterwards we found it was well stocked with a small species of Charr. Indeed, we did not ascertain that any of the lakes that contained fish froze to the bottom. The evidence tended to the contrary." This is satisfactory evidence that in localities where the cold is now as severe as it was further south during the glacial period, lakes exist with fish.

Many lakes in districts which present abundant evidence of the reign of ice, and show no traces of subsidence since the glacial period, contain Charrs. And in many of the fresh water lakes of Norway, and of Sweden, there are marine crustacea, such as the red Copepod *Harpacticus chelifer*, and such marine crustacea as *Mysis relicta*, *Gammarus cancelloides*, and species of *Pantoporeia*.

There has been no subsidence there since the glacial period.

This fauna, as a whole, is not only common in those inland lakes, but it has a vast lacustrine distribution in America and Asia. In some of the fjord-shaped Scandinavian lakes with this fauna, is *Cottus quadricornis*, a marine fish. Many years since, Lovén, that accurate naturalist, knew all this, and asserted that the lakes of his native country, thus provided, had never been in relation to the sea since the glacial period, and that they could not have been formed by glaciers.

The Lake of Geneva, and its neighbour, of Neuchatel, contain lake Trout, fresh water Bryozoa, and amongst the gasteropods *Limnæus pereger*, which has its respiratory chamber modified into branchiæ, and is a deep water form. There are large Copepods of the genus *Bythotrephes* and *Leptodora*, and there are two members of the Scandinavian crustacean lake fauna. There are Amphipoda, and Cladocera, Isopoda and Ostracoda. The greater part of this fauna lives on the soft mud of the floor, which is at a depth of 984 feet. The Copepods swim by night, and descend into the gloom of the depths by day. This is a very old fauna which could not have been introduced since the glacial period.

Now the lakes are not choked with moraine matter, there is no current on their floor to erode, and the great travelled blocks, found far beyond and above the present level of the Lake of Geneva, were carried down by the Rhone glacier to the lake, and thence moved by surface ice during times of great water level, probably at the very end of the glacial epoch. The Lake of Geneva has a fault on its south margin, along the Triassic rocks; on the north, the secondary and tertiary strata dip in a roll to the lake, and on the east of the lake, on either side of the valley of the Rhone, there are tremendous reversals of strata to the south. There is no evidence whatever to show that any animals could have migrated into the lake since the glacial period, and the evidence is as strong in relation to the Lake of Neuchatel. The Lake of Brienz is 620 feet higher than the Lake of Geneva, and is 2,000 feet deep or lower at the floor than the sea level. Probably it was in the névé during the glacial epoch.

Between the Rhine and the Mont Blanc chain, near Annecy, there is Lake Bourget, and it contains a Blenny, a marine form, and there is no possibility of fish entering now from the sea. In fact, the faunas of the other Swiss lakes indicate a great antiquity, and that they were stocked under marine conditions and before the glacial period.

The great Italian lakes, south of the Alps, have their floors

deeper than the sea level by hundreds of feet. They contain species of the marine genera, *Gobius*, *Blennius*, and *Atherina*, and the shape of the floor, especially of the Lake of Como, and the depth are quite opposed to the notion that glacier excavation prevailed, and certainly there has been no subsidence since the glacial period.

In the far east of the Russian Empire, north of the Altai, and higher than the source of the Lena and Amoor, and on their water parting, is Lake Baikal. It is even now in a severe climate.

It is a long, narrow lake, a holy lake, a grand feature in a dreary district of rugged hills, of granites, syenites, crystalline schists, limestones, and conglomerates. It is 12,500 square miles in extent, and the hills to the north, between it and the distant ocean, are from 3,500 to 4,000 feet high. The lake is 397 miles long, and from four to thirteen miles broad, and 1,800 feet above sea level. It is on a table land with a very gentle slope to the sea, which extends like a gigantic water parting, for hundreds of miles to Behring's Straits. Numerous minor lakes are in the neighbourhood, and they all form part of a very grand water system. The great lake receives large rivers, which drain a district as large as the United Kingdom, and only one small river, the Angora, arises from it, and flows down a rapid and torrential course to the Yenisei River. Baikal is 1,200 miles from the sea.

The lake is of fresh water and is frozen over in winter, by more than 40 inches of ice, and the summer is short.

A promontory nearly cuts the lake in half, and in many parts vertical cliffs of rock stand up out of great depths, and the bottom is singularly uneven in spite of the large number of streams which enter and deposit. Part of the lake is 800 feet in depth, but in laying a telegraph cable it was found to be much deeper in some places, and for many miles.

A ridge in the midst of the lake is 3,300 feet deep, and then the floor slopes to 3,600, 4,200, 3,900, 4,200 feet, that is to say to far below sea level. At the base of the cliffs the depth of 330 feet is met with. The depth is therefore considerable, and the floor in places is lower than the level of the distant sea by at least 2,000 feet. The whole district is ice-marked, and yet the quantity of drift in the lake is inappreciable. It is impossible that there can be any scour going on on the floor.

The temperature of the bottom (constant) is $3\cdot5^{\circ}$ Centigrade, but the surface is often covered by many feet of ice. It is a

greater lake than Tanganyika, and there are terraces around it denoting a former extension.

This lake has *Salmon*, *Trout*, and *Sturgeon* in it, and a dwarfed Cod or *Gadoid* of the genus *Comophorus*.

One of the seals, *Phoca sibirica*, a variety of *Phoca vitulina* of the N. Pacific, inhabits Lake Baikal, and another lake called Lake Oron, which is far to the north and near the river Vikin, a branch of the Lena.

The marine crustacea of the Scandinavian fresh water lakes are also found in Baikal, *Mysis relicta* and *Gammarus cancelloides*.

The seal, the gadoid, and the crustacea, are the descendants of those which lived in the sea of which the Baikal area once formed a part. The Baikal area has not subsided since the glacial period, and nothing can get into it from the sea.

Lake Baikal is a more decided and greater example of a method of origin which applies also to the Caspian and Aral Lakes, for such they are, although called seas.

The surface of the Caspian is below that of the Black Sea by 84 feet, and its depth attains in some places 3,000 feet, being much less in the north. It is a vast sheet of water, 740 miles long and from 210 to 243 miles broad.

Away to the east is Aral, 117 feet above the level of the Caspian. They were formerly connected along what is now a dry, low valley, on the floor of which the common shells of the Caspian are found—*Cardium edule*, *Cardium trigonoides*.

Both lakes are supplied by great rivers, and are saline to a certain extent, and more so away from the rivers which enter them, and the surrounding soils often contain salt. They come under the rule that lakes without rivers leading from them, are brackish or salt.

Aral is not so salt as the Caspian, but it is shallow, and is 72 feet deep in the middle and 216 on the western side, near very perpendicular cliffs which are in relation to a plateau. It occupies 24,536 square miles.

The Caspian fauna consists of a *Phoca* (a variety of *P. fœtida* of the Atlantic) and of *Salmon*, *Sturgeons*, *Sturlets*. Aral has no seal, and its fish are of the same genera as those of the Caspian. In both of the faunas there is a mixture of marine and fresh water types.

Dried-up lakes and terraces denote a former extension of both of these lakes, and it appears impossible to resist the evidence that

these great Asiatic inland waters, despite their differences of altitude, were once parts of the sea.

Between the Caspian and the Black Sea, and east of Erivan in the Ararat district, is a plateau between ridges of mountains, some being extinct volcanoes. The height is 5,800 feet above the Black Sea. A lake is there, Lake Goktcha, twice as large as the Lake of Geneva, 350 feet deep in the middle. There is sweet water in the neighbourhood of the incoming rivers, but it is brackish elsewhere. There is no outlet, and Trout and Salmon exist in vast numbers. The lake is covered with ice in the winter. The fauna must have been introduced when the aspect of nature there was very different to what it is now.

The next group of lakes to be considered is amongst the most extraordinary phenomena of physical geography.

Lakes do not exist along the lines of the Glacier valleys to the south of the Himalayas, but they are found at great altitudes, on an irregular table land which stretches from the Kuen Lun Mountains through Western Tibet eastward, and to the head waters of the rivers watering China. To the south are the greatest elevations of the Himalayas, and to the north a more or less gradual slope to Turkestan. The most important landmarks are the Indus and Sutlej rivers at their origin and early east to west course; and extending far to the east and south is the Brahmaputra or the Tsampou. There are lakes north and south of these east and west running rivers, separated by many hundreds of miles.

Firstly—North of the Indus, south of Kotan, and east of the line joining Yarkand and Leh (78° E. long.) are the *Pangong* series and others. One is 100 miles long and seven broad, and the depth is 136 feet; the height of the plateau is 15,000 to 16,000 feet.

Secondly—South of the line of the Indus and Sutlej, but to the east of those rivers, in Nari Khorsum or Hundes, is *Langcho* lake, which is 13,000 to 15,000 feet above sea level, and *Chomopang* or *Manasarowar* lake. To the east of this last, a range of hills separates the valley of the Brahmaputra or Tsampou.

Far away to the east (10° long.), north of the easterly flowing river, is a small lake 15,190 feet above sea level, and separated from the river, by a pass of 17,200 feet. This Tangri lake is embedded in hills, and is 45 miles long by 25 broad. It contains islands,

is the recipient of the waters of two considerable rivers, has no outlet, is brackish, yet freezes. There are cyprinoid fish and mollusca in these lakes. Hot springs, 130-137° F., exist to the south of the area. South of the lake is a grand range of peaks and glaciers, 25,000 feet being attained.

On the southern side of the river Tsampou are several lakes—Yemdok, at an altitude of 13,500 feet, being the most noteworthy. Still further north-eastwards is the Kakonur lake, on the road from Lhasa to Pekin.

The Himalayan moraines under present formation reach down on the south of the chain to 14,000 to 16,000 feet, and are much higher to the north. The drift of the river-wearing and of the old glaciation of the Himalayas is found up to 16,000 feet, and yet these lakes are not filled with it, and they contain in some instances, fish and mollusca. It appears that every geologist who has visited these upland regions, notices the slight relics of the presupposed ice action. Of fluvial and subaerial erosion there is abundant evidence, and of much that occurred before the glacial period.

The Pangong series of saline lakes shows very distinctly, especially Lake Tso Morisi, 248 feet deep, that they are part of a long valley, stopped up here and there by the alluvial deposits of streams running more or less across its line. Many small lakes are marked in this great upland district on the survey map of India, and nearly all tell the same story. They have rarely any outlet, are more or less brackish, are at great elevations 15,000 feet being the highest point. They are on the table land, and not in the line of the glaciers, but on the line of strike of the mountain mass and in old valleys of fluvial erosion. No marine strata, younger than the nummulitic, are near, the Himalayas having attained their greatest development in the Pliocene age, before the glacial epoch.

The valleys of the Himalayas were mainly worn before the glacial period, and fluvial drift fills up enormous old lakes. The remains of old glacial action are to be traced on the river drift to 8,000 or 10,000 feet above the sea level.

Before passing on, it is as well to sum up the bearings of the facts just considered. Lakes of very different elevations, many within the areas of present and past glaciation, are deep, uneven on their floor, and are not crowded with glacial *débris*; moreover they contain a fauna, a large portion of which indicates a marine origin. This fauna cannot have been introduced in most places

since the glacial period, and its presence is incompatible with the erosion of such lakes by glaciers. But the sea could not excavate such lakes any more than glaciers; its eroding power, except in such places as the tidal bay of Fundy, being restricted to a few fathoms of depth.

The terrestrial condition must, therefore, have preceded the marine, and the lakes were worn, in the first instance, by rain and rivers, and then their areas participated in the crushing, subsidence, faulting, and upheaval which have affected all their regions during the later tertiary ages. The fauna has lasted on, and is a relic of the past.

Eastern Africa, a grand country of table land, has of late years been the subject of much geographical research, and everybody is aware of the wonderful travels of Livingstone, Speke, Stanley, Cameron, and Burton. The search for the sources of the Nile abolished the mountains of the moon, and established the existence of a grand series of lakes, some in relation to that great river, and others feeding the Zambesi to the south and east, and possibly the Congo to the west. These lakes are separated from the sea to the east, by the Abyssinian table lands and mountains, by the Somali country, and the chain of hills bordering the Mozambique Channel. They are isolated by high land, and they are at considerable elevations above sea level.

From the Red Sea at Massovah south to Somali-land there are not only high mountains (that of Kenia reaching 18,000 feet), but abundant evidences of great volcanic activity having taken place in late geological times, such as extinct craters, hot springs, and lava flows. These extend into Abyssinia, where volcanic energy developed itself on a very grand scale. Moreover, there is a decided parallelism between some of the lakes and the strike of the mountains, and they occupy vast valleys, often surrounded by high ground or table-land. No tertiary strata are known in the districts, which consist, it is said, of crystalline and schistose rocks.

The Nilotic group of lakes are large, and they are the Victoria Nyanza, Albert Nyanza, Dembea lake, and probably the Boringo lake. The Victoria Nyanza is 3,300 feet above the Albert, which is 2,500 feet above sea level. Dembea is at an elevation of 6,000 feet on the Abyssinian plateau.

South is Tanganyika, a lake separated from those just mentioned by hills of 10,000 feet, and enclosed by plateaux and steep

mountain masses. There is a small outlet, not always permeable, but it is mentioned by Cameron. The water is sweet, and the height is 2,756 feet. If it joins the Congo, then it is associated with the next group of lakes in relation to the rivers Lualaba and Congo; Bembo, 4,000 feet, 150 miles east and west by 75; Moero and Ulenge, 2,000 feet. Finally, Nyassa, 1,300 feet, a north and south lake, opens into the Zambesi by the Shir, and has two lakes associated with its outlets. A great mountain system, remote from that of the coast range, environs it.

In considering these vast lakes which are supplied by numerous rivers, one is struck by the presence of islands in some of them, of scarped hills surrounding others, and terraces rising from them. For instance terraces occur, denoting a former higher level to the water of Nyanza, and there are levels at 3,800, 4,500, and 5,100 feet. There are no evidences of volcanic action in the immediate neighbourhood. Unfortunately these lakes have yet to be carefully examined. The depths are not satisfactorily given, the geological sections are not dealt with, and finally, the faunas of the lakes have not been described.

But Edgar Smith, of the British Museum, has lately written on the mollusca of Tanganyika, and finds that some resemble marine forms in a most remarkable manner. They are not identical with known forms, but the spinose ornamentation would immediately suggest marine progenitors. Moreover, they belong to a genus found to exist in the lower tertiary of North America.

The difficulty of accounting for these lakes is great, but they were not of glacial origin, and the sea did not erode them.

That vast changes of level have occurred in the north-east of Africa and far away to the north, and along the line of the Jordan, is evident. There is the grand fissure of the salt Dead Sea, which is 1,390 feet below that of the Mediterranean, and the Lake of Galilee, 380 feet below sea level. The Jordan's waters lose themselves in the salt sea. Yet Günther recognises Nile fish in the sweet waters of Galilee.

Denudation, when the surface was higher, faulting and steady local subsidence to below sea level, and then diminution in breadth and increase in depth, produced during the lateral thrusts which developed the last mountain masses in the neighbourhood, and last of all upheaval. These may have produced the lakes, while volcanic undermining may also have had its effects.

It is now necessary, in conclusion, to pass to a totally different series of lakes, the grandest in the world in point of size, and which, although they are not at great altitudes above the sea, have their floors for the most part lower than sea level. The greatest series of lakes is in North America, and the surface covered by their water is greater than that of any other lacustrine area.

Lake Superior is a lake of irregular outline, of vast dimensions, and land-locked, except on the south-east, where it enters a system of two lakes, which have a more or less longitudinal direction. One of these, Lake Huron, has an irregular outline and a considerable development of islands in its north-east part, and the other, Lake Michigan, is a long, narrow lake whose southern extremity is further south than that of Lake Huron, the territory of Michigan separates these lakes, which latter passes by the St. Clair into the small lake St. Clair, and thence to Lake Erie. Lake Erie, a long and comparatively narrow lake, has its long axis at right angles to that of Huron, and passes by Niagara Falls and River, to Ontario, a great lake whose water flows into the St. Lawrence River.

The dimensions of these lakes and their altitude above sea level diminish to the south-east, as may be seen by the following list :—

	Altitude.				Depth.
Superior	...	630 feet	...	...	800—900—1,026 feet
Michigan	...	600	,	...	870
Huron	...	600	,	...	204—750
Erie	...	563	,	...	72—210
Ontario	...	234	,	...	400—738

Lake Superior may be compared to a vast crescentic basin with a high rocky rim scooped out of the plateau extending from the Alleghanies to the Mississippi River ; the high land to the north divides the water flow, some going north to Hudson's Bay, and some south to Lake Superior. Its greatest length must be 360 miles (north and south 140), and it is 1,500 in circumference. The mountainous rim is almost unbroken, and its height ranges from 800 to 1,300 feet. The northern sides of the lake have abrupt rocks, and the southern sloped ones. To the north the shores are composed of large and angular stones, and sand is hardly seen, except at the mouths of the large rivers ; but to the south the beaches are low and sandy, and the rivers are frequently

filled up. The northern and eastern rivers enter it by rapids. This huge basin is filled with clear, pure water, faintly greenish in hue, and of from 37-40° F. in the summer. It is 630 feet above sea level (627 feet, Bayfield).

The northern shores of Lake Superior and the mountainous country inland, show unmistakable ice-work. The rocks are polished, scratched, smoothed, rounded, almost uniformly in the direction of north and south. Agassiz noticed that for 1,500 miles the heterogeneous materials of which the rocks consist, are cut down to one continuous level, adapting itself, however to the general undulations of the country. The hills show abrupt slopes and rough and sharp curves to the south, but they are smoothed off towards the north. Many valleys, running more or less east and west, are crossed by north and south scratches; and here and there on the sides of the lake, and amongst its islands there are confused striæ, indicating no prevailing direction of ice movement. Accumulations of glacial drift, more or less stratified, are found on the smoothed surfaces, and boulders are mingled with them; and all these materials are scratched and more or less polished.

The floor of Lake Superior is gently undulating, with steep margins. The mean depth is 800 feet below the present surface. Some soundings exceed 900 feet, and one is 1,026 feet. The greatest depths are nearer the shore than the centre, which is uniform and a great dead level, and on the north-west the great depths are close to the shore. Hence the floor of the lake is below sea level, is flat in the greater part, and deep near the rim. The lake floor, to the north, consists of the bases of the same rugged hills of crystalline and metamorphic rocks which bound the lake. The floor throughout is not covered with any great depth of drift deposit, hard and rocky bottoms being constantly found in sounding; but dredging brings up fine drab or bluish clay. The temperature below 200 feet is 39°.

Two very important physical phenomena are to be considered. First, terraces of sand and shingle covering striated and polished rocks, ascend in grand steps. The highest terrace is 300 feet above the present lake level. Corresponding terraces and slopes, one over the other, are found on the flanks of the river valleys entering the lake. The sand and shingle is worn-down drift. The second fact is, that the great depths of the lake form a channel of 200 miles in length, eroded out of the north-west part of the lake's floor.

That the terraces were produced by shore action of the water of the lake, is beyond doubt; but was the water ever 300 feet higher than it is now? Had it been so, it would have overwhelmed everything to the south; and then how should we account for the lower terraces?

Again, how could a deep channel 200 miles in length, and some 20 or 30 broad, be formed in hard rocks at a depth below sea level?

The terraces were produced during slow upheaval and occasional stationary conditions, and the channel belongs to an age long anterior, and which relates to the initiation of the lake.

A considerable vertebrate and invertebrate fauna exists which cannot have co-existed with the phenomena of rock erosion by ice, nor has it been introduced since the glacial period.

Amongst the fauna are the *Lepidosteus*, or Gar Pike—a genus of ganoid freshwater fish, found also in the great American rivers; peculiar species of sturgeon, *Amia*—a siluroid, percoid fish closely resembling European forms, sticklebacks, pikes, gadoids—of the genus *Lota*, *Coregonus* or White fish of the salmonidæ, carp, gobies, roach, the lake herring, and lampreys.

This fauna is essentially a fresh water and continental one, and the affinities of its species with those of the other parts of the North American continent and Europe-Asia, denote a long duration of terrestrial conditions. The *Lepidostei* and the *Siluroids* point to a very considerable antiquity.

The invertebrate fauna contains the genera *Limnæa*, *Physa*, and *Planorbis* amongst the freshwater shells, and a *Hydra* and *Tubifex*. But the crustacea, *Mysis relicta* and *Pontoporeia affinis*, are present, and certainly they had a marine ancestry, as in the European lakes already mentioned.

As the boundaries of this great lake are so rocky, they present a great distinction from those of the other lakes, which, as they pass southwards, become flat at their margins, and, as far as scenery is concerned, often resemble the sides of great ponds.

Lake Michigan has a very level floor, deepest in the northern part, and shallowing to the south. It is for the most part a very plain surface, 600 feet deep to the north and 300 feet to the south. The deepest sounding is 870 feet, and this part of the floor is below sea level, but is on a higher level than the profound depths of Lake Superior. The pitch is often not more than 40 feet in a

mile, yet near the eastern side there is a line along which the depth increases from 102 feet to 456 feet, so that there is, as in Lake Superior, a submerged ravine or canon. The *Mysis* and *Gammarus* are present, and *Trigloopsis*, a marine-looking fish.

Lake Huron, 600 feet above the sea, is shallow in parts, being seldom 210 feet deep in the south-west, but it has a channel 300 feet in the midst. Shallow water also exists (204 feet) to the north. But in the north-east 750 feet is attained, and there are plane surfaces and deep ravines on the floor, which lead from the northern parts of the lake, and unite as they proceed southward, being separated by elevated tracts. It must be specially noticed that the shores to the south-east of the lake have drifts 130 feet deep on them.

Lake Erie, 563 feet above sea level, is a shallow lake, and has its bottom as nearly level as any terrestrial surface. For 156 miles from the western border its mean depth scarcely varies 72 feet; then there is an area 210 feet in depth, followed by shallower water, then a deeper channel is found, taking its course between Long Point and the exit of the lake in the Niagara River, that is, in a north-easterly direction.

Lake Ontario, 230 feet above sea level, is a broad, not very deep basin, with an escarpment at the western end and terraces between it and the shore. The floor of the lake slopes gradually down to the mean depth of 400 feet at the rate of 30 feet in the mile; then there is a deeper part of 540 feet, with a trough in it reaching down to 600 feet, and in some places to 738 feet. This is a long channel nearer the American shore than the Canadian, and it is from 3 to 12 miles in breadth. The study of the soundings indicates that the southern margin of Lake Ontario has a series of submerged terraces, and, in fact, if it could be lifted out of water, the landscape would present the terraced appearance of the Niagara side. Now, these submerged terraces are, of course, separated by escarpments, and thus the outline of the floor will be more or less stepped, and will show a great longitudinal chasm.

On land, on the Niagara side, east of Niagara, and corresponding to the position of the end of the deep channel of Lake Erie, remains of a vast cañon filled with drift, and 743 feet in average depth, have been found. That is to say, a deep and wide gorge, down which a river flowed, connected Erie and Ontario, and the floor of

the river in it was 180 feet *below* the present surface of Ontario. This gorge is filled with drift, and therefore was in being before the drift. It existed before Niagara River and Falls.

On mapping out the direction of the deep channels of Huron, Erie, and Ontario, it becomes tolerably evident that a deep valley in a rather flat country, assuming now and then the characters of a cañon, ran from Lake Huron through the land to Lake Erie, and from Lake Erie to Lake Ontario, and then along the American side of the latter.

Late researches have indicated that Lakes Michigan and Superior discharged towards the Mississippi, but the first entered Superior by an eastern cañon. But all these deep channels, cañons, and flat and sloping and rocky bottoms, belong to a system of drainage which existed *before* the age of the drift. The present drainage is the result of the blocking up of the former outlets by drift.*

Hence the great lakes were in existence before the glacial period, and the greater part of their fauna lived then, and the species have never become extinct.

Covered and nearly filled with ice during the severe winters, and crowded with icefloes and small bergs, the relics of the broken ends of the great glaciers which came down to and into the lakes for a certain distance, the lakes were yet never entirely filled with ice which could carve them out of the hard rocks of their area.

The only manner in which the present floors could have been made, was by subaerial erosion in preglacial times, and then were formed the valleys and cañons. The fauna existed then, and probably the sturgeon, salmon, and crustacea made their way from the sea along the outflowing river. Then came the subsidence which enabled the waters to collect, and finally to reach to 300 feet higher than now, and to cover the sloping lands by the sides of the long chasms. Subsequently the glacial period began, and ice reigned to a certain extent supreme. No sea reached the lakes, and they were not filled with drifts, but were carriers of some of it by their floating ice. Gradually upheaval commenced, and terrace after terrace was developed, and the present level at last was gained.

The theory of the subaerial denudation of the floors of these lakes

* Surveyed by Spencer.

appears to simplify the notions regarding the course of the contours of the great African lakes, and even of Baikal.

Time will not render it possible to do more than notice the fact that there are around and beyond the great American lakes, especially to the north-west, a great series of smaller ones.

The last lake to be mentioned in South America is Titicaca, 100 miles north of Arica on the western side of the continent, and it is the highest known lake of any very considerable dimensions. Placed on a table land of some breadth, and with hills in the distance, this large lake is 12,800 feet above sea level, and its greatest depth is 924 feet. Many parts are shallow and even swampy; there are islands also, and the whole area covered is 4,600 square miles. A small river issues from the lake to the south, and runs for 180 miles, and terminates in the Lago del Desaguero.

The lake is beyond all glacial action, and contains *Siluroïd* and *Cyprinoid* fish, besides some very remarkable crustacea belonging to the Amphipod group and to the genus *Allorchestes*. These are remarkable for being small, many-legged things with one of the front claws greatly enlarged. Some are found at a depth of 396 feet in the lake, which is of fresh water. Now, these crustacea belong to a genus which is usually marine and found on the shore. But fresh water species are found in streams and by the side of still water all over the American continent.* The deep-dwelling species from Titicaca are examples, then, of a genus which is pre-eminently littoral. No fresh water forms of the genus are found in the Old World.

The principal interest, however, of this lake is, that there are indications of great upheaval of the country during the latest geological age. On the coast to the west of Titicaca, and distant 20 miles from the Pacific, corals were found attached to rocks under the great deposit of nitrates which is found there. They were from 2,500 to 3,000 feet above the level of the sea. They were not of ancient species, but belonged to the present day, and moreover a species of nullipore and a crustacean were found in a pool of salt water at about the same level. Saline deposits on the west slope of the Andes exist even to 7,000 feet, and all this evidence tends to prove, that within the days of the existing marine animals, the West Coast of South America

* Surveyed by A. Agassiz and De Pourtales.

has slowly risen from the waves, to its present grand development.

But even with this explanation of the present height of the lake, and the existence of its marine-looking crustacean fauna, the cause of the lake and its very considerable depth remain unexplained. It is situated in palæozoic rocks of carboniferous age, and there are at some distance, and at a height of 15,000 feet, extensive volcanic rocks. Subaerial erosion and volcanic undermining probably occurred before the subsidence which let the area below water and filled it, forming a deep sounding in the sea.

In concluding, it is necessary, briefly, to sum up the facts and arguments which have been brought to bear on the question of lakes. It is clear that these beauties of Nature have usually been associated with grand movements of the crust of the earth, with the subsidence and upheavals and curvings of the strata which have developed, at last, the present continental systems. Every great lake has had its floor eroded, in the first instance, by subaerial agents, and it formed then part of a tract of subaerial wear and tear. This erosion may have been intensified by movements such as curving, faulting, and local subsidences, until a district became lower than the neighbourhood. Subsequently the valley within or outside a mountain system, had its own watersheds, and was part of a hydrographical basin.

The next stage was one of partial subsidence, and greater or less intrusion of the sea, and then came participation in the continental movements which developed table lands and great anticlinals and synclinals; a great altitude being given to the lakes in the one instance, and a great depth of the bed in others, with diminution of breadth.

When within the influence of the glaciation of a mountain range, the lake being already formed, and in a line of drainage, it was in some instances a tract of floating ice carrying glacial *débris*, and as the land rose or the waters became less in the lake, this was deposited on its flanks and shallows.

There are good reasons for discrediting the hypothesis that the sea, or ice in the form of a glacier, can erode and wear out bottoms some hundreds of feet deep, and the remarkable fauna of some lakes gives them a certain geological age.

The impossibility of the introduction of such a fauna as that of the lakes of Geneva, Brientz, and of Northern Italy, of Baikal, Aral,

and Tanganyika, and the great American lakes by the accident of the carrying power of birds is tolerably certain. Migration from a watery source, over land, is impossible in the majority of the present lacustrine faunas, the fish with protected gills being alone capable of it.

It follows that the present faunas of lakes are the outcome of marine, brackish, and fresh water accessions during the mutations in the level of the surrounding areas.

ANNUAL GENERAL MEETING,

FEBRUARY 3, 1882.

W. H. HUDLESTON, Esq., M.A., F.G.S., President, in the Chair.

The following report was read :—

The Census of the Association on January 1st, 1882, was as follows:—

Honorary Members	...	...	...	...	...	15
Ordinary Members—						
<i>a</i> Life Members (Compounded)	...	...	...	...	...	85
<i>b</i> Old Country Members (5s. Annual Subscription)	...	...	...	...	...	20
<i>c</i> Other Members (10s. Annual Subscription)	...	...	...	...	...	370
						<hr/>
Total	...	...	...	...	...	490
						<hr/>

Showing an increase of 34 Members for the year.

The Association has experienced very considerable losses by death during the past year. Allusion has already been made, at the meeting in March, to the death of Professor Tennant (see "Proceedings," vol. vii., p. 95), who was the third President of the Association (1862-1863), and whose services were so valuable in its earlier years. Under his auspices good work was done. Among the "Proceedings" and Papers of this period we find the following :—"On Ancient Flint Implements in Yorkshire," by