When triangulation is resorted to, base-lines are measured sometimes with a patent log, sometimes by sound, by noting the interval in time between the flash and the report of a gun. The great length of modern ironclads presents a base-line which is occasionally very convenient : points are taken at each end of the ship, as far apart as possible, from which two observers can see each other ; they are carefully marked, and the distances between them determined for future reference ; then angles between moderately distant objects and observers standing at these points, taken simul­taneously from each point, enable the required distances to be obtained. The magnetic variation is determined by observing the azimuth of the sun, when on or near the horizon, with a standard compass fixed amidship, care being taken beforehand to determine any deviation of the needle which may be due to the attraction of the surround­ing ironwork, by observing the bearing of a distant mark as the ship is swung round and her head laid on different points of the compass. See also Navigation (Practical), vol. xvii. p. 264.

VIII. Mapping.

*Graticulation.—*The sheets of paper on which the details of the survey of any large area of country are to be laid down must be furnished with a system of conventional lines, drawn with a view to assimilate the margins of con­tiguous sheets and to form a graticulation within which the details may be accurately inserted. The graticule is sometimes rectangular, sometimes spherical, sometimes a combination of both, as when points of which the latitude and longitude coordinates are given have to be plotted within rectangular marginal lines. Spherical graticules are constructed in various ways, usually in accordance with some specific method of projection ; see Geography (Mathematical), vol. x. p. 197. The following convenient method is not referable to any demonstrated projection, but is generally employed on the Indian Survey. Suppose the intersection of two meridians by two parallels to form a small spherical quadrilateral, with sides of aliquot parts of a degree in latitude and in longitude ; let *m* be the length of each of the meridional arcs, *p, p* the lengths of the arcs on the upper and lower parallels, and let *q* be a diameter, then

*q*=√*m*2+*p*.*p'* ;

thus, *m,p,* and *p*' being given, *q* is calculated. With these data, which are tabulated for different arcs and scales, the corner points of a number of quadrilaterals are laid off in suc­cession on either side of an adopted meridian, and lines are drawm through the points to indicate the collateral meri­dians and the parallels of latitude. The latter are always curved, more or less sensibly ; the former are also curved, though in a much less degree, being concave to their initial meridian, and the more so the farther they are from it. When the area is small and the scale large, the meridians are practically straight lines, and the several sheets of a map, each projected on its own meridian, will fit together closely when carried on in any direction. But, when the area is large—exceeding 8 or 10 square degrees —and the scale small, the sheets will not fit together con­tinuously unless they are projected with reference to a single meridian for the whole map, to which the meridians on either side will be increasingly concave, or unless all the meridians are made straight lines, by slightly contract­ing each of the intermediate arcs of parallel to a length which is exactly proportioned to the lengths and relative distances of the upper and lower parallels of the map from it. There must be some distortion in either case : in the first, meridians which are actually straight lines are repre­sented as being curved ; in the second, straight meridians are obtained, but the distances between them are exact

only on the upper and lower parallels, and are too small elsewhere, more particularly on the middle parallel, the length of which necessarily exceeds the mean length of the upper and lower parallels.@@1 But distortion is inevitable whenever a spherical surface is projected on a plane.

When a map is constructed in rectangular sheets, some station is adopted as the origin and its meridian as the principal axis, to which the corner points of the sheets are to be referred ; the coordinates of these points are given such dimensions as are most suitable for the size and scale of the map, and are equivalent to the rectangular spherical coordinates of imaginary points on the curved surface of the earth, at corresponding distances from the origin and its meridian. These being given, the distances of the points from the origin in latitude and longitude may be computed, as already shown (p. 706) ; thus data become available for projecting the graticulation of meridians and parallels within the rectangular marginal lines of each sheet, or for introducing the divisions of latitude and longi­tude on the marginal lines if preferred. Conversely, when the latitudes and longitudes are given, the rectangular spherical coordinates are computed and the marginal lines projected around the graticulation. Filling in is then commenced : the principal stations are laid down by their coordinates and the topographical details pencilled around them by copying or tracing the field sheets of the survey ; the names and the outlines are then inked in ; the shad­ing for delineating the features and general configuration of the ground is usually done last of all. The manner in which the details are inked in and rendered permanent depends on whether the map is to be reproduced by hand only—as when it is to be engraved or lithographed—or whether in its reproduction photography is to be employed and the action of light invoked, either in entire superses­sion of or in partial co-operation with the labour of the draftsman. In the former case the map is made as perfect a pictorial representation of the surface of the ground as possible, the hill features being represented artistically in mezzotint shading with a brush or in chalk drawing, and a variety of colours used to facilitate discrimination of differ­ences of topographical detail. In the latter no colours are used which will not photograph well, nor flat shades of any colour, nor—as a rule—mezzotint shading, but only some substitute therefor in pen and ink. This last condition is essential for the commonly employed processes of photo­zincography and photo-lithography ; but endeavours have recently been made, with some degree of success, to re­produce mapping in middle tones by the processes of photo­collotype and photo-gravure.

Photography is much employed as an auxiliary in map­ping ; for when a map is to be published on various scales the hand-drawn details of the largest scale edition may be reduced by its means as accurately as by the familiar pantagraph, and of course very much more rapidly. Thus in the Ordnance Survey town maps on the scale of 1/500 are reduced to the scale of 1/2500 for incorporation into the parish maps ; the latter are reduced for insertion in the 6-inch maps, and they in turn for the 1-inch map. By limiting the dimensions of each sheet for reduction to 3 feet by 2, and by a judicious use of stops to lenses, the re­ductions are made without any error in scale or any distor­tion that can be detected by the most rigid examination. But photography reduces every part of the original alike, the printing of words and names as well as the topographi­cal details, and it reproduces all the minor and less import-

@@@1 In Mr O’Farrell’s pamphlet *On the Construction and Use of the Six Sheets of Marginal Lines for Maps of every part of the World,* published by the Ordnance Survey, tables are given of the lengths of meridional and longitudinal arcs, their versines and diagonals, for every ten minutes in latitude from the equator to 80° N. and 80° S.