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AN EXPERIMENT ON THE SIZE OF THE EARTH

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AMONG certain experiments in mathematical geography in which the writer has become interested, two, one on earth sphericity, the other on earth size, are believed to have more than a personal value. In an account of the experiment on the rotundity of the earth,¹ a simple but effective method of showing earth curvature was outlined. No attempt was made in the experiment at quantitative work. In more recent experiments the obtaining of sufficient data to calculate the size of the earth was the object.

The experiment was performed on Lake Quinsigamond, a long and narrow lake on the eastern boundary of Worcester, Massachusetts. The surface of the lake is dotted by a number of small islands, and numerous salients are the feeding grounds of bars which extend into the deeper waters. All these make the performance of the experiment relatively easy as they furnish a variety of choice for stations to accommodate the different parts of the apparatus. In the previous experiment, on earth sphericity, no effort was made to fix on points equally distant from the central location. The apparatus was set up in line with certain marked points (STU, Fig. I) at a uniform distance above the water surface and a sighting was taken along the points. In the later experiments stations were selected at more regular intervals. The accompanying map (Fig. I) of a portion of the lake shows the location of different parts of the apparatus. At A, fastened to a wall built at the water's edge and facing down the lake, a board about two feet square was located. This board was divided horizontally and the

¹ An experiment on Earth Curvature. *Nat. Geog. Mag.* XVIII, p. 771, Dec., 1907.

upper portion was blackened. The line, the junction of the light and dark surfaces, was made horizontal by placing both ends at the same distance above the water surface. A note was made of this height. At B, on a bar extending into the lake from the headland, the second portion of the apparatus was erected. This consisted of a white rod, one inch in diameter, mounted on an ordinary chart stand (Fig. II). Suspended from the rod was a cardboard scale. This scale was seven inches by ten inches and was covered with alternating black and white bands, parallel to the rod, each band one inch wide. The top of the first black band was one inch below the middle of the rod. By driving the legs of the stand into the sand, a steady location was assured. The middle of the rod was placed at the same height above the water as the horizontal line of the board at A. It was hoped that the line of the two pieces of apparatus would be projected on the bar of island M, as this location would make B a central location

FIG. I.

between A and the telescope. The bar was found to be impossible as great steadiness was required in order to read the scale at B. The third location was finally taken on a wharf at N. The telescope, an ordinary field glass magnifying about twenty-five diameters, was suspended by straps from a railing on the wharf. The axial point of the telescope at the place of suspension was fixed at the same height as the horizontal line at A and the middle of the rod at B. In sighting on the horizontal line at A, the white rod at B appeared in the field of vision projected against the top of the board. Inasmuch as the line on the board, the rod and the telescope were equidistant above the surface of still water, and the accuracy of their positions was guaranteed by repeated measurements, the result indicated that the water surface was not a horizon. The scale suspended from the rod was visible and the reading of this scale gave the departure of the rod from a straight line (Fig. III). The distance of the rod above the line from the

telescope to the line on the board was read. It was five inches and something more. The estimation of a fractional part of the inch was possible, but the limit of the field of visibility for the inch was being approached. The fractional reading was not sure enough, even after a number of readings, to be satisfactory. The distance was recorded as five and one-fourth inches. A check was made on this record. The rod appeared through the

FIG. 2.

telescope at the top of the board. The width (vertical) of the board was read on the scale. The black band on the board was $10\frac{1}{2}$ inches wide, and the white band was $11\frac{1}{2}$ inches wide. The 21-44 part of the portion of the scale covering the board, read from the top down, yielded $5\frac{1}{4}$ inches. The distance from A to B was found to be 4,000 feet, from B to N, 4,500. In a simple reduction of the 5.25 inches to suit a position halfway between A and N, 4,250 from each, 4.96 was obtained. The letters which follow refer to Fig. IV. The use of the data and the explanation of the final reduction is shown, in part, by the figure. ADF is the line of sight; BD, the position of the rod; BM, the diameter of the earth. AB and BD are known, 4,250 feet and 4.96 inches respectively. The triangles ABD and

ABM are similar. A proportion growing out of a law of similar triangles is possible, namely,

BD:AB::AB:BM, or substituting for the numbers their values,

$$4.96 : 4250 \times 12 :: 4250/5280 : x \text{ (the diameter)}$$

FIG. 3.

FIG. 4.

The terms of the first ratio have been reduced to inches, of the second to miles. This gives for the diameter of the earth 8,276 miles.

The result is an approximation. Many conditions enter into the experiment and prevent accurate results. The apparatus is of crude workmanship, the readings are not delicate and atmospheric refraction is a factor in the projection and readings. Other results, from other readings and with similar reductions ranged from 8,400 miles to 7,894 miles.

The writer believes that the experiment may be performed on any moderately level tract of land. The letters in the following discussion refer to Fig. V. Let a surveyor's leveling instrument be set at A. At a certain convenient distance, one-half mile, on opposite sides of A, erect stakes. By means of the instrument make them of the same height so that the line across the top of the stakes passing through the instrument will be a chord of a circle which is for all purposes the circumference of the earth. Transfer the instrument from A to B, a position on the opposite side of D at a distance equal to AD. Erect a third stake at E, at a distance from B

FIG. 5.

equal to BD and in line with A and D. By means of the instrument make its height equal to that of DP. The line PN will be another chord, and M, P and N will be points in the arc of the circumference. A sighting from M to N may be taken and the amount by which P departs from the straight line is a function of the curvature. The reduction of the data is by the process which was employed in the explanation of the experiment on Lake Quinsigamond. An approximate measurement of the size of the earth is obtainable by the problem of Eratosthenes.¹ The writer, in a note in *THE JOURNAL OF GEOGRAPHY*,² reported the result of such an experiment. This was performed by a class in the New Bedford, Massachusetts, High School; the co-operating station at Roxbury, Massachusetts, was in charge of Mr. I. H. Upton of the Roxbury High School. In this case the apparatus at each station consisted of a vertical stake casting a shadow upon a horizontal surface. It is necessary to have the two stations along the same meridian. The length of the stake and the length of the shadow at noon, local time,

¹ For fuller explanation see W. M. Davis, *Physical Geography*, 386.

² *JOURNAL OF GEOGRAPHY*, Vol. V, 187, 1906. For sun declination read sun's zenith distance.

on some appointed day are the data required from each station. In the right triangle formed by the stake, its shadow and the sun's ray just over the top of the stake, one of the complementary angles represents the altitude of the sun, the other its zenith distance. The difference of the zenith distances for the two stations is the number of degrees of arc along the circumference between the two stations. If the distance between the stations is known, the following proportion is solvable.

Number of degrees of arc : 360 :: number of miles between stations : x (the circumference).

In the instance cited, 25,046 was obtained.

Of the three methods, the writer believes that the first is the most effective. The experiment is performed under the simplest conditions possible by a process which is familiar to most pupils almost from the beginning of their geography study. It has a personal factor which is of value. The second might seem to fall into the same class, but the horizons of the instruments in the two positions, A and B, (Fig. V) to pupils unfamiliar with the leveling instrument, as they must be to a large degree at this stage, savors of arbitrariness. They can be convinced, but the strange element detracts from the simplicity of the experiment and acts as a slight barrier to the mental progress. The method of Eratosthenes has the same conditions to contend, namely, abstraction which lessens the force of the experiment. In the discussion the pupils had a tendency to speak of it in an impersonal light, as something not wholly within their experience.

A NEW COURSE IN GEOGRAPHY AT THE TEACHERS' SCHOOL OF SCIENCE, BOSTON, MASS.—The Teachers' School of Science at the Boston Society of Natural History has recently added instruction in geography to the courses previously given in botany, zoology and geology. The course, under the instruction of Professor D. W. Johnson of Harvard University, will consider the following topics each for a year: The Geography of the Lands; Economic Geography; Geography of the United States and Geography of Europe. Each year's work consists of classroom and laboratory exercises for 30 hours, at the close of which a certificate will be given to those who have done satisfactory work. The new department has enrolled 156 members, practically all Boston school teachers