table on a ray, adjusting it on the back station—that from which the ray was drawn—and then obtaining a cross intersection with the sight rule laid on some other fixed point, also by interpolating between three fixed points situated around the observer. The magnetic needle may not be relied on for correct orientation, but is of service in enabling the table to be set so nearly true at the outset that it has to be very slightly altered afterwards. The error in the setting is indicated by the rays from the surrounding fixed points intersecting in a small triangle instead of a point, and a slight change in azimuth suffices to reduce the triangle to a point, which will indicate the position of the station exactly. Azimuthal error being less apparent on short than on long lines, interpolation is best performed by rays drawn from near points, and checked by rays drawn to distant points, as the latter show most strongly the magnitude of any error of the primary magnetic setting. In this way, and by self-verificatory traverses “ on the back ray ” between fixed points, plane-table stations are established over the ground at appropriate intervals, depending on the scale of the survey; and from these stations all surrounding objects which the scale permits of being shown are laid down on the table, sometimes by rays only, sometimes by a single ray and a measured distance. The general configuration of the ground is delineated simultaneously. In *checking and examination* various methods are followed. For large scale work in plains it is customary to run arbitrary lines across it and make an independent survey of the belt of ground to a dis­tance of a few chains on either side for comparison with the original survey; the smaller scale hill topography is checked by examination from commanding points, and also by traverses run across the finished work on the table.

4. Geographical Surveying

The introduction by mechanical means of superior graduation in instruments of the smaller class has enabled surveyors to effect good results more rapidly, and with less expenditure on equipment and on the staff necessary for transport in the field, than was formerly possible. The 12-in. theodolite of the present day, with micrometer adjustments to assist in the reading of minute subdivisions of angular graduation, is found to be equal to the old 24-in. or even 36-in. instruments. New Methods for the measurement of bases have largely superseded the laborious process of measurement by the align­ment of “ compensation ” bars, though not entirely independent of them. The Jäderin apparatus, which consists of a wire 25 metres in length stretched along a series of cradles or supports, is the simplest means of measuring a base yet devised; and experi­ments with it at the Pulkova observatory show it to be capable of producing most accurate results. But there is a measurable defect in the apparatus, owing to the liability of the wires to change in length under variable conditions of temperature. It is therefore considered necessary, where base measurements for geodetic purposes are to be made with scientific exactness, that the Jäderin wires should be compared before and after use with a standard measurement, and this standard is best attained by the use of the Brunner, or Colby, bars. The direct process of measurement is not extended to such lengths as formerly, but from the ends of a shorter line, the length of which has been exactly determined, the base is extended by a process of triangulation.

There are vast areas in which, while it is impossible to apply the elaborate processes of first-class or “ geodetic ” triangulation, it is nevertheless desirable that we should rapidly acquire such geographical knowledge as will enable us to lay down political boundaries, to project roads and railways, and to attain such exact knowledge of special localities as will further military ends. Such surveys are called by various names—military surveys, first surveys, geographical surveys, &c.; but, inasmuch as they are all undertaken with the same end in view, *i.e.* the acquisition of a sound topographical map on various scales, and as that end serves civil purposes as much as military, it seems appropriate to designate them geo­graphical surveys only.

The governing principles of geographical surveys are rapidity and economy. Accuracy is, of course, a recognized necessity, but the term must admit of a certain elasticity in geo­graphical work which is inadmissible in geodetic or cadastral functions. It is obviously foolish to expend as much money over the elaboration of topo­graphy in the unpeopled sand wastes which border the Nile valley, for instance (albeit those deserts may be full of topographical detail), as in the valley itself—the great centre of Egyptian cultivation, the great military highway of northern Africa. On the other hand, the most careful accuracy attainable in the art of topographical delineation is requisite in illustrating the nature of a district which immediately surrounds what may prove hereafter to be an important military position. And this, again, implies a class of technical accuracy which is quite apart from the rigid attention to detail of a cadastral survey, and demands a much higher intelligence to compass.

The technical principles of procedure, however, are the same in geographical as in other surveys. A geographical survey must equally start from a base and be supported by triangulation, or at least by some process analogous to triangulation, which will furnish the necessary skeleton on which to adjust the topography so as to ensure a complete and homogeneous map.

This base may be found in a variety of ways. If geodetic triangulation exists in the country, that triangulation should of course include a wide extent of secondary determina­tions, the fixing of peaks and points in the landscape far away to either flank, which will either give the data for further extension of geographical triangulation, or which may even serve the purposes of the map-maker without any such extension at all. In this manner the Indus valley series of the triangulation of India has furnished the basis for surveys across Afghanistan and Baluchistan to the Oxus and Persia.

Should no such preliminary determinations of the value of one or two starting-points be available, and it becomes necessary to measure a base and to work *ab initio,* the Jäderin wire apparatus may be adopted. It is cheap (cost about £50), and far more accurate than the process of measuring either by any known “ subtense ” system (in which the distance is computed from the angle subtended by a bar of given length) or by measurement with a steel chain. This latter method may, however, be adopted so long as the base can be levelled, repeated measurements obtained, and the chain compared with a standard steel tape before and after use.

The initial data on which to start a comprehensive scheme of triangulation for a geographical survey are: (1) latitude; (2) longitude; (3) azimuth; and (4) altitude, and this data should, if possible, be obtained *pari passu* with the measurement of the base.

A 6-in. transit theodolite, fitted with a micrometer eyepiece and extra vertical wires, is the instrument *par excellence* for work of this nature; and it possesses the advantages of portability and comparative cheapness.

The method of using it for the purposes of determining values for (1) and (3), *i.e.* for ascertaining the latitude of one end of the base and the azimuth of the other end from it, are fully explained in Major Talbot's paper on *Military Surveying in the Field* (J. Mackay & Co., Chatham, 1889), which is not a theoretical treatise, but a practical illustration of methods employed successfully in the geographical survey of a very large area of the Indian transfrontier districts. It should be noted that these observations are not merely of an initial character. They should be constantly repeated as the survey advances, and under certain circumstances (referred to subsequently) they require daily repetition.

The problems connected with the determination of (2) longitude have of late years occupied much of the attention of scientific surveyors. No system of absolute determination is accurate enough for combination with triangulation, as affording a check on the accuracy of the latter, and the spaces in the world across which geographical surveying has yet to be carried are rapidly becoming too restricted to admit of any liability to *error so* great as is invariably involved in such determinations. It is true that absolute values derived from the observation of lunar distances, or occultations, have often proved to be of the highest value; but there remains a degree of uncertainty (possibly due to the want of *exact* knowledge of the moon’s position at any in­stant of time), even when observations have been taken with all the advantages of the most elaborate arrangements and the most scientific manipulation, which renders the roughest form of tri­angulation more trustworthy for ascertaining differential longitude than any comparison between the absolute determination of any two points. Consequently, if an absolute determination is neces­sary it should be made *once,* with all possible care, and the value obtained should be carried through the whole scheme of triangula­tion. It rests with the surveyor to decide at what point of the general survey this value can best be introduced, provided he