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THE LAKES OF THE BALKAN PENINSULA.*

By Dr. KARL PEUCKER, Vienna.

IN the atlas of the lakes of the Balkan peninsula, just published, Prof. Cvijić has filled a distinct gap in our knowledge of the lakes of Europe. The atlas forms the cartographic section of his great lake studies, of which the literary part will appear in the course of this year. Some of the main results of his researches into the forms of lake-basins and their origin have already been communicated to the *Journal*, and provisional bathymetrical maps have been published of the three largest of the ten actual lakes mapped in the atlas (the other lake-basins represented are marshes). The atlas contains the final maps, on the scales of 1:100,000 and 1:75,000, with full detail and distinctive colouring. Following the example of the atlases of the Austrian lakes and the maps of the English lakes which have appeared in the *Journal*, both the lakes and the country surrounding them are contoured and coloured in appropriate tints. The map characteristics also disclose an abundance of new facts. Places covered with reeds, steep rock slopes, and more particularly the remains of ancient shore-lines, are clearly indicated. A special map, worked out in admirable detail, shows the neogene extension of the lakes of the peninsula. The present lakes are clearly relics of the large and deep lakes of the beginning of the Tertiary period, surviving from the general drying up of the region. Only the Ohrid and Scutari lakes, as laid down from the excellent surveys of the Austrian officers, show the original forms in their present outline. The detailed new surveys of the Serbian savant have revealed important and hitherto unknown features in the western and south-eastern parts of Lake Prespa; the form of the Kastoria lake, and of the two lakes of the Chalcidice peninsula, and the position and form of the island of Scutari, have been considerably modified. The soundings, given below in Table B, although not as numerous as those taken in the lakes of Central and Western Europe, are quite sufficient to indicate fully the relief of the basins; the network of soundings is open where the bottom is uniform, and close where it is irregular. Only by this method was it possible to find the deep holes in the bed of the Scutari lake already mentioned, or a sub-lacustrine river-bed in the Ohrid lake. In places the lake-bed is represented by isobaths 10 metres apart; in others the vertical intervals are 5 metres and 3 metres; and in shallow lakes, or in regions of complicated form, 1 metre, coloured in four shades of blue. The distribution of temperature in the water of the Ostrovo lake is shown on a special sheet by means of curves. The "limnometric values" for the different lakes, given in the tables appended, are brought up to date by the addition of some republished figures, and the numbers are here converted to English measures. The last two sheets of the atlas give a special graphic representation of the numerical values, worked out by the writer of this article, in which the relations of form and size of the lake surfaces and basins are clearly depicted.

In the tables the lakes are arranged in order of size, beginning with the smallest, the Yannina lake in Epirus, with an area of 18·8 square kilometres, or 7·3 square miles, and ending with the Scutari lake, with 356 square kilometres, or 137·6 square miles—a range equivalent to the distance from Loch Rannoch in Scotland, or the Walchensee in the Bavarian Alps, to Lough Neagh in Ireland, or the Lake of Garda in the Italian Alps. The Yannina lake is the smallest of the ten, but the Kastoria lake is the shortest. The Scutari lake is both the largest

* 'Atlas der Seen von Makedonien, Altserbien und Epirus.' Von Jovan Cvijić. Prof. a.d. Kgl. Universität in Belgrad. Ten sheets in portfolio. Belgrad, 1903.

and longest; the second in size, Lake Prespa, has the greatest mean breadth. The tabular values for length and breadth furnish a new definition of the "length" of a lake; it appears for the first time as the shortest line measured along the water surface between the two most distant points of the shore. This line admits of precise construction, and has a distinct significance in relation to commercial geography as the shortest line of communication between these two points. In lakes having a curved outline—valley lakes, etc.—the "length" is a broken line, compound from tangents on the curves of the shore; otherwise it is a straight line identical with the "air line." The limnometric sheets of the atlas also furnish a new and precise idea for the determination of "articulation" (*Gliederung*), a conception which has been the subject of endless discussion in German geographical literature since Karl Ritter. According to this the Dojran lake, east of the Vardar valley, is the least articulated; it has only five inlets, forming together about 4 per cent. of the total area. The Beshik lake is the most highly articulated; its exploration, and that of the sister lake, Lake Ajvasil, has been very fully carried out by Jan-kovic, a pupil of Prof. Cvijić; we find that its seven inlets make up 48 per cent. of the total area, or nearly one half. On the other hand, the Ohrid, Ostrovo, Prespa, and Scutari lakes have a greater number of articulated members, but the total area of these members is relatively less; the inlets and bays in the Scutari lake include thirteen of the first order, eleven of the second, and nine of the third, but together they make up only 25 per cent. of the whole area. Its thirty-four islands, which, as in all these lakes, lie close to the shores, make up only 0.4 per cent. of the area. The bays formed by submerged river-valleys in the north-west and north-east of this interesting Montenegro-Albanian lake cut off large peninsulas from the surrounding land, which is thus also highly articulated by no less than forty peninsulas of the three first orders, compared with five in the Dojran lake. Of the five larger lakes only the Beshik and Ohrid have no islands, and of the five smaller only the Tannina and Malo lakes have any; in contrast to the Scutari lake, all have only one or two. The Prespa lake has absolutely the largest, the Malo lake relatively the largest, island area.

The soundings taken during the summer months of the years 1899 to 1901 have shown that the Malo lake is the shallowest, the Ohrid lake the deepest; the latter, with a maximum depth of 938 feet, is actually one of the deepest lakes in Europe, although not in relation to its size. Its volume nearly equals that of the Lake of Constance, more than seven times that of the Prespa lake, which drains into it subterraneously, and twenty-three times that of the Scutari lake. The other lakes, with the exception of the Ostrovo, are amongst the shallowest known. The Scutari lake is not more than 20 to 26 feet deep in the centre, and in the holes, which are of insignificant area compared to the total, the depth only attains a maximum of 144 feet ("Oko" of Raduš). The shallowness is also apparent from the slope-angles of the bottom, the values being mostly under 1° . The Ostrovo and Ohrid lakes are, on the whole, not so level; the mean slope of the latter is the same as of the Lake of Constance. The last sheet of the atlas gives a graphic analysis of these slopes, from which one can form an opinion as to the relations between surface and slope at various depths. Angles and surfaces are strictly comparable in "hypsoclinographic surfaces," which is not the case with "hypsoclinographic curves" like those published for the lakes of Central Europe.

In contrast to the land surface, the water surface of lakes gives a surface mathematically parallel to the form of the ideal spherical earth. This spherical form of the lake surface is an important characteristic of the whole type of geographical form, and its importance becomes apparent even in lakes of medium size. In the Ajvasil lake, 7 miles in length, the margins of the opposite eastern and

western shores would lie hidden from one another were it not for well-known optical phenomena: a wall of water rises 8 feet above the straight line of the lake. This is an important limnological fact in the discussion of optical questions. It is only possible to see across the three smallest of the lakes dealt with here in all directions; in the three largest one cannot see from shore to shore in the broadest places. On the Ohrid the wall of water rises 10 feet, on the Scutari over 17 feet, on the Prespa 20 feet. Longitudinally the height is five to six times as great in these lakes, and on the Scutari lake the height is 100 feet. It follows that the share of the spherical segment in the total volume of water increases with the size of the lake; the height of the arc is a function of its area. In order to obtain trustworthy values, the irregularly bounded spherical segment of the lake surface must be replaced by a segment of equal area having a regular boundary.

The relation between the depth and area of a lake is a factor whose importance must not be underestimated in the discussion of questions relating to its origin. The relation of the volume of the spherical surface segment to the total volume of the basin is the same as that of the mean height of that segment to the mean depth. The former corresponds to the area, as has been seen; but we have now, for the first time, rational values for this important relation in the new conception of "relative depth," an expression analogous to the "relative height of mountains," and to the relation between mean breadth and length employed by British limnologists, and there called "relative breadth." It is interesting to note how, in the Scutari lake, the segment and volume nearly coincide (1.06), and how Lake Prespa, which is mostly over 60 feet deep, is relatively shallower than most of those of the ten lakes which are absolutely shallowest. It is not surprising that the deep Ohrid lake has a relative depth of over 43, but it is remarkable that this value is more than double those for the larger lakes of Constance and Geneva, nearly double that for the Lake of Neuchâtel, and considerably greater (29 : 43) than that for the slightly larger Lake of Garda.

The last diagram in Cvijić's atlas gives an instructive picture of the elevation of the ten lakes, and of the general form of their basins. If one regards the chief point of contrast in the form of the basins as depending on whether the curvature from the margin at the deepest part is concave or convex, the formula given in one table, and already accepted by some limnologists, gives the criterion required according as the values are positive or negative. The positive values indicate a basin which contains more water than a hollow cone of the same basal area and depth, and the negative values one which contains less, and the numbers give the actual relation to the cone. The high positive values for Dojran and Ajvasil show that the general form of their basins is that of a truncated zone; those for Ohrid and Malo indicate a trough shape (hollow segment), and intermediate between these we have the Beshik. In the other lakes the bottom does not run down evenly, but shows varying depths. The slope is, on the whole, approximately a tangent to the general curve, the curvatures near the margins and in the depths neutralizing one another so far as the effect on the volume is concerned; thus the numerical values work out nearly to zero, the value for the theoretical hollow cone. This is especially the case in lakes Prespa and Kastoria, and also in Tannina and Ostrovo. The numbers below zero indicate lake-bottoms with convex slopes, where the incline in the depth is markedly steeper than round the margin, or is funnel-shaped; this form is prominent in the Scutari lake. While the trough-shaped Ajvasil holds two and a quarter times as much water as the simple conical form, the value (−0.67) for Scutari shows that that lake only holds one-third as much.

A.—SURFACE OF LAKE.*

Lake.	Scale of map.	Elevation of surface above the sea. (e)	Length. (l)	Breadth. miles.		Mean diameter. (2r)	Reduced circumference. (c)	Area of lake. (a)	Mean breadth per cent. of length (relative breadth). $\frac{l}{100 b_m}$ %	Islands. (i) A. of i. (: number of i.). $i_a (: i_m)$
				(b _m)	(b)					
		feet.	miles.	mean.	max.	miles.	miles.	square miles.		square miles.
Jannina	1:75,000	1640	5.0	1.46	1.9	3.0	23	7.3	29.3	0.8 (: 1)
Kastoria	1:100,000	2100	4.2	2.20	3.4	3.6	29	10.5	46.0	—
Dojran	"	485	5.0	3.29	4.6	4.6	24	16.5	65.4	—
Ajvasil	"	160	7.0	2.79	3.7	5.0	30	19.5	40.0	—
Malo †	"	2990	10.9	1.84	3.8	5.1	45	20.0	16.9	0.36 (: 2)
Beshik	"	160	14.7	1.80	2.9	5.8	55	26.5	12.2	0.8 (: 1)
Ostrovo	"	1730	10.6	2.68	4.9	6.0	55	28.4	25.4	0.002 (: 1)
Ohrid ...	"	2300	18.3	5.68	7.8	11.6	83	104.0	31.0	—
Prespa	"	2980	18.3	6.06	11.0	11.9	104	111.0	33.1	0.4 (: 2)
Scutari	1:75,000	20	27.3	5.03	10.2	13.3	162	137.6	18.4	0.6 (: 34)

B.—BASIN OF LAKE.*

Lake.	Number of soundings.	Depth. feet.		Volume. (a . D _m = V). milliards of cubic feet.	Height (H) of Segment (S) feet.			Basin-form. $\left(\frac{3D_m - D}{D}\right)$	Relative depth. $\frac{S}{V}$ or $\frac{H_m}{2D_m}$	Mean slope. $\frac{S}{V}$
		(D)	(D _m)		(H _i)	(H _o)	(H)			
		max.	mean.		for length.	for max. breadth.	for mean diameter.			
Jannina	82	34.5	14.1	2.83	4.1	0.6	1.5	+0.23	18.60	0.24
Kastoria	106	33.8	12.1	3.53	3.7	1.9	2.2	+0.08	11.20	0.18
Dojran	111	32.5	22.3	10.24	4.2	3.5	3.5	+1.06	12.60	0.16
Ajvasil	104	27.6	20.7	11.30	8.0	2.4	4.0	+1.24	10.30	0.14
Malo ...	80	25.3	11.5	6.36	11.0†	2.4	4.3	+0.36	5.10	0.15
Beshik	140	73.2	45.3	33.55	36.0	1.4	5.7	+0.86	15.90	0.42
Ostrovo	198	202.0	87.0	68.87	18.4	4.0	6.0	+0.29	29.10	1.17
Ohrid	204	938.0	479.0	1391.60	56.0	10.0	22.2	+0.53	43.10	3.00
Prespa	250	178.0	60.7	187.44	52.0	20.0	23.6	+0.02	5.30	0.32
Scutari	240	144.0	15.7	60.00	100.0	17.4	29.5	-0.67	1.06	0.8

* Formula and construction of the new limnometric conceptions or determinations announced in this article, will be developed in H. Gravelius's 'Zeitschrift für Gewässerkunde,' Dresden.

† = small lake, wrongly called Ventrock-See.

‡ With 8.1 miles visible distance.