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ORDNANCE SURVEY

The Second Geodetic Levelling of England and Wales, 1912–1921, published by order of the Ministry of Agriculture and Fisheries. **Colonel Sir Charles Close, K.B.E., C.B., C.M.G., F.R.S.,** Director-General of the Ordnance Survey. Southampton, 1921; H.M. Stationery Office, 1922. Pp. 62, *with* xlvi. *Plates. Price* 17*s*. 6*d*. *net.*

THE volume under review is the record of ten years' work carried out between 1911 and 1921 under the directorship of Sir Charles Close, who recently retired from the position of Director-General of the Ordnance Survey, though the programme was inaugurated by his predecessor, Colonel S. C. N. Grant. The first primary levelling of Great Britain was made between the years 1840 and 1860. It was from the nature of the case by no means up to the modern standard of precise levelling. The bench-marks were not satisfactory and many of them have disappeared, having been cut on gate-posts, mile-stones, and other sites liable to be disturbed, without much consideration being given to the stability of the underlying formation. There was also reason to think that one or two actual mistakes of the order of one foot had been made in the initial levelling, and that these had been distributed throughout the initial network by the least-square adjustment. In fact, the old primary levelling no longer fulfilled its purpose, and it was becoming increasingly difficult to close revisional levelling satisfactorily upon it. It was absolutely impossible to draw any satisfactory conclusions as to any alterations in the general ground-level, or to carry out the recommendations of the Royal Commission on Coast Erosion (1911), that steps should be taken by the Ordnance Survey to determine any relative movements of land and sea, unless the network of levelling were entirely revised and based on a primary system of bench-marks which are reasonably stable, and of which the relative altitudes are known with the highest accuracy attainable in modern practice.

The revision having been decided upon, Sir Charles Close and his assistants, Major E. O. Henrici, Lieut.-Colonel A. J. Wolff, D.S.O., and Mr. H. L. P. Jolly, M.A., Research Officer, are to be congratulated on the thorough and scientific manner in which the new programme was studied, formulated, and carried out. In 1911 Major (then Captain) Henrici had studied and tested the methods and instruments in vogue in other countries, particularly France, Switzerland, and the United States. As a result of these tests the Zeiss level No. 3 model was chosen. A great and characteristic improvement on old conservative practice was made in the levelling staff. These for ordinary use are for some reason, possibly lightness, still made of wood, a substance which not only changes length with temperature but with the hygrometric state of the air in a way which cannot be accurately allowed for. Pine rods have long been abandoned in base-line measurement, but were still in use for geodetic levelling; and in India elaborate comparisons were made before and after the day's work with a metal standard, in order to attempt to correct for these changes. In France, Mons. Ch. Lallemand had introduced as a further improvement a strip of invar connected to the shoe of the staff and running freely inside. Changes of length in the wooden casing could be read at the upper end of this at any time by means of a magnifying glass against a scale engraved on the invar strip. Lallemand's staff was at first adopted by the Ordnance Survey, but soon an improved staff was designed there and made by the Cambridge Scientific Instrument Company, in which the graduations are painted on the invar strip, thus obviating all temperature and hygrometric corrections.

Great attention was paid to the design of a stable form of primary bench-mark. These so-called " fundamental bench-marks " are fixed at 25 to 35 miles apart, and there is always one at the junctions of circuits. They are all fixed in solid rock or in concrete on solid rock. Each has three fiduciary points, one on an external granite pillar for public use, and two—one a gun-metal bolt and one a polished flint—sunk in a covered concrete well about 3 feet deep for departmental use only. The circuits and positions of fundamental marks were planned so as to avoid, as far as possible, the softer rocks and those liable to surface changes. In the selection of the lines of levelling the successive directors of the Geological Survey were consulted. In addition to these fundamental marks specially designed bronze " flush brackets " were cemented into the face of buildings at intervals of about a mile along all the primary lines, and gun-metal bolts were let into horizontal surfaces of stone or brick at about quarter-mile intervals, but these last are not regarded as permanent marks.

The total length of the levelled lines is 3009 miles, the number of fundamental bench-marks is 86, and the number of intermediate bronze brackets is 3021.

The connection between the old level network and the mean sea-level datum at Liverpool was not precise. It was therefore decided that three mean sea-level stations should be established, and, on the advice of the late Sir George Darwin, Dunbar, Newlyn, and Felixstowe were selected. Self-recording tide-gauges were set up at these places and connected to the nearest fundamental bench-marks. The datum to which the new system of levels is referred is the mean sea-level at Newlyn, in Cornwall, as derived from the mean of the hourly readings recorded by the automatic tide-gauge there for the period of six years from 1 May 1915 to 30 April 1921.

In the reduction of the network of levelling the observed differences of height were first converted to orthometric differences by M. Lallemand's formula and the least-square adjustment was performed with these corrected differences. The network comprised eighteen closed circuits excluding the enveloping circuit, necessitating the solution of eighteen normal equations, which was carried out by the Gaussian method as developed by the late Mr. Doolittle of the U.S. Coast and Geodetic Survey. The lines were weighted inversely as their lengths, and, as the result of an elaborate investigation into the effect of accidental and systematic error on the proper method of weighting where the sides of the circuits differ much in length, this procedure was justified when the corrections were obtained. The probable accidental and systematic errors as calculated by the formulæ of the International Geodetic Association were about half the values assigned by that body in 1912 as the maxima for Levelling of High Precision. In English units the probable accidental error per square root of the mileage may be taken as ±0·0077 foot and the corresponding figure for the old levelling as ±0·03 foot, or about four times as great.

When the adjustment of the levelling was completed it was found that mean sea-level at Dunbar as determined by levelling from the tide-gauge at Newlyn came out 0·81 foot higher than as determined by the tide-gauge at Dunbar The calculated probable error of the levelling was only 0·16 foot, so that the actual difference was about five times as great as the probable error. As to the probable error of the mean sea-level at Dunbar as determined by the tide-gauge there, the eight years' record shows a difference of 0·191 foot between the highest and lowest annual means, while the probable annual fluctuation is 0·038 foot. For Newlyn, with six years' record, the corresponding figures are 0·194 foot and 0·042 foot. An elaborate comparison of these variations of mean sea-level with the corresponding barometric heights has successfully demonstrated a correlation between the two, and it is estimated that about 0·12 foot of this difference is due to this cause. The residual difference is supposed to be likewise mainly due to an atmospheric cause—the effect of the prevailing winds, locally and regionally. We are thus forced to the conclusion that there is a real difference in mean sea-level between Newlyn and Dunbar, the latter being permanently raised above the former. Indications are given as to how the law of these atmospheric effects should be investigated, but it is clear that further observations over a long period will be required before we are able to calculate and eliminate their effects from the tidal record, at any particular station. The decision to base the levelling on a provisional value of the mean sea-level at one station and not to force it into agreement with the tidal observations at the other two is for these reasons amply justified.

We end by quoting the last paragraph of Sir Charles Close's Introduction :

" It is hoped that all this labour, and the large sum of money spent on the work, will be found to be justified in the future ; and it is believed that England and Wales are now provided with a primary level network which is second to none in the world, and that it will serve all practical requirements and be available in future ages for use in the study of those larger and more important problems which belong to the domain of science." A. E. Y.

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THE CHOICE OF A GRID FOR BRITISH MAPS

Read at the Afternoon Meeting of the Society, 17 *March* 1924.

I. THE NATIONAL GRID

Colonel H. S. L. Winterbotham, C.M.G., D.S.O.

IN the January number of *Annales de Géographie*, Mr. de Martonne gives certain details of French plans for the new 1/50,000 map. It would appear, from this description, that the projection which characterized the earlier sheets of the 50,000—the polyhedric—is to be abandoned, and to be replaced by an orthomorphic projection. The sheets are to be rectangular and are to show a " national grid."

The United States of America have achieved considerable progress in the spread of their one-inch maps, which are on a polyconic projection, The sheet lines of this series, being defined by meridians and parallels. do not lend themselves to the introduction of a " national grid." Nevertheless, tables have been prepared to facilitate the overprinting of a grid for military, if not for civil, purposes.

Recent military and scientific German periodicals give details of a change of German national mapping policy. A commission or board