each point the angle between the back and forward lines ; he runs his lines as much as possible over level and open ground, avoiding obstacles by working round them. The system is well suited for laying down roads, boundary-lines, and circuitous features of the ground, and is very generally resorted to for filling in the interior details of surveys based on triangulation. It has been largely em­ployed in certain districts of British India, which had to be surveyed in a manner to satisfy fiscal as well as topo­graphical requirements ; for, the village being the adminis­trative unit of the district, the boundary of every village had to be laid down, and this necessitated the survey of an enormous number of circuits. Moreover, the traverse system was better adapted for the country than a network of triangulation, as the ground was generally very flat and covered with trees, villages, and other obstacles to distant vision, and was also devoid of hills and other commanding points of view. The principal triangulation had been carried across it, but by chains executed with great diffi­culty and expense, and therefore at wide intervals apart, with the intention that the intermediate spaces should be provided with points as a basis for the general topo­graphy in some other way. A system of traverses was obviously the best that could be adopted under the cir­cumstances, as it not only gave all the village boundaries but was practically easier to execute than a network of minor triangulation.

*Procedure of the Indian Survey.—*The traverses are executed in minor circuits following the periphery of each village and in major circuits comprising groups of several villages ; the former are done with 4'' to 6" theodolites and a single chain, the latter with 7" to 10" theodolites and a pair of chains, which are compared frequently with a standard. The main circuits are connected with every station of the principal triangulation within reach. The meridian of the origin is determined by astronomical observations ; the angle at the origin between the meridian and the next station is measured, and then at each of the successive stations the angle between the immediately preceding and following stations ; summing these together, the “inclinations” of the lines between the stations to the meridian of the origin are successively determined. The distances between the stations, multiplied by the cosines and sines of the inclinations, give the distance of each station from the one preceding it, resolved in the directions parallel and perpendicular respectively to the meridian of the origin ; and the algebraical sums of these quantities give the corresponding rectangular coordinates of the successive stations relatively to the origin and its meridian. The area included in any circuit is expressed by the formula

area = half algebraical sum of products *(x1 + x2)* (y2-y1) (30), *x1, yl* being the coordinates of the first, and *x2, y2* those of the second station, of every line of the traverse in suc­cession round the circuit.

Of geometrical tests there are two, both applicable at the close of a circuit : the first is angular, viz., the sum of all the interior angles of the described polygon should be equal to twice as many right angles as the figure has sides, less four ; the second is linear, viz., the algebraical sum of the *x* coordinates and that of the *y* coordinates should each be = 0. The astronomical test is this : at any station of the traverse the azimuth of a referring mark may be determined by astronomical observations ; the in­clination of the line between the station and the referring mark to the meridian of the origin is given by the traverse ; the two should differ by the convergency of the meridians of the station and the origin. In practice the angles of the traverse are usually adjusted to satisfy their special geometrical and astronomical tests in the first instance,

and then the coordinates of the stations are calculated and adjusted by corrections applied to the longest, that the angles may be least disturbed, as no further corrections are given them.

*Convergency of Meridians.—*The exact value of the convergence, when the distance and azimuth of the second astronomical station from the first are known, is that of *B*-(π + *A*) of equation (11); but, as the first term is sufficient for a traverse, we have

convergency*=x* tan λ cosec 1''/*v*,

substituting *x,* the coordinate of the second station per­pendicular to the meridian of the origin, for *c* sin *A.*

*Adjustment of a System of Traverses to a Triangulation.—* The coordinates of the principal stations of a trigonometri­cal survey are usually the spherical coordinates of latitude and longitude ; those of a traverse survey are always rect­angular, plane for a small area but spherical for a large one. It is often necessary, therefore, for purposes of comparison and check at stations common to surveys of both descriptions, to convert either rectangular coordi­nates into latitudes and longitudes, or *vice versa,* in order that the errors of traverses may be dispersed by proportion over the coordinates of the traverse stations, if desired, or adjusted in the final mapping. The latter is generally all that is necessary, more particularly when the traverses are referred to successive trigonometrical stations as origins, as the operations are being extended, in order to prevent any large accumulation of error. Similar conversions are also frequently necessary in map projections. The method of effecting them will now be indicated.

*Transformation of Latitude and Longitude Coordinates into Rectangular Spherical Coordinates, and vice versa.—*Let *A* and *B* be any two points, *Aa* the meridian

of *A, Bb* the parallel of latitude of *B* ; then

*Ab, Bb* will be their differences in latitude

and longitude ; from *B* draw *BP* perpendi­

cular to *Aa;* then *AP, BP* will be the rect­

angular spherical coordinates of *B* relatively to

*A.* Put *BP = x, A P = y,* the arc *Pb = η,* and the

arc *Bb,* the difference of longitude, — ω ; also let λa, λb, and *λp* be the latitudes of *A, B,* and the point *P, ρp* the radius of curvature of the meridian, and *νp* the normal termin­ating in the axis minor for the latitude *λp ;* and let *p0* be the radius of curvature for the latitude 1/2(λα + λp). Then, when the rectangular coordinates are given, we have, taking *A* as the origin, the latitude of which is known,

*hp = hα+~* cosec 1" ; 17 = — tan λ∏ cosec 1" ; Ί

„ P" 1(81).

λ⅛-λα = -cosecl"-y ; *ω = -* sec(λ⅞+ 377) cosec 1" I *Pο vp '*

And, when the latitude and longitude are given, we have@@1

17 = (^) — sin 2 λ6sin 1" )

2∕=Po{λ4-λα + ,z}sinl" „ Γ (32)'

*χ=ωvp* cos (λ⅛ + ⅜y) sin l" *J*

*Graphic Method of Determining the Coordinates of an Un­visited Point observed from Several Stations.—*When a hill peak or other prominent object has been observed from a number of stations whose coordinates are already fixed, the converging rays may be projected graphically, and from an examination of their several intersections the most probable position of the object may be obtained almost as accurately as by calculations by the method of least squares,

@@@1 In the Indian Survey, tables are employed for these calculations which give the value of 1" of arc in feet on the meridian, and on each parallel of latitude, at intervals of 5' apart ; also a corresponding table of arc-versines **(*Pb*)** of spheroidal arcs of parallel (*Bb*) 1° in length, from which the arc-versines for shorter or longer arcs are obtained pro­portionally to the squares of the arcs ; *x* is taken as the difference of longitude converted into linear measure.