SURVEY OF SCOTTISH LAKES.

DURING the past three or four years the bathymetrical survey of 554 of the fresh-water lochs of Scotland has been completed under the direction of Sir John Murray and Mr. Laurence Pullar. This practically means that all the Scottish fresh-water lochs have now been surveyed, except some small ones on which no boats could be found. A large staff has been employed during the course of the work—about forty voluntary and paid assistants, in addition to a great many boatmen and other workmen. Up to the present time, the charts of 180 lochs, with descriptions, have been published in the *Geographical Journal,* and arrangements have now been made for the publication in the same journal during the present year of the descriptions and charts of the thirty-three lochs in the Ness basin. This will complete the publication of the observations made in the more important lochs. The results obtained in the case of the remaining 340 lochs will be published, as a special volume, by the Royal Geographical Society in about eighteen months from this date, the charts being at present in the course of printing by Mr. J. G. Bartholomew.

Besides the purely bathymetrical aspect of the survey, papers have been published by Prof. Chrystal on seiches, by Mr. E. M. Wedderburn on the temperature of Loch Ness, by Mr. E. R. Watson on ionisation of air in vessels immersed in deep water, by Dr. Wesenberg-Lund on a comparative study of Scottish and Danish lakes, by Prof. Bachmann on phytoplankton of Scottish and Swiss lakes, by Mr. G. West on aquatic plants, by Mr. James Murray on fresh-water animals, by Drs. Peach and Horne on the geological surroundings of the lochs, and other papers.[1]

The last published paper[2] treats of the lochs within the basin of the Lochy, the relative positions of which are shown in the little index map of the district (Fig. 1). The total area of the basin exceeds 400 square miles, the diameter from east to west exceeding forty miles, and from north to south exceeding twenty miles. Of the ten lochs within the basin, five exceed three miles in length and four exceed five miles in length, while Loch Lochy is nearly ten miles, and Loch Arkaig twelve miles, in length; five of the lochs exceed 100 feet in depth, and three exceed 300 feet in depth, while Loch Lochy exceeds 500 feet in depth; five of the lochs cover a superficial area in each case exceeding a square mile, and four exceeding two square miles, while Loch Arkaig and Loch Lochy each cover an area of about six square miles. The two largest lochs (Arkaig and Lochy) drain into the River Lochy, while the remaining lochs within the basin (Pattack, East and West na h-Earba, Laggan, Ossian, Ghuilbinn, Treig, and an Dubh Lochan) drain into the River Spean, which joins the River Lochy shortly after its exit from Loch Lochy; the little Loch nan Gabhar and Lochan Lùnn dà-Bhrà drain by independent streams into Loch Linnhe. In these twelve lochs, which cover an area of about twenty square miles, nearly 2600 soundings were taken, or an average of 214 soundings per loch, and 129 soundings per square mile of surface; the aggregate volume of water contained in the lochs is about 85,855 millions of cubic feet, or more than one-half of a cubic mile, and the area draining into them is more than 270 square miles, or fourteen times the area of the lochs.

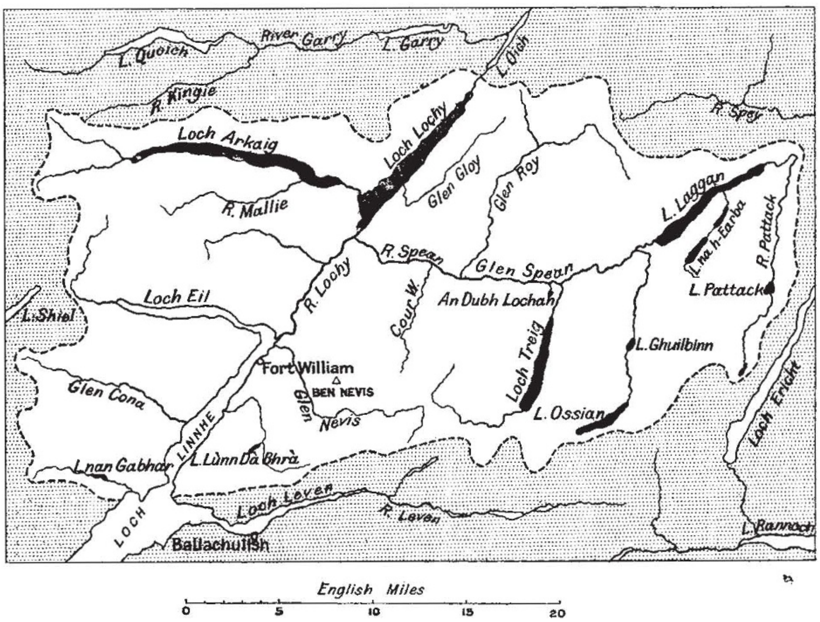

FIG. 1.—Index Map of the Lochy District.

Loch Lochy (see Fig. 2), the southernmost of the chain of lochs occupying the Great Glen, utilised in forming the Caledonian Canal, is a straight loch, having the form of a narrow triangle with the apex at the north-east end, whence it widens gradually southward to Bunarkaig, where the maximum breadth of a mile and a quarter is found, the average breadth of the whole loch being three-fifths of a mile. The superficial area is nearly 3800 acres, and the volume of water about 37,726 millions of cubic feet, the maximum depth being 531 feet and the mean depth 229 feet. All the contour lines are continuous, the 100-feet contour enclosing an area little less than the total length of the loch, while the areas enclosed by the 200-feet, 300-feet, and 400-feet contours are respectively $6\frac{1}{2}$, $4\frac{3}{4}$, and 3 miles in length. The 500-feet contour encloses a very small area, one-third by one-eighth of a mile, just about the middle of the loch.

Loch Arkaig (see Fig. 3), a long, narrow, curved loch, trending nearly east and west, lying about a mile to the west of Loch Lochy, is of somewhat irregular outline, broadest in the middle parts, where the loch is nearly a mile wide, and tapering towards each end, the mean breadth being half a mile. The superficial area is about 4000 acres, and the volume of water about 26,573 millions of cubic feet, the maximum depth being 359 feet and the mean depth 153 feet. The basin is nearly simple, the slight irregularities being doubtless correlated with the curving outline. The 100-feet contour is continuous, but the 200-feet contour is broken into two basins, and the 300-feet contour into three basins. The largest 300-feet area, just about the middle of the loch, is two miles in length, and includes the maximum depth of 359 feet.[1]

Loch Treig occupies a deep, narrow valley trending north and south among very high mountains in the region of Lochaber, the West Highland Railway running along the east side. It is more than five miles in length, with a maximum breadth of three-quarters of a

[1] See Trans. Roy. Soc. Edin., vol. xli. pp. 367, 599, 677, and 823; vol. xlv., p. 261; Proc. Roy Soc. Edin., vol. xxv., pp. 1, 401, 593, 609, 637, 967; *Geogr. Journ.*, vol. xxiv., p. 429.

[2] "Bathymetrical Survey of the Fresh-water Lochs of Scotland." Under the direction of Sir John Murray, K.C.B., F.R.S., and Laurence Pullar. Part xii., The Lochs of the Lochy Basin (*Geogr. Journ.*, vol. xxviii., pp. 592-615; with 8 plates of maps).

[1] It is odd that surveys were apparently made of Lochs Arkaig, Lochy, and Ness about eighteen years ago by a German military officer named Sandler, who lived for some months in the district. The results of these surveys have never been published, but a copy of that of Loch Arkaig was obtained from Mr. Honeyman, factor to Cameron of Lochiel, which corresponded very closely with the results of the Lake Survey.

mile, and a mean breadth of half a mile, covering an area of 1540 acres, and containing 13,907 million cubic feet of water; the maximum depth is 436 feet, and the mean

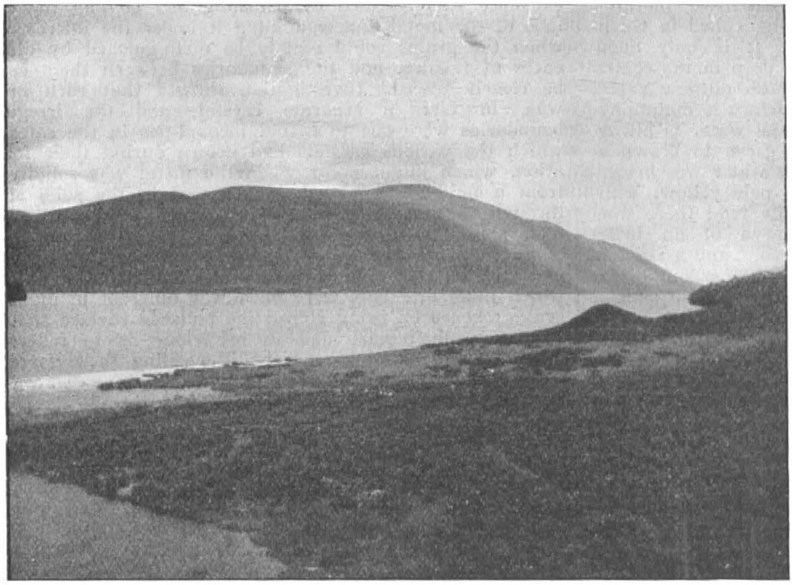

Photo.] FIG. 2.—Loch Lochy, from the southern end. [James Chumley.

depth 207 feet. The loch forms a narrow triangle, broadest towards the south and tapering towards the outflow, the steep slope of the hills being continued under water. The basin is simple, all the contours approximately following the shore-line, but the line of greatest depth is nearer the western shore. The 400-feet area is about two miles in length, the two ends approaching very close to the west side, where the steepest slopes occur. The valley is so narrow relatively to the depth of the loch that, in the central parts, the steep slopes reach far towards the middle and leave comparatively little level bottom, but towards the south end, where the loch is broader and not quite so deep, there is a greater extent of nearly flat bottom. It is interesting to note that seiches were first observed by the staff of the Lake Survey in Loch Treig.

Loch Ossian lies at an elevation of about 1270 feet above the sea to the north of Rannoch Moor, trending north-east and south-west, with its long axis slightly curved, and of nearly uniform breadth throughout. It is $3\frac{1}{4}$ miles long, and nearly half a mile in greatest breadth, the mean breadth being one-third of a mile. The superficial area is nearly 660 acres, and the volume of water about 1224 million cubic feet, the maximum depth 132 feet, and the mean depth 43 feet. The lake-floor is very uneven, both the transverse and longitudinal sections being undulate.

Loch Laggan, situated between the Highland and West Highland Railways, the coach road from Kingussie to Tulloch passing along the northern shore, trends north-east and south-west, and is of the usual elongate, narrow form of Scottish lochs, narrowest in the central parts and somewhat expanded towards each end, where deeper water occurs; the outline is very irregular, and the bottom correspondingly irregular, with a number of larger and smaller islands in the narrower parts. It is more than seven miles in length, two-thirds of a mile in maximum breadth, the mean breadth being nearly half a mile, and the superficial area about 1900 acres. The maximum depth is 174 feet, the mean depth 68 feet, and the volume of water about 5600 million cubic feet. The shallower contour lines are continuous, and follow approximately the outline of the shore, but all the deeper contours are much broken up. There are four 75-feet areas and six 100-feet areas, the largest and deepest approaching the west end.

Lochan na h-Earba is the name applied to two distinct lochs (now differing by nearly 10 feet in level, though they may once have formed a single loch) lying in a valley running nearly parallel to, and about a mile to the south of, that occupied by Loch Laggan. The *west loch* is the larger and deeper of the two, nearly two miles long by one-third of a mile in greatest breadth, covering an area of about 263 acres, and containing 408 million cubic feet of water, with a maximum depth of 81 feet and a mean depth of $35\frac{1}{2}$ feet. The basin is simple, the contour lines being continuous, but narrowing more decidedly than the outline from the centre to each end, the slopes being much steeper towards the centre of the loch. The *east loch* is about half a mile distant from the west loch, the stream conveying the overflow from the west loch winding through the boggy flat between them. It is $1\frac{1}{4}$ miles long by a quarter of a mile in greatest breadth, covering an area of about 146 acres, and containing 191 million cubic feet of water, with a maximum depth of 69 feet and a mean depth of 31 feet. The deep water is all towards the upper end, the lower half being very shallow.

Besides the larger lochs thus briefly summarised, details are given in the paper of Loch Pattack, the highest loch surveyed in the basin, with a maximum depth of 58 feet and a mean depth of 14 feet; of Loch Ghuilbinn, with a maximum depth of 49 feet and a mean depth of 13 feet; of an Dubh Lochan, a very small but relatively deep loch near Loch Treig,

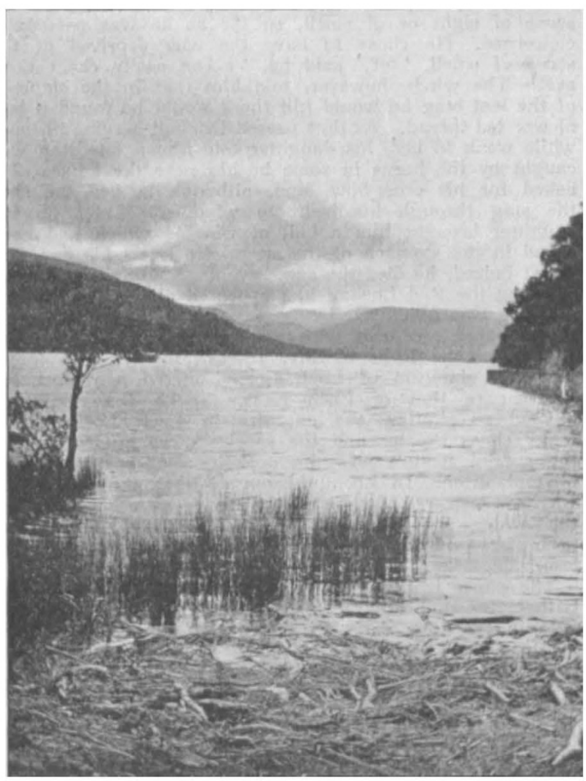

Photo. James Chumley.
FIG. 3 —Loch Arkaig, from the east end.

with a maximum depth of 40 feet and a mean depth of $15\frac{1}{2}$ feet; of Lochan Lunn dà-Bhrà, with a maximum depth of 25 feet and a mean depth of $8\frac{1}{2}$ feet; and of Loch nan Gabhar, a little weedy hollow only 5 feet deep, which is evidently being rapidly silted up. An interesting account is also given of the Red Lochan at Tulloch, a small pond lying in an extensive morainic terrace near the north end of Loch Treig, called in Gaelic by a name signifying "brown eye." It is only about 30 yards in longest diameter and 5 feet deep in the centre, fed only by rains, and, though it has no outflow except by percolation through the gravel, its surface is maintained almost constantly at the same level. The water is always turbid, and varies in colour from dull green to brown or red. When examined in May, 1902, the water was brown, the collection with the coarse net was pale yellow, while that taken by the fine net was decidedly red; there were only two abundant organisms, the larva of an insect (Corethra) known as the "phantom larva," and a reddish-coloured rotifer, *Anuraea valga*, to which the colour of the water was evidently due, for none of the other organisms were abundant enough to be held responsible for the colour of the water. On placing the collections in formalin, a blood-red sediment was deposited, which was found to consist chiefly of *Anuraea valga* and myriads of its red eggs. Examined subsequently at different seasons, the changes of colour were doubtless correlated with the predominance of one or other organism. None of the other ponds in close proximity shared the turbidity and reddish-brown colour of the Red Lochan, the peculiarity being probably due to its being more closely shut in, the surrounding rim of gravel being 14 feet or more above the pond, and there is besides a fringe of birch trees. The water is stagnant, which favours the growth of certain organisms, particularly *Anuraea valga*. It is said that wildfowl never settle on the pond, and that the common frog cannot live in it. The following legend was related to Sir John Murray concerning this Red Lochan:—"Many centuries ago there lived in these parts a noted hunter named Donnuil. In return for some services rendered to the witch of Ben-a-Vreich, she offered to deprive the deer of the sense of sight or of smell, so far as he was personally concerned. He chose to have the deer deprived of the sense of smell, 'for,' said he, 'I can easily cheat their eye. The witch, however, told him that in the stomach of the last stag he would kill there would be found a ball of worsted thread. As time passed Donnuil became ill, and, while weak in bed, his daughter told him a fine stag was caught by the horns in some bushes near the house. He asked for his cross-bow, and, although in bed, he shot the stag through his bedroom window. Later on his daughter brought him a ball of worsted which had been found in the stomach of the stag. He knew his end was near; indeed, he died the same evening. On the following morning the Red Lochan had appeared at the place where the stag was killed."

The paper concludes with some interesting notes on the biology of the lochs by Mr. James Murray, who found that the plankton of Loch Lochy offered a remarkable contrast to that of Loch Ness, though the conditions seemed so similar, the quantity in Loch Lochy being many times greater and the species more numerous, but the special feature was the quantity and variety of the phytoplankton. In Lochan Lùnn dà-Bhrà the Diaptomus was so deep red that when the nets were drawn from the water they seemed to contain blood; the same peculiarity was observed in An Dubh Lochan, but in a lesser degree.

The paper is illustrated by coloured maps showing the bathymetry and orography, and there are several woodcuts in the text, some of which are reproduced in this notice.

THE STRUCTURE OF METALS.[1]

THE lecturer said that his purpose was to give some account of researches in which he had been engaged for a good many years, dealing with the manner in which metals were built up and the manner in which their structures allowed them to yield when they were compelled to change their shape by being overstrained. A piece of metal was not a homogeneous single thing; it was a collocation of grains or granules, which built it up just as granules of ice built up a glacier. The grains of metal were irregular in shape and unequal in size. Their existence was revealed by polishing and etching the surface of the metal and examining it under the microscope, when the grains could readily be distinguished by differences of texture, and the boundaries between them could be clearly traced. Investigation showed that each grain was, in fact, a separate crystal, and the irregular boundaries were due to casual inequalities in the rates at which the various crystals had grown during their formation, which might occur when the metal was solidifying from a fluid state, or when it passed in the solid state through certain temperatures at which re-crystallisation took place. Each grain might be regarded as composed of an immense number of molecular brickbats grouped in perfectly regular tactical formation, but the direction in which these brickbats were piled was different in different grains; hence on being etched the polished surface showed differences in texture and in behaviour as to reflecting light. Microscopic photographs illustrating these features in iron and other metals were exhibited.

When the metal was strained beyond the elastic limit, and thereby compelled to change its form, the change of form took place by slips occurring between the layers of molecular brickbats in the individual granules. The discovery of these slips had been made by the lecturer in conjunction with Mr. Walter Rosenhain, by noticing certain lines to appear on the polished surface of a piece when subjected to severe strain. These lines, which they called slip lines, looked like minute crevasses, but were really steps caused by the slipping of one layer on its neighbours, just as cards might slip in a pack. In any one crystal grain there were at least three sets of independent parallel planes in which such slips could take place, and these allowed the grain to undergo complete alteration of form as a result of the straining. Microscopic photographs were exhibited showing three systems of slip lines on the surface, corresponding to slips in three directions throughout the substance of the grain. The true nature of these slip lines was made apparent by means of obliquely incident light, which showed them as little steps in the surface. An interesting direct confirmation of this had been afforded by recent experiments of Mr. Rosenhain in which cross-sections of the stepped surface had been obtained.

Dr. Ewing next explained, by aid of models, a theory which he had recently advanced as to the structure of the crystal granule itself. This theory might be regarded as an extension of the views he put forward fifteen years ago to explain the phenomena of magnetic induction by the mutual actions of polarised magnetic molecules. Cohesion in the crystalline structure might similarly be regarded as due to the mutual forces between polarised molecules, the polar quality of which determined the regular tactical formation in which they grouped themselves to form the crystal. For this purpose he conceived of each molecule as possessing polarity along each of three rectangular axes; in other words, as having six poles exercising forces of attraction on the opposed poles of neighbouring molecules.

The lecturer proceeded, by aid of the model, to demonstrate the process of crystal-building with these polarised molecules for brickbats. He showed how, under certain conditions, a group of dissenting molecules might be formed within the crystal grain, possessing a certain degree of stability, though not in complete harmony with the molecules around them. Evidence for the existence of such groups was furnished by the microscope in the examination of iron and other metals. The process of straining was next considered, and it was shown that the conception of polarised molecules was in agreement with what was known of the actual behaviour of metals during, first, the elastic stage of straining, and, second, the stage where much greater yielding took place and permanent set was produced. The molecular theory explained how energy was dissipated in the process of straining, and also how elastic "fatigue" resulted. After any severe strain the piece was a long time in recovering its full amount of elastic quality, but the recovery could be accelerated by heating it. These phenomena were accounted for by

[1] Abstract of "Wilde" Lecture, delivered by Dr. J. A. Ewing, F.R.S., before the Manchester Literary and Philosophical Society on February 18.