ends of lines of level in the northern hemisphere. On long lines, the employment of a second observer, working independently over the same ground as the first, station by station, is very desirable. The great lines are usually carried over the main roads of the country, a number of “bench marks” being fixed for future reference. In the Ordnance Survey of Great Britain lines have been carried across from coast to coast, in such a manner that the level of any common cross­ing point may be found by several independent lines. Of these points there are 166 in England, Scotland, and Wales ; the dis­crepancies met with at them were adjusted simultaneously by the method of minimum squares.

*Sea-Level.—*The sea-level is the natural datum plane for levelling operations, more particularly in countries border­ing on the ocean. The earliest surveys of coasts were made for the use of navigators, and, as it was considered very important that the charts should everywhere show the minimum depth of water which a vessel would meet with, low water of spring-tides was adopted as the datum. But this does not answer the requirements of a land survey, because the tidal range between extreme high and low water differs greatly at different points on coast-lines. Thus the generally adopted datum plane for land surveys is the mean-sea level, which, if not absolutely uniform all the world over, is much more nearly so than low water. Tidal observations have been taken at nearly fifty points on the coasts of Great Britain, which were connected by levelling operations ; the local levels of mean sea were found to differ by larger magnitudes than could fairly be attributed to errors in the lines of level, having a range of 12 to 15 inches above or below the mean of all at points on the open coast, and more in tidal rivers.@@1 But the general mean of the coast stations for England and Wales was practically identical with that for Scotland. The observations, how­ever, were seldom of longer duration than a fortnight, which is insufficient for an exact determination of even the short period components of the tides, and ignores the annual and semi-annual components, which occasionally attain con­siderable magnitudes. The mean-sea levels at Port Said in the Mediterranean and at Suez in the Red Sea have been found to be identical, and a similar identity is said to exist in the levels of the Atlantic and the Pacific Oceans on the opposite coasts of the isthmus of Panama. This is in favour of a uniform level all the world over ; but, on the other hand, lines of level carried across the continent of Europe make the mean-sea level of the Mediterranean at Marseilles and Trieste from 2 to 5 feet below that of the North Sea and the Atlantic at Amsterdam and Brest,—a result which 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 raised or lowered, here and there, under the influence of local and abnormal at­tractions, presenting an equipotential surface—an ellipsoid or spheroid of revolution slightly deformed by bumps and hollows—which 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 feet higher at Kurrachee 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 wholly compensate for the excess of the mountain masses and deficiency of the ocean, and leave the surface undisturbed. If any bumps and hollow's exist, they cannot be measured instrumentally ; for the instru­mental levels will be affected by the local attractions pre­cisely as is the sea-level, and will thus invariably show level surfaces even should there be considerable deviations from the geometrical figure.

IV. Survey of Interior Detail.

(1) *General Principles.—*We have seen that the skeleton framework of a survey may be either a triangulation or a system of traverses ; very generally it is a combination of both. 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 minutiæ. 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 field-book 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.

(2) *The Scale.—*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 table of maps and scales under Map, vol. xv. p. 522. In the Ordnance Survey of Great Britain and Ireland both forms of expression are adopted, the smaller scales being 1 inch and 6 inches to a mile for provinces and counties, the larger 1/2500 for parishes and 1/500 for towns. In the Indian Survey the standard topographical scale is 1 inch to a mile, diminishing to 1/2 and 1/4 inch for geographical reconnaissance, and rising by multiples of 2 to higher scales, of which the greatest, for other than city surveys, is 32 inches, for cadastral purposes. In both surveys the double unit of the foot and the Gunter’s link (=66/100th of a foot) is employed, the former invariably in the triangu­lation, the latter very 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.

(3) *Ordnance Survey Methods.—*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, when bearings are taken with the prismatic compass. 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.

(œ) *Detail Surveying by Triangles.—*This 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

@@@1 In tidal estuaries and rivers the mean-water level rises above the mean-sea level as the distance from the open coast-line increases ; for instance, in the Hooghly river, passing Calcutta, there is a rise of 10 inches in 42 miles between Sagar (Saugor) Island at the mouth of the river and Diamond Harbour, and a further rise of 20 inches in 43 miles between Diamond Harbour and Kidderpur.