MODERN TOPOGRAPHY.

By H. E Coane.

Read before the Victorian Institute of Surveyors

IN none of the Australian colonies has any serious attempt been made to conduct a general systematic topographical survey, although the necessity has long been urged by the Technical Associations.

The Geological and Mining Departments of the various colonies have certainly compiled some very excellent geographical maps of the more important goldfields, and, together with the Lands Departments, have insisted on their surveyors showing general topographical features on lease and selection plans, but these latter, as we know, are usually sketched in the roughest manner.

The principal uses for which topographical maps are required are for the location of railroads, reservoir sites, roads, canals, &c., &c., and for military purposes. For the successful prosecution of geological investigations they are an absolute necessity, and the existence of complete maps would be a great boon to the Departments charged with this duty, and would facilitate their work immensely.

It is not until within the last few months that most people have realised how important a part correctly delineated maps play in modern warfare. Leaving out the loss of life and the suffering entailed by the early unfortunate operations in Natal, enough money would probably have been saved to map the whole province, had really accurate and useful plans been available. That our local military authorities are alive to the necessity for reliable maps, showing features definitely and accurately, is proved by their action in preparing good topographical plans of the Mornington Peninsula between Port Phillip, Western Port, and Bass Straits.

Almost every other civilised country, not excepting even China, has completed, or is now engaged in compiling, topographical maps of its territory, including vast areas of waste or undeveloped country ; and why we in Australia should have made no serious move is remarkable, and explicable only by assuming that the expense has been the deterrent. As will be seen below this is scarcely an adequate reason for our inaction. It is to be hoped that the efforts of this Institute may be successful in getting an early start made on a topographical survey, to be proceeded with gradually till completed. A commencement could be made in the coastal districts and in localities where public works of any magnitude were contemplated, and there is little doubt that the utility of good maps would be so much appreciated as to secure the continuance of the work.

In view of the possibility of the early commencement of this work —and surely we cannot much longer delay it—it may be useful to review the requirements in good topographical work, and, considering the methods recently adopted elsewhere, sketch out a scheme, fitting in with local conditions, that should at any rate serve as a basis for discussion.

REQUIREMENTS OF THE MAP.

It is required of the map that it should show faithfully, in horizontal projection and vertical relief, all the topographical features, such as hills and valleys, rivers and lakes, watercourses, plains, and certain artificial features such as roads, railways, buildings, &c. It should be purely a topographic, and should not be either a cadastral or a geological map, although it should be sufficiently clear to enable it to be used as a base for the latter.

To this end something more than an indefinite, possibly erroneous, picture is required for a topographic map worthy of the name. It does not appear that there is any true economy in the preparation and publication of any but complete maps, as faulty ones do not fulfil the requirements of Engineers and others, and consequently are in poor demand; moreover, many of the items of expense are the same for bad as for good ones. In other words, the survey on which the plan is based must be fairly detailed in all respects, and little must be left to sketching by eye.

It is everywhere agreed that such detail is not expected of any State maps as would enable, say, the centre lines of proposed roads or railways to be located without running a line of trial survey. The object in view is to give sufficient material for the selection of the best route to be followed by those engaged on the trial, and, by presenting to them a picture of what lies ahead, obviate the necessity for *reconnaissance*.

The artificial features shown on the map should depend to a large extent both on the scale and the purposes to which it is to be applied. On any map that is intended to be a permanent record, it is wise to suitably limit their number to those which are likely to remain unaltered for a considerable period, and thus avoid frequent revision. The features usually shown are as follows:—Towns, roads, watercourses and canals, shore lines, lakes, lagoons, marshes, Crown allotments, Parish and County boundaries, railways, permanent buildings, bridges, fords, ferries, important mining shafts, tunnels, piers, breakwaters, public parks, contours, and the principal bench marks. Temporary features, such as fences, small outbuildings, cultivation, and timber or vegetable growths, are liable to change at any time and should not be included.

There has been considerable difference of opinion as to the utility or otherwise of distinguishing timbered tracts of country. A knowledge of the timbered belts is certainly of importance for military purposes, but there is no reason why the War Office should not from time to time obtain this information where they require it, and chart it on the published plans.

Vertical relief may be indicated either by hachures or contours. Whilst imparting to the map a decidedly artistic appearance, hachures give only the faintest idea of the relative heights of the ground, and should not be used except to represent precipitous cliffs.

More recent practice certainly tends to larger scales for topographic maps. The scales should be sufficiently large to be of the greatest practicable service for industrial uses, such as the general location of railway routes and public works, and for scientific purposes (as the preparation of geological maps) without unduly multiplying the number of sheets. The scales need be no larger, however, than will allow of plotting corresponding in accuracy with the field work. The limit of error in the fixing of comparatively unimportant points on the plans should not generally exceed $\frac{1}{50}$ in. on the published sheets, but in exceptional cases $\frac{1}{30}$ in. might be permitted.

Slightly more latitude may be permitted in locating the contour lines which to a certain extent are necessarily sketched in. A surveyor to be a successful sketcher must possess as one of his qualifications a sound knowledge of the principles of geology.

METHODS OF SURVEY.

The only methods of survey that need be mentioned in detail as not being in ordinary use in Australia are tacheometry, plane tabling, and phototopography.

TACHEOMETRY.—The aim of tacheometric surveying is to obtain bearings, distances, and differences of level with one instrument and without the use of a tape. The advantages of being in a position to dispense with the latter in rough country are obvious. The use of the tacheometer is common throughout Europe, while in America the transit, fitted with stadia wires, substantially a tacheometer, is fast supplanting every other instrument for topographic and rapid preliminary survey.

Optical measurement of distances requires the determination of the angle subtended at the telescope by a base of known length. This is accomplished by (*a*) observing the distance intercepted upon a graduated staff by fixed cross wires, when the angle they subtend is known, or (*b*) observing the angle subtended at the instrument by a base of constant length measured on a rod. Of these methods the former is the simpler, and is in general use, especially for sights not unduly long. Eckhold's omnimeter is an instrument typical of those used with the latter system, but micrometer arrangements are frequently added to an extra cross wire in the ordinary telescope to effect the same purpose.

A tacheometer is simply an ordinary transit theodolite, with the addition of two horizontal cross wires to the diaphragm, sometimes fitted with an anallatic telescope.

It has been wisely recommended that surveyors ought never in the future to purchase theodolites as ordinarily made, but should insist on the makers fitting to them telescopes of more than the usual power, and containing stadia wires. Distinctness of vision is the very foundation of good work, yet many of the English-made 5in. theodolites are provided with telescopes magnifying only 11 or 12 diameters. Although it is inadvisable to make a telescope too powerful, since it must be at the expense of a serious diminution in the light received at the eyepiece, and consequently in the clearness and brightness of the image, we might reasonably expect a power of at least 30 diameters in a telescope suited to an instrument of that size. This would enable the intercept on an ordinary levelling staff to be read with an error not exceeding ·01ft. at a distance of ten or twelve chains. Formerly the horizontal circle of the tacheometer was divided centesimally into 400 degrees, but this is now being abandoned; it was originally adopted, no doubt, to facilitate slide-rule computations.

A recent improvement consists in the division of the vertical circle from 0° to 180°, so that readings less than 90° are angles of elevation, and those over 90° depression angles.

In the tacheometer or theodolite intended for vertical angle work, it is a distinct advantage to have the principal bubble attached directly to the vernier arms of the verticle circle, instead of to the telescope tube. The saving in time when levelling up at each station is considerable, and the bubble is always visible as a check against any accidental derangement of the levels.

The general principles of subtense measurements are concisely explained in several papers* on the Tacheometer.† In them it is clearly explained how, with stadia wires fitted to the diaphragms of the telescopes ordinarily supplied with theodolites and levels, the centre of anallatism, or the point from which the distance of any object is proportional to the intercept upon the staff, is situated at the anterior focus, distant the focal length of the telescope in front of the object glass. Thus, with a telescope of 10″ focus for average sights, every measurement will be from the staff to a point about 15″ in front of the axis of the instrument. This is no obstacle to its use for stadia measurements.

The anallatic telescope, invented by Porro, is arranged so that by the introduction of another lens the centre of anallatism is brought directly over the vertical axis of the instrument, any correction being thus rendered unnecessary. These telescopes are usually made of high power, but have not come into general use owing to the decrease in light received at the eyepiece, the difficulty of keeping the anallatic lens clean, and the less important fact that distances under about 50ft. cannot be accurately determined.

FIELDWORK.—No expensive outfit is necessary for stadia surveys. A tin megaphone for shouting directions is the latest addition to the equipment. The method of survey is simply to run rapid traverses along leading lines, between points whose positions are fixed with reference to the trig or cadastral survey. From selected stations on the traverse, radiations are established to every point whose position and elevation are required. The whole of the artificial features can be quickly picked up, and at the same time many points fixed solely for the purpose of enabling the contours to be correctly plotted. The relative heights are deduced from vertical angles read to every station, and the errors that will creep into these heights from instrumental imperfections and discrepancies in horizontal distances, on which of course depend the vertical components, are kept within a reasonable limit, say one or two feet, by comparison with Bench Marks established by lines of accurate spirit levels.

A fully-manned field party usually consists of the surveyor in charge, the observer, the recorder who enters the readings in the field and makes detailed sketches where required, and two or more staff and axemen who move about holding the staff at each point to be determined. Instrumental stations are generally identified in the field notes

* Mr. H. P. Seale, in Vol. VI. Trans. Australian Inst. Mining Eng., 1900.

† Mr. Neil Kennedy, in Vol. XCIX. Min. Proc. Inst. Civil Engineers, 1890

and sketches by assigning to each a letter of the alphabet; staff stations are recognised by numerals attached.

The observations to each staff station are considered to be best read in the following order:—(1) The reading on the staff of the stadia hairs; (2) The vertical angle to some definite point on the staff, and (3) the azimuthal angle.

When traversing, the observation is repeated to the back station, and the mean of the results adopted, corrections for curvature and refraction being thus eliminated, and a check at the same time being afforded on the work. When possible, the telescope should be used as an ordinary level, so as to minimise computations; this of course is practicable only when the traverse runs approximately along a contour. The average length of sights, on main traverses, may be set down as from five chains for medium telescopes to ten chains with powerful ones. The shorter the sights, within limits, the greater will be the accuracy; for minor radiations to less important points, 20 to 30 chain shots are permissible.

There is a diversity of opinion as to whether the staff should be divided to true units or into arbitrary units to suit each particular pair of stadia wires. Seeing the stadia rods must also be available as levelling staffs, it is almost imperative to have them divided to true units.

The usual practice is to have the stadia wires arranged so as to intercept one foot on the staff when the centre of the instrument is distant 100ft. + the constant f + c.

In the event of the intercept being slightly in error, a percentage correction to each reading will overcome the difficulty; certainly with the anallatic telescope small corrections can at any time be made by altering the relative positions of the two lenses. Great care must be taken to determine the interval under average working conditions, since the varying influences of terrestrial refraction affect the stadia intercept.

The usual practice is to hold the staff vertical at all times, and not at right angles to the line of sight. To facilitate computation, tables* have been computed on the assumption that the staff is held truly vertical, giving values of heights and horizontal distances for various intercepts and for every minute in altitude from 0° to 30°.

Their use involves no more effort in the reduction of an observation than that of using an ordinary traverse table. Slide rules of special construction and graphic methods are sometimes resorted to. The continual use of the former is a great strain on the eyesight, and no method is so reliable and convenient as the use of compact tables.

Considering the accuracy obtainable under working conditions, it may safely be stated that errors in the measurement of distances can be kept below 1 in 500 in the roughest country.

On the survey of the Mexican Boundary† the division line was measured both by an accurate triangulation and by stadia for a distance of 182 miles. The total of the differences amounted only to $\frac{1}{5873}$ of the

* See Mr. Kennedy's paper and the last edition of "Gillespie's Surveying."

† Mr. J. L. Van Ornum, in Vol. XXXIV., Trans. Amer. Soc., C.E., October, 1895.

length. Some stadia surveys conducted in 1899 in North America for water conservation schemes gave an average error of closure of from $\frac{1}{1200}$ to $\frac{1}{1100}$ without any unusual precautions being taken by the Engineers.

Plane Tabling.—The plane table* is not generally held in the estimation it deserves as an auxiliary in the preparation of maps in most descriptions of country. Without entering into a lengthy description of its construction and manipulation, such as may be found in a number of text books, an attempt will be made to sketch its general application to topographic surveying.

Essentially, the plane table is a wooden board some $\frac{1}{2}$in. or $\frac{5}{8}$in. thick, mounted on a tripod, and capable of being levelled, revoled on a vertical axis, and clamped in any position. The most convenient form now in use is said to be that invented by Mr. W. D. Johnson, of the United States Geological Survey.

When in use on any particular survey, the board is levelled and oriented, so that one edge is at every station on the same bearing. Azimuths are plotted on the paper direct, with the aid of the alidade, consisting of a brass ruler about 20in. long with a chamfered edge. To its ends are attached raised sights, or for better work, a telescope, carrying stadia wires, and fitted with a vertical circle reading to minutes. The field sheet is made of two thicknesses of paragon paper, mounted on either side of a piece of cloth. The usual procedure is to lay down on the field sheets all the primary control points available, and by occupying successive stations, locate minor points by the well-known method of intersections; in fact, to conduct a graphic triangulation without subsequent calculation. Any points so located may, if required, be occupied as stations, and the detail work carried as far as is necessary. Vertical locations of points are determined by the observation of vertical angles, involving the solution of right-angled triangles, and the necessary correction for curvature and refraction. When traversing, the table is generally oriented by compass and the distances, as measured by stadia or odometer, are necessarily plotted as the work proceeds.

Phototopography.—Phototopography, or the construction of topographic maps from photographs, was introduced in the middle of the present century. Since then it has made rapid strides in progress, until to-day, when, with instruments fitted with the latest improvements, we are enabled to compile accurate maps of rugged country at an astonishingly small cost

It is proposed to deal at present with only the bare outlines of the methods adopted. A very concise and interesting account of the progress of phototopography is given in a paper by Mr. P. Barrachi, Government Astronomer, reprinted in The Surveyor (N.S.W.), of December 20th, 1897. A technical description of the principles is to be had in "Photographic Surveying," by Capt. E. Deville, Surveyor-General of Dominion Lands, Canada. Much that follows on this subject has been gathered from that very excellent work. As in every other method of topographic survey, the first step is the establishment

* See paper by Mr. Josiah Pierce, Vol. XCII., Min. Proc. Inst. Civil Engineers, 1888.

of a primary triangulation ahead of the detail survey. A secondary system of triangles, subsequently adjusted and calculated, is extended along with the photographic work to locate the camera stations both horizontally and vertically.

The Canadian practice is to equip a party with one 3in. transit theodolite, reading to minutes, and two fixed focus cameras carrying flat glass plates ($4\frac{3}{4}$in. x $6\frac{1}{2}$in.), and fitted with levelling screws similar to those of a theodolite. The surveyor, accompanied by one man, carries the theodolite and one camera, with one tripod fitting both instruments. The assistant and another field hand take the second camera. All the angles of the secondary triangulation are read with the small theodolite, and connections made at the same time to extra camera stations. Signals are left at each station to serve as sights in continuing the triangulation. Great care is exercised in selecting the camera stations, which must be chosen with regard to the fact that every point on the plan is located by the method of intersections just as in plane tabling, and that ill-conditioned triangles should be avoided. Should great trouble be experienced in obtaining two photographs that will provide suitable intersections for any particular part of the area under survey, the method of vertical intersections from views taken at different altitudes is occasionally resorted to. The number of exposures required will vary with the character of the country and the scale on which the plan is to be plotted. Camera stations are frequently over one mile apart where the maps are to be plotted on a scale of 50 chains to an inch.

Italian and French topographers have for some time past used a combined transit theodolite and camera with satisfactory results, while in England Mr. Bridges Lee* has introduced a photo. theodolite with up-to-date improvements. Since images formed by photographic lenses of special construction, such as the rectilinear or Zeiss anastigmatic, are true perspectives, it follows that the methods to be adopted in plotting will be the converse of those followed when constructing a perspective drawing from the usual data. Having fixed the positions of the triangulation points and camera stations on paper, the next step is to identify the positions of a sufficient number of points on at least two of the enlarged prints, and to plot the intersections. The heights of each are deduced from the horizon lines appearing on the photograph, and are figured on the plan, thus enabling contours to be sketched in without difficulty. The production of the maps from the photos is a simple operation at any time. With the aid of such instruments as the perspectograph, centrolinead, and perspectometer, a great many points can be located in a short time.

It is claimed for the method of phototopography that the horizontal control is almost as accurate as when the plane table is used. It seems, however, that the precision with which small vertical angles, and the heights of points calculated therefrom, can be deduced, is not very satisfactory. The heights of points near the horizon are specially uncertain. Generally it may be stated that phototopography has been amply

* Photographic Surveying, by Mr. J. Bridges Lee, M.A., in Transactions of the Society of Engineers, 1899.

proved to be an excellent method of compiling topographic maps in rough and mountainous country presenting bold features. For economy it has not been approached by any other system of survey; the field work requires only a party of four in all, and the cost of producing maps in mountainous regions is no more than one-third that of work of the same detail executed by the plane table.

Of course for the successful application of phototopography, the surveyor must be possessed of a specially constructed though simple camera of fixed focus carrying a wide angle lens very truly ground. He must in addition be a capable photographer. Although a thorough knowledge of the principles of descriptive geometry and perspective will be of the greatest assistance to him, there is no reason why anyone not well up in these subjects should be discouraged from taking up phototopograpy, since in all ordinary operations the work is of a mechanical nature.

METHODS ADOPTED IN OTHER COUNTRIES.

The following is a brief résumé of the methods adopted by some of the principal countries of the world in the production of their topographic maps.

Great Britain.—The topographical maps being based on the ordnance sheets, previously published to scales 1 : 500 for towns and 1 : 2500 for agricultural districts, their production was comparatively easy work. Contours were located in most cases by the costly method of detailed spirit levels. The sheets are all published on a scale of one mile to an inch, and are reproduced in black and white by photozincography. Vertical relief is indicated in some cases by contours and in others by vertical hachures. All roads, watercourses, buildings, parks, railways, &c., are shown. The maps are printed on good paper and sold at 1s. per sheet.

India.—The topographic survey, based on the Great Trigonometrical Survey, is being extended and mapped at the rate of about 15,000 square miles per annum. The plane table has been for over a century—and is now—used to fill in the details. It has been found a suitable instrument for the quality of work demanded, especially on account of its simplicity, which permits of the employment of native surveyors for filling in details. Although formerly nearly all the sheets 30in. x 17in. were published on a scale of one mile to an inch, the 40 chain scale has also been adopted in recent work, including that of the survey of Sind.

The average cost of mapping on the smaller scale has been given at £2 5s. per square mile; this of course being exclusive of the primary triangulation.

United States of America.—The Coast and Geodetic Survey Bureau has compiled elaborate maps on scales 1 : 10,000 and 1 : 20,000 (about 12½ and 25 chains to an inch), for the double purpose of supplying charts for navigational and maps for defence purposes. The work is based on a computed primary, secondary and tertiary triangulation, with stations about one to two miles apart; the altitude of each is also determined. The details are chiefly filled in by plane table, although stadia traverses are frequently resorted to. Vertical relief is indicated by contours at intervals of from 5 to 10 feet, depending on the nature of the country.

The Geological Survey Bureau commenced to compile a topographical map of all the States in 1882. Although originally intended as a base for geological maps, its scope has been somewhat extended, so as to meet engineering and economical requirements so far as the scale will permit. It is based on a computed triangulation, except in level country, where a system of primary and secondary traverse lines is adopted. The number of governing positions thereby determined averages 1½ per square mile, and with these as control points the details are filled in with a Johnson plane table fitted with a distance measuring alidade. Full advantage is taken of all information that can be gathered from reliable sources after it has been connected with, and, if necessary, corrected to agree with the primary triangulation or traverse.

Lines of precise levels are run throughout the country not further apart usually than five miles, but closer when necessary. These with trigonometrical levels determine definitely the elevations of about 2½ points per square mile. Vertical angles read with the alidade of the plane table, and barometric observations to determine elevations, enable contours to be sketched at intervals of from 5ft. in easy slopes to 20ft. in ordinary cases, and to 100ft. in the most hilly regions.

The plane table sheets are on the same scales as the finished maps, viz., one mile to an inch, and two miles to an inch. The sheets measure about 17½in. x 14in., and projection is on the polyconic system. The maps (sold at 1s. 6d. per sheet) are published in three colours, black for artificial features, blue to represent drainage, relief in brown, every fifth contour being a heavier line. The introduction of colours necessitates the preparation of three copper-plate engravings, but adds materially to the artistic effect. The cost of mapping Massachusetts on one mile scale with contours at 20ft. intervals is given at about £2 10s. per square mile, exclusive of primary triangulation expenses; of Rhode Island and Connecticut, £2; of New York State, £1 per square mile in level country to £4 10s in broken country. The mountainous regions in the South and far West on scale two miles to an inch with contour interval 100ft. cost £1 per square mile, but the amount of detail is necessarily limited.

Up to the present about one-third of the whole area has been mapped.

Canada.—The topographic surveys, although not far advanced, have been almost entirely effected by photography. Plots on scale 1 : 20,000 are reduced for publication to 1 : 40,000 (about 50 chains to an inch), with contours at intervals of 100ft. and over.

The work, based on triangulation, has been as yet principally confined to the Rocky Mountains district, for a strip about 20 miles wide on each side of the Canadian Pacific Railway, and along the Alaskan boundary.

It is estimated that the cost of mapping the former did not exceed 12s. per square mile.

The Alaskan boundary maps were published in 1896 in three colours, on scale of about 2¼ miles to an inch, contour interval 250ft. Irrigation surveys, commenced in 1894, are carried on by phototopography; the object in view is to find suitable reservoir sites.

Italy.—Topographical surveys are carried on under the direction of the War Department, and are based on a triangulation which is constantly kept two years in advance of the detail work. Field work is carried on almost entirely by plane table or tacheometer in the more settled districts, and by phototopography in the mountainous regions. The field sheets are plotted on scales 1 : 25,000 and 1 : 50,000, and reproduced by lithography, with contours drawn at 5 and 10 metre intervals, on sheets about 15in. x 14½in. The map is nearly completed, but is constantly under revision. Topographical maps are also reduced by photozincography to scales of 1 : 75,000 (95 chains to an inch) and 1 : 100,000, with contours at 50 metre intervals.

The average cost of mapping has been given as under £3 per square mile. It must be noted that considerable advantage has been taken of former surveys.

GERMANY.—The topographical maps are based on an accurate survey, with precise levels, and are considered by good authorities to be of high quality. The plane table, with distance measuring alidade reading up to 25 chains, and the tachymetric plane table, are chiefly used for filling in details. Phototopography has been extensively practised on the Military survey, in very hilly and steep-cliffed regions, with success.

The maps are published on scale of 1 : 25,000 (about 31 chains to an inch), on sheets about 19½in. by 18in., with contour intervals from 5m. upwards.

Those of Baden and Saxony are completed and printed from copper-plate engravings, the former in four colours with contours in red, price 2s. per sheet. In Prussia and Bavaria, the map as completed is lithographed in black with water surfaces hand-coloured blue; timber growths are indicated by conventional signs; the sheets are sold at 1s. each.

The cost per square mile is stated to be about £16.

FRANCE.—The topographical surveys are now carried on in this country by the "Service Géographique de l'Armeé." For a great part the cadastral survey maps on scale 1 : 2,500 were available for reference, although not published. These are reduced to 1 : 20,000 on plane table sheets taken into the field, corrected where necessary, and brought up to date, use being made of the distance measuring alidade. Precise levels are carried along all roads.

The maps are published on scales 1 : 80,000 and 1 : 50,000 (63 chains to an inch), printed in black on sheets 18¼in. x 10¼in., and sold at 10d. per sheet for copper engravings, or 3d. per sheet for zinc prints. Hills are indicated by vertical hachures with the main heights in metres.

BELGIUM.—The cadastral survey on scale 1 : 2,500, unpublished, serves as an excellent base for the topographic maps now being published on scale 1 : 20,000 (about 25 chains to an inch). They are produced both in black and in 8 colours on sheets measuring 20½in. x 16¾in. and sold at 1/3 and 1/6 a sheet. Contours are at intervals of 1 metre, every fifth curve being thickened.

AUSTRIA-HUNGARY.—The Military topographic map on scale 1 : 75,000, completed in 1891, was based on the cadastral survey maps on a scale of 240ft. to an inch, themselves based on a trigonometrical and plane table survey. In 1892 an entirely new map was commenced from a new survey. The details are filled in by plane table on scale

1 : 25,000, great use being made of aneroid barometers, especially those of the Goldschmidt type. The German and Austrian Alpine Club has recently completed some very elaborate topographical maps, controlled horizontally by the ordnance survey. The vertical relief was filled in entirely by phototopography.

SWEDEN AND NORWAY.—The trigonometrical survey already finished and the cadastral maps based upon it to a scale of 1 : 4,000 serve as a good foundation for the topographic map, which is being published on scales 1 : 20,000 for settled districts, and 1 : 50,000 and 1 : 100,000 for less important localities. The system of contours is adopted and vertical control obtained by running lines of precise levels across the country, establishing some 25 points per square mile. In Norway the maps are lithographed in four colours, with contours 100 feet apart on sheets 17½in. x 14½in., the hills being stumped brown. In Sweden the maps are engraved on copper and printed in black on sheets 20in. x 17½in., but roads, water surfaces and boundaries are afterwards coloured by hand.

SWITZERLAND.—The topographical surveys are nearing completion on scales 1 : 25,000 and 1 : 50,000. The plane table, with distance measuring alidade, is the principal field instrument. Contours are at intervals of 10m. and 30m. Every tenth contour is broken and has number written on it. Sheets 13⅓in. x 9½in. are printed in four colours and sold at 1s. each.

HOLLAND.—The topographic maps of Holland, now almost finished, are noted for the completeness of detail delineated. The character of vegetation and the hills are expressed by various shades of colour. Maps are published on scale 1 : 25,000.

NATAL.—In 1863 the British War Department lithographed a map of all the country between Durban and Laing's Nek on scales 4 miles to an inch. The hills were represented by hachures and shading, heights were given only occasionally, and all main roads and towns shown. In 1897 the War Office prepared in three colours a more detailed map of the country north of the latitude of Ladysmith on a scale of 1 mile to an inch. The hills are shaded and heights given in feet. It would appear that these maps did not extend far enough south to assist General Sir Redvers Buller in his operations for the relief of Ladysmith.

In addition to the foregoing, surveys are completed or proceeding in the following countries:—Russia, Finland, Caucasia, Transcaspia, Denmark, Bavaria, Spain, Portugal, Turkey, Servia, Montenegro, Bulgaria, Persia, Turkestan, Siberia, China, Java, Tunis, Algeria, Mexico, Japan, etc., yet we in Australia are practically doing nothing in this direction.

It will be seen that there is no absolute uniformity of practice as to the class of map or scope of Topographical surveys undertaken elsewhere. At a Conference of Topographers* of the United States Coast and Geodetic Survey, held in Washington in 1892, some very valuable recommendations were submitted, the principal being that topographic maps should be drawn to a scale of 1 : 30,000 (about 38 chains to an inch), except in very flat or very hilly country, where

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* Report of the United States Coast and Geodetic Survey for 1893, part 2.

1 : 40,000 (50½ chains to an inch) is recommended and named as the smallest scale on which a reliable map can be plotted.

Comparisons of the cost in various countries are of little value on account of the totally different conditions existing as to methods adopted, existing surveys, scales of maps, climate governing, length of field season, forest growths, the salaries of the surveyors and the wages pair for labour.

REQUIREMENTS FOR AUSTRALIA CONSIDERED.

Although we have not yet succeeded in convincing our respective Colonial Governments of the wisdom of commencing forthwith the preparation of topographic maps, there is the consoling fact that, in the light of the experiences of other countries, we shall be able, when we do commence, to set about the work with confidence as to the result.

The author ventures, with great respect, to suggest to the Institute that the requirements for Australian State maps would be met by the procedure outlined below.

Considering first under whose control systematic surveys should be conducted, it seems that, since the Lands Department of each State is in possession of the bulk of the data relative to existing surveys, the Surveyors-General are the proper persons to direct them. It may be argued that the Mining and Geological Departments should be charged with the duty of carrying them out in conjunction with geological surveys, or that a new Department, created by act of the Commonwealth, should have control of all topographic work. Whatever the system may be, uniformity of practice for the whole of Australia is absolutely essential.

Horizontal Control.—It is agreed that the only reliable basis for a map of any region consists in a rigid triangulation, so that the preliminary towards securing adequate horizontal control should undoubtedly be the extension, connection, and adjustment of the trignometrical surveys of each of the States. Then would follow the connection of some controlling points of the cadastral surveys already carried out by the Lands and Mining Departments with the trig-survey, broken down to a secondary system of triangulation, and the adjustment of the cadastral work, where discovered to be erroneous. A few standard traverse lines would suffice in place of triangulation in flat country. When adjusting there should be no necessity for elaborate re-surveys, except perhaps in districts where the original surveys were of a very inferior quality. By collating the results of our permanent and trial railway locations, and by taking advantage of such surveys as have been effected for the office of Titles, etc., a reasonably accurate idea of the facts as they exist could be formed, and we should be enabled to distribute the discrepancies with at any rate sufficient exactitude to admit of correct plotting. All bearings should be adapted to conform to the true meridian. Generally full advantage should be taken of all reliable information obtainable from official or private sources, including the results of surveys by the Water Supply and Public Works Departments, so that the expense of field parties may be reduced to a minimum. The lines, boundaries, and points so determined would serve as excellent bases for the detail work, which latter would be accomplished by methods suitable to each set of circumstances. In unsettled districts to which the cadastral surveys are not as yet extended, a system of tertiary triangulation, not necessarily computed, would probably provide the most economical framework for the details.

As regards the accuracy with which the cadastral survey lines should be delineated, it is evident that having adjusted the property boundaries as nearly as possible to the truth, errors of $\frac{1}{80}$in. in the plotting, corresponding to 50 links on the 40 chain scale, must be regarded as considerable, and should not be exceeded. As to features such as buildings, contours, etc., it has been already stated that errors in location of interpolated or comparatively unimportant points, on the published sheets of $\frac{1}{50}$ in., corresponding to 80 links, are admissible, while those of $\frac{1}{30}$ in., corresponding to $1\frac{1}{3}$ chains, should be allowed only in exceptional cases. It should be sufficient to keep the accuracy of field work within these limits.

It might be reasonable to require all tacheometer traverses to close within 50 links, in latitude and departure, when intended for use in the preparation of maps on the 40 chain scale, or 25 links when the scale is to be 20 chains to an inch. To ensure this result the lengths of circuits should be kept within reasonable limits.

Vertical Control.—Practically, in Victoria at any rate, only the Departments of Railways and Water Supply are in possession of details valuable for establishing vertical control. In this State the Railway datum of Low Water Mark Hobson's Bay has been adopted by the other Departments, but in New South Wales several datums are in existence. It would be desirable for the purposes of a topographic survey that a common datum, preferably mean tide level, should be adopted for all Australia; but if it were considered that the alterations would lead to confusion, there would be no serious objection to the work of each State being continued on any reasonable datum already in use, if not altogether too discrepant The Railway levels as we know attain considerable precision, and, a few ascertained discrepancies having been adjusted, would form a sufficiently accurate basis for vertical control. Lines of precise levels should be carried through new country, and really permanent Bench Marks established at suitable intervals. Spur lines of spirit levels of ordinary accuracy might be run along all the leading lines of roads and connected with the principal trig stations. The contour interval will necessarily be adjusted to the horizontal scale, and will range from 3ft. to 100ft., varying with the nature of the country. Contours would generally be drawn in by interpolation (it being impracticable in a State survey to traverse them on the ground) between points whose horizontal positions and heights are known. The elevation of these minor points can only be determined economically by the observations of vertical angles; to resort to spirit levelling for such work would be entirely out of the question, and as fatal to the economy of any scheme as would be an attempt to measure every distance with the steel tape. An exception to this rule would be found in mapping very flat areas, such as the plains of Riverina or Northern Victoria. In such places spirit levels would be an essential; distances would be determined by stadia wire readings. It is suggested that for tacheometer traverses in fairly hilly country the permissible error in the determination of the height of any station would be about 2ft., with 5ft. as the limit for minor location points, provided in all cases that the error does not amount to more than one-half the contour interval.

The aneroid barometer is likely to be of service only where the contour interval is large, such as 50 or 100ft. Even then it should be used only for measuring small differences of elevation with short intervals of time between the readings. Even admitting that the elevation of any particular point can be obtained with sufficient accuracy from barometric observations, there still remains its horizontal location; since this is almost invariably obtained by instrumental observation, the extra labour of reading a vertical angle and deducing the reduced level is slight and well repaid by the certainty of the determination.

SCALE.—There is no reason why the atlas should be published on the same scale throughout, although it would perhaps be unwise to select more than two. The scale of the published sheets that would probably meet all demands, and yet be within our means, might be set down at 40 chains to an inch for all localities, with a second scale of one mile to an inch for mountainous, unsettled, or very flat districts of no special interest.

Sheets embracing 10 min. both of latitude and longitude would, for the 40 chain maps, be of a convenient and manageable size. For the latitude of Brisbane they would measure 23in. x $20\frac{1}{2}$in., and for that of Melbourne 23in. x $18\frac{1}{4}$in., over the work in each case, exclusive of margins. Maps on the one mile scale would embrace one-third of a degree, and the plotting would need to conform to some recognised system of projection, such as the polyconic.

The sheets are usually distinguished by numbers and referred to an index map on a small scale, say 20 miles to an inch, showing the system of numbering.

Minor errors of plotting would be practically eliminated if the practice were adopted of compilation on a large scale with subsequent reduction for publication. It has been wisely suggested that draughtsmen should have a knowledge of field methods, and should serve at least a term in camp before being allowed to undertake responsible work in the office

The question of reproduction will be one requiring consideration by experts. As yet no process gives a better result than that of copperplate engraving, the cost of which, however, is high.

In view of the facilities afforded for revision and additions in subsequent issues, the process of photo-lithography has much to commend it. Great skill, however, is required to obtain a photographic reduction exactly to a desired scale. It would add greatly to the effect if contours were in some distinctive colour, preferably brown, and water surfaces tinted blue; the Continental practice of colouring by hand might be followed with regard to the latter.

DETAIL WORK.—Reference need not be made to the methods of trigonometrical or cadastral survey, but the means adopted for recording topographic details will admit of unlimited discussion.

In settled districts, only moderately timbered, and not mountainous, two methods seem to be open for work—viz., tacheometry and plane tabling. As mentioned before, the system of phototography has been found to be particularly effectual in very mountainous, and at the same time sparsely timbered, regions. We have in this country many localities where minute details are not required to be shown, and in them the camera would be found useful, more particularly where a scale of one mile to an inch is adopted.

For open, rolling, and moderately hilly country with a number of commanding peaks and ridges, such, for example, as are found in the Bacchus Marsh district, it is probable that the progress of the work would be greatly facilitated by a method of intersections that has been adopted elsewhere with advantage. Two of the most favourably situated instrumental stations in the minor triangulation, or tacheometer traverse are occupied by tacheometers, theodolites, or plane tables. Azimuths and vertical angles are read on given signals to the points occupied by the staff holder, who moves rapidly about under direction. All note by watch the exact times of readings, this affording the means of distinguishing the various observations. As the heights of instrumental stations are in every case known within a very little, it will be possible to check the elevation of each point observed to in this manner by a second computation; in most cases it will be sufficiently accurate to scale the horizontal distance from the plot, reducing only where the vertical angle is considerable. Topography may be taken by this method with sufficient precision when the sights are not unduly long (say under 60 chains), and when a good telescope is available.

It is not suggested, however, that it would be wise to locate points within ten or twelve chains of the instrument station, by the method of intersections, when one observation to the staff would be sufficient to determine the bearing, distance, and difference of level.

The accuracy with which details can be drawn will depend entirely on the number of locations per square mile, which again will vary with the local conditions and requirements.

Speaking generally of the field work, we may be certain that no one rigid method of obtaining the details can, or will be, adopted for any survey, and that a combination of several systems will in most cases be the best.

For the greater part of the detail work, however, the tacheometer seems to be specially adapted, and to be preferred to the plane table; for the following reasons it is coming into more general use from year to year :—

(*a*) Because in timbered country, triangulation is impossible.
(*b*) The increased accuracy, especially in the measurement of vertical angles, or in astronomical observations, attainable by its use.
(*c*) Its greater portability and easier manipulation.
(*d*) Because work may be carried on in damp weather, when it would be impossible to expose the plane table sheet.
(*e*) Because the field notes enable the plan to be reproduced at any time, while the plane table sheet is the only field record.
(*f*) Because traverses can be run with much more facility and accuracy with the tacheometer than with the plane table.
(*g*) Because field work being much more expensive than office work, it is more economical to have all reductions and plotting done indoors.

The principal advantage claimed for the plane table lies in the fact that the topographer has the map before him at the time of survey. This, certainly, is an important consideration, but carries hardly enough weight to counterbalance the disadvantages attending the use of this instrument generally.

Estimate of Cost.—The cost of Topographic Maps for Australia would, of course, vary greatly with local conditions, but on an average the production of really good work as outlined above, including triangulation, should not involve an expenditure of more than the amounts set out below :—

	Per Sq. Mile.
(*a*) Rolling or moderately hilly lands in settled country, where advantage can be taken of existing surveys, scale 40 chains to an inch	£4
(*b*) Plain country, contours determined by spirit levels	£3
(*c*) Forest and densely timbered lands	£8
(*d*) Mountainous country, not densely timbered, details by phototopography, maps generally on scale of one mile to an inch	£1 10s.