

IV. "India's Contribution to Geodesy." By General J. T. WALKER, R.E., C.B., F.R.S., LL.D., late Surveyor-General of India. Received April 27, 1895.

(Abstract.)

This paper gives a summary of the operations which have been completed up to date in India to furnish the necessary data of the lengths and the amplitudes of meridional and longitudinal arcs for a mathematical determination of the mean figure of the earth. It shows that geodetic investigation has already greatly influenced the operations of the Great Trigonometrical Survey of India, from its very commencement at the beginning of the present century. It describes the principal triangulation which has been laid out over the whole face of the country, mostly in meridional and longitudinal chains, and shows how it has been finally reduced and made consistent throughout by processes of calculation which are fully set forth in the published accounts of the operations. Brief statements of the discrepancies which were met with at the base-lines and the sides of junction of the chains of triangles, and the average values of the angular corrections which had to be applied to satisfy the discrepancies and produce harmony and consistency throughout, are given to indicate the extent to which the triangulation may be relied on for geodetic investigations. Then the astronomical determinations of latitude, and those of differences of longitude by the electro-telegraphic method, are described and the results are compared with the corresponding geodetic determinations from the triangulation.

All the facts of observation having been given, the question is considered of the extent to which the astronomical determinations have been influenced by local deflections of the plumb line. The views which have been put forward as regards the attraction of the great Himalayan Mountains on the plumb line are considered; it is shown that the magnitudes of the attractions computed on the theory of gravitation are considerably greater than is necessary to explain the discrepancies between the astronomical and the geodetic results, and this fact is fully explained by the Indian pendulum operations, which have thrown great light on the constitution of the earth's crust. They indicate that there is an excess of density under the sea-level and a deficiency above that level which increases to a very notable magnitude at a high altitude in the Himalayas; thus, therefore, there must be a condensation of matter under ocean beds, and an attenuation under mountains; and consequently points must be sooner or later reached at which the positive attraction of a mountain mass is cancelled by the negative attraction of the mass under

the mountain. The geodetic operations of the survey show the same thing in the Southern Peninsula, which is the part of India closest to the ocean. Here the latitude stations almost invariably show deflection of the plumb-line towards the ocean, instead of away from it, as might naturally be expected. Here, too, the astronomical amplitudes of the longitudinal arcs are all too small, with one exception, which can be readily explained, thus also showing deflection of the plumb-line towards the ocean at the stations on the coast-line.

It is not difficult to draw a line beyond which Himalayan attraction need not be feared. Excluding all stations obviously under Himalayan influence, 148 latitudes and 50 longitudinal arcs remain for employment—with similar data obtained in other parts of the world—in determining the figure of the earth. But on comparing the astronomical with the geodetic determinations it is seen that the former are often grossly influenced by deflections of the plumb-line at points where there is nothing visible to suggest disturbance. Thus, at the Colaba Observatory, Bombay, there is probably 8" deflection to the north, while at the Madras Observatory there is probably as great deflection to the south, neither place having any apparent source of meridional attraction; here the astronomical amplitude is 16" less than the geodetic, a difference which is fully twenty times greater than any error that can have been made in the triangulation. There are also discrepancies of corresponding magnitude in the longitudinal arcs at places where there is no apparent source of attraction on the prime vertical.

Clearly, therefore, no single astronomical determination can be regarded as sufficiently free from deflection of the plumb-line to be safely employed in an investigation of the figure of the earth. But all investigations hitherto made have rested on single determinations. This, however, must be almost certainly due to the paucity of data; had a sufficiency of astronomical results been forthcoming to indicate the presence of large local disturbances of the plumb-line and emphasise the necessity to eliminate these disturbances as far as possible before proceeding to employ the astronomical results, there can be no doubt that some attempts at elimination would have been made.

There is only one way of eliminating these errors, and that is to combine the astronomical observations together in groups, each containing determinations at as many places in a given belt of latitude as possible, and to take the mean of the group; for the mean astronomical latitude of a number of points may certainly be assumed to be far more free from deflection than that of any single point. The geodetic latitudes of the same points, as obtained from the triangulation, would be similarly combined; and thus the most accurate

data for a mathematical investigation of the earth's figure would be obtained.

In this way eight meridional arcs, extending from latitude  $8^{\circ} 43'$  to latitude  $30^{\circ} 9'$ , have been produced for India; they rest on an average of over sixteen stations for each of the fundamental latitudes, and not, as usual, on one more station than the number of arcs. The amplitudes of these arcs vary from  $2^{\circ} 23'$  to  $3^{\circ} 38'$ , ranging in magnitude with the magnitudes of the mean ultimate local attractions, in accordance with a rule which has been derived from the formula which expresses the error of a geodetic arc in terms of the errors of the major and minor axes. Two great longitudinal arcs, exceeding  $24^{\circ}$  in amplitude, have been produced by summations of the observed smaller arcs, thus eliminating all errors caused by deflections of the plumb-line at the intermediate stations, and retaining only those at the eastern and western extremities of the entire arcs.

These eight meridional and two longitudinal arcs are put forward as the most valuable data for the investigation of the figure of the earth which have yet been published. They are the result of operations which have been made in India during a period of over ninety years, always with the cordial support and approval of the Government of India.

The Society adjourned over Ascension Day to Thursday, May 30.

*Presents, May 16, 1895.*

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