it is not easy to explain on mechanical principles. In India various tidal stations on the east and west coasts, at which the mean sea-level has been determined from several years’ observa­tions, have been connected by lines of level run along the coasts and across the continent; the differences between the results were in all cases due with greater probability to error generated in levelling over lines of great length than to actual differences of sea-level in different localities.

The sea-level, however, may not coincide everywhere with the geometrical figure which most closely represents the earth’s surface, but may be τaised or lowered, here and there, undeτ the influence of local and abnormal attrac­tions, presenting an equipotential surface—an ellip­soid or spheroid of revolution slightly deformed by bumps and hollows—which IT. Bruns calls a “ geoid.” Archdeacon Pratt has shown that, under the combined influence of the positive attraction of the Himalayan Mountains and the negative attrac­tion of the Indian Ocean, the sea-level may be some 560 ft. higher at Karachi than at Cape Comorin; but, on the other hand, the Indian pendulum operations have shown that there is a deficiency of density under the Himalayas and an increase under the bed of the ocean, which may w∙holly compensate for the excess of the mountain masses and deficiency of the ocean, and leave the surface undisturbed. If any bumps and hollows exist, they cannot be measured, instrumentally; for the instrumental levels will be affected by the local attractions precisely as the sea-level is, and will thus invariably show level surfaces even should there be considerable deviations from the geometrical figure.

3. Topographical Surveys

The skeleton framework of a survey over a large area should be triangulation, although it is frequently combined with travers­ing. The method of filling in the details is necessarily influenced to some extent by the nature of the framework, but it depends mainly on the magnitude of the scale and the requisite degree of minutiae. In all instances the principal triangles and circuit traverses have to be broken down into smaller ones to furnish a sufficient number of fixed points and lines for the subsequent operations. The filling in may be performed wholly by linear measurements or wholly by direction intersections, but is most frequently effected by both linear and angular measures, the former taken with chains and tapes and offset poles, the latter with small theodolites, sextants, optical squares or other reflect­ing instruments, magnetized needles, prismatic compasses and plane tables. When the scale of a survey is large, the linear and angular measures are usually recorded on the spot in a field­book and afterwards plotted in office; when small they are sometimes drawn on the spot on a plane table and the field-book is dispensed with.

In every country the scale is generally expressed by the ratio of some fraction or multiple of the smallest to the largest national units of length, but sometimes by the fraction which indicates the ratio of the length of a line on the paper to that of the correspond­ing line on the ground. The latter form is obviously preferable, being international and independent of the various units of length adopted by different nations (see Map). In the ordnance survey of Great Britain and Ireland and the Indian survey the double unit of the foot and the Gunter’s link (=66/100 of a foot) are employed, the former invaτiably in the triangulation, the latter generally in the traversing and filling in, because of its convenience in calculations and measurements of area, a square chain of 100 Gunter’s links being exactly one-tenth of an acre.

In the ordnance survey all linear measures are made with the Gunter’s chain, all angular with small theodolites only; neither magnetized nor reflecting instruments nor plane tables are ever employed, except in hill sketching. As a rule the filling in is done by triangle-chaining only; traverses with theodolite and chain are occasionally resorted to, but only when it is necessary to work round woods and hill tracts across which right lines cannot be carried.

*Detail surveying by triangles* is based on the points of the minor triangulation. The sides are first chained perfectly straight, all the points where the lines of interior detail cross the sides being fixed; the alignment is effected with a small theodolite, and marks are established at the crossing points and at any other points on the sides where they may be of use in the subsequent operations. The surveyor is given a diagram of the triangulation, but no side lengths, as the accuracy of his chaining is tested by comparison with the trigonometrical values. Then straight lines are carried across the intermediate detail between the points established on the sides; they constitute the principal “ cutting up or split lines”; their crossings of detail are marked in turn and straight lines are run between them. The process is continued until a sufficient number of lines and marks have been established on the ground to enable all houses, roads, fences, streams, railways, canals, rivers, boundaries and other details to be conveniently measured up to and fixed. Perpendicular offsets are limited to eighty and twenty links for the respective scales of 6 in. to a mile and 1/2500∙

When a considerable area has to be treated by traverses it is divided into a number of blocks of convenient size, bounded by roads, rivers or parish boundaries, and a “ traverse on the meridian of the origin ” is carried round the periphery *of* each block. Be­ginning at a trigonometrical station, the theodolite is set to circle reading 0° 0' with the telescope pointing to the north, and at every “ forward ” station of the traverse the circle is set to the same reading when the telescope is pointed at the “ back ” station as was obtained at the back station when the telescope was pointing to the forward one. When the circuit is completed and the theodo­lite again put up at the origin and set on the last back station with the appropriate circle reading, the circle reading, with the telescope again pointed to the first forward station, will be the same as at first, if no error has been committed. This system establishes a convenient check on the accuracy of the operations and enables the angles to be readily protracted on a system of lines parallel to the meridian of the origin. As a further check the traverse is connected with all contiguous trigonometrical stations by measured angles and distances. Traverses are frequently carried between the points already fixed on the sides of the minor triangles; the initial side is then adopted, instead of the meridian, as the axis of co-ordinates for the plotting, the telescope being pointed with circle reading 0° 0*'* to either of the trigonometrical stations at the ex­tremities of the side.

The plotting is done from the field-books of the surveyors by a separate agency. Its accuracy is tested by examination on the ground, when all necessary addenda are made. The examiner —who should be surveyor, plotter and draughtsman—verifies the accuracy of the detail by intersections and productions and occasional direct measurements, and generally endeavours to cause the details under examination to prove the accuracy of each other rather than to obtain direct proof by remeasurement. He fixes con­spicuous trees and delineates the woods, footpaths, rocks, precipices, steep slopes, embankments, &c., and supplies the requisite infor­mation regarding minor objects to enable a draughtsman to make a perfect representation according to the scale of the map. In ex­amining a coast-line he delineates the foreshore and sketches the strike and dip of the stratified rocks. In tidal rivers he ascertains and marks the highest points to which the ordinary tides flow. The examiner on the 25·344 in. scale (=1/2500) is required to give all necessary information regarding the parcels of ground of different character—whether arable, pasture, wood, moor, moss, sandy— defining the limits of each on a separate tracing if necessary. He has also to distinguish between turnpike, parish and occupation roads, to collect all names, and to furnish notes of military, baronial and ecclesiastical antiquities to enable them to be appropriately represented in the final maps. The latter are subjected to a double examination—first in the office, secondly on the ground; they are then handed over to the officer in charge of the levelling to have the levels and contour lines inserted, and finally to the hill sketchers, whose duty it is to make an artistic representation of the features of the ground.

In the Indian survey all filling in is done by plane-tabling on a basis of points previously fixed ; the methods differ simply in the extent to which linear measures are introduced to supplement the direction rays of the plane-table. When the scale of the survey is small, direct measurements of distance are rarely made and the filling is usually done wholly by direction intersections, which fix all thc principal points, and by eye-sketching; but as the scale is increased linear measures with chains and offset poles are introduced to the extent that may be desirable. A sheet of drawing paper is mounted on cloth over the face of the plane-table; the points, previously fixed by triangulation or otherwise, are projected on it—the collateral meridians and parallels, or the rectangular co­ordinates, when these are more convenient for employment than the spherical, having first been drawn; the plane-table is then ready for use. Operations are begun at a fixed point by aligning with the sight rule on another fixed point, which brings the meridian line of the table on that of the station. The magnetic needle may now be placed on the table and a position assigned to it. for future reference. Rays are drawn from the station point on the table to all conspicuous objects around with the aid of the sight rule. The table is then taken to other fixed points, and the process of ray-drawing is repeated at each; thus a number of objects, some of which may become available as stations of observation, are fixed. Additional stations may be established by setting up the